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Safety aspects of riding with children: Descriptive analysis of adult riders' self-report

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ABSTRACT

Active transport, including cycling, is promoted as an effective way of increasing children's physical activity and health. Parents can support children's riding by riding with them and it is important to address relevant safety issues. Little is known about parents' experience of safety-relevant aspects of riding with children. Participants in the *Safer Cycling Study* in New South Wales, Australia, who reported that they had ridden with children in the last 12 months were questioned about how they ride with children, and their experience of safety issues and crashes. Among the 187 respondents who had *ridden with children on their bicycle*, the most common form of carrier was a rear-mounted seat (48%) followed by a trailer (29%). Many respondents (79%) identified risks specific to riding carrying children, including those linked with specific carrier types and with use of footpaths. Most (92%) indicated that they change their behaviour when carrying a child on their bicycle; for example, riding more slowly, more carefully, and away from roads. Among crashes with a child on the bicycle, most were falls. Among the 345 participants who had *ridden to accompany a child on a bicycle,* approximately three quarters identified risks specific to accompanying children, such as managing the child's limited skill, awareness and predictability. Ninety-seven percent reported behavioural changes including positioning themselves as a barrier for their child and caution crossing roads. Findings suggest strategies to support parents in riding safely with children.

1. Introduction

Active transport, including cycling, is promoted as an effective way of increasing children's physical activity and health (Chillón et al., 2010; Mackett et al., 2005; Lubans et al., 2011; Tudor-Locke et al., 2002). Further, Jordi-Sánchez (2018) suggested that children's early experience of cycling may influence their adult cycling behaviour, including transport cycling.

Cycling with parents could be a key point of access to riding for children. When a child is old enough to sit upright unaided but too young to ride their own bicycle, they can start to experience cycling as a fun activity and mode of transport from a suitable carrier (such as a bicycle-mounted seat or trailer). Sensations experienced in a bicycle-mounted seat may assist with balancing on a bicycle later. When children are physically able to ride a bicycle but not yet cognitively ready to negotiate paths and/or roads by themselves[1], their riding can be enabled by an adult companion. Jordi-Sánchez (2018) highlights the importance of early "embodied" experience of cycling to later transport choices. Muir et al. (2017) highlight that parents can play an important role in developing children's road safety behaviour via modelling and teaching, and the same may be true of their travel decisions. Sigurdardottir et al. (2013) found that Danish adolescents' intentions to commute by bicycle as an adult were associated with positive cycling experiences and parents' current mode choice to daily activities.

If riding with children is to be encouraged, it is imperative to address relevant safety issues –as a duty of care and because perceived

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[1] For example, the Department of Education in New South Wales, Australia, where the present study was conducted, states "Primary aged students [up to approximately 11 years old] are safest when they are supervised by an adult when riding" (https://education.nsw.gov.au/road-safety-education/safe-student-travel/bikes). The Department of Education and Training in Victoria, Australia states "Road safety authorities recommend that before the age of nine or ten years children should not ride a bicycle in traffic without adult supervision" (http://www.education.vic.gov.au/school/principals/spag/safety/Pages/ridingandwalking.aspx)

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safety is positively associated with participation (Santacreu, 2018). Parents' acceptance and manner of riding with children is likely to be strongly influenced by safety considerations. Perceived safety of riding is recognised to have a strong influence on whether adults ride themselves (e.g. Australia-wide: Australian Bureau of Statistics, 2012; Cycling Promotion Fund, 2011; Vancouver: Winters et al., 2011; Portland: Dill and Voros, 2007), and on whether they allow their children to ride independently (Ghekiere et al., 2017; Nevelsteen et al., 2012; Timperio et al., 2004). Further, riding with children may introduce a unique set of safety considerations (additional to those relating to cycling more generally). For example, bicycle seats may alter the balance of the bicycle resulting in falls (Murray and Ryan-Krause, 2009; Rafferty et al., 2016), while the low stature of trailers may reduce visibility resulting in collisions with motor vehicles (Powell and Tanz, 2000). Parents may adapt their riding to "protect" an accompanying child (e.g. via route choice or road positioning), or to model safe cycling behaviours (e.g. wearing a helmet). Adult companion helmet use is associated with bicycle helmet use by children (Khambalia et al., 2005).

Very little research has examined the prevalence of child transportation, the characteristics of cyclists who transport children, parents' decisions about riding with children (including the type of carrier used), or parents' safety-relevant behaviour and experience of safety issues while riding with children. To address this knowledge gap, Rafferty et al. (2016) conducted an online survey of 100 cyclists with children aged five years or younger. Six participants did not transport their children by bicycle and cited reasons including safety issues associated with bicycle carriers, as well as children being too young, and having too many children to transport. Among the 94% of participants who reported transporting at least one child (aged five years or younger) by bicycle, most transported one (69%) or two (29%) children. Rear mounted seats, front mounted seats and trailers were the most common carriers. Choice of carrier was most commonly based on practicality. Participants were more likely to ride on paths and less likely to ride on roads when transporting children. A substantial majority modified their route at least most of the time when riding with children and 45% reported choosing low traffic times. Most types of near misses were less frequent when transporting children than when riding alone. Perceived risks specific to transporting children on bicycles were changes to the weight/balance/handling of the bicycle when moving or stationary, the child being bored or uncomfortable and moving around, and problems with the child carrier.

In the Rafferty et al. (2016) study, cyclists reported eleven crashes and "eight non-crash incidents resulting in injury" when transporting at least one child. Based on participants' description of these incidents, primary safety issues for bicycle-mounted seats appeared to be loss of balance when stopping suddenly, turning slowly, and unloading children. Primary safety issues for trailers were clipping objects or straying from paths due to trailer widths. Other research shows that most injuries to child passengers result from falls (Hagel et al., 2015; Murray and Ryan-Krause, 2009; Powell and Tanz, 2000), while a small proportion result from collisions with motor vehicles (Hagel et al., 2015). Although more injuries to child passengers have been associated with bicycle-mounted seats than with bicycle trailers, this may reflect their greater popularity (Murray and Ryan-Krause, 2009).

This paper seeks to add to the knowledge base about safety-relevant aspects of riding with children, by addressing, for riding with children in bicycle-mounted carriers as well as riding to accompany children, the research questions:

- What are the characteristics of cyclists who transport children?
- How do they ride with children; in terms of frequency, purpose, location and equipment use?
- What safety issues do they experience while riding with children (including crashes)?
- Do they adapt their riding behaviour when riding with children?

The paper reports survey data from adult cyclists who participated in the Safer Cycling Study conducted in New South Wales (NSW) Australia and reported ever riding with children. Findings might support refinement of standards that apply to bicycle-mounted child carriers (e.g. seats and trailers), and of design guidelines and advisory/regulatory policy for infrastructure that supports riding with children.

