The Journal of Health Design

LITERATURE REVIEW

Are traditional head size and shape measurements useful in modern medical design? A literature review

Jonathan Rex Binder, Ertu Unver, Omar Ivan Cardoso Huerta

Department of Architecture and 3D Design, School of Arts and Humanities, Huddersfield University, Huddersfield, UK

To Cite: Binder JR, Unver E, Huerta COI. Are traditional head size and shape measurements useful in modern medical design? A literature review. JHD.2022;7(2):500–506. https://doi.org/10.21853/JHD.2022.183

Corresponding Author:
Jonathan Rex Binder
Department of Architecture and 3D Design
School of Arts and Humanities
Huddersfield University
Huddersfield, UK
j.binder@hud.ac.uk

SUMMARY

Scalp cooling is a clinically proven treatment for addressing chemotherapy-induced alopecia (CIA). Previous studies show that the efficacy of this treatment relies on accurate cranial data so that designers can produce close-fitting scalp cooling caps. The cephalic index is often used, but are that data still accurate? In this literature review, we identified and explored previous studies concerning head size and shape with the goal of identifying shortcomings for design purposes. The literature review indicates that a more suitable method is needed to collect data to enable mass customisation of scalp cooling caps. Head data are more complex for design.

Key Words

Cephalic Index; chemotherapy-induced alopecia; scalp cooling; mass customization; cranial anthropology

ABSTRACT

Background

Clinicians and Paxman Coolers Ltd. would like to prevent patients from suffering from chemotherapy-induced alopecia (CIA), which requires a close-fitting cap. The cephalic index, which is often used for head size analysis in many medical conditions, is insufficient for applications of design.

Aims

The authors conducted a detailed literature review on available human head data because access to accurate and up-to-date anthropometric data are crucial for wearable design. The authors conducted this literature review for a project focused on developing a wearable medical cooling cap. The design must be as close-fitting as possible to obtain the highest levels of efficacy. One of the best options for achieving an improved fit is through customised designs. The aims of this literature review was to identify if the current literature on cranial anthropology is sufficient to provide designers with the data required to achieve a mass customisation approach to tailored wearable medical designs for scalp cooling.

Method

In an extensive literature review conducted over the past year between 2020 and 2021 the researchers retrieved more than 175 papers, including journal articles, clinical studies, conference

studies, and content from master's and PhD theses. The research terms used included a systematic review according to Paxman's critical design inputs for efficacious cap fit. Primary outcome measure were global anthropometric studies in cranial anthropology.

From the 175 studies a collection of relevant papers[1,2,3,4,5,6] focused on the human head size data, which had the most impactfil influence on this study, including studies such as SizeChina, Caesar, Gayre's race studies, and some of the research team's published literature.

Conclusion

The literature review revealed shortcomings with traditional ways to measure human head size and the challenges of using them for mass customisation of scalp cooling caps. More data, including individual data, are required for mass customisation. Designing scalp cooling caps to be effective for all head sizes and shapes requires an elevated level of design complexity.

BACKGROUND

Head shapes and sizes are widely studied by researchers conducting studies about face masks, childbirth defects, biological analysis, and race identification. Little data exist about product development applications that will help researchers and designers create products worn on the head and those requiring a close fit to the scalp. We conducted a literature review to assess what information about head shapes and sizes is already available. To achieve high levels of efficacy, patients require a fit that closely mimicks their scalp. Such data require a wealth of parameters to be considered, including head shape profiles. The cephalic index, one of the most common measures used, is an equation of the maximum width of a head, divided by the maximum length x 100. This equation is one key parameter that helps to differentiate between different human races.

Historical studies with univariate data show the shape differences between Asian and Western head sizes. However, the information available to designers has traditionally been based on mainly Western Caucasian data such as the research by Godil & Ressler.[7] Quantitative 3-D human head shape data analysis from CAESAR[8] and SizeChina[9,10] discuss anthropometric clustering, whereas Azouz studies[11] explored automatic locating of anthropometric landmarks on 3-D human models.

METHOD

The research team conducted a systematic review between 2020 and 2021. The research team used Elsevier, Google Scholar, Science Direct, Scopus, Core, Crossref metadata, local libraries, Summon, and Pure (for Paxman papers).

The search terms used came from Paxman's critical design inputs for efficacious cap fit. Search terms included cephalic index, chemotherapy-induced alopecia, scalp cooling, mass customization, and cranial anthropology. We looked for studies on cranial birth defects, cranio-reconstruction, cranio-facial reconstruction, biological studies, and cranial forensic studies. As many studies focus on cranial anthropology, including biological studies and reconstruction etc., the focus was mainly on anthropometric only. Primary outcome measures were global anthropometric studies in cranial anthropology.

