Analysis of the Facial Anthropometric Data of Korean Pilots for Oxygen Mask Design

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- 3D Facial Measurement
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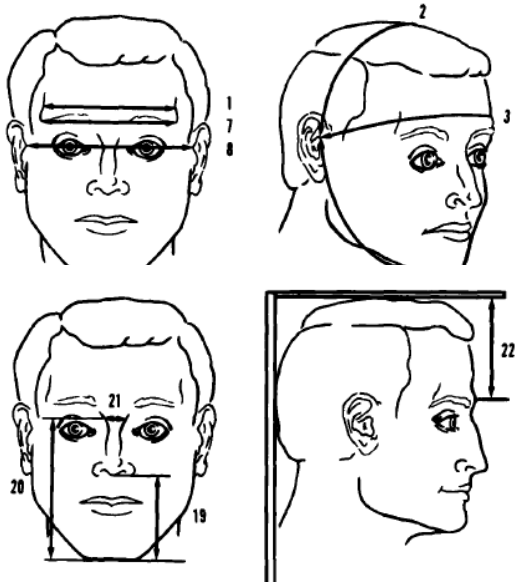
Background

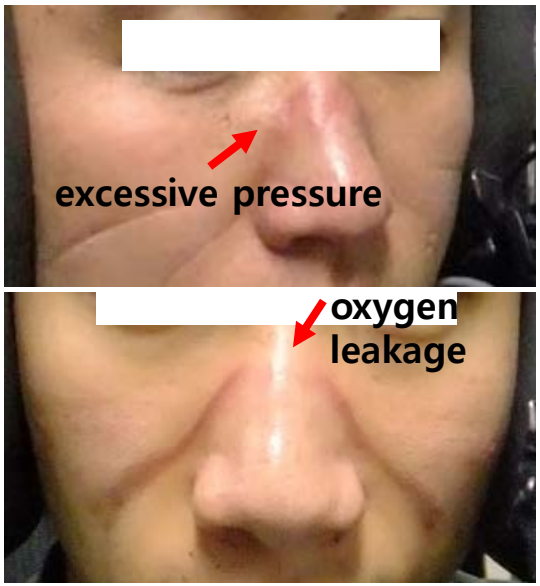
- **MBU-20/P OM designed based on USAF facial measurements are worn by Korean F-15/F-16 pilots**
- **Unfit to a significant percentage of Korea Air Force pilots**
  - ⇒ **Excessive pressure and/or oxygen leakage at the nose**
  - ⇒ **High level of discomfort during flight operation**

⇒ **Required a new OM design which is better fit to KAF pilots**



US Air Force face anthropometric data (1967)

MBU-20/P oxygen mask (Gentex Corp., USA)



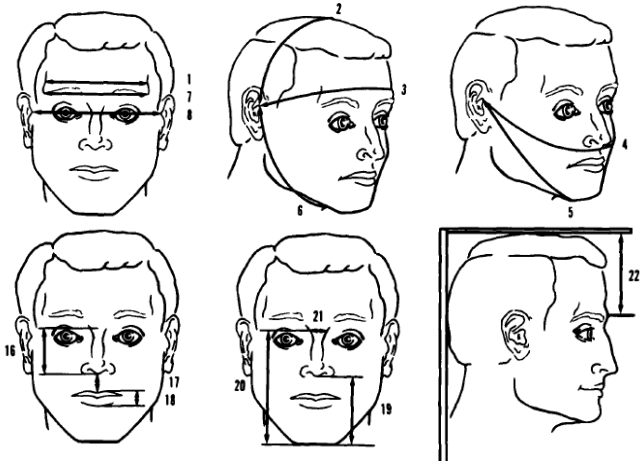
Ergonomic Design Technology Lab

MBU-20/P Pilot Oxygen Mask

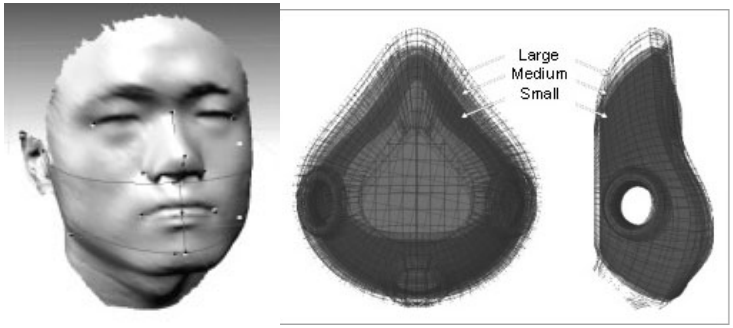
- Manufactured by Gentex in the US
- Half-face respirator
- Proper oxygen supply at high altitude and high gravity situation
- Initially designed based on USAF facial anthropometric data (1967)
- Modified based on 60 USAF 3D facial scan data (Gross et al., 1997)

Research Needs

- **Oxygen mask needs to designed based on facial characteristics of OM users**
  (Hack and McConvillie, 1978; Han et al., 2004; Oestenstad et al., 1990; Young, 1966)
- **Required to understand facial characteristics of KAF pilots to design oxygen mask for KAF pilots**
- **Lack of the facial anthropometric data of KAF pilots**



Facial anthropometric dimensions applied to OM design (Alexander et al., 1979)



Industrial mask design for Korean workers based on 3D facial scan data (Han et al., 2004)