2. Methods

2.1. Setting

The Safer Cycling Study was undertaken in New South Wales (NSW), Australia, in 2011/2. NSW is Australia's most populous state. At the time of the study, just over two thirds of its residents (approximately 4.6 million people) lived in the Greater Sydney area. NSW has numerous regional cities and towns, as well as some remote areas. Policy at the state and national levels seeks to increase cycling participation (e.g. National Cycling Strategy 2011–2016), and cycling infrastructure is increasingly available, particularly in population centres. The standardised 2011 Australian Cycling Participation Survey (Austroads, 2011) suggested that 14.5% (95% CI: 13.3%–15.9%) of NSW residents rode a bicycle in the past week, while 36.6% (95% CI: 35.0%–38.1%) rode in the past year. Approximately 42% of children aged 0–9 years rode a bicycle in the past week, with the rate in Sydney being lower than in regional NSW. Anecdotally, increasing numbers of parents "are choosing wheeled trailers, wheelbarrow-style cargo boxes, front-mounted baby seats and bucket bikes for family transport" (Carroll, 2014) in Sydney, Australia. At the time of the study the Australian Standard for bicycle-mounted seats was under revision and there was no Australian Standard for bicycle trailers. Since then, the relevant European Standards have been adopted with modifications (Standards Australia, 2016, 2018). Most such equipment is imported into Australia. At the time of the Study in NSW adults were permitted ride on footpaths only when accompanying children up to 12 years old and there was no rule specifying the minimum distance that motor vehicles must allow when passing bicycles. Behaviour on footpaths and shared paths is regulated by the NSW Road Rules which require people using wheeled recreational devices or wheeled toys (e.g. scooters, skateboards, rollerblades) to keep to the left of the path where practicable and to give way to all pedestrians who are not using wheeled recreational devices or wheeled toys. Bicycle riders must also keep to the left where practicable and must give way to all pedestrians on the path, including those using wheeled recreational devices or wheeled toys. The NSW law making it compulsory in NSW for bicycle riders and their passengers to wear "an approved helmet securely fitted and fastened" on "roads and road-related areas" (https://www.legislation.nsw.gov.au/#/view/regulation/2014/758/part15/rule256) has been in place since 1991.

2.2. Study design

The Safer Cycling Study was a prospective study of adult cyclists (aged 18 years and older) who resided in NSW and rode a bicycle at least once per month. The study recruitment utilised the extensive email lists of a state cycling advocacy organisation, social media sites, community cycling events, bicycle shops, media publicity, and word of mouth within the cycling community. Enrolment occurred between March and November 2011. Participants completed on-line questionnaires at baseline and during six reporting weeks (seven consecutive days commencing within weeks 8, 16, 24, 32, 40 and 48 from baseline). The details of the study protocol are provided elsewhere (Poulos et al., 2011). The study was approved by the University of New South Wales Human Research Ethics Committee.

2.3. Questionnaires

The baseline questionnaire collected data such as cyclist

demographic characteristics (e.g. gender, age, education), self-identification of cyclist type (as mainly transport or recreation), self-reported cycling experience (novice, intermediate, experienced, advanced, or expert/professional), confidence on busy main streets (not at all, low, moderate, or high), and what proportion of the time riding in the previous 12 months was spent on each of six different types of infrastructure (*a pedestrian footpath*, defined as a sealed or unsealed path for pedestrian use; *a shared path*, defined as a path that is off the road and is signed or marked for use as a shared path for bicycles and pedestrians; *a bicycle path*, defined as a path that is signed or marked for use by bicycles only, including paths that are not on the road and paths that are on the road but separated by a curb or other physical barrier; *a bicycle lane*, defined as an on-road lane that is signed or marked with painted lines or a coloured surface for use by bicycles; *a road* that is shared with motor vehicles and does not have a signed or marked bicycle lane; *other*, e.g. cross-terrain, skate park, grassed area etc.).

During reporting weeks participants reported daily about cycling patterns and safety-related events (crashes, crash-related injuries, and near misses). At the end of each reporting week participants were asked some additional questions on a cycling-related topic of interest.

In their sixth reporting week participants were asked questions about riding with children. First, all participants were asked whether in the last 12 months they had "ridden with a child on your bike", defined as "riding with a child on your bike (in a child carrier), towed by your bike (in a child trailer), or towed by your bike using a tagalong type trailer". Thus, "on the bicycle" means "on or towed by the bicycle" throughout this manuscript. Participants who responded in the affirmative were asked a series of questions about riding with children on their bicycle. Specifically:

- how often they rode with children on their bicycle over the last 12 months (*Less frequently than 1 day/week*; *1 day/week*; *2 days/week*; *3 days/week*; *4 days/week; 5 days/week*; *More than 5 days/week*), as well as the average time and distance they did so per month.
- what proportion of the time riding with a child on their bicycle was spent on each of six different types of infrastructure (*options defined as above*).
- how many children they usually ride with on their bicycle at once, which carrier(s) they use (*a rear-mounted child seat*; *a front-mounted child seat*; *a child trailer attached to my bike*; *a tagalong bike*; *Other*), and at what age they would consider "a child to be old enough" to use each of these types of carrier (all without reference to the last 12 months).
- how often the children wore a helmet (*Never*; *Rarely*; *Some of the time*; *Most of the time*; *Always*).
- their reason(s) for choosing to ride with a child/children on their bicycle (*Exercise*; *Convenience*; *Recreation/family activity*; *Modelling healthy behaviour*; *Transport*; *Environmental benefit*; *Other*.)
- whether riding with a child/children on their bicycle changes their riding behaviour, with space to describe up to three changes.
- whether they have discovered any risks or hazards that are specific to riding with a child on the bicycle, with space to explain.

Participants who reported riding with a child on their bicycle in the last 12 months were then asked "Have you had a collision or fall when riding with a child/children on your bike over the last 12 months?", with a collision defined as "an event in which the bicycle hits, or is hit by an object, person or animal, regardless of fault", and a fall defined as "an event (not caused by a collision) where the bicycle and/or bike rider lands on the ground". Participants who responded in the affirmative were asked how many events involved each type of child carrier (same response options as previously), various collision partners (*a motor vehicle, including motorcycle*; *another bicycle*; *a pedestrian*; *an animal*; *a stationary object*; *other)*, and each type of infrastructure (same response options as previously). They were then asked whether either they or the child(ren) sustained a significant injury (at least serious enough to require medical attention at a general practice or emergency department).

Next, all participants were asked "Have you, while riding your bike, accompanied a child under 12 on their own bike in the last 12 months?" Instructions clarified that a child who rides their own bike "is not generally requiring assistance to push their bike along and is not attached to your own bike in any way". Participants who responded in the affirmative were asked a series of questions that paralleled those relating to riding with a child on the bicycle. For example, participants were asked "At what age would you consider a child old enough for you to start accompanying them on their own bike (rather than riding on your bike)?" Response options for the question about reasons for accompanying children were slightly modified to include "Exercise for myself" and "Exercise for the child". Participants were asked whether "Have you or a child/children had a collision or fall while you were riding together over the last 12 months?"

2.4. Data analysis

Quantitative data were analysed descriptively. Open-ended responses were analysed qualitatively. Inductively generated themes identifying behavioural changes when riding with children, and safety issues specific to riding with children, were developed by the first author (JH) and confirmed by others (RP and CR) from the textual descriptions given by cyclists. Qualitative responses were coded by JH to indicate the frequency of the most commonly occurring themes.

3. Results

3.1. Sample description

Among the 2383 cyclists who completed the baseline questionnaire, 345 did not provide exposure data to meet the criteria for inclusion in the Safer Cycling Study cohort, which therefore included 2038 participants. Of these, 1237 contributed cycling diary data during the sixth reporting week, although more completed some "cycling issues" questions at the end of the week.

Among 1356 participants who responded to the question "Have you ridden with a child on your bike in the last 12 months?" 187 responded in the affirmative. However, two of these answered no further questions so were removed from relevant analysis. Among 1351 participants who responded to the question "Have you, while riding your bike, accompanied a child under 12 on their own bike in the last 12 months?" 344 responded in the affirmative (five gave no response and the remainder responded in the negative). However, two of these answered no further questions so were removed from relevant analysis. Demographic characteristics of each of these samples are reported in Table 1.