The researchers retrieved more than 175 papers, including journal articles, clinical studies, conference studies, and content from master's and PhD theses. From the 175 studies a collection of relevant papers[1,2,3,4,5,6] focused on the human head size data, which had the most impactfil influence on this study, including studies such as SizeChina, Caesar, Gayre's race studies, and some of the research team's published literature.

RESULTS

Existing research does not help to categorise head shapes for optimal fit on different head shapes globally. Previous research often generalises nuances of head shape profiles. Numerical dimensions, spreadsheets, and unprocessed 3-D scans cannot be integrated easily into the established methodology of design, which centres on sketching, model-making, rapid prototyping, animation, digitising, computer-aided design (CAD), tooling, and manufacturing.[12]

We show early geographical mapping of the cephalic index from 1896 (Figure 1). This equation does not account for idiosyncrasies in racial cranial traits. The cephalic index and head circumference are measured using the reference points in the broad literature for these topics (around the occipital bone, forehead, squamous suture, and sagittal suture). Tape measures, head calipers, and digital verier capilers are used to record numeric data whereas a contour tool is used to capture shape profiles. The cephalic index broadly illustrated cranial differences by looking at the top profile proportions of the head (Figure 2).

Figure 1: Illustration of the 3 main head shape classifications on the global map–1896
(modified from Macgowan and Hester[13])

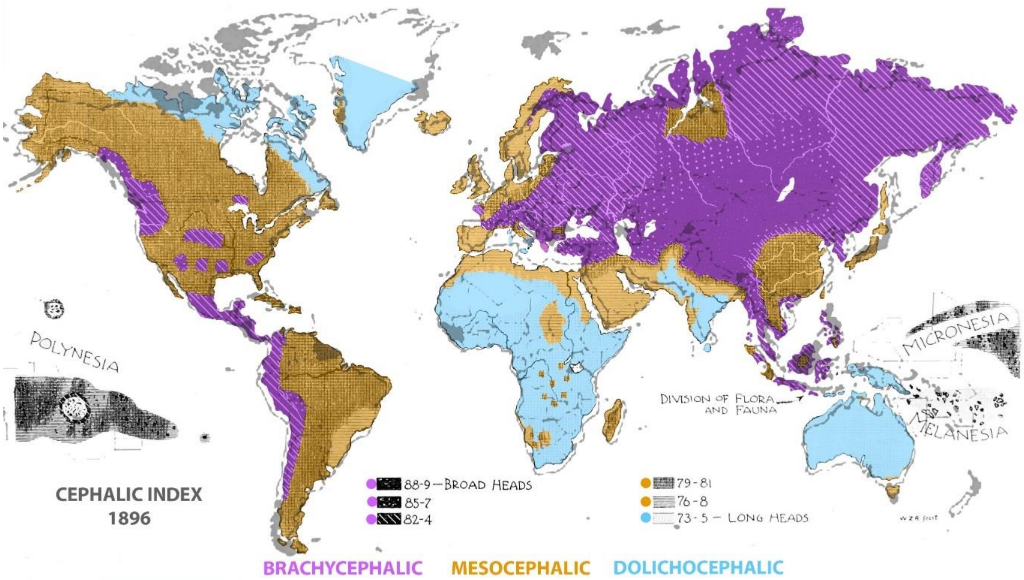
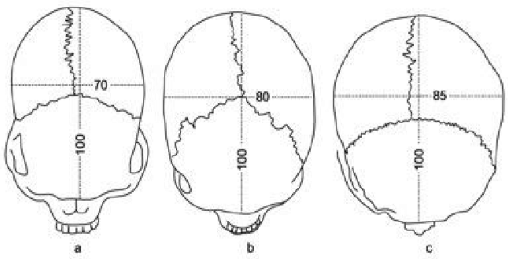
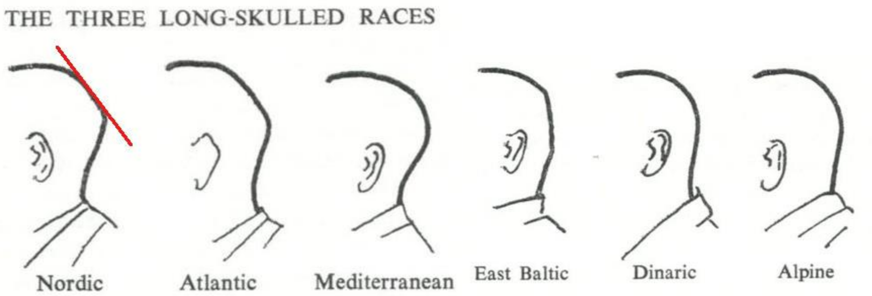


Figure 2: Average head shapes: a-dolichocephalic, b-mesocephalic, c-brachycephalic head shapes (Štefánková[14])



Previous research[15] demonstrates that the crown of the skull that is a main cause of hair loss. Since each head type has distinct, individual characteristics, the authors determined it is necessary to at least generate classifications based on sagittal, coronal, and transverse projections to assimilate a broader understanding of modern international crania. Robert Gayre's miscellaneous racial studies, 1943–1972,[16] determined that additional subcategries within the main categories of head shape types define shape profiles. Gayre's study outlines typical formations of six Caucasoid head shape side profiles (Figure 3).