- **Measure the facial dimensions of KAF pilots**
- **Compare KAF pilot facial data with USAF facial data to identify the causes of KAF pilots' discomfort with MBU-20/P**

Research Objectives

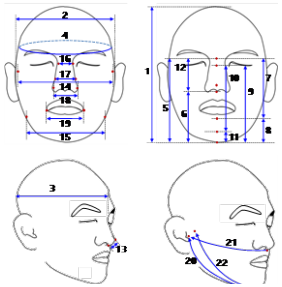
Analysis of the Facial Anthropometric Data of KAF Pilots for Oxygen Mask Design

1. **Measure the faces of KAF pilots in 3D**
   - ✓ Facial dimensions were selected as those applicable to design of an oxygen mask
   - ✓ KAF pilots' faces were captured using a 3D scanner
   - ✓ Facial dimensions were measured using the 3D face scan data

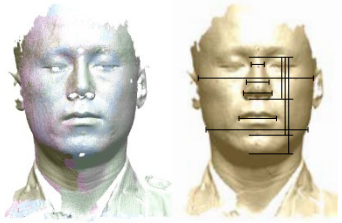
2. **Understand the facial characteristics of KAF pilots for OM design**
   - ✓ Facial characteristics of KAF pilots were compared with those of Korean civilians and USAF personnel.

Approach

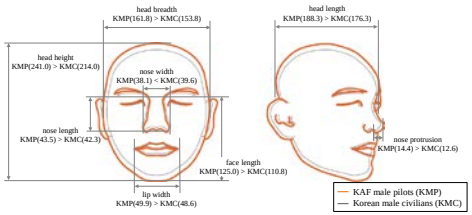
S1. Selection of facial dimensions and landmarks



S2. Measurement of facial dimensions by 3D scanning

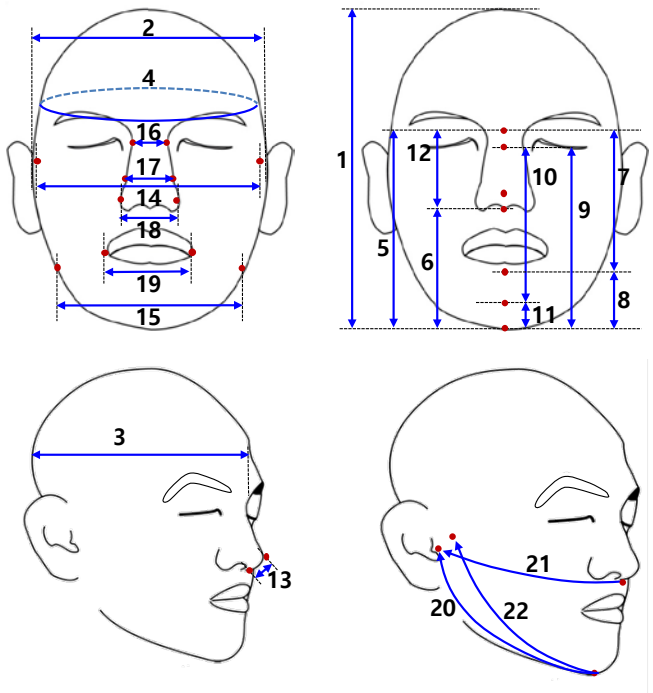


S3. Analysis of KAF pilots' facial measurements



Selection of Facial Dimensions

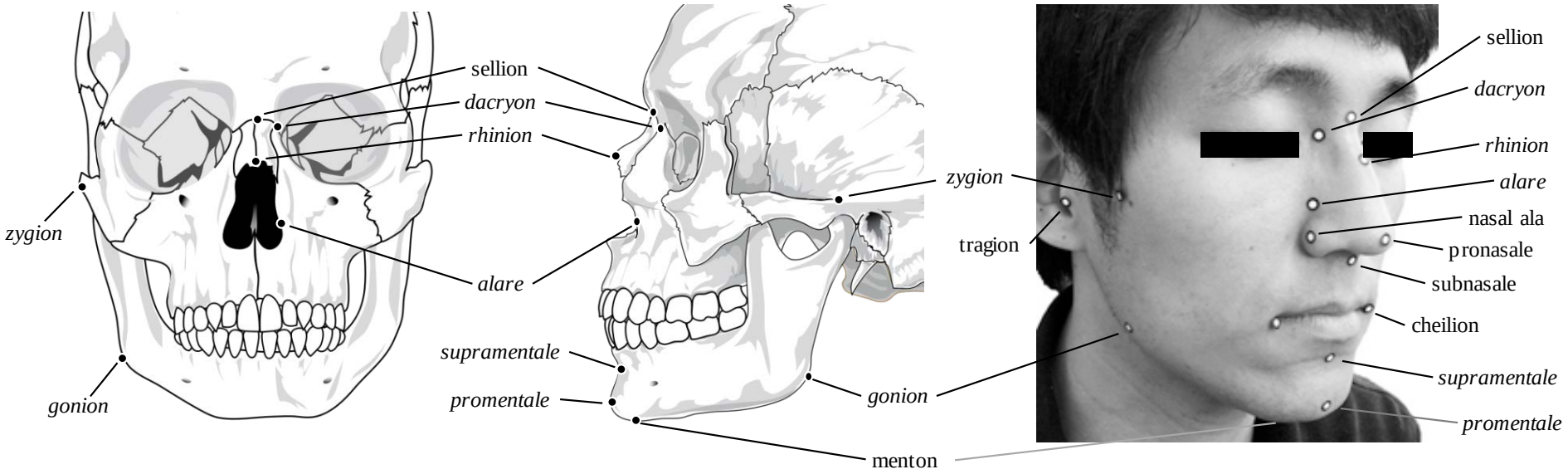
- **Identified 107 head and facial dimensions by referring to 15 previous studies**
- **Selected 22 head/facial dimensions related to half-face mask design** (length: 9, depth: 2, width: 7, circumference and arc: 4)



