Principles of Fit to Optimize Helmet Sizing

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Overview

• How Has It Been Done in the Past?
• What Is Wrong With the Past Practices?
• What is Different With This Study?
• Methods
• Results and Conclusions
How has it been done in the past?

- Arbitrary size boxes on a chart
- One case called a “fit model” scaled up and down
- Averages scaled up and down
- Percentile people

- Why rectangular size?
- Why not triangular?
- How do you know it fits this group?
WHY FIT MAP? DESIGN AND REALITY ARE DIFFERENT

Areas of Fit for 3 Sizes of a Helmet
## Fit Mapping Process

### Anthropometric Fit Range

#### Anthropometric Fit Ranges

**SUbject #**

**SS#:**

**DATE:**

**DATA COLLECTOR:**

**DATE ENTERED:**

**PLANT OF BIRTH:**

**RANK/OCCUPATION:**

<table>
<thead>
<tr>
<th>ITEM1: UG</th>
<th>TOP</th>
<th>FIRST</th>
<th>SMALLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLLAR</td>
<td>Tight OK</td>
<td>Loose</td>
<td>Tight</td>
</tr>
<tr>
<td>SHOULDER</td>
<td>Tight OK</td>
<td>Loose</td>
<td>Tight</td>
</tr>
<tr>
<td>CHEST</td>
<td>Tight OK</td>
<td>Loose</td>
<td>Tight</td>
</tr>
<tr>
<td>SLEEVES</td>
<td>Short OK</td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td>WAIST</td>
<td>Tight OK</td>
<td>Loose</td>
<td>Tight</td>
</tr>
<tr>
<td>WAIST</td>
<td>High OK</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>UPPER TORSO</td>
<td>Short OK</td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td>HIPS</td>
<td>Tight OK</td>
<td>Loose</td>
<td>Tight</td>
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**OVERALL**

| EVAL: | Subject | Real |

### Anthropometric Fit Ranges

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<td>High</td>
</tr>
<tr>
<td>HIPS</td>
<td>High OK</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>CROUCH</td>
<td>High OK</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>THIGH</td>
<td>Tight OK</td>
<td>Loose</td>
<td>Tight</td>
</tr>
<tr>
<td>LOWER LEGS</td>
<td>Tight OK</td>
<td>Loose</td>
<td>Tight</td>
</tr>
<tr>
<td>LEG LENGTH</td>
<td>Short OK</td>
<td>Long</td>
<td>Short</td>
</tr>
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</table>

**OVERALL**

| EVAL: | Subject | Real |

**Comments (Fit Subject's):**

3 = Fair

4 = Poor
Helmet Fit Mapping

- Used human subjects to determine the variety and number of sizes needed
- Collect 3-D and Traditional Head Anthropometry Data on Target Population
  - Match Age, Ethnicity, and Gender
- Measure Fit on Subjects
- Map Fit to Anthropometry
- Recommend How to Improve Fit

Registered helmeted and un-helmeted 3-D scans
Fit Mapping Case Selection

Selection Options
1) Use at least one subject from each category
2) Select subjects only from critical categories

Goal: Determine the range of fit of the size
Fit Metrics

What is important?

- Slippage
- Visibility through optics (Eye positioning)
- Ear position in earcup
- Comfort

How well is the LSM located with respect to the ears?

<table>
<thead>
<tr>
<th>Axis</th>
<th>Description</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Forward too far</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2 OK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Back too far</td>
<td>3</td>
</tr>
<tr>
<td>Y</td>
<td>Not wide enough</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2 OK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not narrow enough</td>
<td>3</td>
</tr>
<tr>
<td>Z</td>
<td>Too high</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2 OK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Too low</td>
<td>3</td>
</tr>
</tbody>
</table>
# Fit Metrics Examples

Rotation Ratings (1=Not measurable, 2= < 5mm, 3=severe)

<table>
<thead>
<tr>
<th></th>
<th>With mask on: Fore-aft movement</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>With mask on: Side-to-side movement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>Without mask: Fore-aft movement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>Without mask: Side-to-side movement</td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

How does the helmet feel overall?

<table>
<thead>
<tr>
<th>Part A</th>
<th>Part B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Extremely loose</td>
<td>1. Comfortable</td>
</tr>
<tr>
<td>2. Somewhat loose</td>
<td>2. Slightly Uncomfortable</td>
</tr>
<tr>
<td>4. Somewhat tight</td>
<td></td>
</tr>
<tr>
<td>5. Painfully tight</td>
<td></td>
</tr>
</tbody>
</table>
## Comfort Metrics by Location

C3. Are you experiencing any pressure from the helmet, earcups, or mask?  
Y  N

C4. If yes where and how severe?

<table>
<thead>
<tr>
<th>Area (circle each)</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Other _____________</td>
<td>1. Comfortable 2. Tolerable 3. Intolerable</td>
</tr>
</tbody>
</table>

Circle each area that is experiencing pressure in the photos below
Results and Conclusions

- Designed for this group
- Reproportioned Sizes

Data points labeled:
- Original Pass
- New Small Pass
- New Large Pass
- Joint Strike Fighter
- Navy Head Study
- Fit Study

Designed for this group:
- Actual fit this group
- Reproportioned Sizes

Designed for this group:
- Proportioned Sizes

Designed for this group:
- This group

Designed for this group:
- This group

Designed for this group:
- This group

Designed for this group:
- This group

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Results and Conclusions

Cross section at 1 inch above the eye for Head 25

- human
- helmet as fitted
- desired location
- new helmet size

½ Impact Liner

Updated XL shell design in magenta
Summary

• Anthropometry alone is not enough
• Fit mapping is essential for good fit with the fewest number of sizes
• Sizes-designed-for ≠ sizes-fit
• As few as two helmet sizes may be sufficient for most populations if they are designed effectively
• Fit data is an essential to good design and should be a part of any Engineering Anthropometry database