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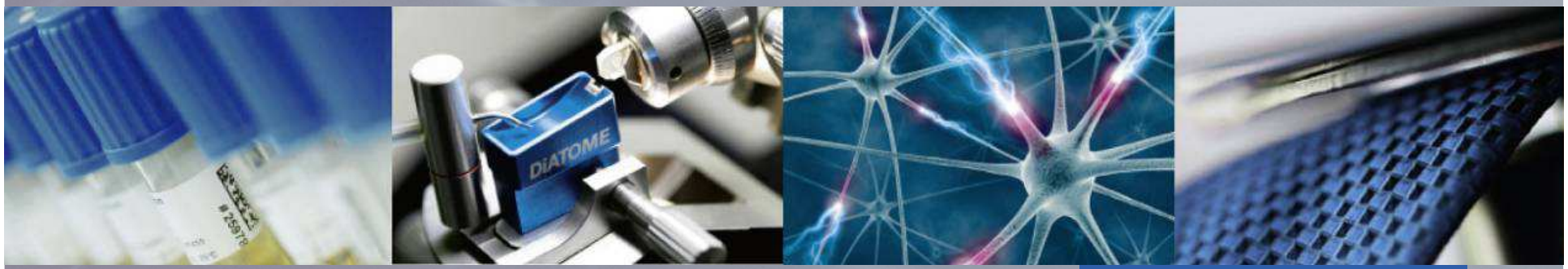
Helmet Fit for Safety and Comfort

New 3D head measurement study helps define parameters for best fit

Dr. Jan Beringer | Hohenstein Institute

Hohenstein Webinar | March 7th, 2013



COMPETENCE IN TEXTILES

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Introduction




Increasing number of users

- Growing markets in job, leisure and sports
- From children to seniors
- Skiing: 16 million skiers in GERmany
- Biking: 68 million bikes in GER, not all bikers wear helmets
- Industry: 10 million workers in GER with need for head protection
- Furthermore: Forest operation, fire dept, police, military, inline skating, rock climbing, horse riding, motorcycling, canoeing and rafting …
- **Growing safety demands by awareness**
  both legal regulation and voluntary motivation

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Introduction

The Facts / Findings

- Helmets avoid or reduce the risk of head injuries
- 2011: 79.000 notifiable accidents at work with head injuries were (according to German statutory accident insurance)
- Head injuries often lead to secondary damage like paralysis and / or speech disorder
- Economic benefit: Reduction of insurance expenses, patient care and rehabilitation
- **Consumer acceptance is needed**
  Only wearing a helmet can prevent from severe head injuries !
- **Fit and wearing comfort optimized helmets are needed !**

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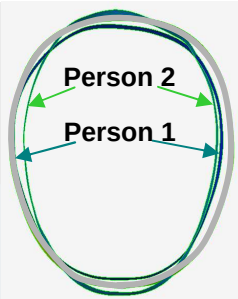
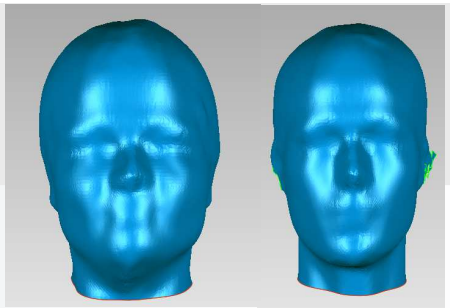
Introduction





The Challenge

- “SizeGERMANY” sizing survey showed remarkable variations in head shapes within the same head circumference
- Additional high-resolution anthropometric head data is needed, in particular shape information
- Market shares in head shape are needed for best market coverage
- Industry standards do not comply with the state of technology anymore, head shape information is missing totally
- Influence of hair on the size measurements and helmet fit is unclear

⇨ **Important basic information for optimized helmet development is not available**

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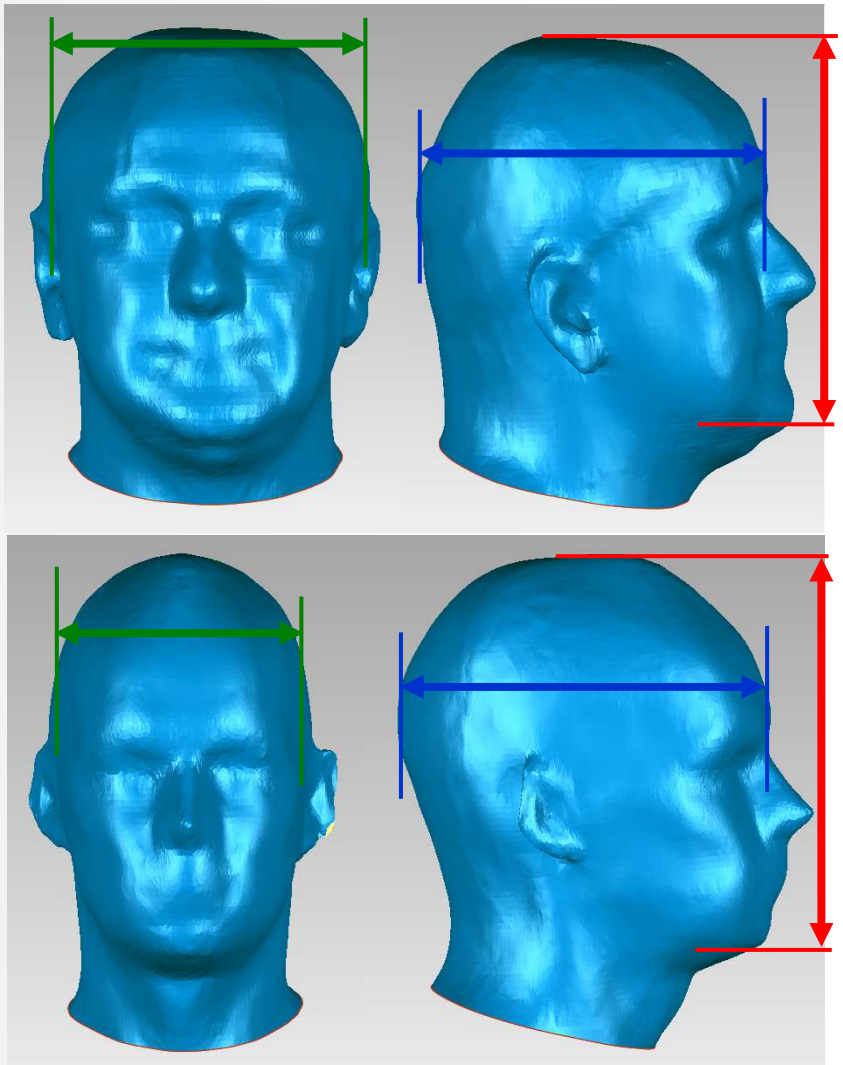
Visual comparison – male subject

male 1

Identical head circumference of 58 cm

	male 1	male 2	delta
Head Height	22,3 cm	22,9 cm	0,6 cm
Head Length	18,8 cm	21,2 cm	-2,4 cm
Head Width	18,0 cm	15,0 cm	3,0 cm



male 2

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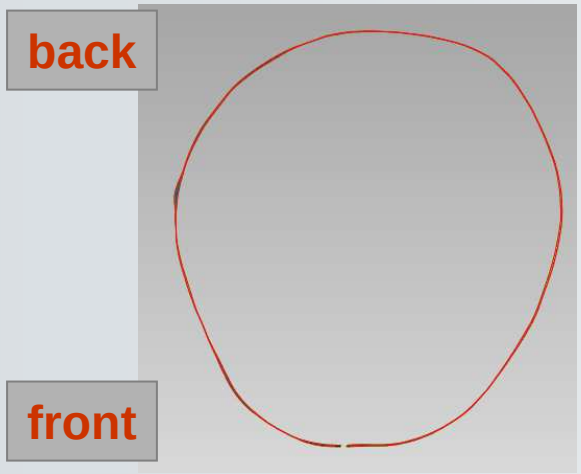
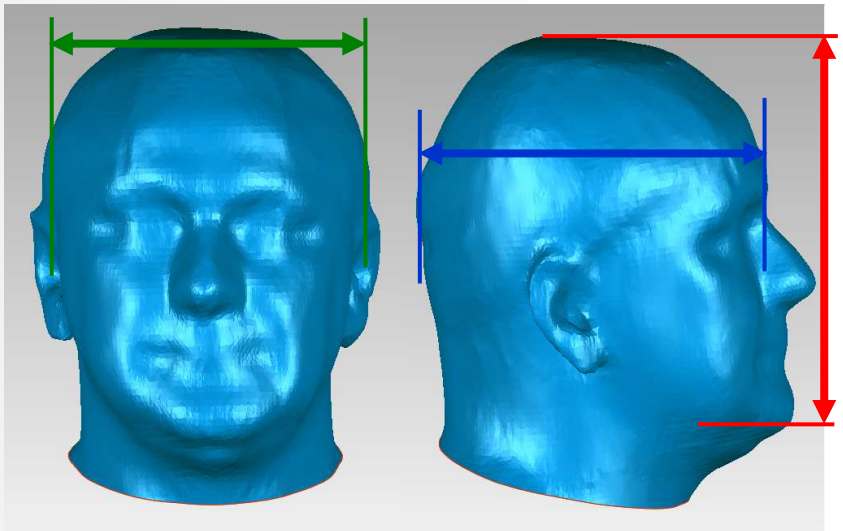
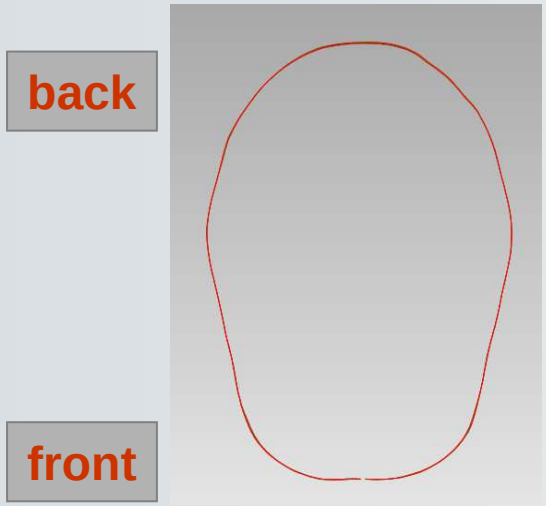
Visual comparison – male subject (view from top)