	Face dimension	Importance		
1	head height	L	head dimensions (4) ⇒ direct measurement	facial dimensions (18) ⇒ 3D measurement
2	head breadth	L		
3	head length	L		
4	head circumference	L		
5	face length	H	length (8)	
6	lower face length	M		
7	sellion-bottom lip length	M		
8	bottom lip-menton length	L		
9	nasal bridge-menton length	M		
10	nasal bridge-chin length	H		
11	chin-menton length	L		
12	nose length	M		
13	nose protrusion	L	depth (1)	
14	face width	L	width (6)	
15	chin width	L		
16	nasal root breadth	H		
17	maximum nasal bridge breadth	H		
18	nose width	H		
19	lip width	H		
20	bitragion-menton arc	L	Arc (3)	
21	bitragion-subnasal arc	L		
22	bizygomatic-menton arc	L		

Facial Landmarks Used for 3D Measurement

- **Used 21 facial surface and cranial landmarks by referring to previous research to measure the 18 facial dimensions**



non-italic: surface landmarks
italic: cranial landmarks

Facial Measurement by 3D Face Scanning

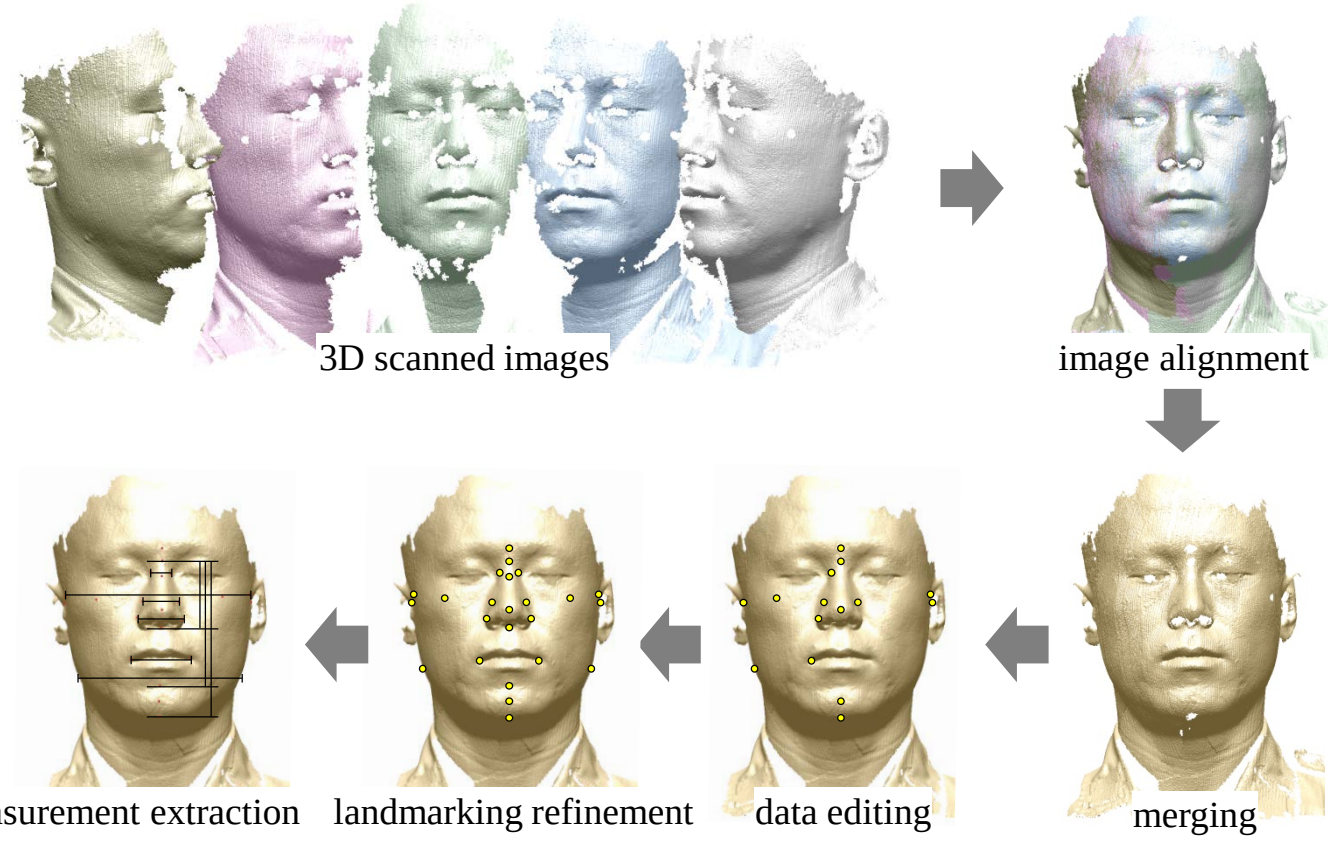
- **Participants: 336 KAF pilots and KAF Academy cadets (278 males, 58 females)**
- **3D scanning method**
  - ✓ **Attachment of stickers on the facial landmarks**
    ⇒ Landmarks are automatically detected by 3D scan image processing software
  - ✓ **Scanning at five positions** (60° left, 30° left , 0°, 30° right, 60° right)