The predominance of males observed in the study cohort was particularly pronounced in both subsamples of cyclists who reported riding with children. Over 90% of cyclists who reported riding with children on their bicycle were aged between 25–44 (compared with approximately 50% for the cohort), which is not surprising because it is this age group who is most likely to have younger children. Approximately 70% of cyclists who reported riding with children on their bicycle self-identified as mainly transport cyclists (compared to approximately 60% for the cohort, and the subsample who reported accompanying children). While 47% of cyclists who reported riding with children on their bicycle reported a high level of confidence on busy main streets, only 39% of the cohort did, while self-reported experience was more homogeneous. Analysis of data for riding with children on an adult's bike and for accompanying children is presented in Section 3.2 and Section 3.3, respectively.

Table 1
Demographic characteristics of Safer Cycling Study cohort, cyclists who reported riding with children on their bicycle, and cyclists who reported accompanying children riding on the child's bicycle.

Parameter	*Level*	*Safer Cycling Study cohort (n = 2038)*	*Cyclists who reported riding with children on their bicycle (n = 185)*	*Cyclists who reported accompanying children riding on the child's bicycle (n = 344)*
Sex	Female	27.6% (563)	15.7% (29)	19.5% (67)
	Male	72.4% (1475)	84.3% (156)	80.5% (277)
Age group	18-24	3.7% (75)	0.0% (0)	0.6% (2)
	25-44	51.8% (1056)	98.9% (183)	58.7% (202)
	45-59	37.1% (756)	1.1% (2)	36.6% (126)
	≥60	7.4% (151)	0.0% (0)	4.1% (14)
Main purpose (baseline)	Recreation	40.1% (817)	30.3% (56)	41.0% (141)
	Transport	59.9% (1221)	69.7% (129)	59.0% (203)
Rider experience	Less experienced	16.7% (340)	12.4% (23)	15.1% (52)
	More experienced	83.3% (1696)	87.6% (162)	84.9% (292)
	Missing	0.0% (2)	0.0% (0)	0.0% (0)
Confidence on busy main streets	Not at all or Low	14.5% (297)	10.3% (19)	14.8% (51)
	Moderate	46.4% (945)	42.7% (79)	42.7% (147)
	High	38.7% (789)	46.5% (86)	42.4% (146)
	Missing	0.3% (7)	0.5% (1)	0.0% (0)

3.2. Riding with children on the adult's bicycle

3.2.1. Frequency

Among participants who answered questions about riding with children on their bicycle (the child being a passenger) over the last 12 months, nearly three quarters (73.0%) reported doing so less frequently than one day per week. A decreasing proportion reported riding with children on their bicycle one day (10.3%), two days (8.1%), three days (4.3%), four days (2.2%), and five days (1.6%) per week. None reported riding with children on the bicycle more than five days per week.

Fig. 1 is a frequency chart of respondents' estimated time per month riding with children on their bicycle (and to accompany children; see commentary in Section 3.3.1) over the past 12 months. Well over half of respondents (62.2%) indicated that they rode on average 2 h per month or less with children on their bicycle, while 15.7% rode six hours or more (which would correspond to around 30 min on three days per week).

3.2.2. Reasons for riding with a child on the bicycle

The reason that respondents most commonly gave for riding with children on the bicycle was recreation/family activity, which was endorsed by 89.2% of respondents. Some of these respondents commented that bicycle riding is fun for themselves or the child. Modelling healthy behaviour was endorsed by 57.3% of respondents, some of whom made comments about developing habits for recreational or transport cycling; for example

"Just trying to get them into cycling so we can enjoy it together in coming years"

"I want my children to grow up considering bike travel to be a normal and acceptable mode of transport."

Two participants talked about getting the child "used to the feel of being on a bike" and "experience of balance and bicycle control as part of learning to ride."

Transport was endorsed as a reason for riding with children on the bicycle by 52.4% of respondents, Exercise by 50.8%, Convenience by 40.5%, and Environmental benefit by only 30.3%.

3.2.3. Riding location

Table 2 presents the mean of the reported proportion of time riding on each type of infrastructure with children on the bicycle (and to accompany children; see commentary in Section 3.3.3). The table also presents the mean proportion of time the same respondents (i.e. those who reported riding with a child on the bike and/or riding to accompany children) reported riding on each type of infrastructure for the 12 months prior to their baseline questionnaire (which may have included some riding with children). It is noted that the mean reported proportion does not correspond to the mean proportion of all riding – because some participants rode more than others.

On average respondents reported that 37.5% of the time riding with a child on the bicycle was spent on a road (including 6.4% on a bicycle lane). On average, shared paths and pedestrian paths were the next most frequently used for riding with children (27.5% and 22.3% of the

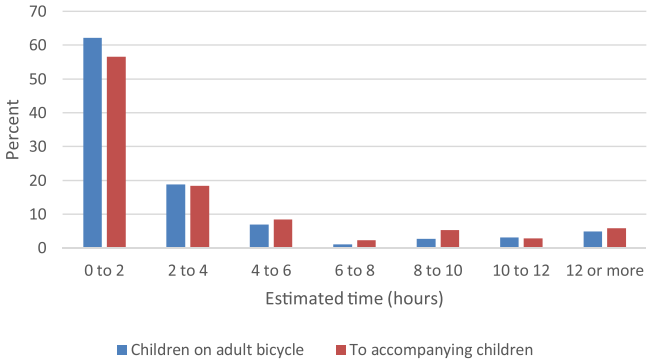

Fig. 1. Frequency chart of estimated time per month riding with children on their bicycle, and to accompany children, over the last 12 months (categories include their upper limit).

Table 2
Proportion of the time riding on five different types of infrastructure when riding with a child on the bicycle[a], when riding to accompany[a], and when riding in general[b].

	Riding with children on the bicycle (n = 185)	*Accompanying children on their bicycle (n = 341)*	*Riding in general (n = 428)*
Road without bike lane	31.1%	17.9%	57.5%
On-road bike lane	6.4%	4.4%	13.6%
Shared path	27.5%	29.4%	13.9%
Pedestrian path	22.3%	26.7%	2.5%
Bike path	11.6%	16.1%	7.1%

[a] for the 12 months prior to the sixth reporting week.
[b] for the 12 months prior to the baseline questionnaire, for members of the entire cohort who reported riding with children (either on the bike, accompanying, or both). May include some riding with children.

Table 3
Minimum age and mean age (with standard deviation) at which children were considered old enough to use different carrier types, and standard deviation (among participants who reported riding with a child on the bicycle).

	Minimum age	*Mean age (s.d.) (months)*
Rear-mounted seat	5	16.9 (7.9)
Front-mounted seat	3	15.8 (11.5)
Child trailer	1	16.7 (18.3)
Tagalong	5	47.6 (13.7)

time, respectively). "Other" locations (1.1% of the time) included bush trails (n = 2), a "park area for kids' bikes" (n = 1), and a "dedicated road cycling track for training" (n = 1).

Among cyclists who reported riding with children on the bike, on average the proportion of riding that took place on the road (both with and without a bike lane) appeared to be lower compared to riding in general. The proportion of time riding on paths appeared correspondingly higher.