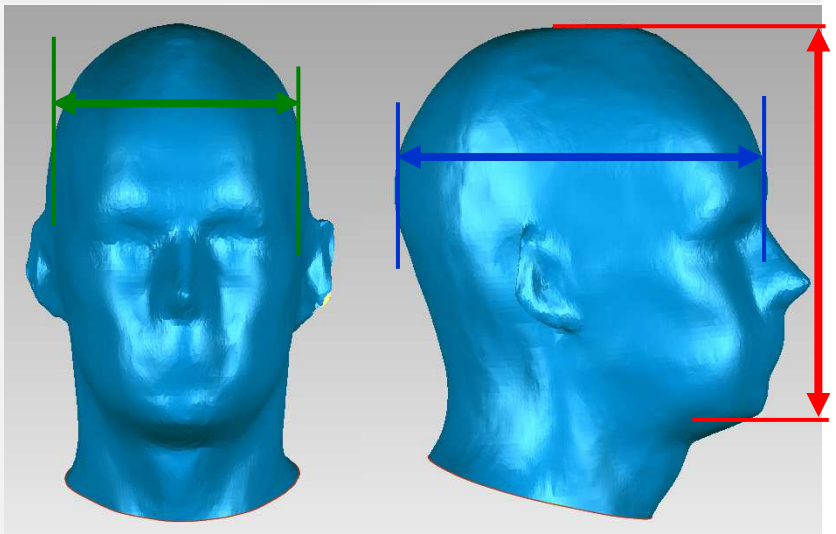
male 1



Circum-
ference
58 cm



male 2



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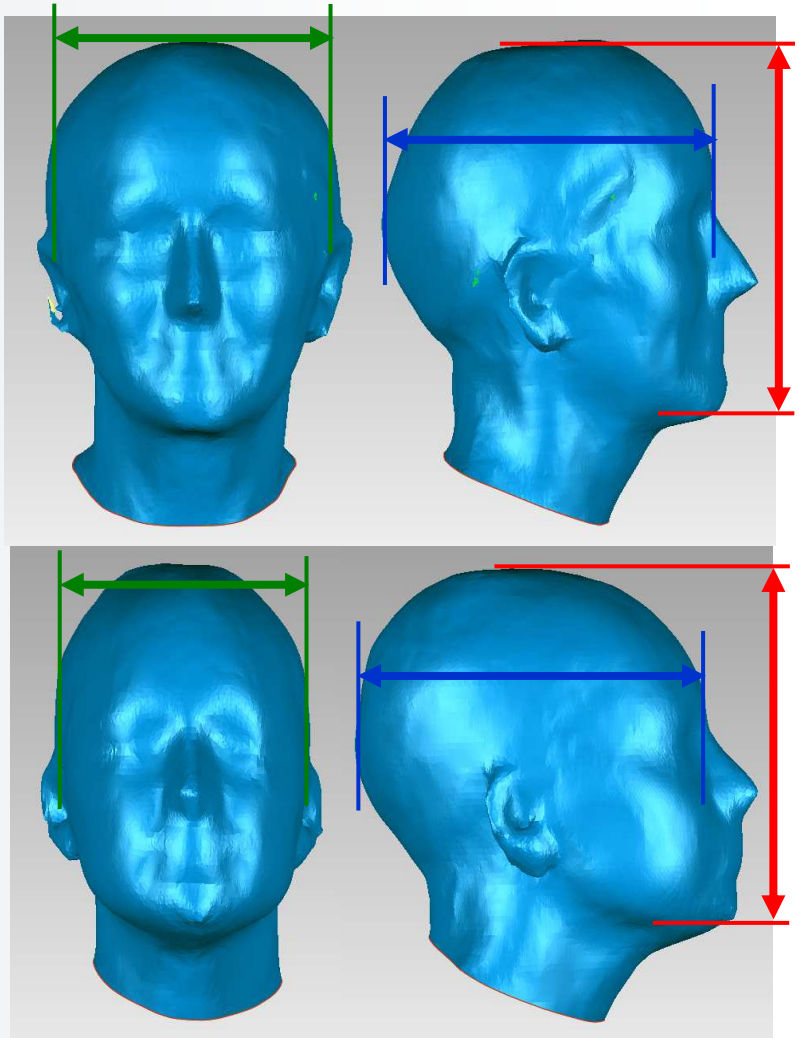
Visual comparison – female subject

female 1

Identical head circumference of 56 cm

	female1	female2	delta
Head Height	21,6 cm	23,1 cm	-1,5 cm
Head Length	19,4 cm	20,4 cm	-1,0 cm
Head Width	17,4 cm	14,8 cm	2,6 cm



female 2

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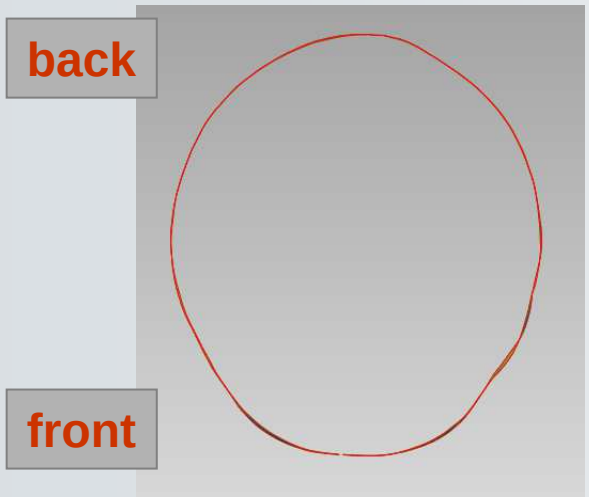
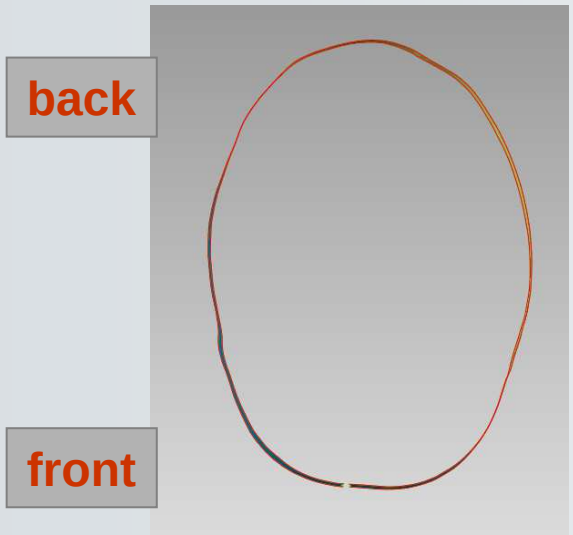
Visual comparison – female subject (view from top)

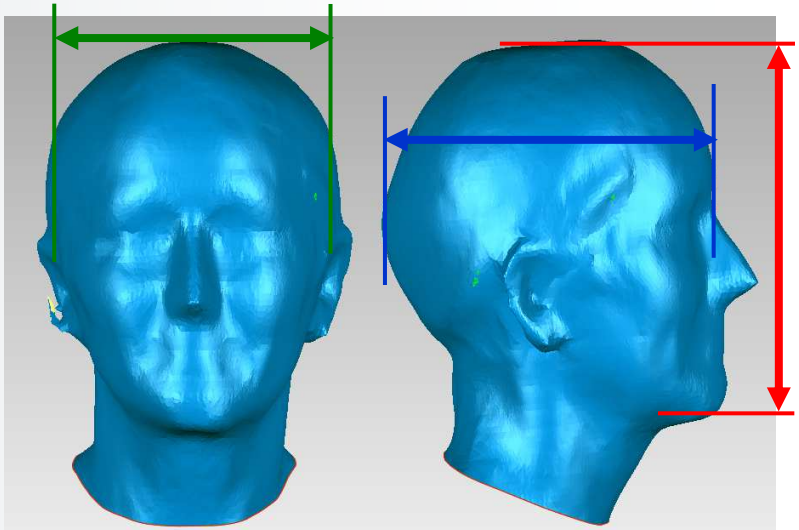


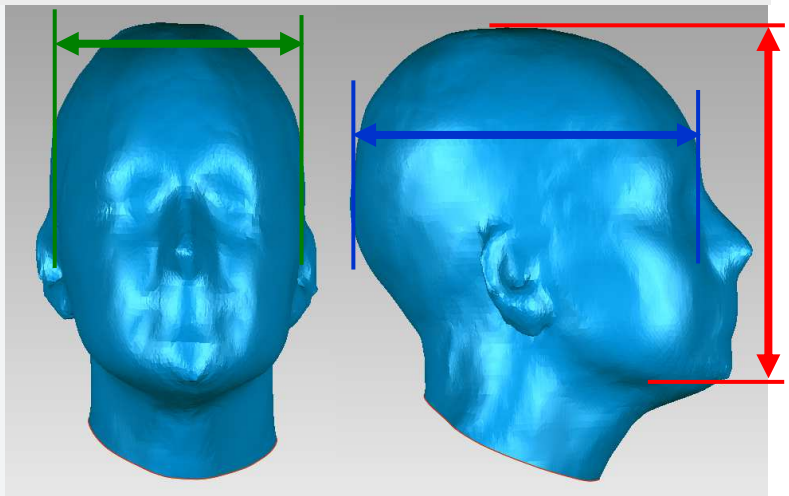


female 1

Circum-
ference
56 cm

female 2





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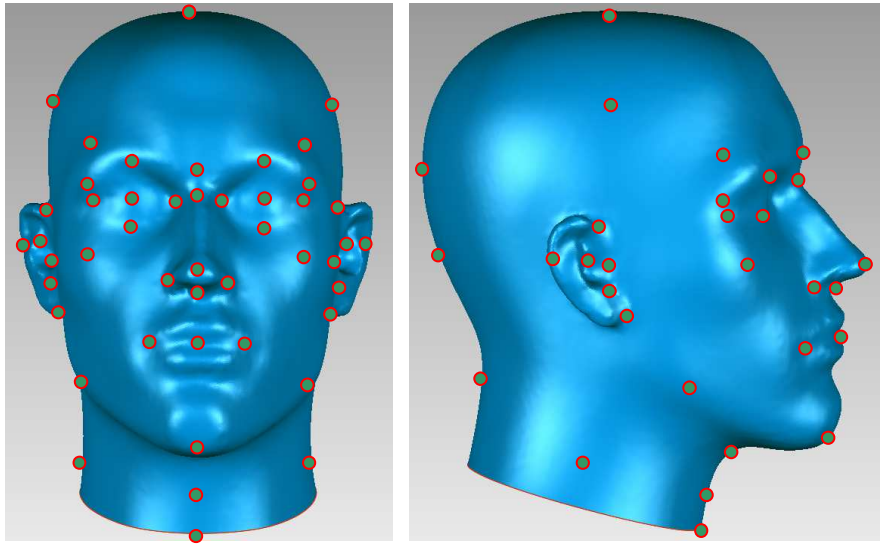
Additional Challenges

- Lack of up-to-date/recent anthropometric face data
- The current industry standards for personal protective equipment (PPE) should be adapted to the state-of-the-art anthropometric data in order to assure best face, ear, eye and respiratory protection



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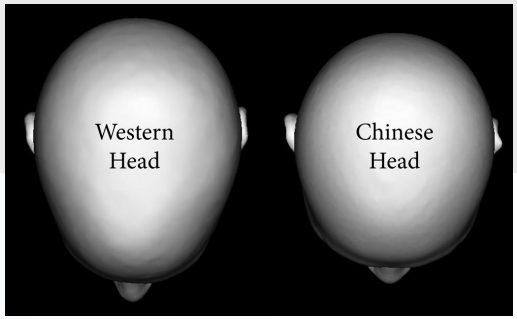
State of technology



Head shape comparison - Size China

Worldwide head-sizing related activities:

- CAESAR-project, 1997-2001 (NL/US)
- NIOSH Anthropometric Survey of Respirator Users, 2001-2004 (US)
- SizeChina (2006): Anthropometric head survey and digital database of Asian heads and faces for use by manufacturers (about 1600 Scans)
- 3D Facial Norms Database (https://www.facebase.org)
  3500 healthy Caucasian individuals age 5-40 (US)
- Various papers (US & CAN):
  - Head-and-face shape variations of U.S. civilian workers (2013)
  - A simple and standardized method for analyzing head and face morphology of a population sample (2010)
  - Sizing trials of a prototype aircrew helmet (2009)
  - Principles of Fit to Optimize Helmet Sizing (2006)
  - Helmet accommodation analysis using 3D laser scanning (2000) etc.