Post Processing & Automatic Facial Measurement

n = 336

- **Post processing by ezScan (Solutionix Inc., South Korea) and RapidForm 2006 (Inus Technology, South Korea)**
- **Automatic measurement by an in-house software developed using MATLAB**



Descriptive Statistics of KAF Pilot Facial Measurements

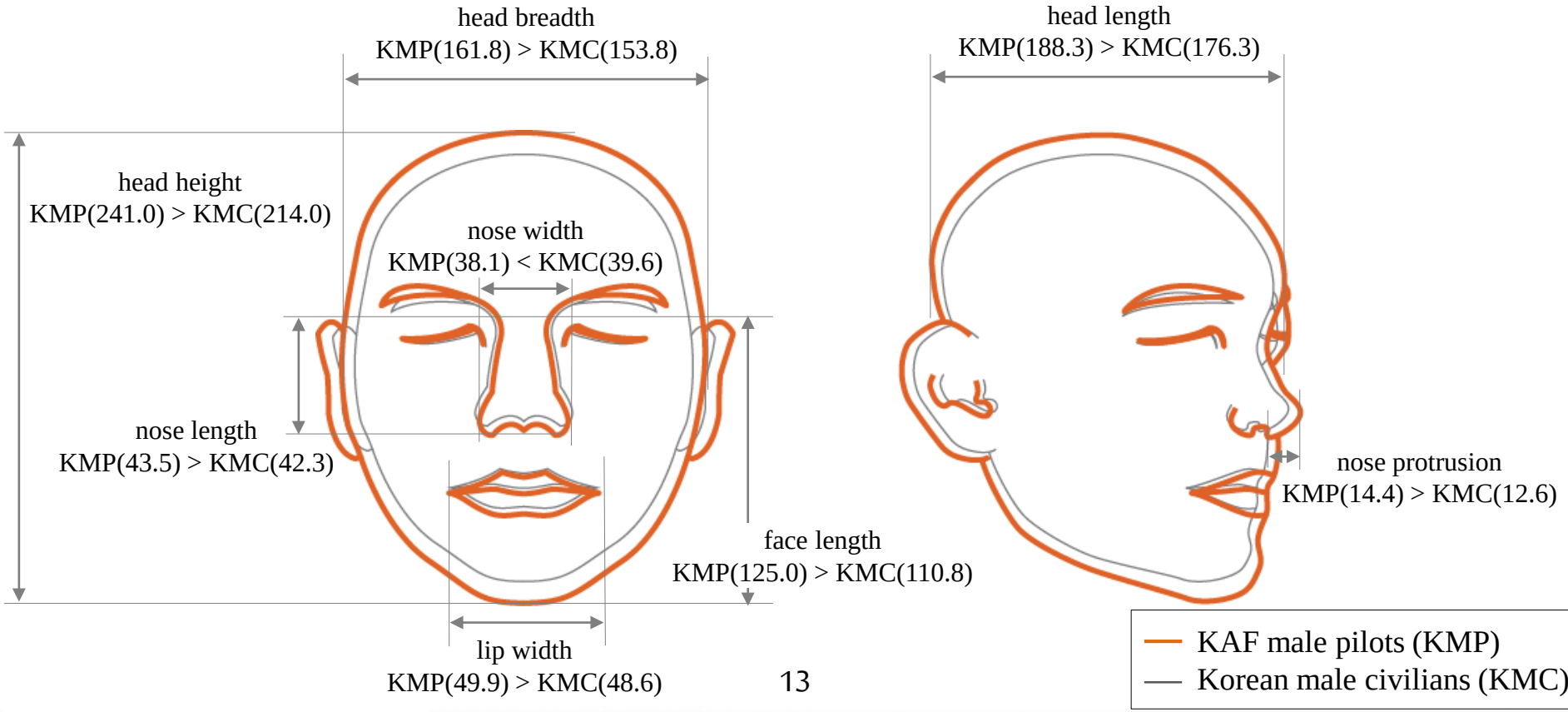
No.	Anthropometric dimension	*n*	Mean	SD	Min	Max	Percentile			
							1st	5th	95th	99th
1	head height	334	238.7	9.6	212.5	263.0	214.7	223.3	255.0	258.8
2	head breadth	335	160.9	6.4	123.5	180.5	146.4	151.4	171.2	175.3
3	head length	335	187.0	6.9	162.0	204.0	168.2	177.0	198.5	202.0
4	head circumference	335	564.5	13.5	516.5	604.5	533.4	543.2	587.2	596.2
5	face length	336	123.4	6.1	106.7	140.4	108.0	113.1	133.2	136.6
6	lower face length	336	69.1	4.5	57.5	83.6	58.6	61.8	76.3	79.4
7	sellion-bottom lip length	336	97.1	5.2	80.7	114.1	85.3	88.3	104.7	109.4
8	bottom lip-menton length	336	26.4	3.0	18.6	36.2	19.7	21.4	31.0	34.6
9	nasal bridge-menton length	336	109.1	5.5	93.2	124.3	95.8	99.8	117.7	120.8
10	nasal bridge-chin length	336	95.8	5.6	78.2	108.9	83.7	86.7	104.9	108.1
11	chin-menton length	336	13.3	2.5	4.9	20.6	7.9	9.5	17.6	19.1
12	nose length	336	54.3	3.4	43.2	62.2	46.6	48.6	60.3	61.9
13	nose protrusion	336	18.4	1.9	12.9	23.9	14.2	15.3	21.6	23.0
14	face width	336	154.8	6.4	132.4	171.5	138.6	144.0	164.2	168.2
15	chin width	336	130.3	8.6	105.4	156.7	112.5	116.5	144.6	150.8
16	minimum nasal bridge breadth	336	20.0	2.8	12.3	27.7	14.0	15.2	24.6	26.8
17	maximum nasal bridge breadth	336	30.5	2.8	22.3	37.7	24.2	25.6	35.3	36.7
18	nose width	336	37.6	2.7	30.3	45.8	31.8	33.4	42.4	43.8
19	lip width	336	49.1	3.8	38.5	58.2	40.7	42.6	55.5	57.4
20	bitragion-menton arc	336	313.7	16.2	269.0	361.1	273.5	284.1	339.1	347.3
21	bitragion-subnasale arc	336	283.0	12.9	234.9	319.6	252.1	263.1	304.5	312.1
22	bizygomatic-menton arc	336	304.8	14.5	261.3	339.6	267.0	277.8	327.6	336.2