Figure 3: Six Caucasoid head shape side profiles (Gayre[16])



Macgowan and Hester[13] hypothesised a paradigm shift of the global cephalic index from a predominantly Dolichocephalic shape (long-headed) to a more round-headed mesocephalic or brachycephalic shape profile (broad-headed). Nair et al.[17] evidenced that an average of 15.48 per cent of the population have an ultra-dolichocephalic to Dolichocephalic shape profile, slightly more so for females. These studies show that there are predominantly more round-headed persons rather than long-headed. Roughly 43.3 per cent of the world's population have the Mesocephalic shape profile, with slightly more males being this shape. The remaining 41.2 per cent are collectively Brachycephalic to Ultra-brachycephalic shape profiles. Studies on Brachycephalic, Dolichocephalic, and Mesocephalic skull patterns by Franco[15] hint at the classification of seven head shapes based on data in the science community. Data from sources, including Farkas,[18] 1,470 healthy subjects (18 to 30 years)—750 males and 720 females—demonstrate that the equation remains relevant today, in accordance with this study, over a century later.

Based on the literature review, we determined that the cephalic index is useful for defining skull types, though it is based on a planar X and Y equation. However, scalp cooling requires more data to present a feasible and effective solution to hair loss for CIA.

DISCUSSION

Individuals have idiosyncrasies in human head data, which could be from birth or environmental during their life. Complex factors, including shape, size, race, gender, and culture, can influence individual human cranial parameters as evidenced in the broad literature. Many studies explore these aspects for individual demographics, partially due to broad global variation, need and complexity. It is extremely difficult to accurately provide close fit when grouping many global demographics. Designers can analyse and group some of these data to generate categories, but this inevitably caps the levels of efficacy that can be achieved.

Designers require an approach that consider the parameters required to accurately design a cap to suit individual users, and which can be customised and rolled out within the healthcare industry. Although it would be easy to assume that a designer could generate a optimally fitting cooling cap for individuals with time and resources, commodities are typically in short supply. Efficiency of treatment is also almost as important as the approach. Mass customisation approaches must utilise human-centred methods to ensure an equilibriate approach to accuracy of design and efficiency of data collection.

Our review of the literature reveals that most studies use one of two approaches, automated and manual methods. Most papers investigated a hybrid approach to collect accurate data; these required large resources through time, funding, and people power. For a new approach to be fully feasible, it must be possible to collect data in 10–15 minutes.

CONCLUSION

The literature review reveals that a gap in knowledge exists in cranial anthropology that hinders the optimal design of scalp cooling caps. Current methods for anthropometric data collection are time-consuming and complex to conduct, requiring teams of individuals and many participants to be accurate. A new method, yet to be developed, must be feasible for healthcare professionals to use. Their limited time and resources are the main factors to ensure a data collection method balances optimal data collected for best scalp fit, versus simplicity and speed. The goal is to create a usable process that can be collated in a timely manner and enable data processing by a design team.

Using this extensive literature review results, the authors have highlighted parameters typically used for these types of anthropometric studies to enable product design for head wearables. The results also show crucial considerations for establishing a feasible mass customisation method.

FUTURE RESEARCH

The team intends to conduct a pilot study where the highlighted parameters will be used to capture human head data. The next phase will be to test the methods for suitability in a healthcare approach, where time, complexity, and accuracy of data are collected. These data will also be compared against the literature identified and explored in this review to further validate the gap in knowledge. Following this pilot study, a refining period will mature the approach for the next phase of data collection to be used to generate proof of concept prototypes.