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Aim of the Hohenstein study

The Aim is the improvement of head gear systems considering fitting plus comfort and function

Results:

- Up-to-date face and head measurements and head shapes of men, women and children in Germany
- German market share tables of sex, age and head shape types
- Head specific grading guidelines
- Virtual 3D-head shape models
- Guidelines and design characteristics for optimized development considering fit, ergonomic comfort, thermophysiological comfort and hygiene

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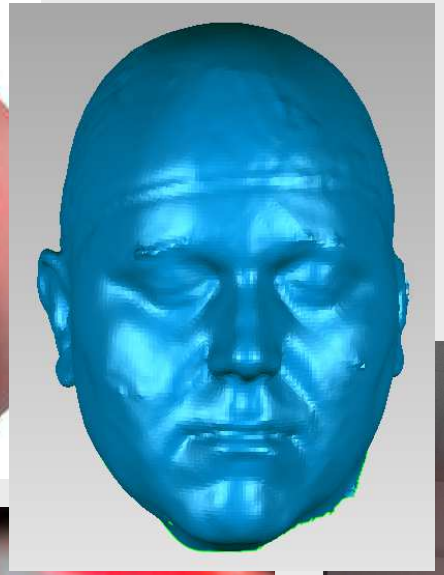
Available 3D Scanner Systems



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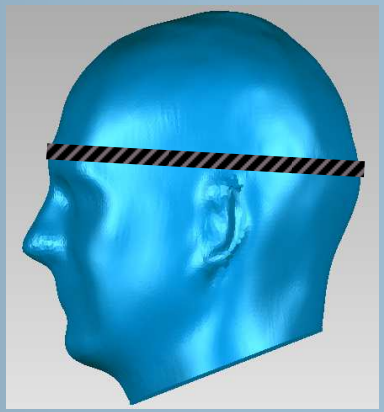
Step 1 of the Hohenstein study

- Detailed analysis of 3D-Scan-data of Hohenstein's own database (17,000+ scans)



- Definition of measurements and methods according to established standards like (ISO 7250, SizeGERMANY etc. plus new additional head and face measurements)

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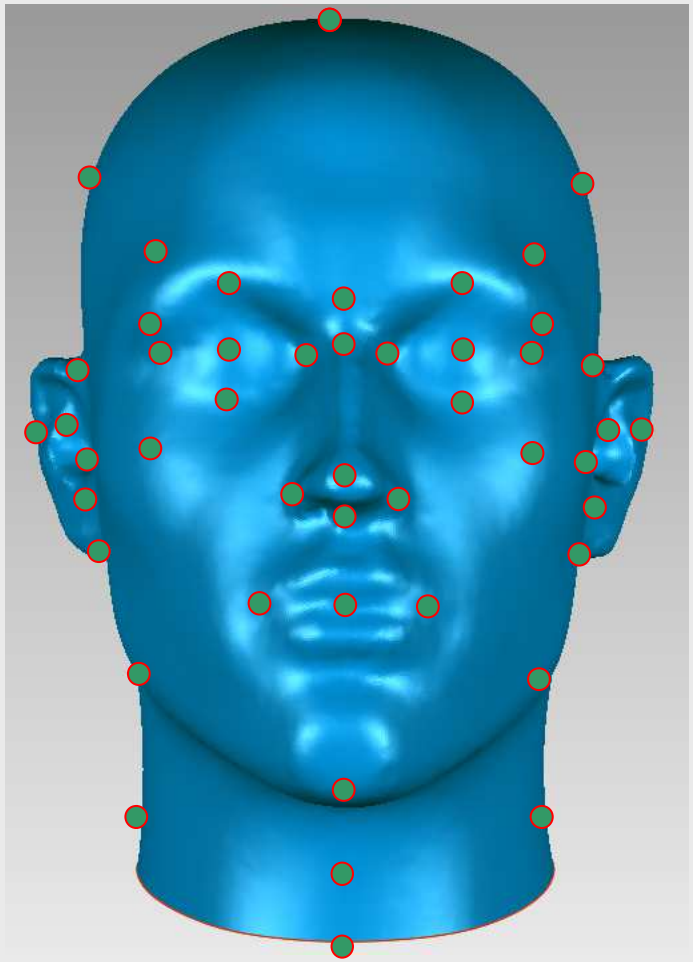
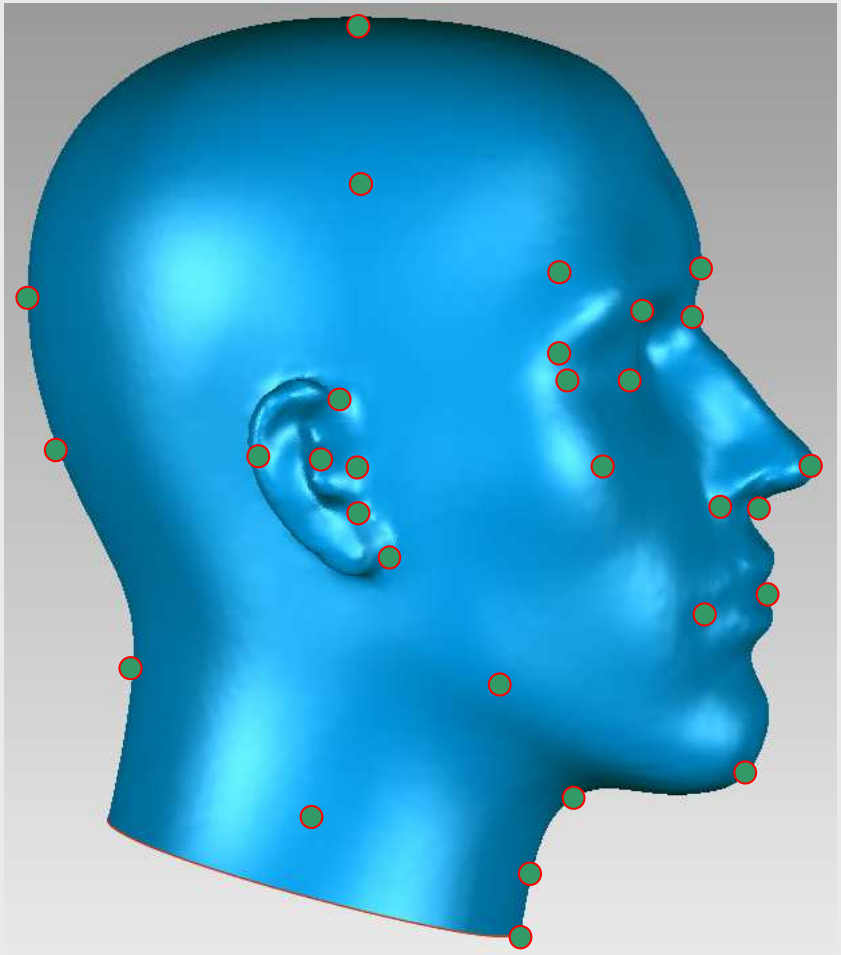
Face Shapes: Landmark scheme





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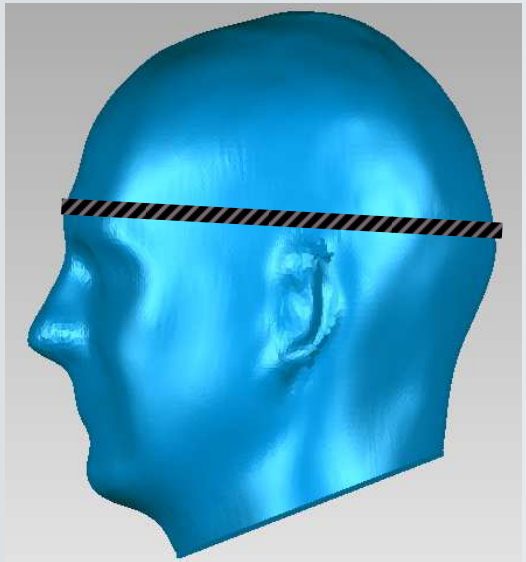
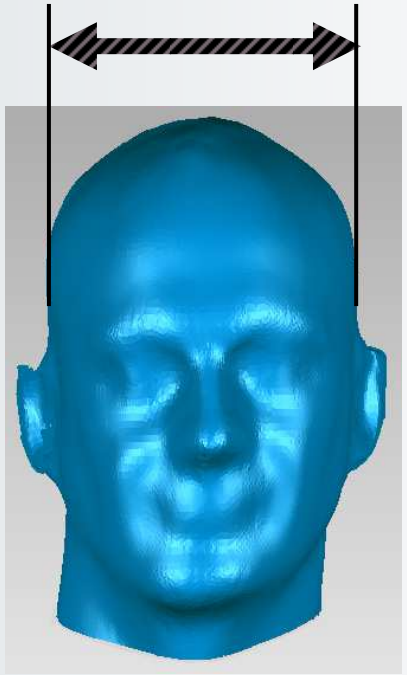
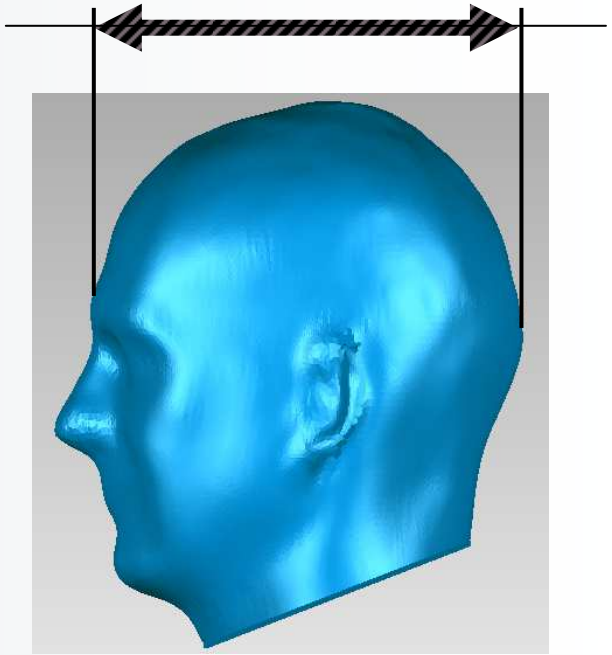
Head, Face and Neck/Chin Measurements



Head Circumference



Head Width



Head Length

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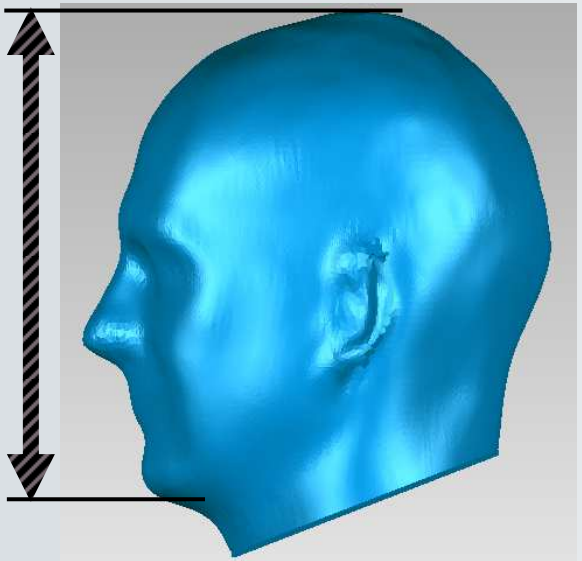
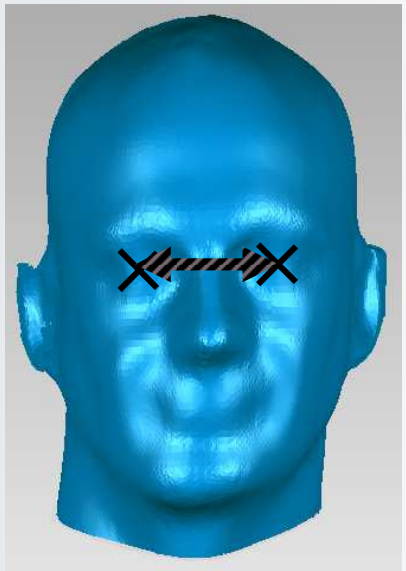
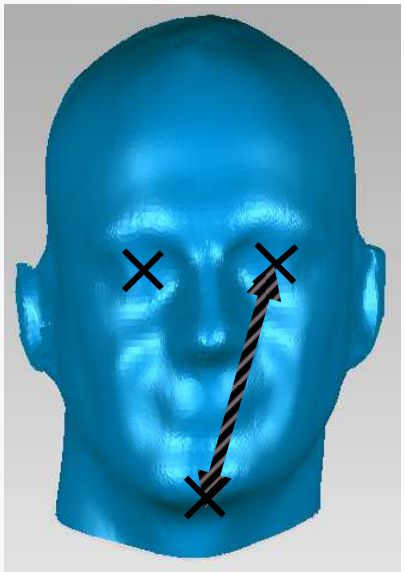
Head, Face and Neck/Chin Measurements