KAF Male Pilots (KMP) vs. Korean Male Civilians (KMC)

Size Korea (2006)

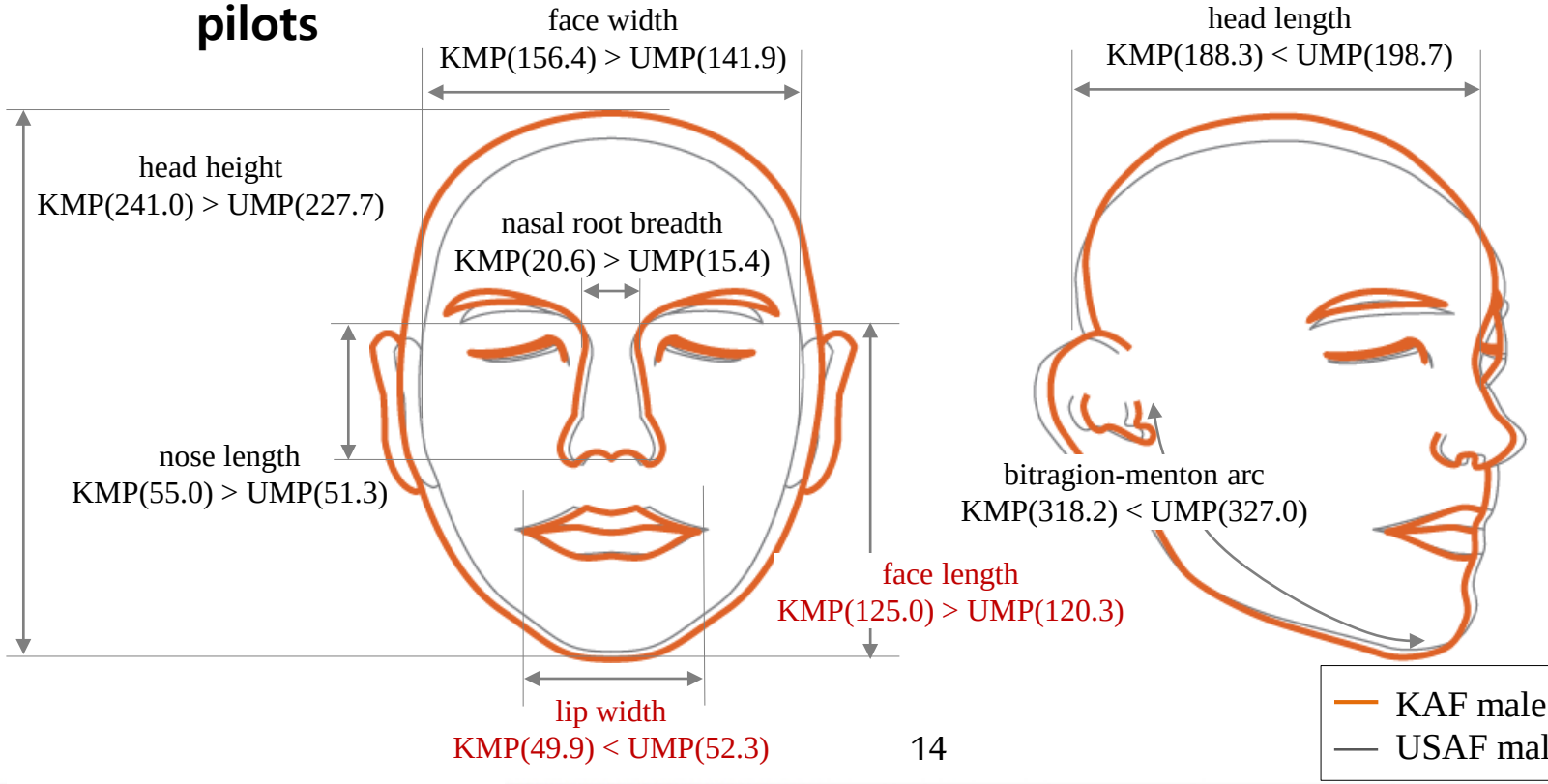
- Mean: KMP ($\bar{d}$ = 6.5 ~ 26.5 mm) > KMC
- SD: KMP (ratio in SD = 0.29 ~ 0.82) < KMC

