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Evaluation of Auricular Morphologies of Motorcycle Couriers Based on Helmet Usage Using Photogrammetric Methods

Evaluación de la Morfología Auricular de Mensajeros en Motocicleta Basada en el Uso de Casco Mediante Métodos Fotogramétricos

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ERDOGAN, M.; COLAK, T.; COLAK, S.; SIVRI, I. & KAYGIN, E. Evaluation of auricular morphologies of motorcycle couriers based on helmet usage using photogrammetric methods. *Int. J. Morphol., 42(5)*:1416-1422, 2024.

SUMMARY: In recent years, the advancement of technology and the pursuit of time efficiency have increased people's interest in online shopping. Various models of helmets are preferred by motorcycle riders, including those that fully cover the face, only enclose the chin, or are half-faced. However, a common feature in all models is that the earlobes remain within the helmet. Anatomically, considering the possibility of changes in the structure of the auricle (pinna) due to helmet usage and the potential impact on the transmission of sound to the middle ear in the future, our study is designed to identify alterations that may occur in the earlobes of motorcycle couriers as a result of helmet use. Participants in our study were selected from individuals working as couriers. A total of 200 participants, comprising 100 individuals who regularly use helmets and 100 individuals who do not use helmets, were included based on voluntary participation. Individuals with a history of earlobe surgery or auricular anomalies were excluded from the study. The selection criteria for helmeted couriers included a minimum of five years of helmet usage. Morphometric measurements were conducted through a photometric method using a digital camera, which is an indirect measurement technique.The distance between the landmark points marked on the auricle and the attachment distance of the auricle to the head were calculated using the MB Ruler program. According to the statistical analysis of the morphometric data obtained, it was observed that the cymba concha height, as well as the width and height of the auricle, were significantly lower in both the right and left ears of couriers. As a result, it can be speculated that prolonged helmet usage may affect the cartilaginous structure of the ear, thereby altering the distance values between landmark points.

KEY WORDS: Auricle; Ear; Ear Cartilage; Pinna.

INTRODUCTION

The outer portion of the external ear, known as the auricle, develops from the sixth mesenchymal condensation located at the dorsal ends of the first and second pharyngeal arches, surrounding the first pharyngeal (hyomandibular) cleft (Shah *et al*., 2022; Helwany *et al*., 2023). During the embryological period, around the sixth week of development, these condensations, referred to as auricular hillocks, are asymmetrically situated on both sides of the external auditory canal. These hillocks progressively enlarge and subsequently fuse to form the external ear. The last segment to develop within the external ear is the earlobe (Schoenwolf, 2009).

In addition to its contribution to the sense of hearing, the position, shape, and size of the auricle on both sides of the head also hold aesthetic significance. The auricle consists of various parts such as the helix, antihelix, concha auricularis, and lobulus auricula. Due to the fixed position of these parts and the proportions among them, the auricle is crucial in craniofacial examinations and forensic anthropology for determining race, age, and sex (Dinkar & Sambyal, 2012). On the auricle, there are certain landmark points that assist in sex and age determination, which are utilized in forensic anthropology (Fig. 1).

Although there is a certain ratio among these landmark points, and it is generally accepted that these ratios remain constant from birth to death (Dinkar & Sambyal, 2012; Boesoirie *et al*., 2022), studies have investigated the impact on the shape and position of the auricle under conditions such as aging, certain illnesses, engagement in professional music, and pressure applied to the auricle through the use of glasses or masks (Sforza *et al*., 2009;

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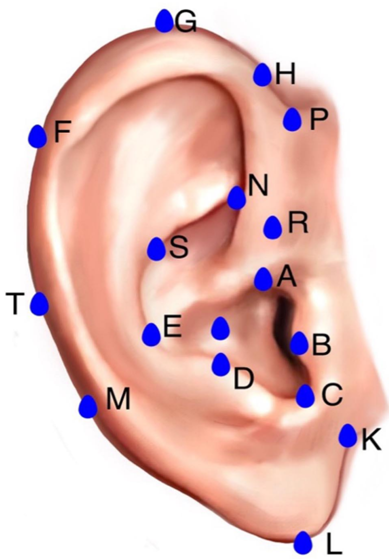

Fig. 1. Auricular Landmark Points (A:Cavum conchae superior (Incisura anterior auris posterior), B: Tragus (T), C: Incisura Intertragica (INT),D:Antitragus (AT), E:Posterior concha (Pc), F:Postaurale (Pa), G: Superaurale (Sa), H: Otobasion superior (Obs), K: Otobasion inferior (Obi), L: Subaurale (Sba), M: The point where the horizontal line drawn from the intertragic notch intersects the auricle from the outside.N: Anterior cymba conchae S: Superior cymba conchae T: Postaurale (Pa) P:Preaurale)

Alexander *et al*., 2011; Wróbel *et al*., 2023). Recognizing situations where the size and shape of the aforementioned auricle are affected is crucial for surgical planning in clinical interventions (Sclafani & Mashkevich, 2006).

