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Anthropometric Study of Human Ear: A Baseline Data for Ear Reconstruction

Arif Tri Prasetyo, MD, MClinMed[*] *and Indri Lakhsmi Putri, MD, PhD*[†]

Background: Creation of an auricular framework plays the main role on first stage of microtia reconstruction. The size of framework is determined based on the size of the contralateral healthy ear and customized with Nagata theory. The height of rib that added behind the previous framework is the same with the projection of the normal ear. But the height of rib needed and framework in bilateral cases is unknown. A population based auricular framework pattern and projection are urgently needed.

Objectives: This study aimed at determining the mean values of normal anthropometric measurement of external ear and projection of human ear in males and females and their comparison on either sides and in either sex.

Materials and Methods: Measurements are taken from 524 subjects (96 men and 428 women) aged 17 to 35 years using a Vernier caliper. The parameters measured were total ear height, ear width, lobular height, lobular width, upper pole, middle upper pole, middle pole, lower middle pole, lower pole, each subject's right and left ears.

Results: Comparisons between gender were performed by independent *t* test and paired *t* test for comparison between right and the left ear. All dimensions were significantly different between male and female ($P < 0.05$) except the right lobular height ($P > 0.05$). There was no significant difference both side among groups ($P < 0.05$) except total ear height on female group ($P > 0.05$). All projection dimensions were significantly different between male and female. There was no significant difference of auricular projection of right and left auricular on the male ($P < 0.05$) groups except the projection of lower pole. There were significant between auricular projection of right and left ears on the female groups ($P > 0.05$).

Conclusions: These findings suggest that the normal anthropometric study will have implication in the ear reconstruction especially on bilateral cases as a baseline for reconstruction.

Key Words: Anthropometric, ear, microtia, auricular projection, ear projection, innovation

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Anthropometry refers to the measurements of living human body dimensions for the purpose of understanding human physical variation as it plays an important role in reconstruction surgery, prosthetics, and so on for data collection.[1] The ear is composed of a delicate and complex-shaped cartilage framework covered on its visible surface with thin, tightly adherent, hairless skin.[2] Ears increase in both length and width with increase in age, from birth to 9 years of age. The increment was continuous in females, but for males it stopped around age of 50 and 70 for ear width and length, respectively.[3,4]

The modern era of auricular reconstruction began with Tanzer who reintroduced the technique of autogenous costal cartilage grafts as a method of auricular reconstruction. Tanzer's results inspired Brent who modified, improved, and standardized a 4-stage technique of auricular reconstruction. Nagata developed a more complex technique that condensed microtia repair into 2 stages. The Nagata technique requires more cartilage and the construction of a higher profile, more detailed framework than the Brent technique. Firmin analyzed those characteristics of a "Brent ear" that fall short of a normal ear and reported a large series using her modification of the Nagata technique.[2]

The cartilage graft is the "foundation" of an auricular construction, and as in construction of a house, it should be built and well established under ideal conditions before further stages or refinements are undertaken.[5]

Each technique has its own size of auricular framework template. If the microtia is unilateral, the auricular framework is adjusted by the normal one. But if the case is bilateral, the size of framework is adjusted by the surgeon based on the proportion of face. Nagata's cartilage frame size is 56×28 mm and drawn on transparent film templates and various sized are constructed using magnification ratio of photocopier.[6]

Firmin has three types of framework classification based on the anatomy anomalies: microtia without tragus, microtia with a tragus, but without antitragus, and microtia with a good tragus-antitragus complex.[7]

After the first stage of microtia reconstruction as we know as cartilage insertion, microtia patient is planned to have a second procedure, elevation of framework. Elevation of framework is the third stage of the Brent technique and the second stage of the Nagata

From the *Division of Plastic Reconstructive and Aesthetic Surgery, Department of Surgery, Faculty of Medicine, Universitas Padjadjaran, Bandung; and †Department of Plastic Reconstructive and Aesthetic Surgery, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia.