⇒ OM sizing system and OM designs need to be custom designed using facial measurements of the KAF pilots



KAF Male Pilots (KMP) vs. USAF Male Personnel (UMP) (1967)

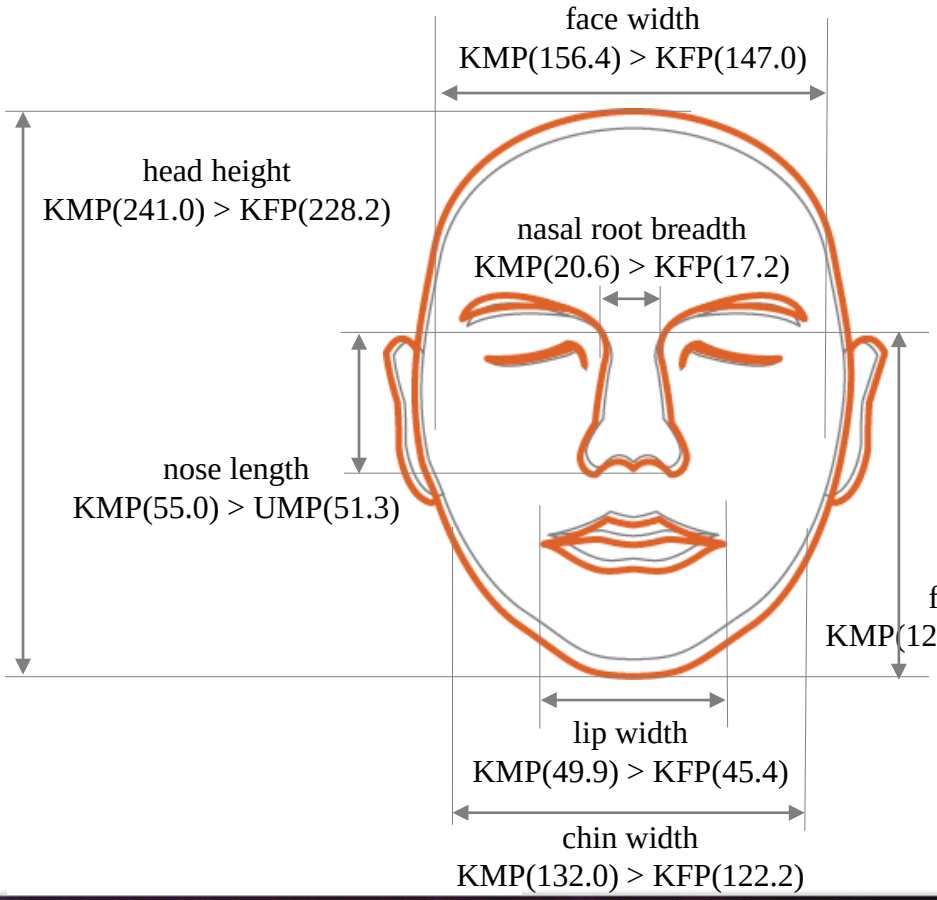
- **Mean** - **Lengths: KMP ($\bar{d}$ = 1.0 ~ 13.3 mm) > UMP**
  - **Widths: KMP ($\bar{d}$ = 3.1 ~ 14.7 mm) > UMP**
  - **Nasal root breadth: KMP ($\bar{d}$ = 5.2 mm) > UMP ⇒ high pressure**
- **The key dimensions (face length and lip width) of KMP and UMP are different in mean**
  ⇒ **OM sizing system and OM designs need to be custom designed to KAF pilots**

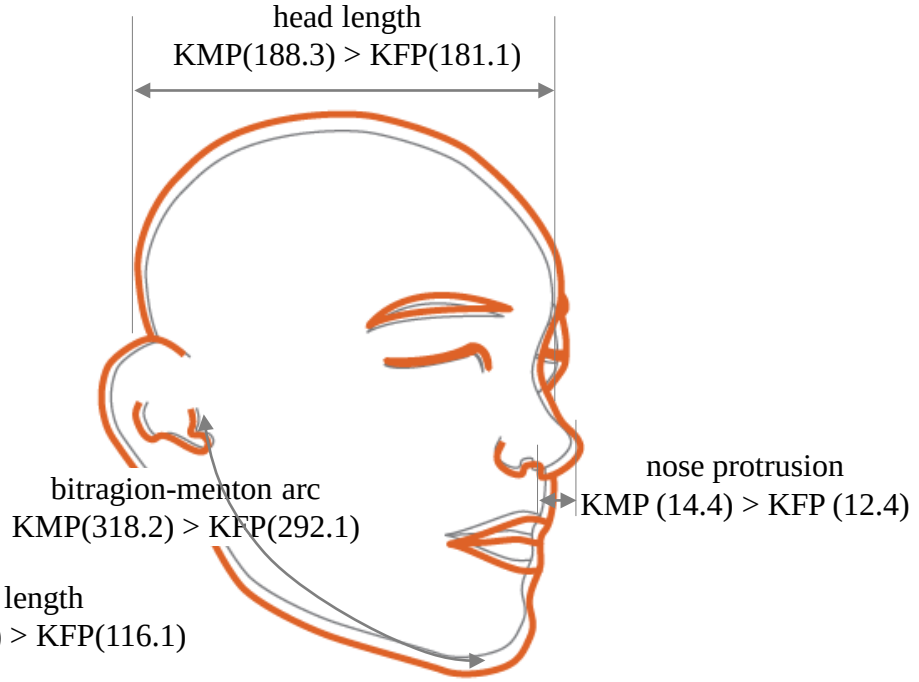


KAF Male Pilots (KMP) vs. KAF Female Pilots (KFP)