3.2.4. Child numbers and equipment use

A strong majority of respondents (89.0%) reported usually riding with one child on the bicycle, while 10.4% reported riding with two, and 0.5% reported riding with three. Table 3 shows that amongst respondents who reported riding with a single child a rear-mounted seat was the most commonly reported carrier-type (51.3% of such respondents), followed by a trailer (23.8%), a tagalong bike (20.0%) and a front-mounted seat 15.6%, (noting that multiple responses were possible). "Other" ways of carrying children (10.6% of respondents) were in a cargo bicycle (n = 3, including two who mentioned having a fitted seat), using an attachment (e.g. a "Trailgator") to attach the child's bicycle to their bicycle (n = 3), a tandem bicycle (n = 3), and sitting somewhere on the adult bicycle (i.e. the seat, the cross-bar, the luggage rack; n = 4). Among those who reported riding with more than one child, trailers were used by a higher percentage of respondents (75.0%), while a lower percentage used a rear- or front-mounted child seat (25.0% and 5.0%, respectively). Again, 20.0% used a tagalong. Respondents also reported carrying children in a cargo bicycle (n = 3), and in a tagalong together with a trailer (n = 3) or together with a tandem bicycle (n = 1).

On average participants would consider "a child to be old enough" at approximately the same time to use a rear-mounted seat, a front-mounted child seat, and a child trailer. The average age at which a child was considered old enough to use a tagalong was considerably higher.

A strong majority of respondents (87.5%) reported that children who had ridden with them over the last 12 months always wore a helmet, with a further 6.0% reporting that a helmet was worn most of the time. Nonetheless it is concerning that a few parents reported that children wore a helmet never (3.3%), rarely (2.2%) or only some of the time (1.1%).

3.2.5. Perceived risks specific to riding with a child on the bicycle

Nearly 80% of respondents (79.5%) reported that they had discovered risks or hazards that are specific to riding with a child on the bicycle, and all but one provided an explanation of their answer.

Some of the issues that were raised frequently were relevant to several carrier types. Many respondents identified that the additional weight of the child(ren) and carrier(s) resulted in reduced acceleration, reduced travel speed, reduced manoeuvrability, and longer braking distance. These changes were perceived to reduce the rider's capacity to avoid crashes, and to increase the possibility of motor vehicle driver impatience or aggression. Reduced acceleration was also felt to result in fewer safe gaps for crossing or turning through traffic, and reduced speed to contribute to balance issues. Several respondents also highlighted the safety implications of distraction from communicating with children and managing children's behaviour. Children dropping or throwing things could result in more turning and stopping manoeuvres. Finally, participants highlighted that severe bumps can injure children's necks.

The main identified issue specific to bicycle-mounted seats was trouble balancing due to the changed gravity centre of the bicycle, and children moving or leaning (e.g. when asleep). Respondents particularly highlighted balance issues in the context of taking the child in/out of the seat, mounting/dismounting, moving slowly, and cornering. It was highlighted that infrastructure that requires the rider to dismount and/or manoeuvre the bike exacerbates these balance issues. Respondents reported that rear-mounted seats can restrict the rider's movement; for example, interfering with pedalling and preventing them from standing in their pedals, increasing the need for appropriate gearing. A couple of respondents reported that children in front-mounted seats may try to interfere with steering.

The main identified issues specific to trailers relate to their dimensions. Specifically, trailers can be too wide for bicycle lanes and paths, perhaps increasing the risk of collision with vehicle doors or moving vehicles, and tipping if one wheel runs off the road/path. They may collide with obstacles, such as bollards and poles. Respondents suggested that because trailers add to the length of the bicycle and are low (relative to a bicycle) motorists may neither see them nor expect them, increasing crash risk. Length may also reduce manoeuvrability, including through narrow openings. Some respondents made specific mention of the positioning of bollards preventing trailer access to paths, so that they must use roads, which are perceived as less safe; for example,

> "*Often on cycle paths there are bollards or turns that trailers cannot fit through.*"

Issues relating to length were also a primary concern for tagalongs (and similar) and respondents also raised the path accessibility issue mentioned above specifically in relation to tagalongs.

> *"Most of the bollards used to block off bike/shared paths have narrow gaps between them and many are located at the immediate ends of the paths making it difficult to turn onto the roads etc at the end due to the extra length of the tagalong."*

However, perhaps the primary issue for tagalongs was compromised handling and balance, including when the child rides differently; for example,

> *"a tagalong is even worse (than a bicycle-mounted seat) in terms of the effect it has upon the stability of the adult's bike. It tends to pull the bike side to side, especially if the child is shifting their bodyweight around."*
> "*sometimes have to brake against the child pedalling or correct the sway of the bike as the child might move in the wrong direction.*"
> *"You have to make sure they are gripping the handle bars with both hands."*

Some of the safety issues specific to riding with a child on the bicycle that were raised by participants related to their infrastructure choices. For example, several participants raised safety issues with footpaths, such as driveways, cars parked across the footpath, plants overgrowing footpaths, poorly maintained surfaces, poles, interactions with pedestrians and their animals. Respondents highlighted that there are often "*no footpath ramps at … crossings*", making it difficult to avoid jolting the child passengers.

3.2.6. Behaviour changes when riding with a child on the bicycle

Over 90% of respondents (92.4%, n = 171) indicated that riding with children on the bicycle changes their riding behaviour. Each of these respondents were invited to describe up to three changes, and 82 gave three changes, 61 gave two changes, while 26 gave one change. Thus, 169 respondents reported 394 reasons. Table 4 reports the frequency of the five most commonly reported changes.

Many of the specified changes to behaviour when riding with a child

Table 4
Frequency of respondents reporting the five most commonly reported changes when riding with a child on the bicycle, with examples.

Change category	*Frequency (n = 169)*	*Examples*
1. Riding more slowly	75%	*I will generally ride at slower speeds… (both for safety reasons and because of the additional weight…).* *Riding more slowly to reduce the risk of a crash.* *Riding more slowly to reduce bumps.* *I ride more slowly as my children are fearful of higher speeds.* *I do not cycle fast as I am riding more for enjoyment than transportation.* *… ride significantly slower as a result of riding on shared pathways and pedestrian paths.* *Slower riding pace (as per trailer instructions).*
2. Avoiding motorised traffic	62%	*Prefer not to ride on road.* *Keep away from traffic.* *Choose less busy streets.* *Travel along pathways, footpaths, and cycleways to avoid traffic.* *I am more likely to cycle on footpaths, especially along busy roads where there is no cycle lane.*
3. Riding more carefully	58%	*I am more cautious.* *I ride more conservatively.* *Ride extremely defensively.* *Less risky behaviour.* *More aware of intersections and potential issues.*
4. Changing route	18%	*Safer route.* *Cycle on backstreets that are quieter and take longer to get to my destination.* *I select routes that are better suited to give cars visibility of us.* *Avoid steep hills.* *I need to minimise the number of bumps by taking the smoothest route to minimise the discomfort of the child.*
5. Selecting particular trip types	7%	*I only do short trips along the bike path or to the shops.* *large group rides that include traffic control.* *I only travel along a bush track to the road where there is a bus stop.* *Only for recreational riding where I have complete control of where I ride.*

on the bicycle appeared to be motivated by safety considerations. Riding more slowly was specified as a change by 75% of respondents (see Table 4). Often this appeared to relate to reducing crash risk, although it sometimes appeared to result from increased weight, infrastructure type, or trip purpose (recreation rather than transport) (see Table 4). Maintaining children's comfort was also mentioned.

