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Original Article

Anthropometric Features of Head and Face in Iran's Multi-Ethnic Workforce: A Framework for Future Studies on Respirator Design and Sizing

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Abstract

Background: Head and facial anthropometric data play a crucial role in designing and properly sizing respirators. Previous anthropometric studies on respirator design have primarily focused on the head and facial dimensions of American and Chinese individuals. However, there is a lack of research for multi-ethnic countries like Iran. We aimed to establish a comprehensive head and facial anthropometric database for Iranian workers. Specifically, we sought to identify differences among gender, age, and ethnicity, as well as determine the predictors that may influence head and facial dimensions.

Methods: This cross-sectional study was conducted among workers who underwent health assessments at Occupational Health and Medical Examination Centers affiliated with the medical universities of Shiraz, Tehran, and Karaj. A total of 1,000 workers (837 males and 163 females) participated in the study in 2022. Nineteen head and facial anthropometric dimensions were measured across six major Iranian ethnic groups. The effects of gender, age, ethnicity, occupation, and BMI on facial dimensions were analyzed using linear regression.

Results: The results revealed a difference between the head and face dimensions of males and females, which indicated that the facial dimensions of males were larger. Linear regression analysis showed gender, ethnicity, occupation, age, and BMI were significant predictors of the facial dimensions.

Conclusion: When designing and sizing respirators, it is crucial to consider the variations in facial anthropometric dimensions. By doing so, we can ensure that the respirators fit well on the face, thus minimizing the chances of injuries and occupational diseases.

Keywords: Anthropometric survey; Ergonomics; Respirator sizing; Facial dimensions

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Introduction

Respirators are considered personal protective equipment that protects users against airborne contaminants and plays a vital role in human respiratory health. Poorly designed and ill-fitting respirators that do not fit users' facial anthropometric dimensions are considered a major factor in reducing efficiency, productivity, and safety. Furthermore, when this equipment does not fit correctly users, it may not be used at all due to work interference or discomfort.

Several studies have been conducted in the field of head and face anthropometry (1-3). The user's anthropometric dimensions should be considered when designing respirators to ensure proper fit. Otherwise, pollutants can enter their respiratory system and pose a threat to their health (4). However, the fit between respirators and users is not always optimal (5). In order to design proper-fitting respirators, manufacturers should gather comprehensive anthropometric data that includes measurements of the face, such as width, length, and height, as well as curvature and landmarks of critical facial features. These measurements may vary among individuals due to factors such as age, gender, BMI, and ethnicity (6). Therefore, it is crucial to collect data from a diverse population to design respirators that accommodate a broad range of users.

There was considerable variation in head and face anthropometric dimensions between different populations, and the "one-size-fits-all" approach for respirators is not sufficient (3, 7, 8). There were differences in facial dimensions between Chinese and Americans. Specifically, Chinese individuals tend to have wider and shorter facial features compared to Americans (1). Zhuang et al. supported these findings and also emphasized the significant differences in facial anthropometry among Caucasians, African-Americans, Hispanics, and Asians (6). Thus, for respirator design and sizing, it is important to consider the facial dimensions and shape of the target users.

Moreover, facial anthropometric dimensions are used to develop respirator fit test panels. To design an effective fit test panel, researchers and manufacturers rely on anthropometric databases that provide data on the facial dimensions of individuals within a specific population. By understanding the diverse range of facial sizes and shapes within a population, manufacturers can develop respirators that accommodate a larger user base. This ensures that individuals with varying facial anthropometry can find a respirator that fits them properly, providing effective protection against airborne hazards (9).

Iran stands as a remarkable example of a multi-ethnic country (10). Understanding head and face anthropometry across different ethnicities is vital for developing respirators that can provide adequate protection for all individuals. However, despite the importance of this research field, there remains a significant gap in knowledge regarding head and face anthropometry specifically tailored to the multi-ethnic population of Iranian workers. This gap hinders the development of respiratory protective equipment that can be properly fit for all individuals within this diverse society.