Head Height



Eye Distance



Eye-Chin-Distance

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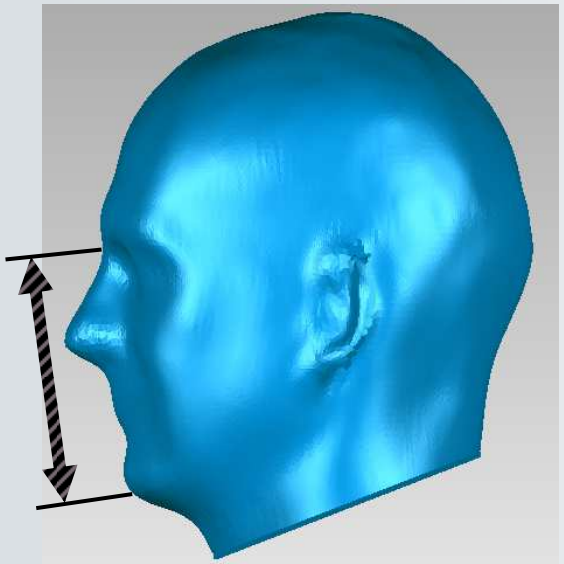
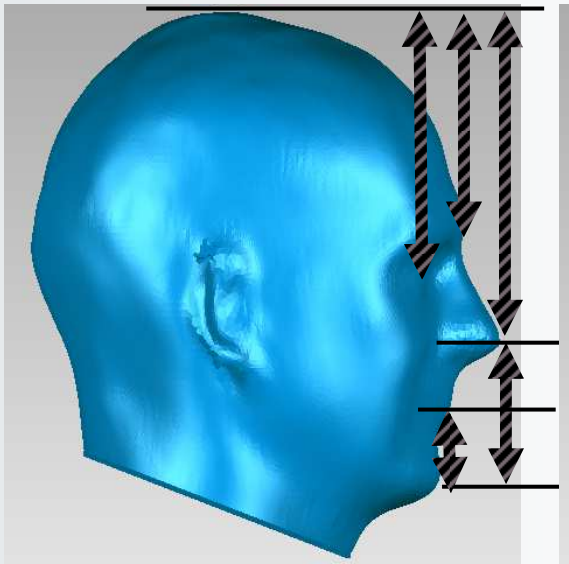
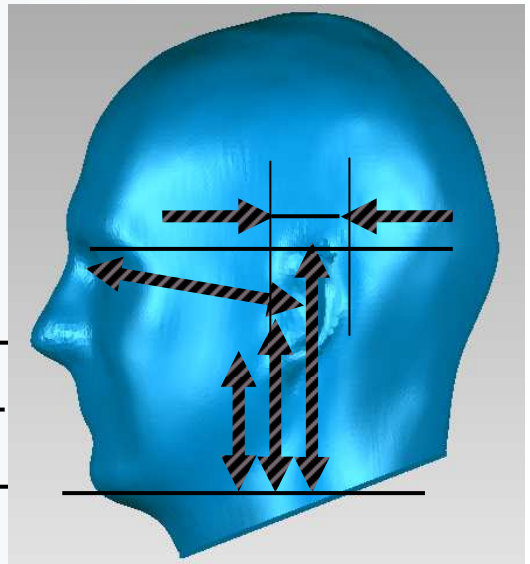
Head, Face and Neck/Chin Measurements



Morphological Face Length



Various Face Lengths



Diverse Ear Distances

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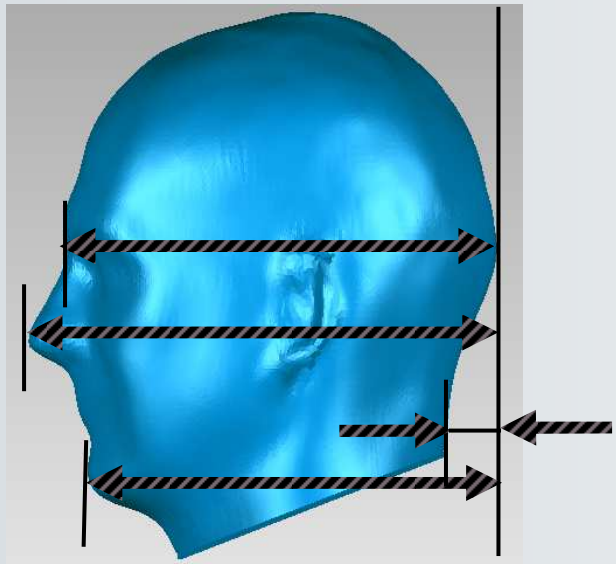
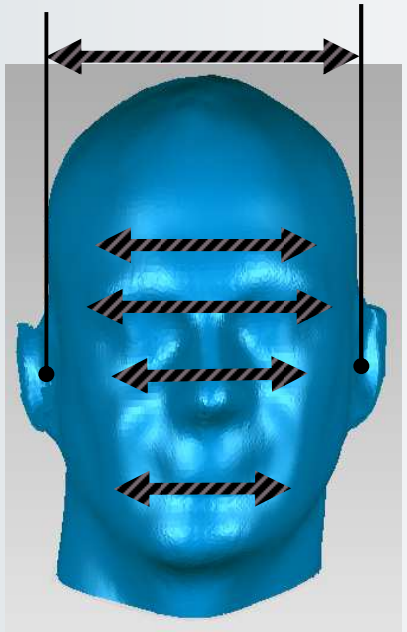
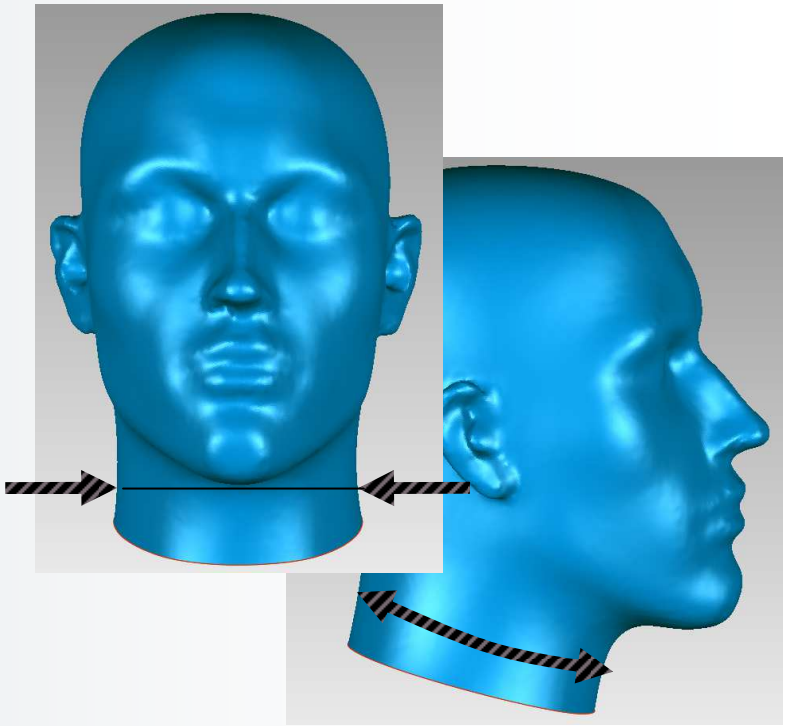
Head, Face and Neck/Chin Measurements



Horizontal Face and Head Distances



Various Face Widths



Various Neck Measurements

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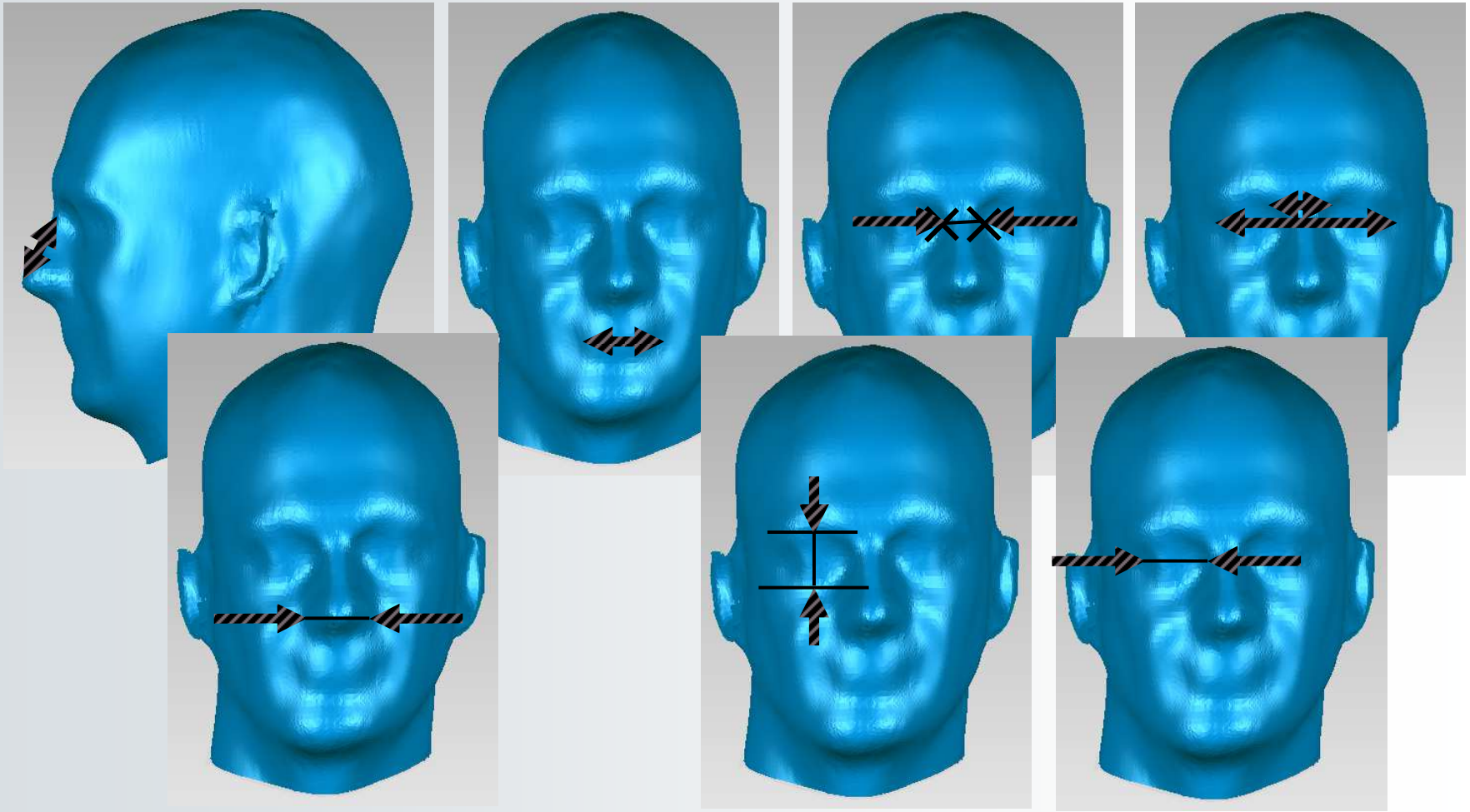
Head, Face and Neck/Chin Measurements



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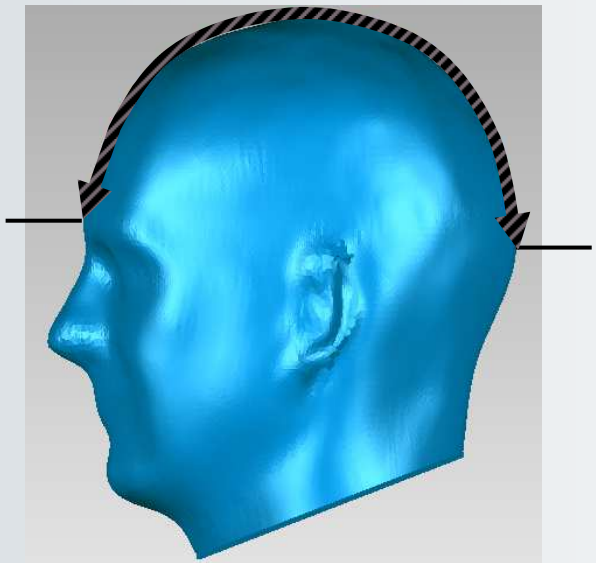
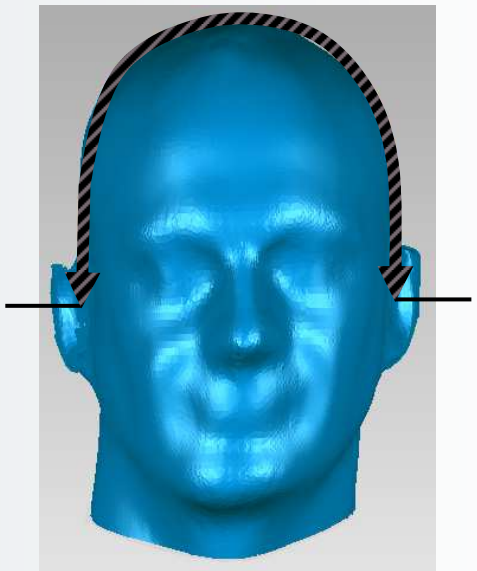
Head, Face and Neck/Chin Measurements