Just over 60% of respondents mentioned changes that appeared to reflect efforts to avoid motorised traffic (see Table 4). Respondents mentioned avoiding roads per se, while others mentioned avoiding "busy" roads or traffic. Respondents also reported increasing their use of footpaths, shared paths and bike paths, and even bicycle lanes.

Nearly 60% of respondents indicated that they ride more carefully, sometimes specifying how or when they were particularly cautious (see Table 4). Some respondents said that they ride in a manner that is less "aggressive" or "risky", or more "conservative", "casual" or "compliant". Respondents also described riding more defensively and being more aware of hazards. Riding in a more central lane position was identified as a strategy for improving visibility, maintaining more room to manoeuvre, and discouraging passing. Respondents mentioned several behavioural changes that represented attempts to address the perceived safety issues described in Section 3.26. For example, respondents reported allowing more space for braking and manoeuvring, as well as being more careful when

- turning or crossing through traffic, or avoiding doing so (e.g. by dismounting to cross, crossing at pedestrian crossings), due to decreased acceleration;
- cornering, due to impaired balance, or tracking of trailer/tagalong;
- passing through narrow openings, due to increased width and/or length.

Nearly 20% of respondents mentioned changing their route, sometimes to allow particular infrastructure choices (even if less direct), and sometimes to minimise duration of exposure by being more direct. Nearly 10% of respondents stated that they ride with a child on their bicycle only for specific trip types, and this appeared to be motivated at least partly by safety considerations (see Table 4).

Cutting across categories in Table 4, some responses relating to choices of route (category 4) or trip type (category 5) appeared to reflect a desire to make the ride pleasant or entertaining for the child; for example

> *"I ride shorter distances and take a few breaks along the way."*
>
> *"I look for interesting places to stop to show the child their surroundings."*
>
> *"Only ride when it is good weather whereas I commute every day to work regardless of wind/rain."*

Similarly, avoiding or minimising bumps was mentioned in the context of speed (category 1) or route choice (category 4), as well as on its own, by around 6% of respondents.

Not accommodated by the categories in Table 4, but of note in the context of the perceived value of riding with children, two participants indicated that they make opportunities to teach their children about safe cycling:

> *"I obey the road rules scrupulously to set a good example."*
>
> *"Pointing out hazards, explaining traffic and rules as we go."*

3.2.7. Experience of crashes

Ten participants each reported that they had one collision or fall when riding with children on their bicycle over the last 12 months, while two participants each reported two such crashes. Given a total estimated time riding with children on the bicycle of 10859.4 h (across participants), this equates to a crash rate of approximately 1.3 per 1000 h.

Details of the 14 crashes are presented in Table 5.

Falls were the most common crash type, accounting for ten of the 14 crashes. There were three collisions with a stationary object and one collision with a motor vehicle. Falls occurred on the road as well as on each type of path (shared, pedestrian, bicycle). Just under half of the crashes occurred "where one infrastructure meets another", despite there probably being more exposure to cycling along the infrastructure. For four of the 14 reported crashes the child was in a tagalong when the crash occurred. Only one crash resulted in the child or adult rider sustaining a significant injury (at least serious enough to require medical attention at a general practice or emergency department).

Table 5
Details of crashes experienced in the last 12 months when riding with a child on the bicycle.

Crash type	*Infrastructure type*	*Location*[a]	*Carrier used*	*Injury outcome*[b]
Fall	Road	Junction	Tandem	Significant injury[c]
Fall	Road	Along	Front-mounted seat	No injury
Fall	Shared path	Along	Rear-mounted seat	No injury
Fall	Pedestrian path	Along	Rear-mounted seat	No injury
Fall	Pedestrian path	Along	Tagalong	No injury
Fall	Bicycle path	Junction	Trailer	No injury
Fall	Bicycle path	Junction	Trailer	No injury
Fall	Other	Junction	Trailer	No injury
Fall	Other	Along	Tagalong	No injury
Fall	Other	Along	Tagalong	No injury
Collision stationary object	Shared path	Junction	Rear-mounted seat	No injury
Collision stationary object	Shared path	Junction	Tagalong	No injury
Collision stationary object	Pedestrian path	Along	Trailer	No injury
Collision motor vehicle	Road	Along	Tagalong	No injury

[a] "along the infrastructure" (Along) or "where one infrastructure meets another" (Junction).
[b] To either child or adult rider.
[c] Defined as "at least serious enough to require medical attention at a general practice or emergency department".

3.3. Accompanying children riding on their bicycles

3.3.1. Frequency

Among participants who answered questions about riding to accompany children over the last 12 months (n = 342), approximately three quarters (76.9%) reported doing so less frequently than one day per week. A decreasing proportion reported accompanying children one day (14.3%), two days (4.4%), three days (2.3%), four days (1.5%), and five days (0.6%) per week. None reported accompanying children more than five days per week.

Somewhat over half of respondents (56.6%) indicated that they rode on average two hours per month or less to accompany children, while 20.5% rode six hours or more (which would correspond to approximately 30 min on three days per week).

3.3.2. Reasons for riding to accompany children

The reason that respondents most commonly gave for riding to accompanying children was recreation/family activity, which was endorsed by 86.2% of respondents. Exercise for the children was also a prominent response, endorsed by 70.6%; but exercise for themselves less so (36.8%). Modelling healthy behaviour was endorsed by 62.9% of respondents, Transport by 32.9% of respondents, Environmental benefit by 20.0% and Convenience by 18.8%. Several respondents reported that they were supporting their children to learn to ride, or to ride safety in a road environment. A few indicated that they wanted to develop a love or habit of cycling in their children. Several respondents identified that they were coaching or training children for events or races.

3.3.3. Riding location

As shown in Table 2, on average respondents reported that 22.3% (s.d. = 28.5%) of the time riding to accompany children was spent on a road (including 4.4% on a bicycle lane). On average, shared paths were used for 29.4% (s.d. = 34.4%) of the time, pedestrian paths for 26.7% (s.d. = 32.8%) of the time, bicycle paths for 16.1% (s.d. = 28.7%), and "Other" 5.3% (s.d. = 18.6%) of the time. "Other" locations specified were paved areas such as school grounds, netball/basketball courts, carparks or private garage/driveway areas (n = 10), off-road trails (mostly fire trails; n = 10), paths in a park, cemetery or zoo (n = 7), dedicated bicycle courses for children (e.g. at Sydney park, n = 4), a velodrome or dedicated road cycling track for training (n = 4). Again, the proportion of riding that took place on the road (both with and without a bike lane) appeared to be lower, and the proportion of time riding on paths appeared to be higher, when riding with children compared to riding in general.

3.3.4. Child numbers and equipment use

Over half of respondents (56.3%) reported accompanying only a single child at once, while 36.0% reported accompanying two, and 6.2%% reported accompanying three or four. The maximum number that respondents reported accompanying was 15.

On average participants would consider "a child to be old enough" to be accompanied on their own bicycle (rather than being carried on their parent's bicycle) at the age of 5.7 years (s.d. = 1.9), with just over a quarter (27.9%) specifying an age of 1–4 years, inclusive.

Almost all respondents (96.5%) reported that children who they had accompanied over the last 12 months always wore a helmet, with a further 3.2% reporting that a helmet was worn most of the time. Only one respondent reported that the child they accompanied never wore a helmet.

3.3.5. Perceived risks specific to riding to accompany children

Approximately three quarters of respondents (74.8%) reported that they had discovered risks or hazards that are specific to riding to accompany children, and all provided an explanation of their answer.