Therefore, the main purpose of this study was to collectdata on head and face dimensions in Iranian workers relevant to the design of respirators and to compare these dimensions with other populations. Additionally, we aimed to identify differences among gender, age, and ethnicity, as well as determine the predictors that may influence head and facial dimensions.

Materials and Methods

Study population

The sample size was estimated using the ISO 15535 standard (general requirements for creating a measurement database) (11). This cross-sectional study was conducted among workers who underwent health assessments at Occupational Health and Medical Examination Centers affiliated with

the medical universities of Shiraz, Tehran, and Karaj. These cities were selected for their ethnic diversity.

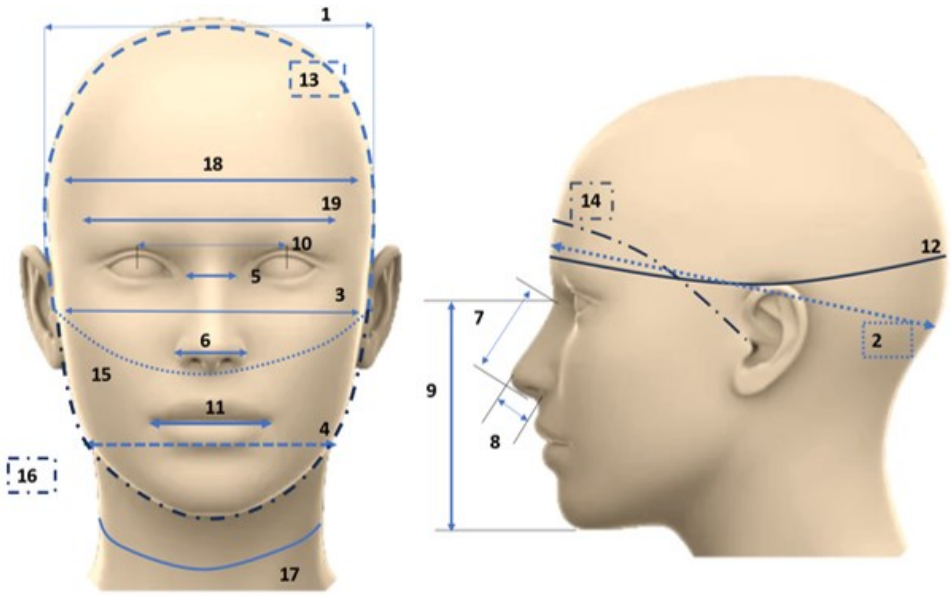
A total of 1,000 workers (837 males and 163 females) participated in the study in 2022. Anthropometric data of the head and face were collected for six ethnic groups (Fars, Turk, Kurd, Lor, Arab, and Baluch) to ensure that the sample accurately represented the Iranian workforce. Participants ranged in age from 18 to 60 years and were employed in various sectors, including manufacturing, construction, office work, and healthcare. Workers with dental or facial deformities, as well as those with beards or mustaches, were excluded from the study.

Ethics approval and consent to participate

Informed consent forms were provided; Ethics approval IR.SUMS.SCHEANUT.REC.1401.032.

Measurement Procedures

Anthropometric reference points on the subject's face were marked using an eyeliner pencil prior to measurement. After landmarking, facial dimensions were measured for each subject, and data were recorded on data sheets. The dimensions measured are shown in Fig. 1. All dimensions were measured in millimeters, and body weight was measured in kilograms.



No.	Anthropometric dimension	No.	Anthropometric dimension
1	Head breadth	11	Lip length
2	Head length	12	Head circumference
3	Bizygomatic breadth	13	Bitragion coronal arc
4	Bigonial Breadth	14	Bitragion frontal arc
5	Nasal root breadth	15	Bitragion subnasale arc
6	Nose breadth	16	Bitragion chin arc
7	Subnasalesellion length	17	Neck circumference
8	Nose protrusion	18	Maximum frontal breadth
9	Menton-sellion length	19	Minimum frontal breadth
10	Interpupillary distance		

Fig. 1: The head-and-face dimensions and landmark location

Participants with abnormalities in the face, a history of trauma, surgery in the facial area, and a beard or mustache were excluded from the study. The data collection was carried out between June 2022 and September 2022. Most of the anthropometric measurements were taken using a spreading caliper, a sliding caliper, a tape measure, and a pupilometer.