Sagittal arc



Bitragion coronal arc

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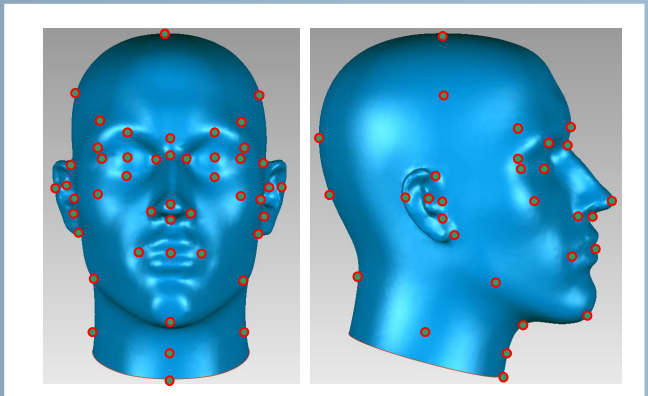
Step 2 of the Hohenstein study

- Analysis und statistical evaluation of 3D-scandata of men, women and children
- 3D-head shape analysis
- Definition of size ranges according to sex, age and head shape types based on percentage shares



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Requirements for statistical evaluation

- Distinction between women, men, children
- Distinction between age groups
- Determination of minimum, average and maximum values and deduction of changes in value relating to the head sizes
- Deduction of measurement correlations, e.g. Head Width to Head Circumference as “head shape indicator”

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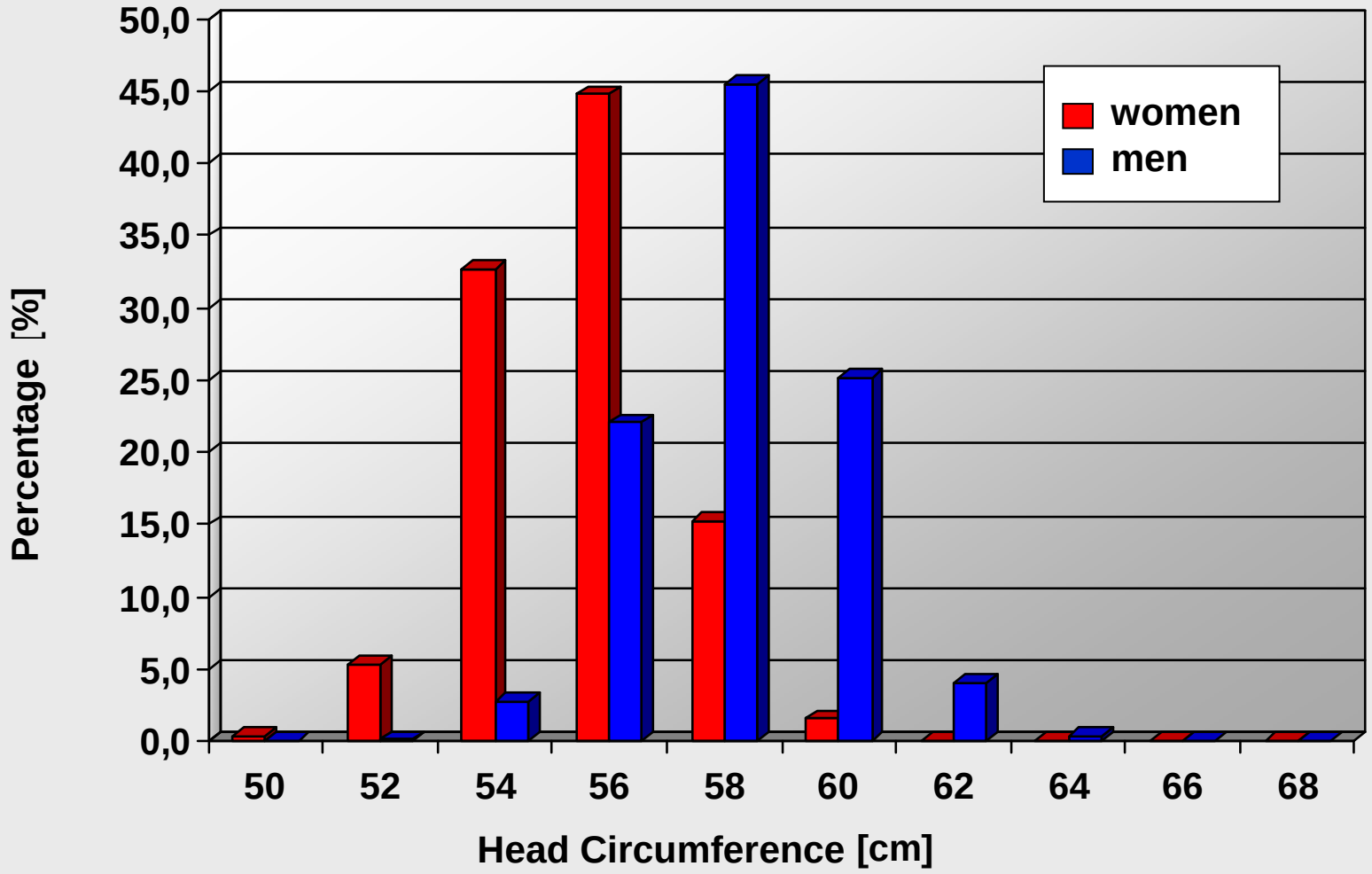
Percental distribution of Head Circumferences



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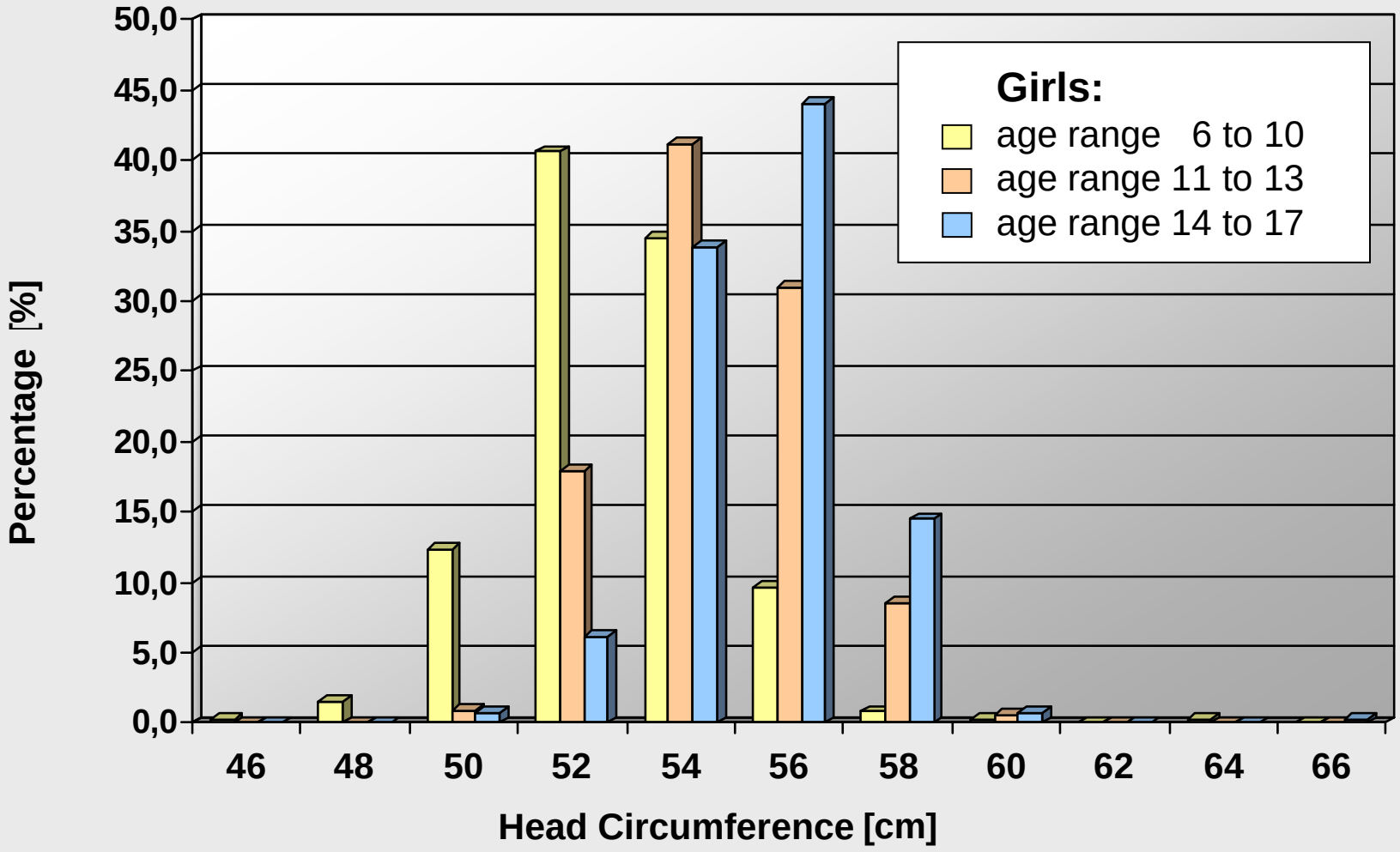
Percental distribution of Head Circumferences



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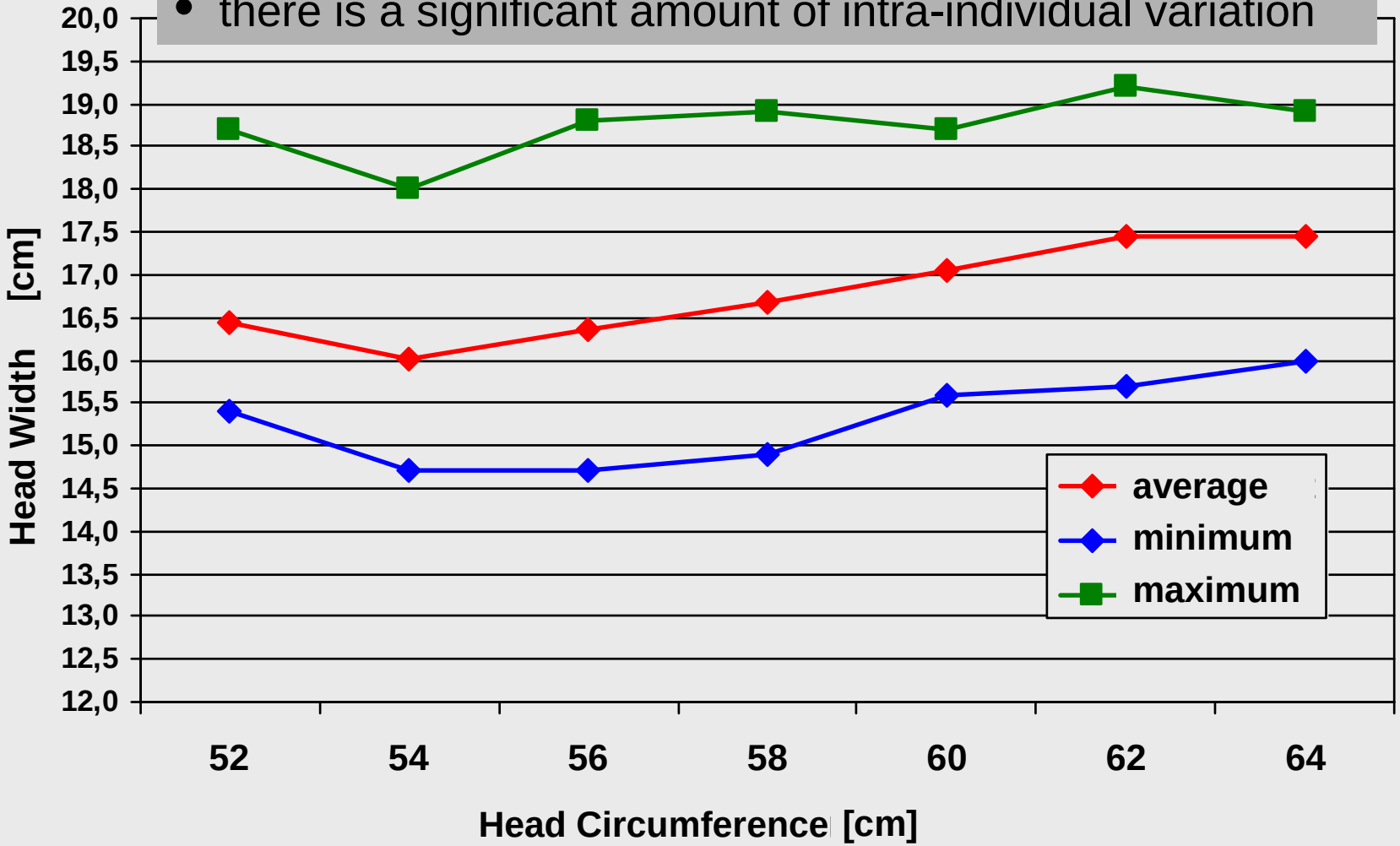
Changes of Head Width related to Head Circumference – Men