Child riders were perceived to experience specific risks due to inexperience and immaturity. Respondents highlighted that children often have incompletely developed bicycle handling skills, so that they can have difficulty balancing, steering a straight course, manoeuvring around obstacles, negotiating hazards (e.g. pavement cracks), or braking effectively. Children may also have lower acceleration and cycling speed, contributing to challenges crossing roads, and impatience/overtaking/aggression from other path/road users. Respondents also highlighted frequently that children have limited knowledge of road rules and limited "road sense", so that children may not be able to pre-empt others' movements and may show little consideration of other path/road users. Respondents highlighted that children show little understanding/awareness of potential hazards (including cars, car doors, pedestrians, other cyclists, surface issues), and tend not to ride defensively. Finally, some respondents noted that children may have trouble judging safe gaps and assessing risk, as well as slower reaction times. Some respondents identified that children have "tunnel vision", in the sense that they focus on only one aspect of the task or environment, rather than showing broader situational awareness. Other respondents noted how readily children's attention can drift from the riding task. Many respondents characterised children as being unpredictable. Some children can be overconfident and engage in risky behaviour (such as speeding down hills). Specific issues raised were weaving (including onto the wrong side of paths), stopping unexpectedly (including in front of adult riders), suddenly changing direction or riding off, following too close, and responding

inappropriately to hazards. Several respondents noted that children can be difficult to see due to their smaller stature.

Lack of awareness about these issues from other path/road users was also raised quite frequently as a specific risk; e.g.

"children often veer across bike lanes erratically. There can be other users who are intolerant/don't expect this."
"Other cyclists not necessarily expecting the random steering of kids."
"Cars reversing out of driveways who simply don't look until on the road."

Safety issues associated with footpaths and, to a lesser extent, other bicycle facilities, were prominent. Among these, cars moving in and out of driveways were frequently identified as a risk. Interactions with pedestrians were also an issue, with lack of awareness from both child riders and pedestrians cited.

"It's difficult to interact with pedestrians as children don't always understand the give way moments… and pedestrians are not always tolerant.
"Many pedestrians unaware that either kids, or adults with them, can ride on the footpath."

Other footpath hazards included poorly maintained surfaces, poles, bus shelters, and overgrown vegetation. The lack of footpath ramps, and other suitable crossing facilities, was repeatedly identified as contributing to the challenge of crossing with child riders.

"Crossing side streets on the footpath is really difficult and dangerous. It's almost better to just ride in the street."
"Many footpaths do not have a ramp to and from the road."
"Crossing some roads with split crossing … there is sometimes insufficient space to store all bikes in the middle island."

Nonetheless, there was a clear sentiment among respondents that roads were a challenging environment for child riders; e.g.

"Due to the unpredictable behaviour of a child, more space around the child needs to be planned, and narrow roads/roads with traffic are not appropriate."
"Kids tend to ride too close to parked cars hence increasing the risk of being 'doored' or clipping parked vehicles."
"Lack of sustained focus/concentration on task e.g. will 'wander' from the shoulder into lane."

Respondents indicated that the constant vigilance required when riding with children can be both tiring and distracting. Keeping groups of children safe and together was identified as a specific challenge.

3.3.6. Behaviour changes when riding to accompany children

Over 90% of respondents (91.4%) indicated that they change their riding behaviour when accompanying children. Each of these respondents were invited to describe up to three changes, and 130 gave three reasons, 119 gave two reasons, while 63 gave one reason.

Respondents commonly indicated that they ride slower when accompanying children, partly to travel at a pace that suits the child, but also for safety reasons; e.g.

"I usually ride slower so we are riding at a pace that suits their ability."
"Travel at a slow safe speed…"
"I ride slower … to be more aware of hazards and can point them out giving time for the child to react."

Respondents also mentioned being more cautious and compliant, particularly at intersections/crossings; e.g.

"I am much more cautious, for example when crossing roads I wait for a bigger gap."
"I am more diligent when crossing the road. I ensure that I come to a complete stop all the time."
"We stop at every junction and only proceed when it is totally clear in both directions, giving her time to cross safely."

Several respondents highlighted that they dismount to cross roads.

Many respondents identified that they would avoid roads, and especially busy roads, and ride more on footpaths or bicycle facilities (including shared paths) – particularly with younger children. Respondents often said that they would change their route to allow these infrastructure choices, or to avoid intersections/crossings or hills. Several respondents indicated that they accompany children only for specific purposes (e.g. recreation), under specific circumstances (e.g. bike specific events or facilities), or for shorter trips.

Respondents frequently indicated that they are more aware of potential hazards when riding with the child, including hazards posed by the child, and some described how their awareness shifts from themselves to the child. Some respondents mentioned riding further from a child than they would an adult; due to the child weaving and stopping unexpectedly.

Respondents commonly described choosing a riding position to allow observation of child and hazards, and to protect the child from hazards. Often participants mentioned riding behind the child, while in some circumstances they ride ahead to identify hazards, and to show directions or manoeuvres. Respondents described "shielding" the child from hazards on roads and on paths; e.g.

"I usually ride in a position where I can guide the child rider and shield them from traffic from behind. Usual position about 4 o'clock."
"On the road take the lead and teach/show them how to negotiate traffic and to explain the road rules."
"Place your bike in a protective position against oncoming bikes."

Respondents also described strategies for "shepherding" children, particularly through intersections; e.g.

"Shadow them at right side rear in case they stray right into the line of traffic out of bike lane."
"I ensure that I shepherd her at junctions (for example when going around a roundabout I will pull up across the access road from the left and tell her to ride past me)."

Respondents frequently described providing instruction or educating their children about cycling behaviour, rules and etiquette. This could be specific instructions about specific behaviours or broader commentary; e.g.

"Ride behind the child and give instructions about negotiating traffic, obstacles, hazards safely."
"I am constantly communicating how to ride and watch for cars coming out of driveways."
"Explain rules and etiquette on shared paths."

Several respondents specifically mentioned modelling appropriate behaviours; e.g.

"I have to make sure than I am setting a good example for them by using hand signals and stopping at traffic lights."
"Less likely to take risks etc. I want to show them the correct way to navigate around people/cars etc."
"Extra care with my manners on shared paths."

Finally, several respondents indicated that they ride a different bicycle or wear different clothing when accompanying children, or talked about accompanying them without a bike or on foot; e.g.

"Always use the commute bike with side mirror to be able to monitor traffic on road rides with child."
"Wear fluoro vests."
"Sometimes opt for a scooter for the adult for the ease of assisting the child."

3.3.7. Experience of crashes

One hundred and eleven participants reported that while they were riding to accompany children over the last 12 months either they or the child had a crash on at least one occasion. While 36.1% of these respondents each reported one crash, 22.1% reported two, and a further 24.6% reported from 3 to 5 crashes. A total of 374 crashes were reported (including six respondents who reported 10, 20 or 52 crashes, which may reflect typographical error). Because it is not clear from the questioning whether the child was involved in the crash no further information about the crashes was analysed. Nonetheless, comments offered about the crashes by some participants suggested that children fall quite frequently when learning to ride, sometimes due to their distractibility.

4. Discussion

The present research suggests that riding with children is accompanied by some specific hazards that might be addressed by refining standards that apply to bicycle-mounted child carriers (e.g. seats and trailers), as well as infrastructure design guidelines and advisory/regulatory policy for infrastructure that supports riding with children. Increasing the safety of riding with children is imperative to promoting this behaviour (Santacreu, 2018), both as a duty of care and because safety concerns are a barrier to participation (see Dill and Voros, 2007; Ghekiere et al., 2017; Nevelsteen et al., 2012; Timperio et al., 2004; Winters et al., 2011). Public education about the hazards specific to riding with children may assist parents and carers with managing their risks.