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Address correspondence and reprint requests to Indri Lakhsmi Putri, MD, PhD, Department of Plastic Reconstructive and Aesthetic Surgery, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia, Jalan Prof. Dr. Moestopo 6-8, Surabaya, 60131, Indonesia; E-mail: indrilakhsmiputri@fk.unair.ac.id

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technique; the previously placed framework is elevated and the retroarticular sulcus is resurfaced. Nagata adds a piece of rib cartilage covered with a temporoparietal flap. The cartilage is banked under the skin at the time of the first stage and is wedged into the sulcus to provide projection to the reconstructed auricle in the second stage.[2]

Nagata recommend that the reconstructive plastic surgeon must project the reconstructed auricle so that the angles of projection of both auricles are identical in unilateral cases. For bilateral cases, the angle of projection should approximate the average angle of projection, which is 30 degrees.[6]

Brent elevated the auricular framework at the third stage. This should only be attempted once edema has markedly improved and the auricular details have become well defined. An incision is made several millimeters' peripheral to the auricular framework and the cartilage is lifted from its bed, maintaining connective tissue on the posterior aspect of the cartilage and some over the fascia and periosteum of the bony floor. If the new auricle needs more lateral projection, a wedge of rib cartilage can be placed behind the elevated ear but must be covered with a tissue flap to allow for skin graft take.[2]

While Firmin has 4 types of second stage techniques based on the abnormality of the ear. If no additional projection is needed at the time of the second stage, Firmin's preferred technique is sulcus creation and grafting without the use of cartilage. However, additional projection is required to match the contralateral side, the piece of banked cartilage stored under the thoracic skin during the first stage must be prepared for reinsertion under the antihelix.[7]

Knowledge of the normal ear dimensions, position and symmetry is also necessary for the timing of surgical reconstructions, when the contralateral organ cannot be used as a template or on bilateral cases.[4]

MATERIALS AND METHODS

The study was carried out on 51 surgery residents and 861 new college students of Universitas Airlangga. From total 912 subjects, 388 subjects are excluded from the study due to congenital ears anomalies and the rest, 524 subjects are included into the study. This study consists of 96 males and 428 females aged 17 to 35 years old. Clearance of institutional ethical committee was obtained before starting the work. The purpose of study was explained to the subjects, their willingness and cooperation were considered.

The parameters measured were total ear height (TEH), ear width (EW), lobular height (LH), lobular width (LW), each subject's right and left ears (Fig. 1A). We divided the ears into 5 points of measurement. The points are upper pole (UP), upper middle pole (UMP), middle pole (MP), lower middle pole (LMP), and lower pole (LP) for each right and left ear (Fig. 1B). Upper pole is defined as the most top point of the ears, LP is defined as the most bottom point of ears, MP is defined as the center point of helix, UMP is defined as point between UP and MP, while LMP is defined as point between MP and LP. The point of the measurement was from helix to the mastoid surface.

All measurements were taken by a single investigator using Vernier caliper, capable of measuring to the nearest 0.1 mm (Fig. 1C) (Fig. 1D). Comparisons of the measurements according to gender were performed using an independent samples *t* test. Comparison of measurements taken from the right and left ears of a given sex was performed using a paired samples *t* test.

RESULT

The measurement and comparison of result according to genders who participate in the study are shown in the Supplementary Digital Content, Table 1, http://links.lww.com/SCS/D322 and Supplementary Digital Content, Table 2, http://links.lww.com/SCS/D323 where all dimensions were significantly different between male and female ($P < 0.05$) except the right LH ($P > 0.05$). The mean of TEH, EW, LH, and LW both ears were found to be bigger in male than female.

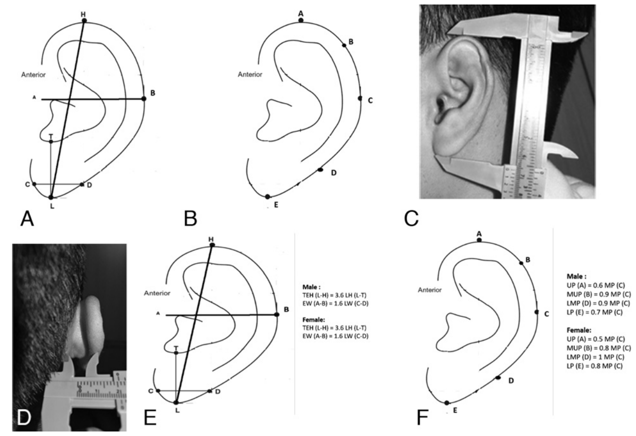

FIGURE 1. A – Reference points used for anthropometric measurements of ear (total ear height = L–H, ear width = A–B, lobular height = L–T, lobular width = C–D). B, Reference points used for projection measurements of ear (UP = A, UMP = B, MP = C, LMP = D, LP = E). C, The measurement of ear by a Vernier caliper (total ear height). D, The measurement of auricular projection (middle pole point). E, Correlation between TEH and LH, EW and LW. F, Correlation between other point and MP.