Statistical analysis

The data were analyzed using SPSS version 26 (IBM Corp., Armonk, NY, USA). Descriptive analysis (mean, standard deviation, and different percentiles) was conducted for all dimensions by gender.

Linear regression analysis was performed to examine the simultaneous impact of age, gender, ethnicity, occupations, and BMI on head and facial dimensions. Nineteen head and facial dimensions were dependent variables, while sex, ethnicity, occupation, age, and BMI were regarded as independent variables. BMI was treated as a continuous variable, while age, sex, ethnicity, and occupation were considered as categorical variables. Age was divided into 3 groups (18–30, 31–40, and 41–60), ethnicity was divided into 6 groups (Fars, Turk, Kurd, Lor, Arab, and Balouch), and occupation was divided into 4 groups (office workers, manufacturing, construction, and healthcare). Male gender, age 18-30, Fars ethnicity, and office workers were considered as the reference group.

Results

Nineteen head and face anthropometric dimensions of 1000 Iranian workers (837 males and 163 females) were measured. The participants in this study included manufacturing workers (64.6%), construction workers (14.2%), healthcare workers (10.6%), and office workers (10.6%).

The majority of the participants (62.3 %) were from the Fars group (Fig. 2). The Fars ethnic group accounted for 65.0% of the Iranian total population (12).

A summary of the mean, standard deviation, and percentile values for each dimension by gender is presented in Table 1.

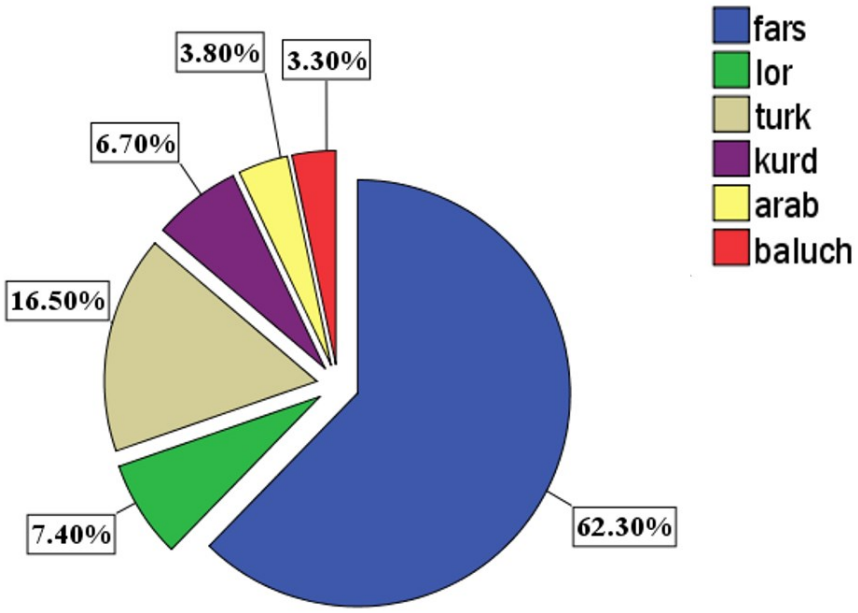


Fig. 2: Distribution of test subjects based on ethnicity (n= 1000)