- **Mean: KMP ($\bar{d}$ = 1.8 ~ 26.1 mm) > KFP**
- **SD: KMP (ratio in SD = 1.03 ~ 1.33) > KFP**

⇒ **KFP facial characteristics should be reflected to the OM sizing system and OM designs considering gender ratio (e.g., male: female = 9: 1)**





KAF male pilots (KMP)
KAF female pilots and KAFA female students (KFP)

Discussion (1/4)

1. Compiled facial measurements of KAF pilots

- ✓ Facial dimensions = 22
- ✓ males = 278 , females = 58

No.	Anthropometric dimension	*n*	Mean	SD	Min	Max	Percentile			
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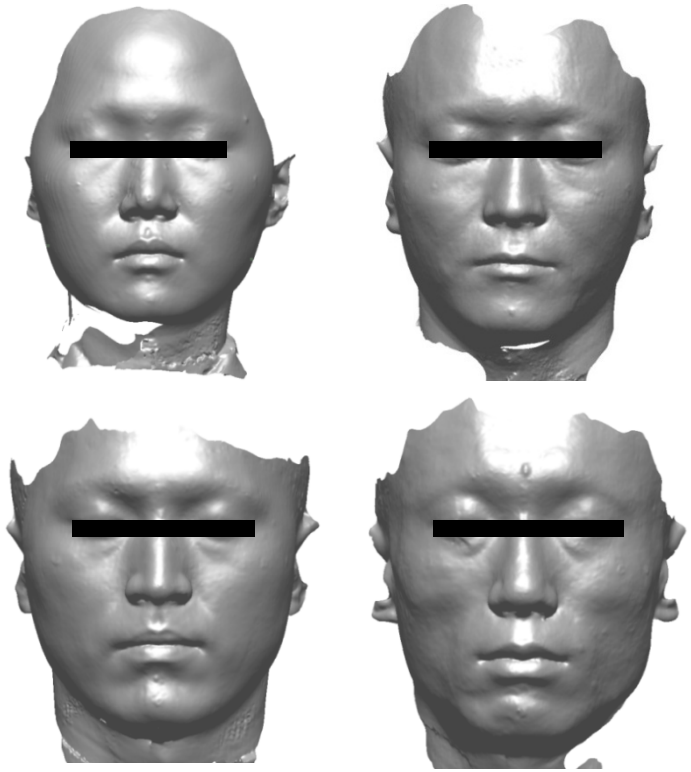
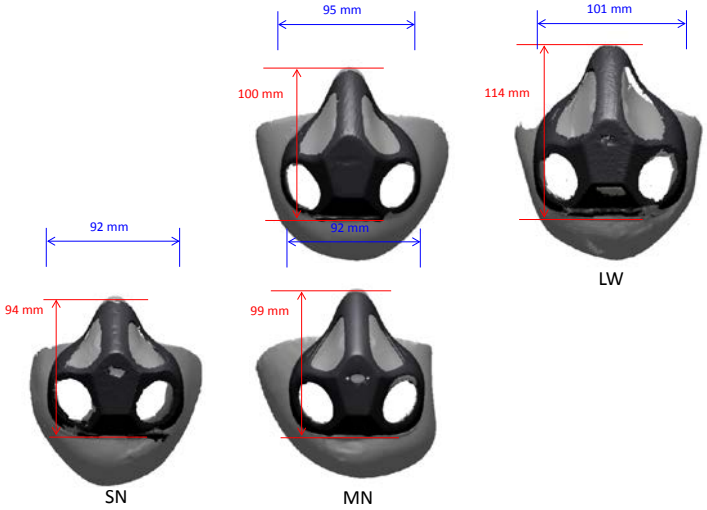


Discussion (2/4)

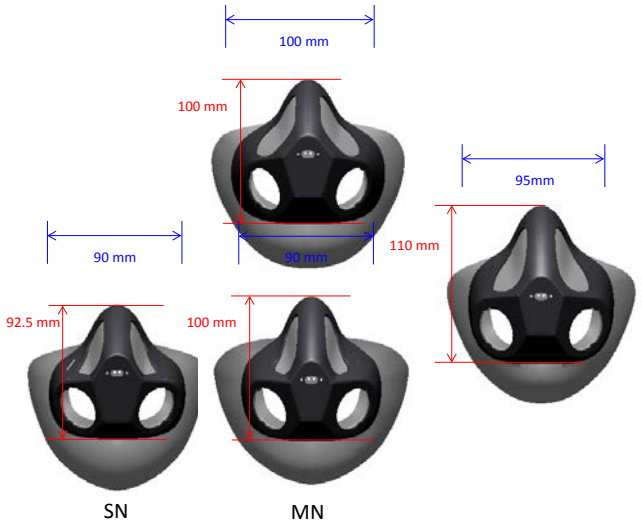
2. Identified the similarities and differences of facial measurements between KMP, KMC, UMP, and KFP in terms of mean and SD