- there is a significant amount of intra-individual variation



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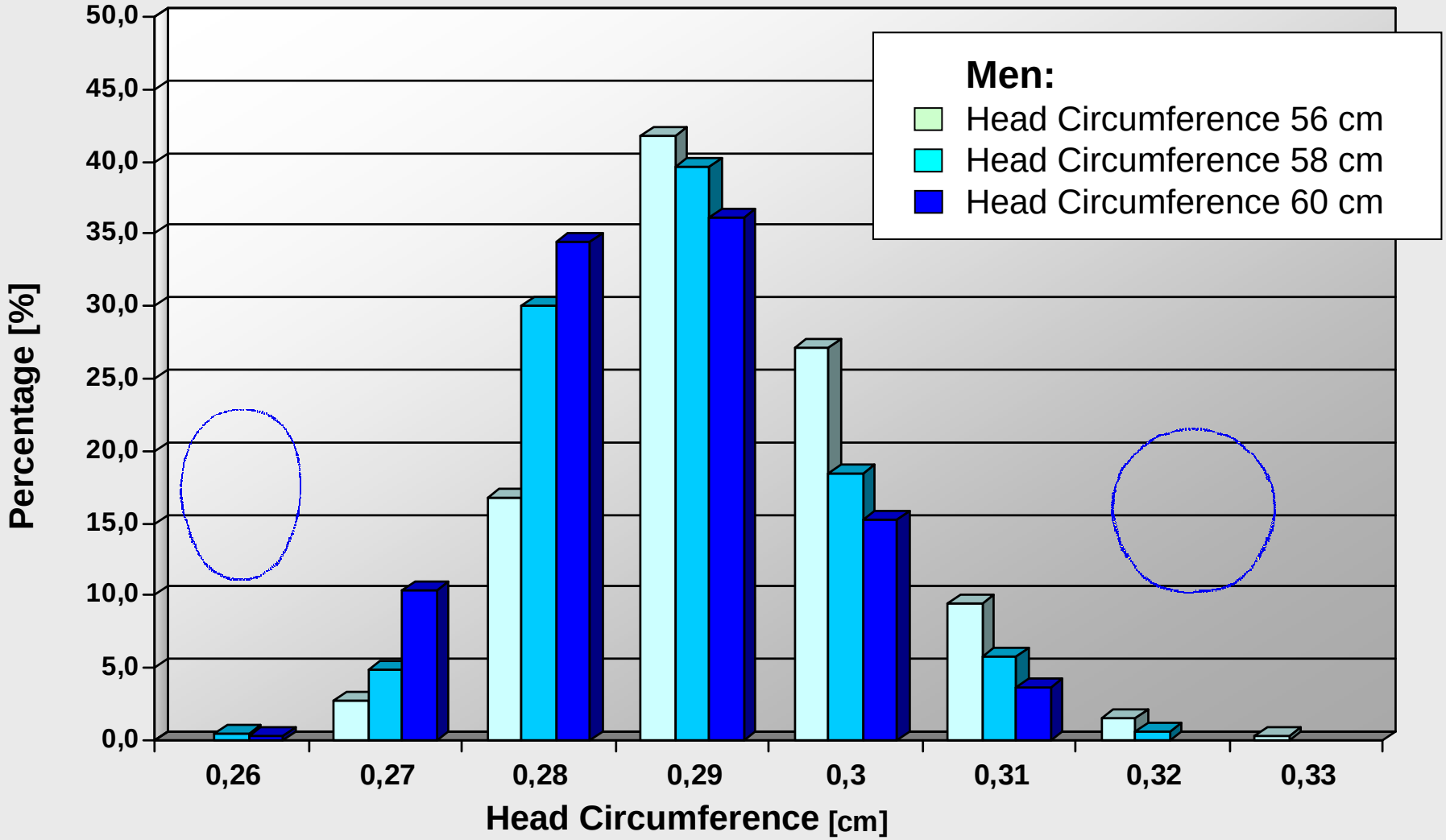
Percentage of correlation coefficients Head Width to Head Circumference – Men



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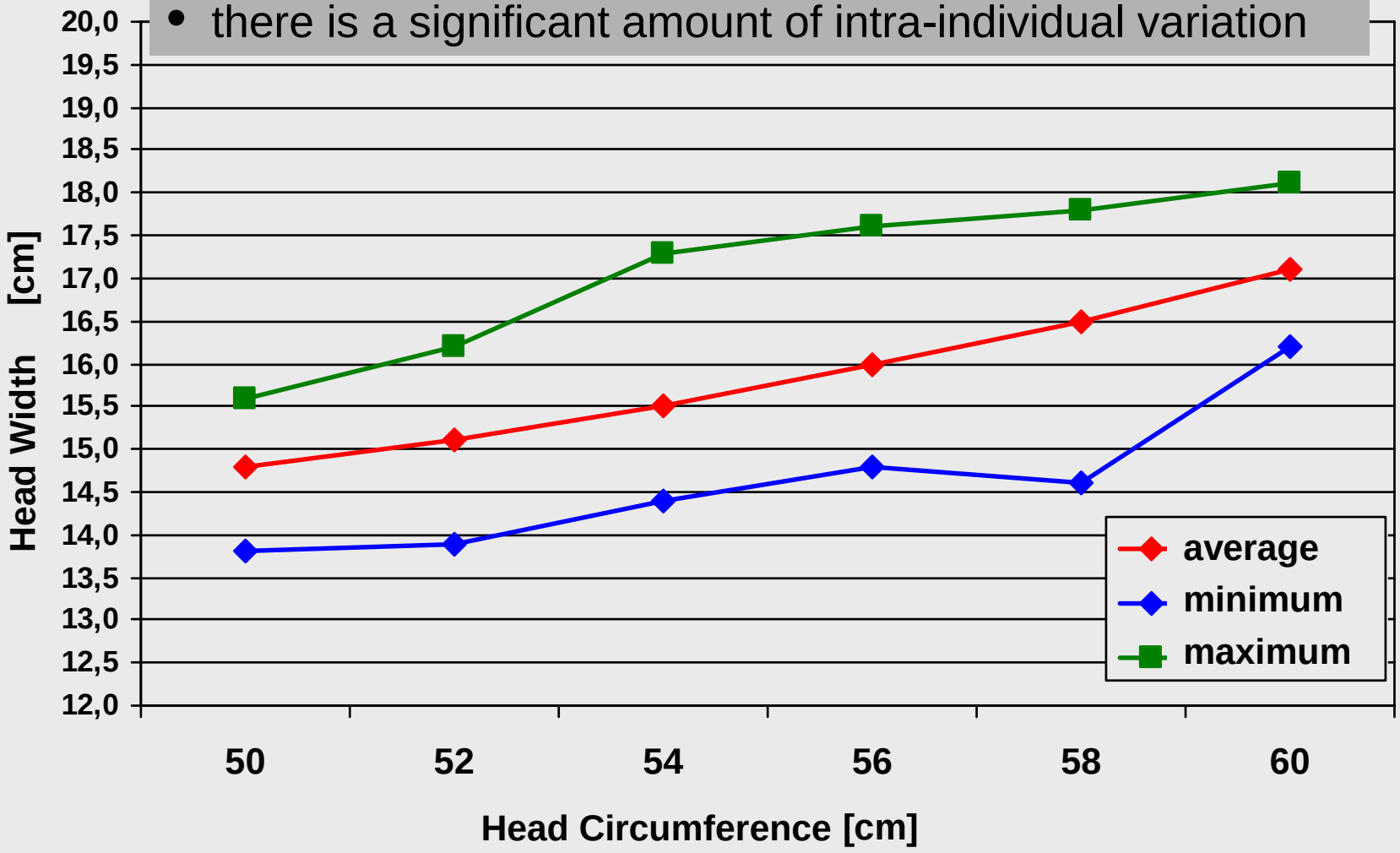
Changes of Head Width related to Head Circumference – Boys

- there is a significant amount of intra-individual variation



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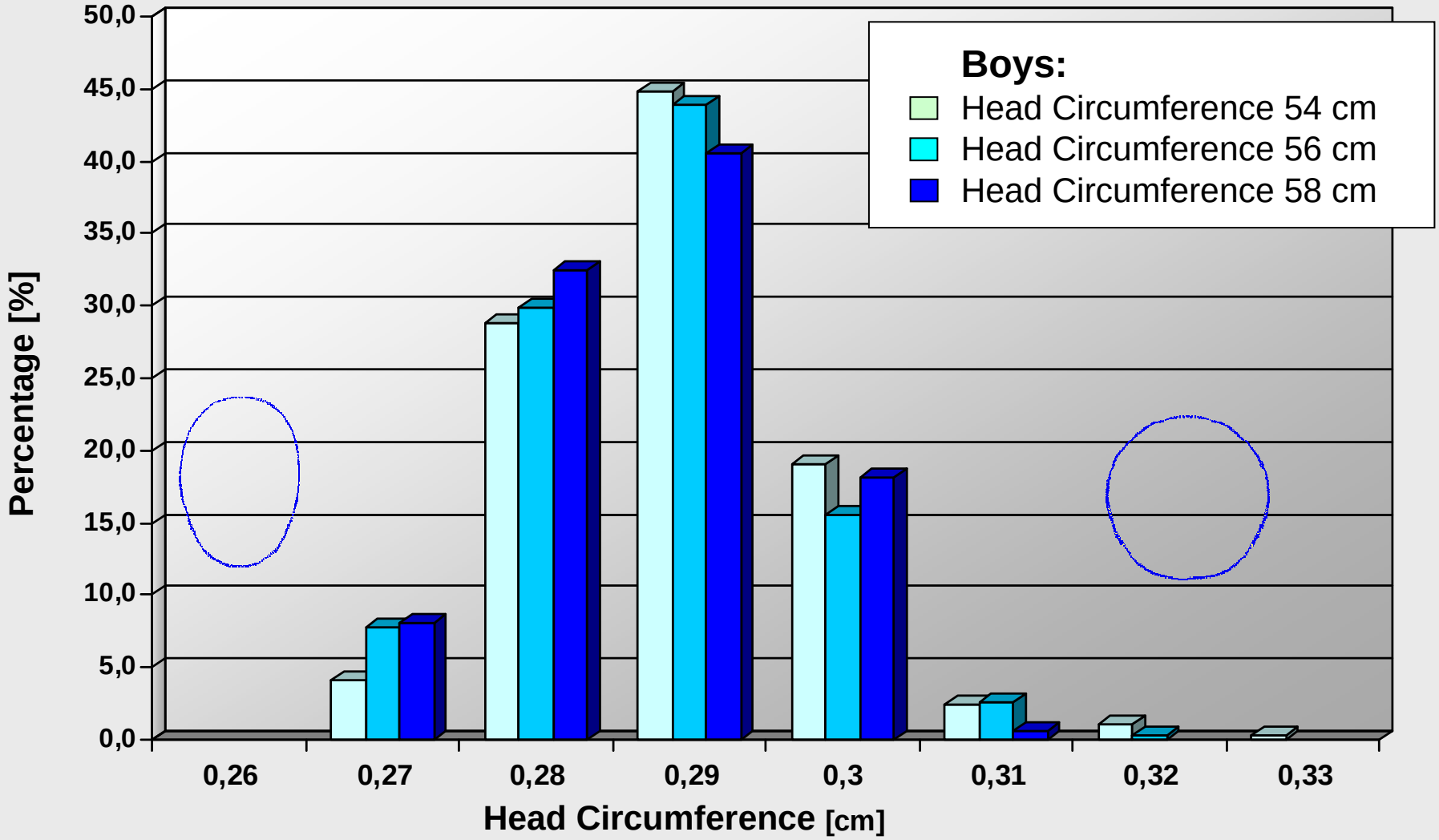
Percentage of correlation coefficients Head Width to Head Circumference – Boys