Table 1: Head and facial dimensions according to gender

Dimensions	Male (n = 837)				Female (n = 163)			
	Mean ± SD	5% tile	50 %tile	95 %tile	Mean ± SD	5% tile	50 %tile	95 %tile
Bigonial breadth	122.0 ± 7.6	109	122	135	111.5 ± 6.3	101	111	123
Bitragion chin arc	325.9 ± 15.1	302	325	352.1	299.0 ± 15.5	279	299	317.1
Bitragion coronal arc	356.6 ± 14.6	332.8	358	381	342.9 ± 13.2	319	344	364.8
Bitragion frontal arc	312.4 ± 12.8	290	312	334	300.1 ± 12.3	279	300	320
Bitragion subnasale arc	292.6 ± 12.2	272	292	313	275.1 ± 10.0	258	274	291.4
Face length	125.1 ± 7.2	114	125	138	116.3 ± 7.3	104.2	117	129.8
Face width	140.4 ± 10.0	124	141	157	133.7 ± 7.8	117	135	144
Head breadth	158.1 ± 7.6	146	158	171	149.2 ± 7.3	137	149	162
Head circumference	567.7 ± 16.6	540	568	596	552.5 ± 17.2	524	551	584.6
Head length	192.6 ± 7.8	181	193	205	184.8 ±6.7	174.2	185	195
Interpupillary distance	61.9 ± 3.1	57	62	67	59.8 ± 2.9	55	60	64
Lip length	46.6 ± 3.9	40	47	53	43.2 ± 3.7	37	43	51
Maximum frontal breadth	125.2 ± 7.2	114	125	138	116.1 ± 6.2	105	116	126
Minimum frontal breadth	114.5 ± 6.6	104	114	125	108.0 ± 5.9	99	108	117
Nasal root breadth	18.5 ± 2.7	14	18	23	17.0 ± 3.0	11.2	17	23
Neck circumference	387.0 ± 28.0	345	386	436.1	336.6± 22.3	299.2	335	379
Nose breadth	35.1 ± 3.4	30	35	41	30.7 ± 3.3	26	31	36
Nose protrusion	23.0 ± 3.6	17	23	29	20.0 ± 3.4	14.2	20	25.8
Subnasale–sellion length	52.7 ± 4.2	46	53	60	50.3 ± 4.0	44	50	58

Head and face anthropometric dimensions are known to vary based on factors such as age, race, gender, BMI, and occupations. In order to examine these associations, linear regression models were used, and the results are provided in Table 2.

Gender: It was found to be a significant predictor for all the nineteen head and facial dimensions, with $P<0.001$. Females have smaller anthropometric measurements for every dimension, and overall, they have shorter and narrower faces.

Age: Regression coefficients for age demonstrate that thirteen values of facial anthropometrics for subjects over 41 years old are statistically different from those measured for subjects between 18 and 30 years old. The difference in facial features between the youngest age group and between the ages of 31 and 40 years was not great, the most noticeable differences between these groups were found in neck circumference, bitragion coronal arc, and head circumference. Generally, measurements of dimensions also change significantly as age increases, and older workers have significantly larger faces with longer and narrower features.

Table 2: The regression coefficients for anthropometric measurements by age, gender, BMI, ethnicity, and occupation

