Using 3D Scanning for Improved Helmet Design

Dr. Jan Beringer | Hohenstein Institute
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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 Germany, not all bikers wear helmets
- Industry: 10 million workers in Germany 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
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!
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
Visual comparison – male subject (view from top)

Circumference 58 cm
State of technology

**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)
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 3D 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
Step 1 of the Hohenstein study and results

- Detailed analysis of existing 3D Scan data of Hohenstein’s own database (17,000+ scans)
- Acquisition of additional high resolution 3D Scan data from typical head shapes
- Definition of measurements and methods according to established standards like (ISO 7250, SizeGERMANY etc. plus new additional head and face measurements)
Available 3D Scanner Systems
3D Scan-Quality
3D Scan experimental setup
Step 2 of the Hohenstein study and results

- Analysis und statistical evaluation of 3D-scandata of men, women and children
- 3D-head shape analysis
- Definition of basic 3D head shapes
- Definition of size ranges according to sex, age and head shape types based on percentage shares
Men & Women: Head circumference - percental distribution
Boys: Head circumference over age groups

Kopfumfang nach Altersgruppen - Jungen

- Altersgruppe 6 bis 10 Jahre
- Altersgruppe 11 bis 13 Jahre
- Altersgruppe 14 bis 17 Jahre

Kopfumfang [cm]
Girls: Head circumference over age groups

Kopfumfang nach Altersgruppen - Mädchen

- Altersgruppe 6 bis 10 Jahre
- Altersgruppe 11 bis 13 Jahre
- Altersgruppe 14 bis 17 Jahre

Kopfumfang [cm]
Men & Women: Rage of head width  
(correlation head width vs. head circumference)

**Korrelation Kopfbreite zu Kopfumfang**

- **Gr. 58 = 3,4 cm Spannweite**
- **MAX**
- **MIN**
- **Mittlere Spannweite 2,5 cm**

**Chart Details:**
- **Kopfbreite [cm]**: 14,0 to 19,0
- **Kopfumfang [cm]**: 52 to 64
- **Frauen**
- **Männer**
Men & Women: Definition of head shapes and types (correlation head width vs. head circumference)
The 5 defined/extracted average head types

- rund extrem
- rund
- normal
- oval
- oval extrem

+0,8cm +0,8cm +0,8cm +0,8cm
Men: percental distribution head types

Prozentuale Verteilung nach Kopftypen - Männer

Kopftypen

- oval extrem: 0,4%
- oval: 19,0%
- normal: 63,0%
- rund: 16,7%
- rund extrem: 0,9%
Women: percental distribution head types

Prozentuale Verteilung nach Kopftypen - Frauen

- oval extrem: 0.6%
- oval: 19.7%
- normal: 62.5%
- rund: 16.8%
- rund extrem: 0.4%
Head height types (…helmet belt)

Definition of 5 head height types:

- X short: +2 cm
- short: +2 cm
- normal: +2 cm
- long: +2 cm
- X long: +2 cm
Average head shapes as 3D data available
Summary

- 3D Scan system and experimental setup defined
- 3D-scandata of men, women and children analyzed and statistically evaluated
- 3D-head shapes analyzed and 5 basic types defined
- Size ranges according to sex, age and head shape types based on percentage shares defined
- Average head shapes in various sizes available as 3D data
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 & Ben Mead
1688 Westbrook Ave | Burlington, NC 27215 | USA
s.moore@hohenstein.com | b.mead@hohenstein.com
www.hohenstein.us