Supplementary Digital Content, Table 3, http://links.lww.com/SCS/D324 showed there were no significant difference both side among groups ($P < 0.05$) except TEH on female group ($P > 0.05$). Supplementary Digital Content, Table 4, http://links.lww.com/SCS/D325 showed the correlation between TEH and LH, EW, and LW.

The measurement and comparison of ear projection result according to genders who participate in the study are shown in the Supplementary Digital Content, Table 5, http://links.lww.com/SCS/D327 and Supplementary Digital Content, Table 6, http://links.lww.com/SCS/D329 where all the projection dimension were significantly different between male and female both point of ears ($P < 0.05$). The mean of UP, MUP, MP, LMP, and LP both ears were found to be more projected in male than female.

Supplementary Digital Content, Table 7, http://links.lww.com/SCS/D330 showed there were no significant difference of right and left auricular projection in the male groups except the projection of lower pole. But, there were significant different between auricular projection of right and left ears in female, the left ears were more projected that right one.

Supplementary Digital Content, Table 8, http://links.lww.com/SCS/D331 showed the size comparison between all the projection point with the MP. Data was analyzed statistically to find the mean and SD.

DISCUSSION

The external ear is an important component of the human facial complex. It defines the face and conveys information about the age and sex of an individual. The external ear's parameters, shape, and proportion to the face are vital in aesthetic surgery as this information helps guide a plastic surgeon in correcting ear defects. It is important to recognize that there is no standard ear morphology and variations across ethnic groups have been noted.[8]

There are no standardized objective measures for outcomes in microtia surgery. Investigators generally assess their work subjectively, with attention to shape, anatomic proportions, thickness, and

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definition Surgeons' techniques evolve over time, and continue to modify their framework patterns based on previous experience. Patient satisfaction is ultimately what should be assessed. Ability to wear hearing aids or glasses is an important feature of reconstructive surgery. Patients with a positive impression of their surgery can be seen with shorter haircuts or earrings, indicating some level of overt satisfaction.[6]

The TEH is important in the evaluation of congenital anomalies (Down syndrome). The ear reaches its mature height at 13 years in males and at 12 years in females.[10] In the study of Bozkir et al,[9] the height of the left ear was found to be 63.1 mm in men and 59.7 mm in women. Brucker et al[10] on their morphometric study of the external ear, age- and sex-related differences, obtained a mean TEH of 6.30 cm. In the study of Quatela, the average ear lengths are reported at 55 to 65 mm with a mean of 62.4 mm in males and 58.4 mm in females. Width is 55% of the length of the ear, achieving a mean of 35.5 mm in males and 33.4 mm in females.[11]

On our study, the mean values for TEH, EW, LH, and LW in male subjects were found to be respectively 61.7 ± 3.9 mm, 26.8 ± 2.4 mm, 19.3 ± 3.6 mm, 19.1 ± 4.6 mm for the right ear, and 61.3 ± 4.2 mm, 26.3 ± 2.3 mm, 19.6 ± 4.2 mm, 18.7 ± 4.1 mm for the left ear. However, in the female subjects, these values were, respectively, 58.1 ± 2.7 mm, 24 ± 3.4 mm, 16.6 ± 2.2, 15.9 ± 2.4 mm for the right ear, and 57.8 ± 2.8 mm, 24.1 ± 2.6 mm, 16.8 ± 3 mm, 16 ± 2.3 mm for the left ear.

Brucker et al[10] observed an average LH to be 1.88 cm and an increase in LH for both sexes. The measurement found in the study of Bozkir et al[9] was 1.8 cm in young men and 1.7 cm in young women. The LH in Deopa et al[12] study was 1.69 cm in young men and 1.68 cm in young women. The values are more in males.

Comparisons between gender were performed by independent *t* test and paired *t* test for comparison between right and the left ear. All dimensions were significantly different between male and female ($P < 0.05$) except the right LH ($P > 0.05$). The mean of TEH, EW, LH, and LW both ears were found to be bigger in male than female.

Comparison between TEH and LH, EW and LW was important to analyzed because these components should be balanced to create a nice framework. From this study seem that total ear height was 3 times larger than lobular height. EW was 1.61 larger than LW. (Fig. 1E)

There was no significant difference both side among groups ($P < 0.05$) except TEH on female group ($P > 0.05$).