Dimensions	Constant (SE)	Age (SE)	Gender (versus male) (SE)	BMI (SE)	Ethnic (versus Fars)					Occupation (versus office worker)			Age (versus 18-30)	
					Turk (SE)	Kord (SE)	Lor (SE)	Arab (SE)	Balouch (SE)	CO (SE)	MF (SE)	HC (SE)	31-40	41-60
Bigonial breadth	97.9 (1.3)	0.1 (0.0) *	-9.9 (0.7) **	1.0 (0.0) **	-1.1 (0.5)	-0.9 (0.8)	0.3 (0.7)	-1.1 (1.1)	-0.6 (1.1)	-2.2 (0.8) **	-2.1 (0.7) **	-2.3 (0.9) *	0.2 (0.5)	1.2 (0.5) *
Bitragion chin arc	284.6 (2.8)	0.1 (0.0) *	-26.1 (1.4) **	1.7 (0.1) **	-1.8 (1.1)	-1.7 (1.7)	0.2 (1.6)	0.4 (2.3)	-4.6 (2.3)	-2.8 (1.7)	-2.9 (1.4)	-2.7 (1.9)	0.7 (1.0)	2.1 (1.0) *
Bitragion coronal arc	339.3 (3.0)	-0.2 (0.1) **	-14.3 (1.6) **	0.9 (0.1) **	4.1 (1.2) **	5.0 (1.8) **	3.5 (1.7) *	3.4 (2.4)	1.0 (2.5)	-3.9 (1.9) *	-3.5 (1.5) *	-5.5 (2.0) **	-4.5 (1.1) **	-4.9 (1.1) **
Bitragion frontal arc	290.6 (2.6)		-12.5 (1.3) **	1.0 (0.1) **	3.9 (1.0) **	3.8 (1.5) *	3.2 (1.5) *	-0.7 (2.1)	4.5 (2.1) *	-5.7 (1.6) **	-5.1 (1.3) **	-6.6 (1.8) **	-1.7 (0.9)	-0.7 (1.0)
Bitragion subnasale arc	260.7 (2.3)		-17.2 (1.2) **	1.4 (0.1) **	-2.7 (0.9) **	-1.6 (1.3)	-0.2 (1.3)	-2.6 (1.8)	-3.0 (1.9)	-4.3 (1.4) **	-3.9 (1.1) **	-3.7 (1.5) *	-1.9 (0.8) *	-1.9 (0.8) *
Face length	119.1 (1.6)	0.1 (0.0) **	-8.5 (0.8) **	0.2 (0.1) **	2.1 (0.6) **	2.0 (0.9) *	1.0 (0.9)	1.9 (1.3)	-0.5 (1.3)	-2.1 (1.0) *	-0.5 (0.8)	-1.8 (1.1)	1.8 (0.5) **	2.0 (0.6) **
Face width	123.9 (1.9)		-8.0 (1.0) **	0.7 (0.1) **	7.9 (0.7) **	7.7 (1.1) **	4.2 (1.1) **	2.5 (1.5)	6.2 (1.5) **	-2.9 (1.2) *	-2.9 (1.0) **	-3.1 (1.3) *	-1.1 (0.7)	0.8 (0.7)
Head breadth	147.9 (1.6)		-8.8 (0.8) **	0.5 (0.1) **	0.2 (0.6)	-0.1 (0.9)	2.9 (0.9) **	-2.7 (1.3) *	0.4 (1.3)	-1.9 (1.0)	-2.8 (0.8) **	-3.0 (1.1) **	-1.1 (0.5) *	-1.4 (0.6) *
Head circumference	530.5 (3.4)		-14.8 (1.7) **	1.6 (0.1) **	-0.4 (1.3)	-1.5 (2.0)	1.0 (1.9)	0.1 (2.7)	-3.9 (0.2)	-4.8 (2.1) *	-3.6 (1.7) *	-3.9 (2.3)	-2.1 (1.2)	-0.8 (1.3)
Head length	183.6 (1.6)		-7.8 (0.8) **	0.4 (0.1) **	2.6 (0.6) **	0.8 (1.0)	-0.2 0.9	0.6 (1.3)	0.0 (1.3)	-1.6 (1.0)	-0.1 (0.8)	-0.4 (1.1)	-1.7 (0.6) **	-0.5 (0.6)
Interpupillary distance	59.3 (0.7)		-2.2 (0.3) **	0.1 (0.0) **	-0.3 (0.3)	-0.2 (0.4)	0.2 (0.4)	-0.4 (0.5)	-0.8 (0.6)	-0.6 (0.4)	-0.7 (0.3) *	-0.5 (0.5)	-0.1 (0.2)	-0.1 (0.3)
Lip length	43.8 (0.9)	0.1 (0.0) **	-2.6 (0.4) **	0.1 (0.0) **	-0.1 (0.3)	-0.6 (0.5)	-0.5 (0.5)	-0.7 (0.7)	-1.0 (0.7)	-0.2 (0.5)	0.4 (0.4)	-0.5 (0.6)	0.9 (0.3) **	1.8 (0.3) **
Maximum frontal breadth	115.1 (1.5)		-9.5 (0.8) **	0.4 (0.1) **	3.2 (0.6) **	2.6 (0.9) **	2.8 (0.8) **	0.5 (1.2)	2.8 (1.2) *	-1.8 (0.9) *	-1.7 (0.7) *	-2.0 (1.0) *	-1.0 (0.5)	-0.9 (0.5)
Minimum frontal breadth	102.5 (1.3)		-6.4 (0.7) **	0.5 (0.1) **	3.7 (0.5) **	3.4 (0.8) **	2.7 (0.7) **	0.1 (1.0)	3.8 (1.1) **	-1.3 (0.8)	-1.6 (0.7) *	-3.0 (0.9) **	-1.1 (0.5) *	-1.3 (0.5) *
Nasal root breadth	15.0 (0.6)	0.1 (0.0) **	-1.1 (0.3) **	0.1 (0.0) **	0.4 (0.2)	0.1 (0.4)	0.8 (0.3) **	0.3 (0.5)	1.0 (0.5)	-0.3 (0.4)	0.1 (0.3)	-1.0 (0.4) *	0.1 (0.2)	0.7 (0.2) **
Neck circumference	252.3 (7.3)	0.3 (0.1) **	-48.8 (2) **	4.7 (0.1) **	-5.8 (1.6) **	0.7 (2.4)	1.1 (2.3)	-0.5 (3.2)	-8.5 (3.3) *	-4.2 (2.5)	-3.5 (2.0)	-1.3 (2.7)	2.5 (1.4)	5.3 (1.5) **
Nose breadth	31.0 (0.7)	0.1 (0.0) **	-4.1 (0.4) **	0.1 (0.0) **	-1.1 (0.3) **	-0.6 (0.4)	0.2 (0.4)	-0.1 (0.6)	-0.5 (0.6)	-0.1 (0.5)	-0.1 (0.4)	-0.2 (0.5)	0.4 (0.3)	1.1 (0.3) **
Nose protrusion	22.7 (0.4)	0.1 (0.0) **	-2.7 (0.4) **		-2.5 (0.3) **	-1.5 (0.4) **	-0.3 (0.4)	0.5 (0.6)	-2.3 (0.6) **	-0.2 (0.5)	-0.1 (0.4)	-0.1 (0.5)	1.1 (0.3) **	1.5 (0.3) **
Subnasale–sellion length	52.7 (0.5)	0.1 (0.0) **	-2.5 (0.5) **		-0.1 (0.4)	-0.1 (0.5)	0.4 (0.5)	1.1 (0.7)	-1.6 (0.8) *	-1.1 (0.6)	-0.6 (0.5)	-0.6 (0.6)	0.7 (0.3) *	1.4 (0.3) **