REFERENCES

1. Unver E. Design and Development of a new Scalp Cooling Cap Stage 1: Confidential Design and Development. [Internet] 2013. [Accessed 2022 MAR 1]. Available from: http://eprints.hud.ac.uk/id/eprint/17750/3/Confidential_Research_Report_for_Paxman 10.pdf
2. Unver E, Clayton J, Clear N, Huerta O, Binder J, Paxman C, Paxman R. The challenges of implementing design research within SME based medical product development: Paxman scalp cooling case study. April 26, 2022. 10.1080/24735132.2022.2060649
3. Binder J, Unver E, Kagioglou M, et al. An Approach of Rapid Tooling for Scalp Cooling Cap Design, Computer-Aided Design and Applications. *Computer-Aided Design And Applications*. 2020:17(2):337–47. doi: 10.14733/cadaps.2020.337-347
4. Kinoshita T, Nakayama T, Fukuma E, et al. Efficacy of Scalp Cooling in Preventing and Recovering From Chemotherapy-Induced Alopecia in Breast Cancer Patients: The HOPE Study. *Frontiers in Oncology*. 2019 Aug;9:733. doi: 10.3389/fonc.2019.00733.
5. Unver. E. Design and Development of a new Scalp Cooling Cap - Stage 1 : Confidential Design and Development Report [Unpublished]. [Internet]. 2013. [Accessed 2022 MAR 1]. Available from: http://eprints.hud.ac.uk/id/eprint/17750/
6. Binder J. Investigation of Additive Manufacturing in New Medical Product Development for Chemotherapy-Induced Alopecia. Masters thesis, University of Huddersfield. [Unpublished]. [Internet]. 2019. [Accessed 2022 MAR 1]. Available from: http://eprints.hud.ac.uk/id/eprint/35118/
7. Godil A, Ressler S. Retrieval and clustering from a 3D human database based on body and head shape, SAE Technical Paper Series. July 3, 2006. doi: 10.4271/2006-01-2355
8. Robinette K, Blackwell S, Daanen H, et al. Civilian American and European Surface Anthropometry Resource (CAESAR), Final Report, Volume 1: Summary. June 2002. [Accessed 2022 MAR 1]. Available from: https://www.humanics-es.com/CAESARvol1.pdf
9. Ball RM, Molenbroek JFM. Measuring Chinese heads and faces. In: *Proceedings of the Ninth International Congress of Physiological Anthropology, Human Diversity: Design for Life.* Delft, The Netherlands, pp. 150–155. Bookstein, F.L., 1991. Morphometric Tools for Landmark Data. Cambridge University.
10. Enciso R, Shaw A, Neumann M, et al. Three-dimensional head anthropometric analysis. In *Proceedings Volume 5029. Medical Imaging 2003: Visualization, Image-Guided Procedures, and Display*. 2003. doi: 10.1117/12.479752
11. Azouz ZB, Shu C, Mantel A. Automatic locating of anthropometric landmarks on 3D human models, Third International Symposium on 3D Data Processing, Visualization, and Transmission, 750–757. June 14–16, 2006. doi: 10.1109/3dpvt.2006.34
12. Ball R. 3-D Design Tools from the SizeChina Project. *Ergonomics in Design.* 2009;17(3):8–13. doi: 10.1518/106480409X12487281219931
13. Macgowan K, Hester JA. Early man in the new world, (Revised ed.). The American Museum of Natural History. (2017, August 26). https://www.gutenberg.org/files/55434/55434-h/55434-h.htm#fig89 (The Natural History Library Edition, 1962) Robert Gayre's on Miscellaneous Racial Studies in 1943-1972
14. Štefánková E, Horn F, Omanik P, Neščáková E. Medical Anthropometry in Pediatric Surgery. SM Journal of Pediatric Surgery. 2015;1:1–3. doi: 10.36876/smjps.1005
15. Franco FCM, Araujo TM, Vogel CJ, et al. (2013, June). Brachycephalic, dolichocephalic and mesocephalic: is it appropriate to describe the face using skull patterns? *Dental Press J. Orthod.* May–Jun 2013;18(3):159–63. doi: 10.1590/s2176-94512013000300025
16. Gayre R. (1972). The typical formations of the rear portions and necks of the six Caucasoid races, the three long-skulled races. *Miscellaneous racial studies, 1943–1972 p102 & 209-218.*

17. Anjankar, Vaibhav., Nair, Shema., Singh, Sandeep., et al. (2014). The Study of Cephalic Index of Medical Students of Central India. *Asian Journal of Biomedical and Pharmaceutical Sciences*. 2014;4:48–50. https://www.alliedacademies.org/articles/the-study-of-cephalic-index-of-medical-students-of-central-india.pdf
18. Farkas LG, Katic MJ, Forrest CR, et al. International anthropometric study of facial morphology in various ethnic groups/races. *The Journal of Craniofacial Surgery*. 2005 Jul;16(4):615–46. doi: 10.1097/01.scs.0000171847.58031.9e.

ACKNOWLEDGEMENTS

The authors would like to thank Paxman Coolers Ltd for their continued support and funding of their research; Paxman Scalp Cooling Research and Innovation Center at the University of Huddersfield Co-funded by the University of Huddersfield; and Paxman Coolers Ltd.

PEER REVIEW

Not commissioned. Externally peer reviewed.

CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

FUNDING

Research is co-funded through the Paxman Research and Innovation Centre at the University of Huddersfield.