Findings suggest that riding with children is quite common, but that there is scope for increasing participation in cycling, particularly as a routine means of transport with children. Considering only the subsample aged 25–44 (the most likely to have young children) 23% reported having ridden with children on their bicycle in the last 12 months, and 31% reported having ridden to accompany children. Among bicycle riders who report riding with children, most appear to ride with children quite infrequently, while relatively few reported a frequency that is consistent with regular transport cycling. Rafferty et al. (2016) reported that 94% of their participants reported transporting[2] at least one child by bicycle. However, their participants were all aged 24–58, had children aged five years or younger, and were asked, in effect, whether they had *ever* transported children on a bicycle – and this explains at least part of the divergence from the present findings.

The greater prominence of transport as a reason for riding with children on the bike (endorsed by 52% of respondents) than for accompanying children (33%) may partly reflect a reduction in parents taking children with them for their own utility trips as the children get older. It may also reflect parents' less discretionary route-choice associated with transport riding along with concerns about children's lower cycling skill and predictability. Parents may be supported to accompany children riding for transport by addressing relevant safety issues. For both types of riding with children, recreation was most frequently endorsed as a reason (by nearly 90% of respondents). Modelling healthy behaviour was also prominent and several respondents made comments about supporting the development skills and habits for recreational or transport cycling. These motivations for riding with children may be useful to harness for encouraging the behaviour more broadly.

Findings suggest that parents' choices of which infrastructure to use when riding with children are influenced by its availability and perceived safety. Respondents reported that the greatest proportion of the time riding with children on the bicycle was spent on roads, perhaps because this is the most widely available infrastructure. Nonetheless, respondents reported avoiding roads when riding with children, and the proportion of time spent riding on roads when riding with children appeared to be lower than when riding in general (including without children; as reported at baseline). The lower proportion of on-road riding to accompany children may reflect concerns about children's lower cycling skill and predictability. Provision of separated infrastructure may do more to encourage parents to ride with children than initiatives to lower motorised traffic speed (Nevelsteen et al., 2012).

Respondents indicated that a considerable proportion of their riding with children was on shared paths and pedestrian paths, and that they perceive paths to be safer than (busy) roads. However, relevant research raises concerns about the safety of both shared paths and pedestrian paths (Reynolds et al., 2009; Poulos et al., 2015). Moreover, paradoxically, participants highlighted a range of safety issues with off-road paths, especially footpaths. There is a critical need to address such issues to improve the safety and comfort of off-road paths, and to support safe riding with children. Respondents also reported riding with children in other off-road locations (e.g. in parklands), presumably in part because of their perceived safety. Provision of such locations may encourage riding with children.

The prevalence of different types of bicycle-mounted child carriers influences the prevalence of their associated safety issues, and so arguably the priority of mitigation efforts. Rear-mounted seats were the most common carrier overall, while trailers were most common amongst those who rode with multiple children. Tagalongs were used by around 20% of respondents. Rafferty et al. (2016) reported broadly consistent findings.

The present results highlight safety issues associated with each carrier type, as well as with riding with children more generally. Reduced speed, manoeuvrability, braking performance, and stability due to the additional weight of the child(ren) and carrier(s) was were highlighted by respondents as key safety issues of riding with children– in keeping with the findings of Rafferty et al. (2016). Public education about these issues may allow both riders and motorists to be more accommodating of them. Specific recommendations might include those reported by respondents (such as allowing more space for braking and manoeuvring).

Compromised balance was the main issue identified specific to bicycle-mounted seats, particularly in the context of taking the child in/out of the seat, mounting/dismounting, moving slowly, and cornering. This issue was also recognised by Murray and Ryan-Krause (2009). Many of the reported issues are consequences of the child/seat combination increasing the mass of the bicycle/rider(s) unit, increasing the height of the centre of mass (CM), and adding a mobile mass. In addition, rearward placement of the child/seat combination alters braking dynamics, changing the front-rear brake force distribution and pitch stability in braking, as a result of mass distribution, which shifts during braking, and increasing momentum at each speed. Designing infrastructure that minimises the need for tight manoeuvring and dismounting may reduce the risk of crashes resulting from child-seat-related balance issues. Carrier interference with balance, and with bicycle operation (e.g. pedalling and steering), may be addressed by carrier design standards. The preface to the Australian adoption of the European standard for child seats for bicycles (Standards Australia, 2016) acknowledges that "the performance specifications relate to … protecting the child from hazards on the bicycle (e.g. moving parts), and minimising lateral sway of the bicycle (by preventing the child's CM falling too far laterally)." (p.2). The standard specifies that the instructions for installation shall include "instruction to check whether all parts of the bike function correctly with the seat mounted" (p.29) without indicating that this check should include a riding test with a focus on braking and stability. The warning required by the standard that "The cycle may behave differently with a child in the seat. Particularly with regard to balance, steering and braking" (p.30) could

[2] Rafferty et al. (2016) used "transporting children" in a manner synonymous with our "riding with children on [the] bicycle". This meaning is apparent in that they asked about transporting children for purposes of commuting/utility (which we refer to as transport), recreation, and sport/exercise.

perhaps describe potential issues more fully and suggest management strategies (e.g. adjustment of brakes). Issues and their management might be raised at the point-of-sale, where there is retail sales support.

Issues specific to trailers generally related to their dimensions. Trailers can be too wide for bicycle lanes and paths, or access-points to paths (e.g. through bollards) – as found in a German-language survey conducted by (Gaffga and Hagemeister, 2015). This may limit access to these facilities, especially because trailer-length may reduce manoeuvrability. In keeping with Powell and Tanz (2000) respondents suggested that the low stature of trailers may result in them not being seen by motorists – a crash risk which might be addressed by consistent use of flags to demarcate the end of bicycle trailers and public awareness campaigns.

The primary issue for tagalongs appears to be compromised handling and balance, often due to the child rider's behaviour. Safety may be improved by advising parents about what to expect from children and what instructions to give them. Tagalongs are also subject to the length-related issues of trailers outlined above. Some safety issues for trailers and tagalongs are consequences of the cycle-trailer combination being an articulated vehicle. When trailer mass is large the trailer may jackknife, in addition to braking deceleration being much reduced. Design guidelines for bicycle lanes and paths, and access points, should accommodate most available trailers (e.g. by positioning bollards with consideration of required turning angles). Improvements to design standards may address some safety issues of trailers and tagalongs. The preface to the Australian adoption of the European standard for cycle trailers (Standards Australia, 2018) explicitly identifies that "the specified safety requirements and test aim to ensure that (i) a child is not exposed to hazards while being transported in a trailer attached to a pedal cycle, excluding hazards arising in a crash… and (ii) the child with trailer represents as minimal a hazard as possible for the operator of the pedal cycle to which they are attached." (p.2). The standard includes a single quasi-static stability test. Greater consideration could be given to design specifications which would further address aspects relating to handling and access to cycling facilities (e.g. dimensions). The standard specifies that the instructions shall include "information on the driving behaviour of the cycle/cycle trailer set, especially when driving downhill or around corners" (p.24) and the warning "a bicycle with a trailer attached may take longer to stop" (p.33), which is a more precise modification of the phrasing from the European Standard. This warning is also included in the Appendix that adds consideration of tagalongs. The standard could mention issues which may arise due to the width, length and low stature of the trailer/tagalong and suggest management strategies. Specifications and test methods relating to the stability of tagalongs do not involve a child rider, and so appear not to respond to issues resulting from their movements and steering.