On our study, range of auricular projection at middle pole point on male group was 19.6 ± 4.2 for the right ear, 19.7 ± 4.4 for the left, meanwhile on the female group was 15.4 ± 3.5 for the right ear and 15.8 ± 3.4 for the left ear. Muteweye[8] in 2015 determined that the normal range for auricular projection was 15 to 21 mm and 90.49% of the subject was on that range.[7,13]

Most of study only did measurement of auricular projection on one point, which in our study was defined as middle pole. Bozkir et al's[9] study on 2016, ear projection was measured as 17.10 mm in the young men and 16.61 mm in the young women. This measurement was generally reported to be 15 to 20 mm. On the Supplementary Digital Content, Table 8, http://links.lww.com/SCS/D331 showed the size correlation between all points with MP (Fig. 1F).

Because the auricular projection was not only middle point from the mastoid surface, author believe that other point of auricular also important. The mean values for UP, MUP, MP, LMP, and LP for female subject were found to be respectively 8.3 ± 2.4 mm, 12.4 ± 2.9 mm, 15.4 ± 3.3 mm, 15.2 ± 3.1 mm, 11.9 ± 3.2 mm for the right ear, and 8.7 ± 2.5 mm, 12.8 ± 2.8 mm, 15.8 ± 3.4 mm, 15.7 ± 3.2 mm, 12.2 ± 3.2 mm for the left ear. However in the male subjects, these values were, respectively, 11.9 ± 3.4 mm, 17.8 ± 5 mm, 19.6 ± 4.2, 17.8 ± 3.4 mm, 14.7 ± 4.9 mm for the right ear, and 12 ± 3.3 mm, 17.5 ± 4.3 mm, 19.7 ± 4.5 mm, 17.8 ± 3.6 mm, 14.3 ± 4.9 mm for the left ear. Comparisons between gender were performed by independent *t* test and paired *t* test for comparison between right and the left ear. All projection dimensions were significantly different between male and female. There was no significant difference of auricular projection of right and left auricular on the male ($P < 0.05$) groups except the projection of LP. There were significant between auricular projection of right and left ears on the female groups ($P > 0.05$).

Statistically, there was no significant difference between UMP and LMP on both side on male groups ($P > 0.05$). Meanwhile on female group there was significant difference between UMP and LMP on both side ($P < 0.05$). On total group, for UMP and LMP point, there was significant difference on right ear and left ear.

Nagata also explained there was relationship of the angle of projection and the distance of the auricle from temporal surface of the head.[14] This relationship is extremely important when projecting the reconstructed auricle, to match the angle of projection of the reconstructed auricle in unilateral cases, since there have been discrepancies between the reconstructed auricle and the opposite normal auricle. For example, the average angle of projection is 30 degrees and the distance from the temporal surface to the highest plane of the auricle is 20 mm. The height of the cartilage block necessary to attain these objectives was calculated to be 14 mm.[6,15]

Different like the others, more recently, Firmin has added a piece of cartilage deep to the root of the helix and the tragus during framework construction, stabilizing the 2. This projection piece, previously known as the "surelevation," has become a significant part of the first stage. This simple addition improved Firmin's results by giving more projection and stability to the tragus and the root of the helix. And Firmin will added more cartilage on second stage if needed.[7,16]

Brent technique also has their own unique. Brent did not add cartilage to create projection on the second stage. He only covers the elevated auricular framework with fascia then covered it up with skin graft.[11,17,18]

Farkas et al[19] in 2005 did anthropometry research on 1470 healthy young subject, 20.4% (300 subjects) are Asian. Farkas also did anthropometry research on length of auricle, so we can compare the results with our data because we use a large data of Asian population especially on Indonesia which has different ethnic from Farkas who did measurement on India, Japan, Chinese Singapore, Vietnam, and Thailand. We only measured the original ethnic of Indonesia, in this case Java people. In contrast with Farkas research, we also measure ear height that can be compared with ear length on his paper, ear width, lobular height, lobular width, and the inclination of the ear which is divided into 5 points of measurement.

On Farkas et al's[19] paper, the normal range of length of auricle in Indian males is 61.1 mm and 57.1 mm on females. While on Singaporean Chinese males 60.7 mm and 57.6 mm on females. The length of Vietnamese male's ear is 59.9 mm, 59,8 mm on Vietnamese's females, 62.4 mm on Thai Males, 60.3 mm on Thai females. Japanese males have 65.6 mm length of ears, 61.9 mm on Japanese females.