SE represents the standard error for a group value; occupation is designated as follows: manufacturing (MF), construction (CO), and healthcare (HC); units are in millimeter except for BMI; * $P< 0.05$; ** $P< 0.001$

BMI: There were significant increases in all anthropometric dimensions when BMI increased, except for nose protrusion and subnasale-sellion length. The most notable effect was observed in neck circumference, with an average increase of 4.7 mm for every 1 unit increase in BMI.

Race/Ethnicity: Turk workers have seven facial features that are significantly larger than Fars subjects, while their bitragion subnasale arc, nose protrusion, nose breadth, and neck circumference are significantly shorter. The Lor groups have wider faces, with statistically significant differences in seven anthropometric measurements compared to Fars subjects. Kurd subjects had significantly larger measurements than Fars subjects for bitragion frontal arc, bitragion coronal arc, maximal frontal breadth, minimum frontal breadth, face length, and face width. However, nose protrusion was slightly smaller in the Kurd samples. All facial dimensions are similar between Arab and Fars subjects, except for head breadth, which is significantly smaller for Arabs. Facial measurements are significantly larger for Balouch individuals than Fars groups for bitragion frontal arc, maximal frontal breadth, minimum frontal breadth, and face width. However, some facial dimensions (subnasale-sellion length, neck circumference, and nose protrusion) were found to be slightly smaller in the Balouch samples.

Occupation. When comparing overall facial size characteristics among different occupational groups, individuals in occupations such as manufacturing, healthcare, and construction showed significant differences in facial features compared to office workers. Office workers had significantly larger bigonial breadth, bitragion coronal arc, bitragion frontal arc, bitragion subnasale arc, face width, head circumference, and maximum frontal breadth than individuals in other occupations.