The current study extends that of Rafferty et al. (2016) by considering risks specific to accompanying children. The most prominent issues related to children's incompletely developed bicycle handling skills, as well as their limited knowledge of rules and guidelines. Lack of awareness or tolerance of these issues from other path/road users was also raised quite frequently as a specific risk. Strategies to mitigate the resulting risks might include infrastructure suited to the characteristics of children's riding (e.g. wider paths/lanes, suitable crossing facilities) and education campaigns to educate accompanying adults and other path/road users about what to expect from child riders.

The potential for benefit of advice to parents is highlighted by aspects of the present results. Respondents reported modifying their behaviour when riding with children, primarily in the interests of the children's safety. Consistent with Rafferty et al's (2016) findings, respondents indicated that they ride more slowly and cautiously, and choose their routes and/or travel times to avoid busy roads. When accompanying children, respondents reported riding in a position to model safe behaviour, identify hazards, or to shield the child from cars. The estimated rate of crashing when riding with children on the bicycle (1.3 per 1000 h) was considerably lower than the overall crash rate estimated for the full Safer Cycling Study cohort (6.06 per 1000 h; Poulos et al., 2015). Similarly, Rafferty et al. (2016) found that reported near misses when transporting children were less frequent than near misses when riding alone Nonetheless, the estimated rate of crashing when riding with children has low reliability because it is based on reports for the previous 12 months (whereas the full cohort estimates were based on weekly diaries). The finding may reflect greater care on the part of surrounding road users, as well as parents' behaviour.

Consistent with earlier findings (Hagel et al., 2015; Murray and Ryan-Krause, 2009; Powell and Tanz, 2000), falls were the most common type of crash when riding with a child on the bicycle, in keeping with the participants' reports of compromised balance associated with child seats and tagalongs. Tagalongs were involved in 5 of 14 crashes (36%), suggesting overinvolvement when compared to their accounting for 20% of carriers used (noting, however, that this comparison does not account for distance travelled).

Our participants appear to be cautious about the age at which a child could start to be carried on a bicycle. Most sources of guidance, including the Australian standards for child seats and trailers for bicycles, indicate that children can be carried on a bicycle when they can sit unaided while wearing a helmet. Although this milestone is normally reached approximately 12 months of age, participants considered "a child to be old enough" to be carried in a seat or trailer at between 15 and 17 months (with a high degree of variability).

Standards for child seats and trailers are silent on head protection, which is provided at best vicariously through other performance attributes (e.g. strength of the trailer or seat, and strength of the restraint harness).

Data concerning children's use of helmets collected in the present study suggest that children are less likely to wear a helmet when on or attached to an adult bike, than when riding on their own bicycle. As would be expected in the context of mandatory helmet-wearing legislation that has operated in NSW since 1991, the proportion of participants who reported that children they rode with always wore a helmet was fairly high; 87.5% for children travelling in bicycle-mounted carriers and 96.5% for children riding their own bicycle. It is acknowledged that these results may be distorted by socially desirable responding. The most recent observational data available for NSW, collected in 1993, indicated a compliance rate of 75% for under 6 year-olds and 82% for 6–12 year olds (Smith and Milthorpe, 1993), while a more recent study in Queensland (Debnath et al., 2016) reported a compliance rate of 94.2% among observed cyclists classified as children (mostly riding their own bicycle). In any case our results indicate a concerning rate of non-compliance, particularly among children travelling on an adult bicycle. This may partly reflect the youngest children, who are more likely to be on an adult bicycle, rejecting the helmet. Allowing children to ride on or attached to an adult bike without a helmet may establish a habit of not wearing a helmet. There may be a need to consider opportunities to educate those who ride with children that children are required to wear a helmet regardless of whether they are riding or attached to the bicycle (including in trailers) and that the carriers themselves do not offer a substitute for a helmet. Observational verification of the reported helmet wearing rates would be a worthwhile subject for future research.

Results of the present study give guidance as to a key target audience for education materials about riding with children. There appeared to be a tendency for bicycle riders who rode with children to be aged 25–44, and to be male, and for bicycle riders who ride with children on their bicycle to be mainly transport riders with high confidence on busy main streets. Relationships between personal characteristics and riding with children were not tested statistically because comparisons are complicated by attrition from baseline to the sixth reporting week (when questions about riding with children were asked).

There are several potential limitations in this research which must be acknowledged. First, the data were collected in 2011/2 and may be

outdated. However, the cycling environment that existed in NSW in 2011/2 is little different to the current environment in NSW and in other developing cycling nations – so the findings are still likely to have broad relevance. Second, the data were provided by a volunteer sample of adult cyclists which, while recruited through a wide variety of channels, may not be representative of the broader population of cyclists in NSW. Therefore, caution should be applied in generalising our findings. However, our sample broadly reflects the gender and age distributions that might be expected from relevant state and national surveys (Rissel et al., 2014). Third, our data rely on self-reports which are subject to errors of recall and/or reporting. For example, we cannot rule out misclassification of infrastructure type or poor estimation of time by cyclists. In addition, specific to the present research questions:

- The number of crashes that occurred with children on the respondent's bicycle was too small to allow meaningful analysis of potential crash factors. Nonetheless, the descriptive analysis undertaken offers some important insights into the profile of crashes that occur with children on the bicycle.
- We could not identify whether crashes that occurred while respondents were accompanying children riding on their own bike involved the child (or just the respondent) so consideration of these crashes was limited.

Our study did not aim to examine reasons for *not* riding with children, and so we did not ask relevant questions of respondents who reported that they had not ridden with children in the past 12 months. We did not ask respondents about whether they had children with whom to ride which is likely to be a primary determinant of riding with children. In the absence of information about this important predictive variable we decided that it was of little value to compare the characteristics of respondents who report riding with children, with those of respondents who did not. Nonetheless, the reported characteristics of respondents who reported riding with children may assist with targeting relevant messages. A study designed to examine the reasons for not riding with children would be a useful addition to the literature.

Nevertheless, the study has substantially extended available knowledge about why and how people ride with children, as well as the safety issues they experience when doing so. It suggests that the safety and uptake of riding with children may be improved by

- refining design standards for bicycle-mounted carriers to
  - ○ Address the instability of child-seats and tagalongs, and minimise the length and width of trailers to improve manoeuvrability;
  - ○ Provide clear and detailed information about the safety issues that may emerge when riding with children (including in specific carriers) and suggest management strategies.
- refining design guidelines for cycling insfrastructure to account for
  - reduced speed, handling, and stability, as well as potentially larger dimensions, of bicycles carrying children. Requirements of access points should be specified (e.g. placement of bollards, ramps);
  - the lower skill and predictability of young children riding their own bicycles (accompanied by parents).
- providing cycling infrastructure that is appealing to adults riding with children. Concern about busy roads, and hazards associated with footpaths and shared paths, suggests prioritising bicycle-only paths, or on-road routes with low traffic volume and speed (see Minikel, 2012).
- providing guidance to
  - adult riders about choice of fit-for-purpose bicycles and bicycle-mounted carriers.
  - adult riders about what to expect, how/where to ride, and what instruction to give children when riding with children in different ways (including using different carrier types).
  - other path and road users about the handling characteristics and dimensions of different child carriers and the behavioural characteristics of child riders.

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