Preemies: Anthropometry and Body Shape Models

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I. INTRODUCTION

Newborns must travel safely and securely on their first car journey, regardless of whether they are born prematurely or extremely small. This is not the case today, as car seats are rarely developed to fit small infants. According to UN R129, child car seats are type-approved based on the child's stature, which also applies to infant seats. It has been shown that the minimum requirements in UN R129 are not sufficient to get a good fit of the harness for small infants [1]. It is well known that the fit of the harness directly affects the car seat's protection in the event of a crash, where poor fit risks the child being thrown from the seat.

Also, there is a lack of anthropometric tools for physical testing representing small infants, the smallest being the Q0 dummy for a 6-week-old infant with a stature just over 50 cm, shoulder height and width of approximately 26 cm and 15 cm, respectively. There are no virtual human body models (HBMs) of children below 1,5 years of age for crash simulations, i.e. the smallest size of the scalable PIPER child model [2]. Hence, there is a need for tools that can be used to develop and assess harness fit and crash safety of infant car seats. Therefore, the aim of this project was to take the first step toward creation of infant HBMs by developing computer-aided design (CAD) surface models representing the bodies of small infants (below 50 cm in stature), that are suitable for use by child car seat manufacturers to evaluate harness fit early in the production process.

II. METHODS

This paper describes the methodology used to develop body shape CAD models representing a population of small infants (preemies), intended for evaluation of infant car seat and harness fit.

NHS Anthropometry Data

A series of anthropometry measurements were collected from babies recently discharged from neonatal units across the UK. All data were gathered by UK National Health Service nurses and specialists in neonatal care and forwarded to CYBEX GmbH for further analysis, as described in [1]. The measurements comprised body mass, total body length (stature), head circumference, shoulder height from groin, and shoulder width. The 5th, 50th, and 95th percentile measurements were calculated for statures of 40, 45, and 50 cm. Each group included individuals with a total body length within ±2 cm of the target stature.

Preemie Model

A baseline preemie CAD model was developed from surface data of a 2-month-old baby, created from medical imaging in the New Mexico Decedent Image Database [3], by morphing it to represent an infant with 40 cm total body length (50th percentile according to NHS data). Morphing was done using the Kriging method within the PIPER tool and 122 target points. Target points were placed on intermediate body areas to proportionally scale body parts where measurements were lacking (Fig 1a).

The baseline model was imported in CREO (PDSVISION) where its facet surfaces were modified to obtain a posture relevant for preemies travelling in car seats. The model was further divided into separate CAD-entities for the torso with head and neck, legs, and the arms. Joints were defined to enable movement of the CAD surfaces for the arms and legs, to enable easy repositioning for child seats with different back angles.

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III. INITIAL FINDINGS

There were complete measurements for 524 premature individuals of which 117 had a stature of 40 ±2 cm, 258 had a stature of 45 ±2 cm, and 91 had a stature of 50 ±2 cm. Table I lists the 5th, 50th, and 95th percentile measurements. There are larger variations in the three stature groups than between them. For harness fit the shoulder height from groin is an important measurement, where the 5th percentile was around 15 cm for all three statures whereas the 50th percentile increased from 18 to 22 cm. Similarly, the 5th percentile shoulder width was approximately 11 cm while the 95th percentile increased from 15 to 20 cm.

The baseline preemie CAD model had a stature of 40 cm, shoulder height from groin was 18 cm, shoulder width 13 cm, and head circumference 31 cm (Fig. 1b). The resulting mass was estimated using a body density of 1000 kg/m^3 [4] to 2.17 kg, which compares well with the median mass of 1.98 kg in Table I.

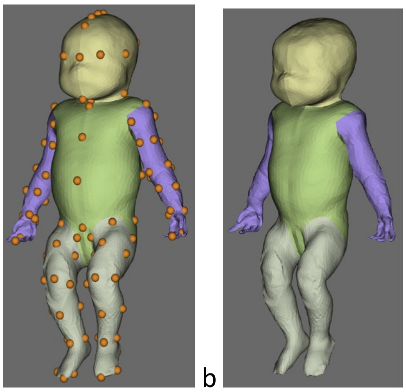

Fig. 1. a) Facet surface of 2-month-old with target points for morphing, and b) 40-cm stature baseline preemie CAD model.

TABLE I
MEASUREMENTS FROM NHS ANTHROPOMETRY DATA

		40-cm stature			45-cm stature			50-cm stature		
		5%	50%	95%	5%	50%	95%	5%	50%	95%
Shoulder width	[cm]	10.0	12.5	15.2	11.0	13.0	16.6	11.0	14.0	18.5
*Shoulder height**	[cm]	14.4	18.0	23.0	15.9	19.0	23.6	17.0	21.0	26.0
Head cir.	[cm]	29.0	31.0	33.1	30.0	31.7	34.5	31.0	34.0	36.8
Mass	[kg]	1.58	1.98	2.47	1.82	2.17	2.86	2.15	2.90	3.78

* Shoulder height from groin.

IV. DISCUSSION

The developed baseline preemie CAD model will be used to morph models representing the 5th and 95th percentile 40-cm stature infants, the 5th, 50th and 95th percentile 45-cm stature infants, and a 50th percentile 50-cm stature infant. Then, these models will be tested in the CYBEX GmbH product development process. User feedback will be used to improve the models before they are released with an Open-Source license, preliminary in the fall of 2024. Body shape models (CAD-models) of small infants can help to improve child seat design and is especially important for harness fit, which directly impacts traffic safety for this young population. This is a first step towards creation of, currently lacking, tools that can be used by child car seat manufacturers to improve infant car seats to fit the population of small infants. One limitation of this study is that it solely focused on obtaining the external dimensions of infants without addressing the internal organ structures.

Future work encompasses creation of finite element HBMs, similar to the PIPER child models [2], that can be used in car crash simulations to improve or assess the crash safety of child car seats for the newborn population. We plan on extending the PIPER child model framework and methods to create preemie FE models from the developed preemie CAD models, thus starting to fill the gap of child HBMs from newborn to toddlers. This requires data on internal organs and skeletal bones, which is currently lacking and therefore publication and sharing of such data is strongly encouraged.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

[1] Schleuning S. *et al.*, Prot. Children in Cars Conf, 2022.
[2] Beillas P. *et al.*, Prot. Children in Cars Conf, 2016.
[3] Edgar HJH. *et al.*, NMDID, 2020.
[4] Bondy M. *et al.*, CMBBE, 2014.