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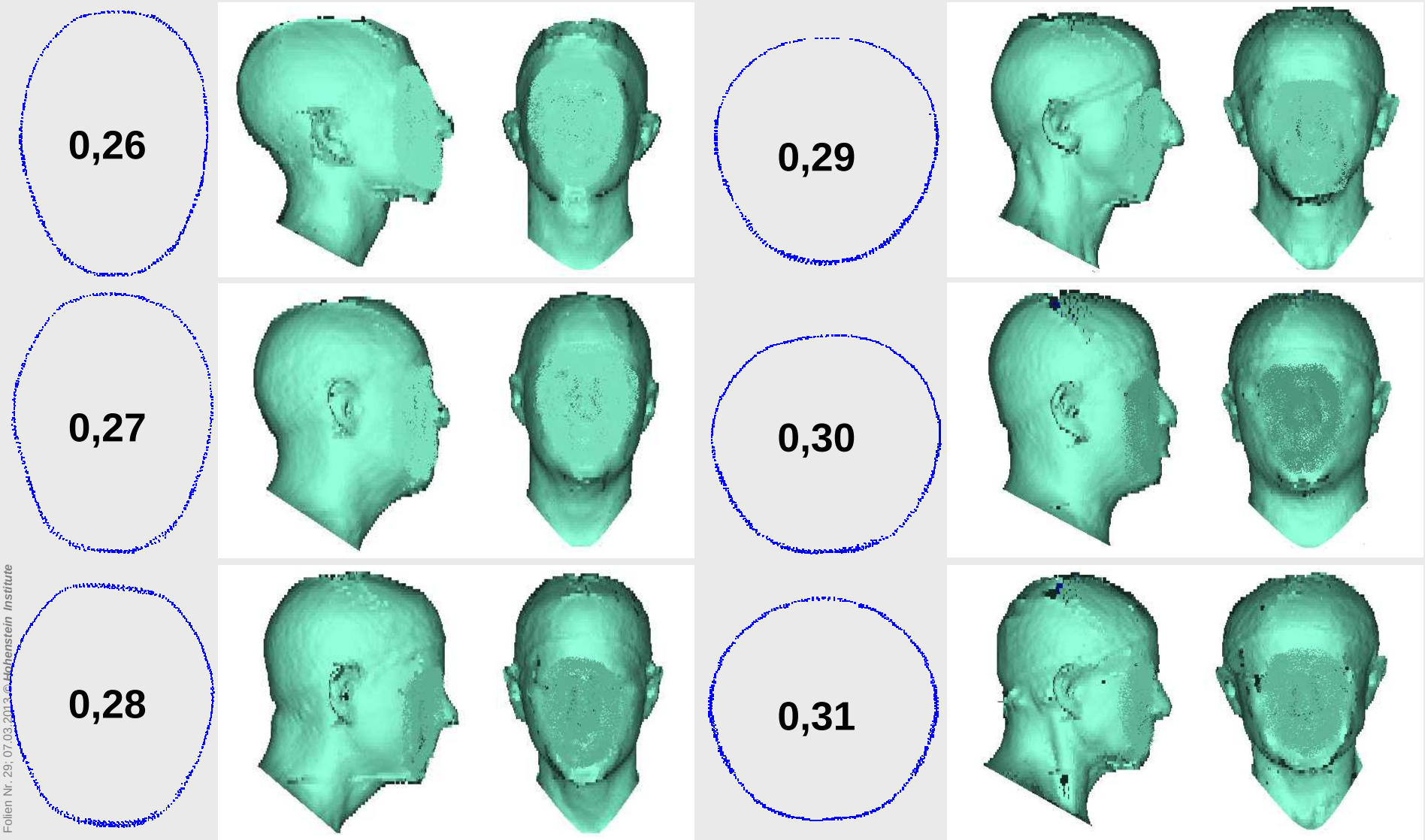
Head shapes variations – Head Circumference 58 cm



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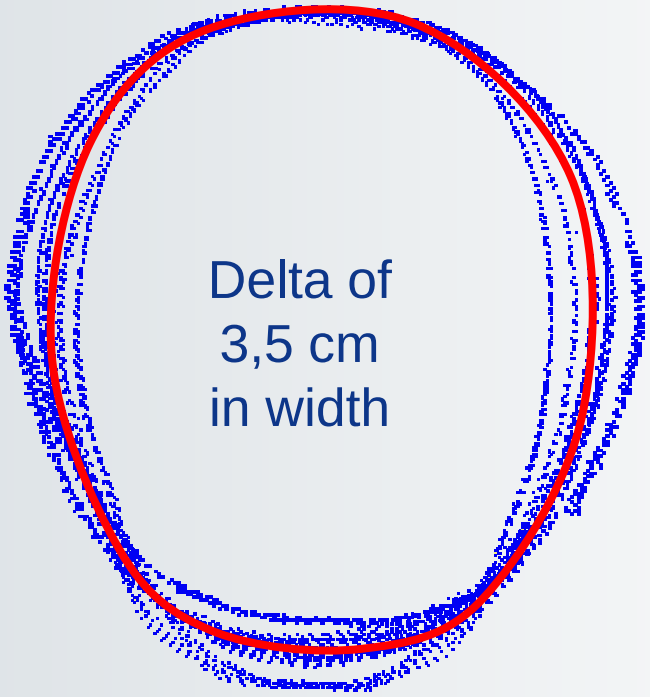
Head Width variance – Head Circumference 58 cm

- Head Width variance 15,0 to 18,5 cm



Cannot be covered by only one helmet size !

Both shape and measurements are essential !

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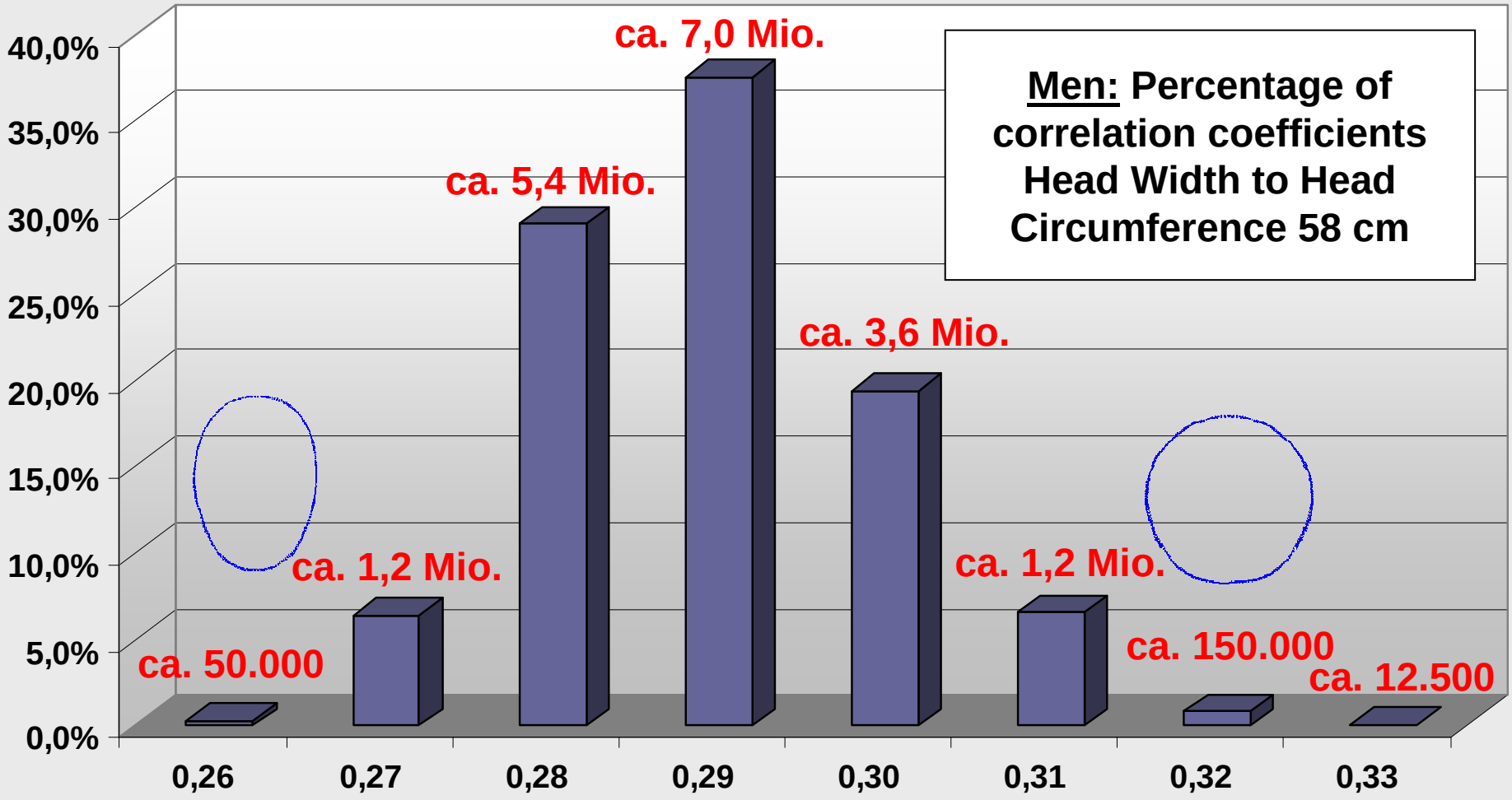
Percentage of potential German male customers related to the different head shapes



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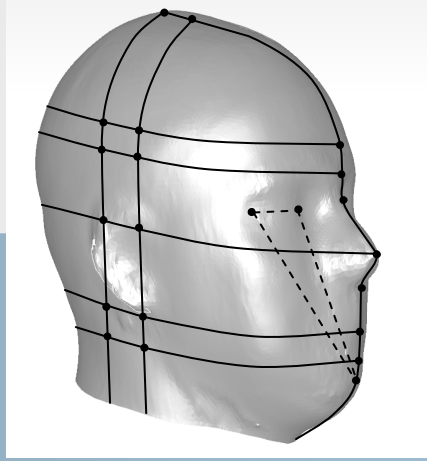
Further Steps



- Ongoing statistical evaluation
  as well as 3D-head shape analysis
- Develop German market share tables
- Develop head shape specific grading rules
- Develop virtual 3D-head shape models representing realistic head shapes of German population for the first time
- Virtual 3D-analysis of fit and ergonomic comfort