The facial dimensions of individuals employed in construction were found to be significantly smaller than those of office workers. Healthcare workers also had smaller facial features than office workers, including bitragion frontal arc, bitragion coronal arc, bigonial breadth, bitragion subnasale arc, face width, head breadth, minimal frontal breadth, maximum frontal breadth, and nasal root breadth.

Discussion

In this study, 19 head and face dimensions of Iranian workers were measured. Generally, these dimensions can be considered the basic information for respirator design and size (2). The results of the linear regression analysis showed that sex, ethnicity, occupation, age, and BMI were predictors for head and facial dimensions.

As expected, male participants had larger head and face dimensions compared to females. Our findings are in accordance with previous studies that showed significant differences in facial dimensions between genders (1, 6, 8). This suggests that respirators might not equally fit males and females. Therefore, respirator manufacturers and suppliers should take these differences into consideration and use sex-based head and face anthropometric data for the sizing and design of properly fitted respirators.

Ethnicity is an important factor in determining the size of facial features (6, 8). The results show that there are significant differences in facial dimensions among different ethnic groups. However, there is no clear pattern indicating that one ethnicity has larger facial dimensions than others. These variations in facial dimensions can be attributed to a range of factors, including genetic differences, dietary practices, lifestyles, and environmental influences such as climate and geographic location (13).

One unexpected result of this analysis was the significant differences in facial anthropometric values between office workers and other occupational groups. The research indicated that office workers in sedentary jobs had wider faces compared to those in physically demanding occupations. This variation in facial characteristics among occupations may be attributed to differences in diet and physical activity levels associated with the job requirements. Therefore, great care should be taken not to use anthropometric data obtained from one

occupational group, such as office workers, to design respirators for other occupations, such as construction workers.

Further research is needed to explore the underlying factors contributing to these differences and to better understand the specific impact of different occupational environments on anthropometric characteristics.

The findings of the study indicated that increases in BMI were associated with significant increases in all facial anthropometric dimensions except for nose protrusion and subnasale-sellion length. The influence of BMI on head and facial dimensions can be attributed to changes in weight and body composition.

Facial dimensions also change significantly as age increases. The most noticeable differences between age groups were found in bitragion subnasale arc, bitragion coronal arc, and face length. Generally, measurements of dimensions also change significantly as age increases, and older workers have significantly larger faces with longer and narrower features. These findings are similar to previous research (1, 6). As age increases, changes in facial dimensions can be influenced by various factors, such as biological processes, environmental factors, and lifestyle. However, it's worth noting that the natural biological process of aging, including the loss of collagen and elastin as well as skeletal changes, plays a vital role in these alterations (14, 15).

The present study had some limitations. A limiting factor in regression analysis was the sample size distribution in various occupations. For instance, the majority of healthcare workers were female, and construction workers were male. However, it was not required that the sample size be equal across types of occupations because the number of respirator users is not the same in each occupation. Moreover, it should be noted that there was the possibility of potential human errors during the measurements, as well as inherent limitations related to measuring instruments. Broadly, conducting more comprehensive anthropometric surveys requires additional resources and time, resulting in a high cost for implementing a nationwide anthropometric survey. The main strength of the current study is that it is the first to report the characteristics of head and facial anthropometrics in the multi-ethnic population of Iranian workers. We could use this information in future studies to design respirators based on Iranian facial dimensions and develop an exclusive fit test panel for Iranian people.

Conclusion

Ethnicity, gender, BMI, age, and occupation impact face size and shape characteristics, so these factors are critical in determining respirator design and sizing. In order to fit more people, respirators should be designed to match users' facial dimensions. Facial dimensions are important factors for respirator design and sizing because differences in facial dimensions can affect the fit and efficacy of respirators.

The present study provided a comprehensive head and face anthropometric data bank for the Iranian worker population with different ethnicities, which can be utilized in future research related to the design and size of respirators and other personal protective equipment (PPE) worn on the head and face. We could use this information for developing an Iranian fit test panel and designing locally respirators that offer better fit, enhanced protection, and increased comfort for users.

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Conflict of Interest

The author declares no conflicts of interest.

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