   (1) Found significant differences in the OM key dimensions (face length and lip width)

   ⇒ Applicable to development of an OM sizing system and corresponding OM designs for KAF pilots



Existing OM designs



OM designs for Korean pilots

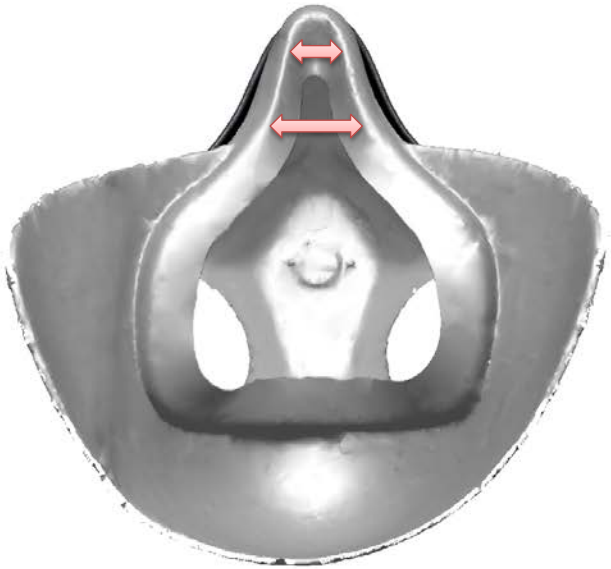
Discussion (3/4)

2. Identified the similarities and differences of facial measurements between KMP, KMC, UMP, and KFP in terms of mean and SD

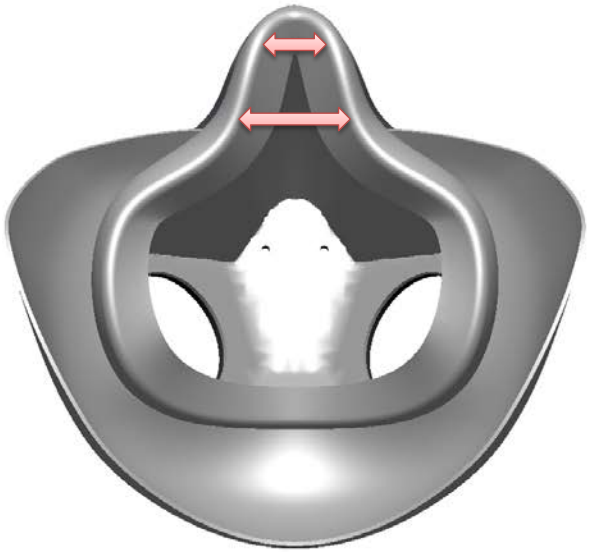
(2) Found significant **differences in the size and shape of the nose** (nasal root breadth and nose breadth) between KMP and UMP

- ✓ **Nasal root breadth**: KMP (20.6 mm) > UMP (15.4 mm)
- ✓ **Nose breadth**: KMP (38.1 mm) > UMP (35.0 mm)

⇒ **Widen the nasal part** of oxygen mask (**3 ~ 5 mm**)



current OM design

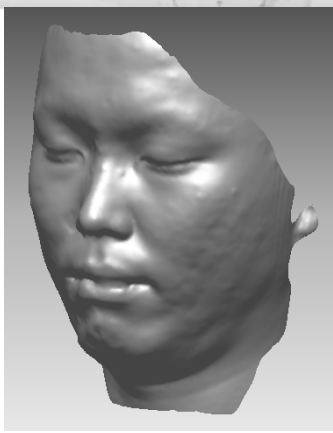


OM design for Korean pilots

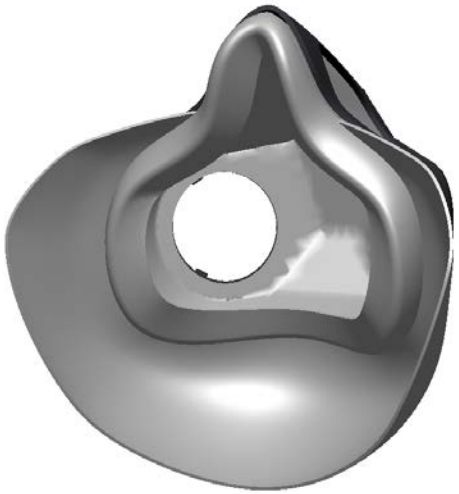
Discussion (4/4)

3. Obtained 3D facial shapes of KAF pilots

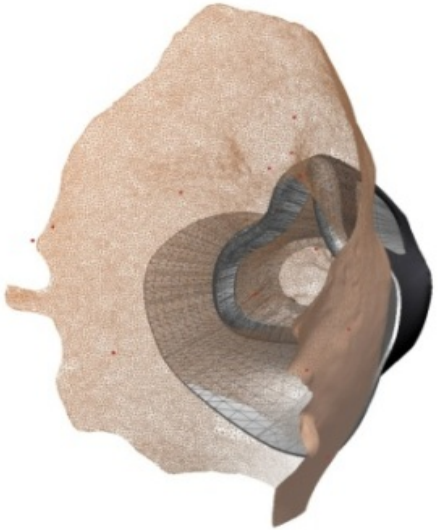
⇒ Applicable to designing a shape of OM and virtual fit assessment of OM designs for KAF pilots



current mask



revised mask



virtual fit assessment

Q & A

Thank you for your attention!