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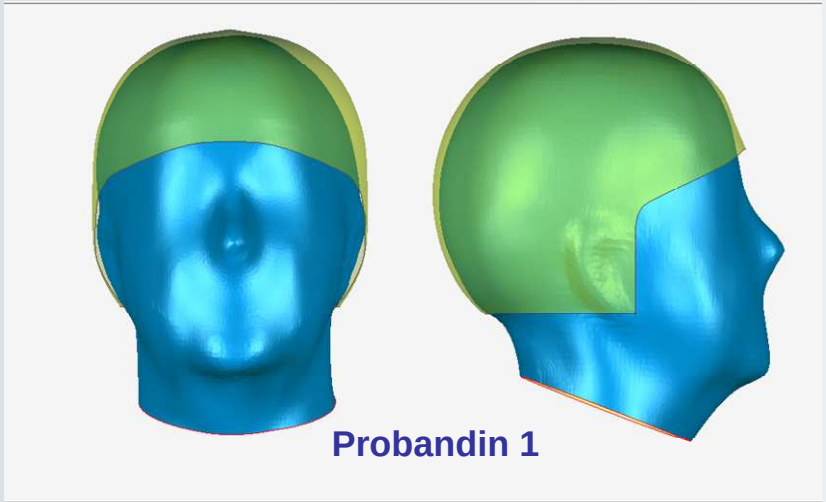
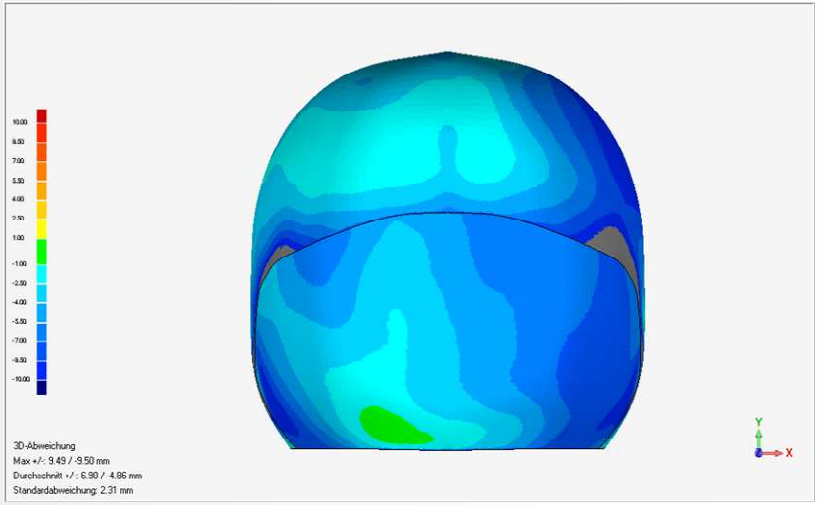
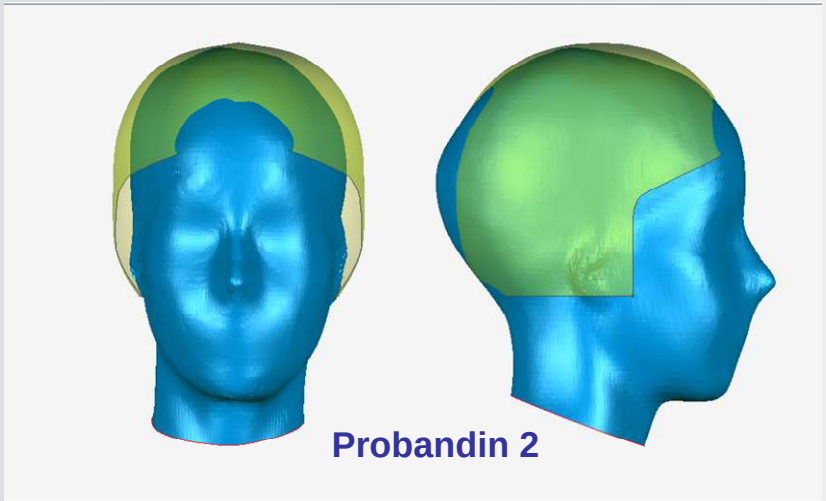
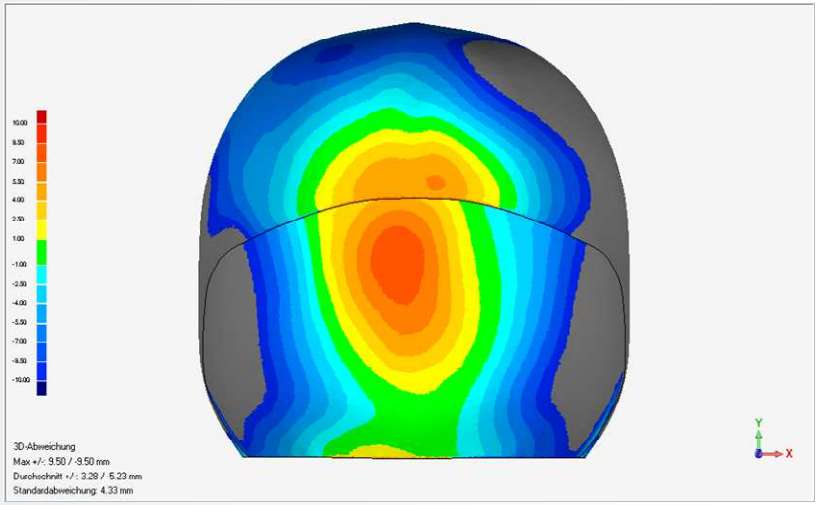
3D-distance analysis „head to helmet inner face“









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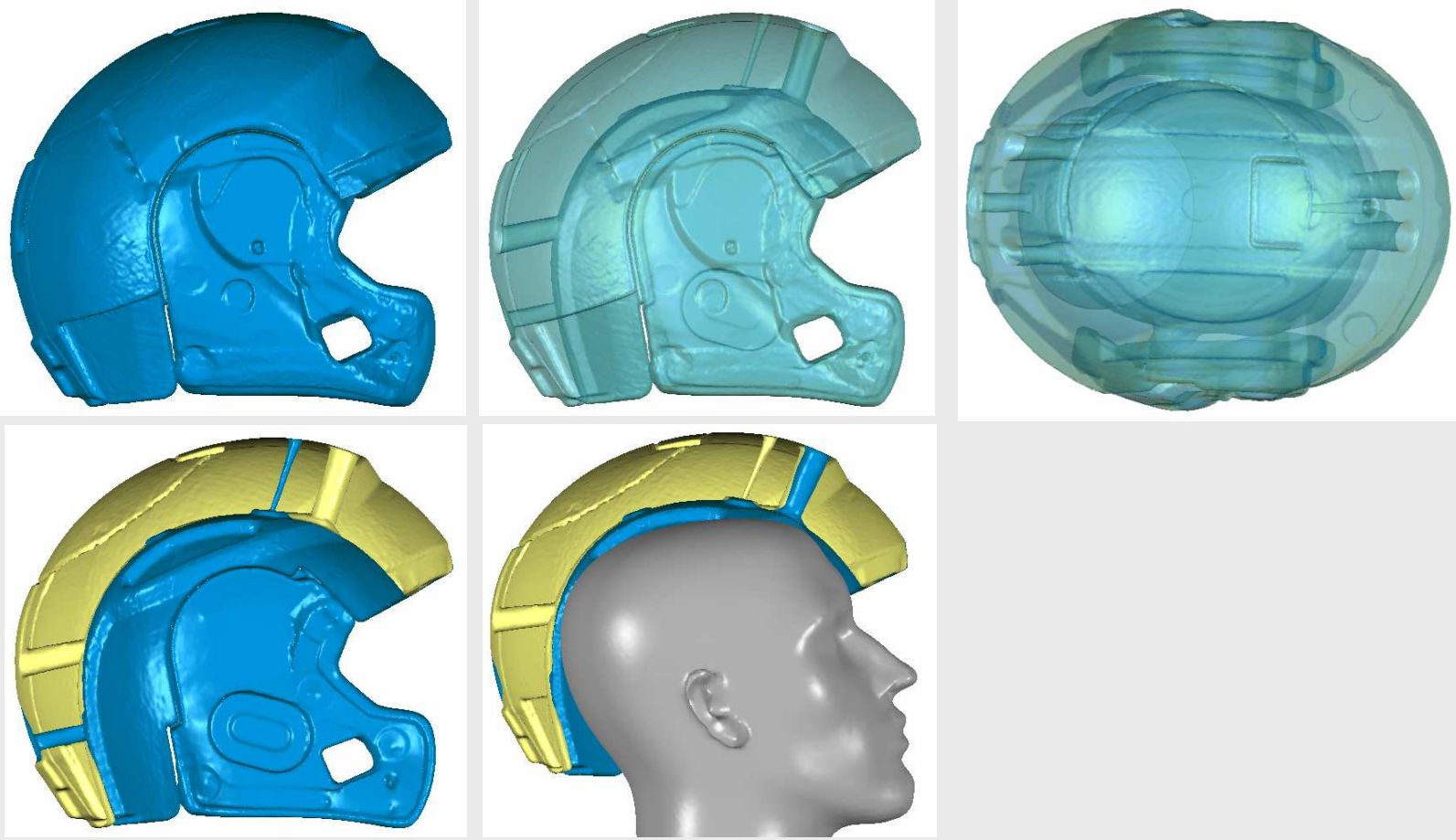
3D-distance analysis „head to helmet inner face“

- Analysis of distance variation between head geometry and real helmet inner face by using 3D-scanning technology



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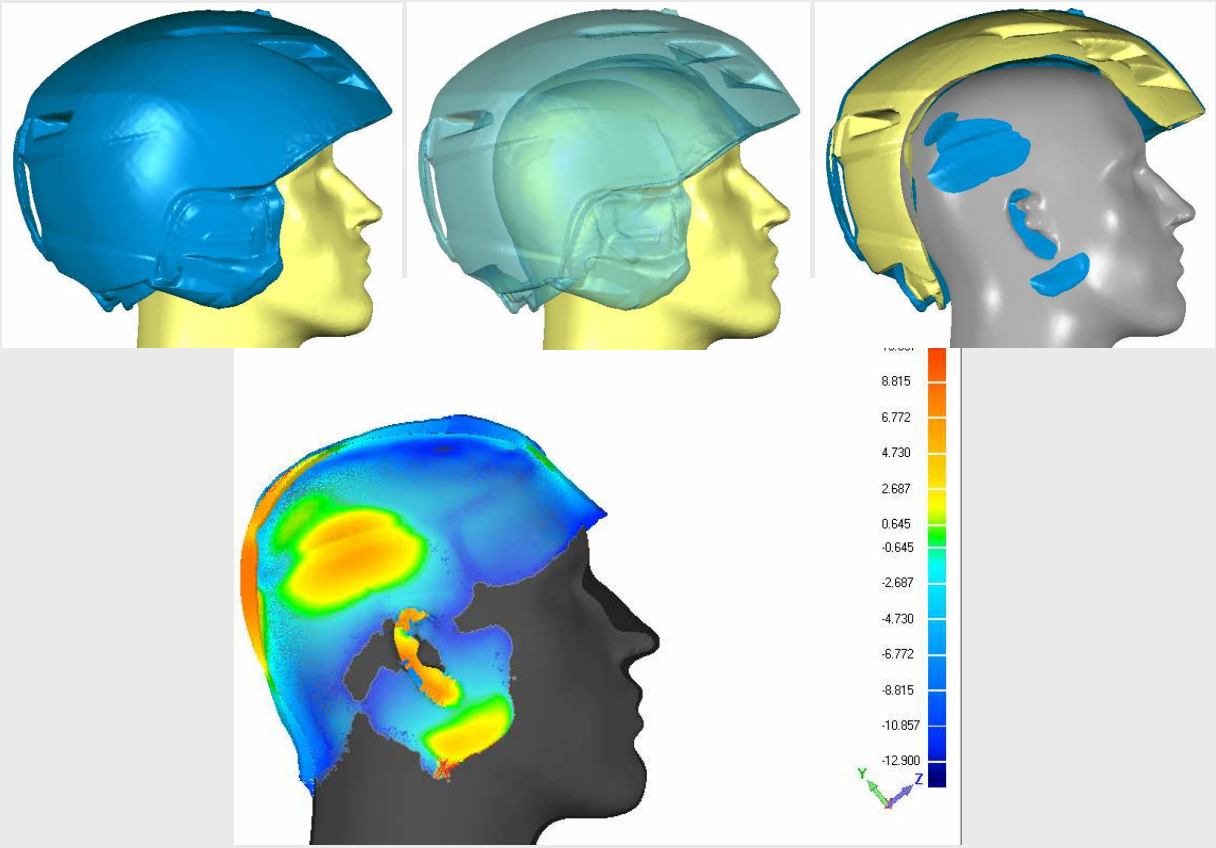
3D-distance analysis „head to helmet inner face“

- Analysis of distance variation between head geometry and real helmet inside by using 3D-scanning technology



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Further Steps

- Evaluation of textile material requirements concerning fit and function
- Evaluation of infection prophylaxis by antimicrobial finishing and/or better temperature and moisture management

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Thank you for your kind attention

Hohenstein Institute
Dr. Jan Beringer & Simone Morlock
Schloss Hohenstein | 74357 Boennigheim | GERMANY
j.beringer@hohenstein.de | s.morlock@hohenstein.de

Hohenstein Institute America, Inc.
Samuel B. Moore, Ph.D | Managing Director USA
1688 Westbrook Ave | Burlington, NC 27215 | USA
Tel 336.269.0959 | s.moore@hohenstein.org | www.hohenstein.us

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