In another study form Farkas et al[20] in 1992, they did measurement which were taken directly from the ears of subject: width and length using anthropometric sliding caliper. Only finding for the left auricle are reported. Those papers measure the ear from 1 year old until 18 years old. The ear width (preaurale-postaurale, pra-pa) was 35.4 ± 2.2 mm on male and 33.5 ± 2.1 mm. Ear width in both sexes showed mild continuous increments between 1 and 18 years old age interrupted with shirt periods of no growth, in males after 10 years and in females after 8 years of age.[20]

Niemitz and Sforza[21] found that the ear size of Caucasians in Germany and Italy kept increasing throughout the life cycle.[22]

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Brooke proposed that the earlobe is the only part of the ear that keeps growing with age. Compared with American children, Chinese people reach their mature age when their ears are longer, and children who have wider ears reach their mature age.[21]Specifically, Chinese boys and girls achieved full ear length growth at the age of 14, while American boys and boys reached 13 and 12 years old respectively; the ear width maturity of Chinese boys was 7 years old, and that of girls was 5 years old. The ear width maturity of American boys is 7 years old and that of girls is 6 years old.[20] Similar to the Caucasians in Germany and Italy, the ear size (including the length and width of the ears) of different populations continues to grow after adulthood, such as Americans, Indians and Chinese Han.[23,24,25] These results indicate that with age, the size of the outer ear will increase, which indicates that age should be considered in related industrial designs. A cross-sectional study was conducted to examine the difference in ear size between different races. Compared with Caucasians, Koreans have longer ears and smaller ear widths.[26] In terms of ear length and width, Indians have the largest ears, followed by Caucasians and Africans. The length and width of the ears of Iranians are larger than those of Caucasians.[27,28]

In addition to age and ethnicity, the researchers also verified the influence of other demographic parameters on ear size. In the same population, men's ears tend to be larger in length and width than women, such as Italians, Indians, Sudanese, and Chinese.[22,27,29,30] Regarding the symmetry of ears, most linear, area, and ratio dimensions show good symmetry between the left and right ears, while angular dimensions tend to be asymmetric.[22,27] In particular, for both men and women, the auricle angle of the left ear of Italian Caucasians is larger than that of the right ear.[22] The width of the left ear of the Turk is larger, and the height of the ear, the height of the lobule and the weight of the lobule are symmetrical.[31] The length of the right ear hole, the length of the ear connection and the length of the auricle are larger in Taiwanese. These studies provide valuable information about the effects of gender and symmetry.[32]

Purkait and Singh's anthropometric study of normal auricles on adult men in central India concluded that Indian men's auricles and lobules appear to have the smallest length compared to other races, although their respective widths are comparable to those of other races. People are comparable. However, we observed that the size of the auricles of Nigerians is smaller than that of Maharashtras. Analysis of our data shows that compared with the Central Indians, people in Maharashtra have larger ear lengths, but smaller ear widths, leaflet lengths, leaflet widths, outer ear lengths, and outer ear widths. Therefore, even within the Indian subcontinent, there are wide variations in the size of the auricle.[33]

On our study, the mean values EW male subjects were found to be, respectively, 26.8 ± 2.4 mm for the right ear, and 26.3 ± 2.3 mm, for the left ear. However, in the female subjects, these values were, respectively, 24 ± 3.4 mm for the right ear, and 24.1 ± 2.6 mm for the left ear. Comparing with Farkas studies, our results on ear anthropometric are not much different on Asian population, but we also provide more details about inclination of the ear.

CONCLUSIONS

Knowledge about the normal ear dimensions is important in the diagnosis of congenital malformations, syndromes, and acquired deformities, as well as in the planning of treatments and hearing instruments' industry. This study provides the mean values of the different anthropometric measurements of the left and right ears in Indonesia. These findings suggest that the normal anthropometric study will have implication in the second stage of microtia reconstruction especially on bilateral cases as a baseline for reconstruction. Middle pole point was the highest point on auricular projection of human ear. Statistically, there was no significant difference between UMP and LMP on both side on male groups. Meanwhile on female group there was significant difference between UMP and LMP on both sides.

As a result, the data presented in this study have yielded parameters for ear morphology that would prove useful in determining ear anomalies and variations, and may help plastic surgeons to reproduce an anatomically correct ear during its reconstruction. It gives new ear measurements for Indonesian population.

Our study just calculated the auricular projection of 5 point of ear. So, we need more studies about how much the cartilage block needed to elevate and create auricular projection based on our anthropometric. Because this study can only do on second stage microtia procedure on microtia population.

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