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Children on bicycles in baby carriers – numerical and experimental approaches

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ABSTRACT: The aim of this paper was to analyse the vulnerability of children travelling in bicycle-mounted child seats and in bicycle-attached trailers. This paper presents an original description of the post-impact kinematics of children transported in a bicycle baby carrier. A focus is given on the influence of the vehicle's velocity and particularly its front-end design on the post-impact kinematics of the child. Experiments with an Anthropomorphic Test Dummy helped to identify the comparability of both head impacts, first to the vehicle's front-end and finally by the side fall to the ground. Moreover, the experiments pointed to the discrepancy between the dummy's rigid head form and the deformable and highly non-linear real head and brain. An aspect, which limits research and experiments toward the ability to identify and explain the nature of common, but tendentially severe head and brain injuries out of bicycle fall and impact situations. Overall, the study found that the crashworthiness of the baby-carrier is inadequate, with accidents often including head side-impact and face-first contact to the bonnet, as well as a high likelihood of secondary impacts.

KEYWORDS: bicycle baby carrier, vulnerable road user, injury biomechanics, finite element head model

1. Introduction

Cycling is promoted as a healthy and safe type of transport in urban and sub-urban areas and while this is relatively true, some study shows it to also be true that crashworthiness must be improved by additional active and passive safety devices for bicyclists and their passengers [1-3]. The focus of this study is to perform a safety analysis of children travelling in dedicated bicycle baby-carriers. The crashworthiness of a popular rear-frame-mounted baby-carrier was investigated. While kinematics and biomechanics are broadly studied for pedestrians and cyclists, there is no clear understanding of the injury risk of child passengers in commonly used bicycle baby-carriers. Commonly affected after a fall or impact are head, elbow and forearm, but also the wrist, hand and foot with ankle. As the head is, in most cases, the main treated body region, the data correlates with the research of Miyamoto and Inoue [4], as well as Kishibe et al. [5]. Thus, this study can contribute to the improvement of the crashworthiness of these devices and of child safety while being transported on bicycles.

2. Methods

The authors simulated variability of possible real-world frontal and side-impact scenarios via a hybrid finite element (FE) multibody framework achieved by coupling LS-DYNA and MADYMO software. The geometrical models of the vehicle, baby-seat and trailer were created using a 3-D scanner and an advanced photogrammetry method to obtain a realistic cloud of points, which was subsequently transformed into FE models. The implementation of an original bicycle model and biofidelic multibody dummy models allowed the authors to evaluate the influence of the transport modes on the resulting kinematics. The constitutive material models, both for the vehicle, the bike and the baby transportation devices, were also investigated through destructive and non- destructive tests. Finally, some parts of the numerical models were validated during experimental research. This two-step approach is illustrated in [6]. The results are compared to full-scale tests presented in the literature, as well as to the authors' preliminary verification test with a bicycle and seated Hybrid III child dummy.

3. Discussion and conclusions

The main goal was to assess the safety measures and injury risk for children transported in commonly used types of baby carrier. The structure of the bicycle-mounted baby-carrier was found to be a very important factor in terms of changed moment of inertia. In addition, we observed a strong likelihood of direct cranial impact for trailer transport. Generally, the resulting child kinematics differs significantly from the kinematics observed for the cyclist. Besides the very high possibility of second impact of the seated child to the ground, it was obvious that seatbelt performance must be improved to enhance the baby carriers' crashworthiness. The flexibility of the baby carrier and of the FE three-point seatbelt means that the infant's harness can loosen in a crash scenario. This is particularly the case when a child is not properly belted or when the seatbelt is affected by the child's clothing, for example when wearing a thick jacket in wintertime [7]. Figure 1 depicts:

(a) 50th percentile male and 1.5-year-old child multibody models coupled with a FE vehicle: child on bicycle-mounted seat – compact car impacts at 40 km/h. The child slips out from seatbelt and impacts the bonnet. The child's seat crashworthiness is assessed – the head bonnet contact is magnified.

(b) The impact scenarios for a bicycle with an attached child trailer. In this case, the combination of bicycle and trailer is hit by the vehicle, with an initial velocity of 40 km/h, at approximately the seating position of the transported child. A direct cranial impact to the front of the vehicle was observed at 55 ms after the initial collision with the side of the trailer.

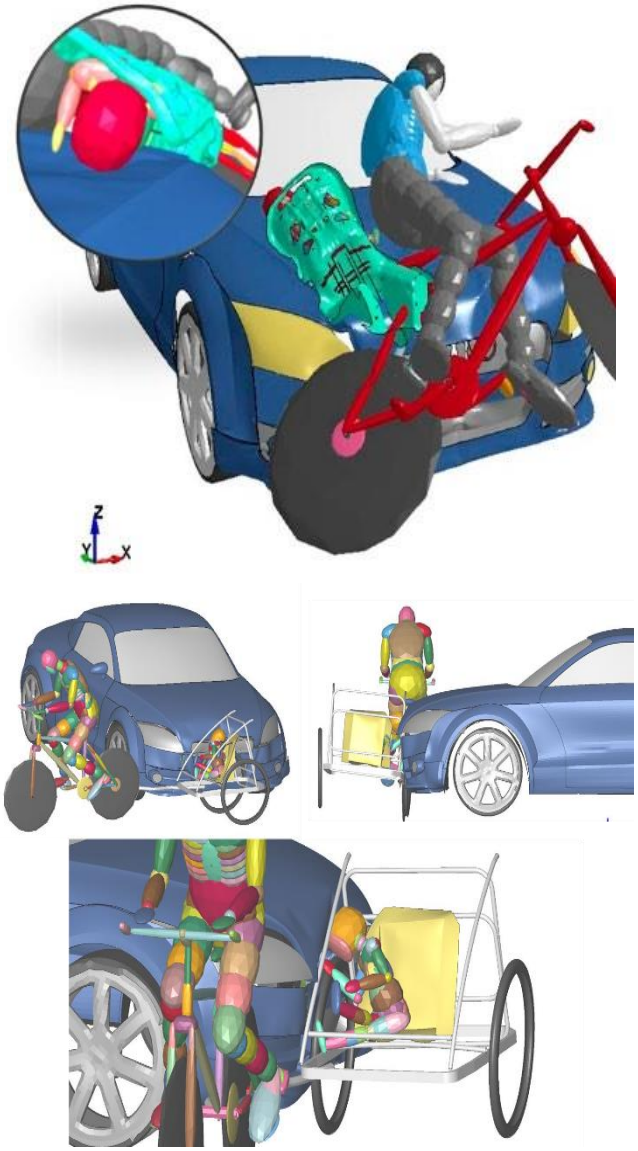

Fig. 1. Impact situations for the bicycle with an attached child: (upper) seat; and (lower) trailer

The bicycle baby seat proved during the simulations of crashes a low crashworthiness and underlined in first line its constructional background as an additional seat for a child on a bicycle only. Nonetheless, the results revealed the higher possibility of multiple occurring head impacts over the full crash and impact situation. Hence, the additional passive safety device U-band was proposed, which is intended to be attached to the baby carrier. It includes the material of agglomerated cork as a shock absorption layer.

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