The aim of this study is to elucidate the changes in shape and position that may occur in the auricle due to pressure related to helmet use. The intention is to contribute to future extended studies, including hearing tests, to further explore the impact of such alterations.

MATERIAL AND METHOD

Our study was conducted within the borders of Kocaeli province between July 2021 and September 2022. The research involved motorcycle couriers who work without any health problems, have not undergone auris externa (AE) operations, and do not have auricular deformities.

The study group consisted of 100 male courier participants who have been working as motorcycle couriers for a minimum of five years, and helmet usage is mandatory due to safety and legal procedures. The comparison group comprised 100 voluntary male participants without helmet usage and AE deformities.

Two hundred male volunteers, divided equally between those who use helmets and those who do not, were included in our research by randomly selecting 100 participants from each subgroup. In total, 400 ear measurements were conducted, covering both the right and left ears. In our study, which was conducted based on voluntariness, participants were initially provided with individual pre-information through one-on-one interviews by the researchers. During the data collection process, utmost attention was paid to pandemic rules. After completing the data forms, ear photographs of the participants were taken by a single researcher from an appropriate distance (1-meter distance) in compliance with pandemic regulations. During the photo shoot, all participants' photos were taken in the same area (with the same fixed background/sitting area and the same distance). A digital camera (Canon EOS1100D) mounted on a stable tripod was used to capture ear views from a fixeddistance of 100 cm between the participant and the camera lens. The photographs were taken with the ear in a lateral profile and Frankfurt horizontal plane position (Fig. 2). The Frankfurt Horizontal Plane is a standard plane used to position the head, determined by a line passing parallel to the ground from the lowest point of the ear hole to the orbit cavity.

During the photographing process, isolated ear photographs, excluding the participants' facial profiles, were numbered and uploaded to the MB-Ruler (Marcus Bader-Ruler) program, which is a photogrammetric method. Participants' photos were taken from the anterior, posterior, and lateral views. To obtain photos in the Frankfurt plane, a device designed by us was utilized (Fig. 3).

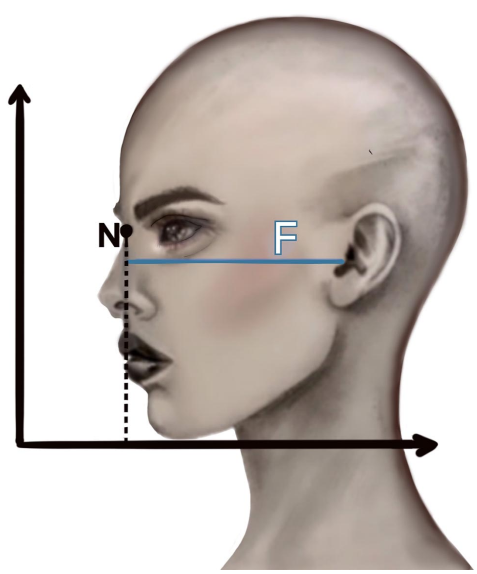

Fig. 2. Lateral position of the head in the Frankfurt plane (N: Nasion, F: Frankfurt plane)

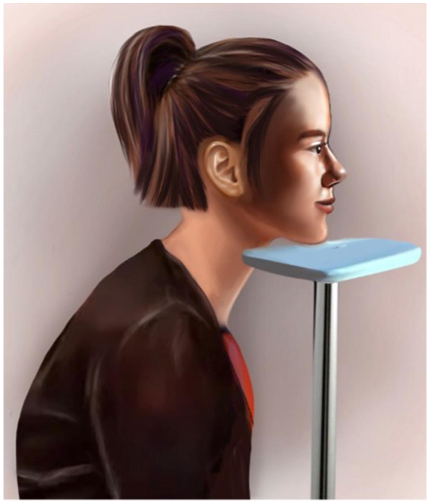

Fig. 3. Illustration of the apparatus designed for obtaining photographs in the Frankfurt plane for our study. MB-Ruler is a photograph analysis program that enables the calculation of distances between marked points visually. This program ensured adherence to social distancing rules, and the time participants spent in the study was minimized. Isolated auricle photographs obtained in the Frankfurt plane were transferred to the computer environment, and measurements of a total of 14 distances, as shown in Figure 4 and Figure 5, were made using the MB-Ruler program.

The total of 12 distances shown in Figure 4 corresponds to specific anatomical landmark points, and their meanings are explained below.

Using ear measurement points such as Superaurale (Sa)- the highest point of the auricle, Subaurale (Sba) - the lowest point of the auricle, Postaurale (Pa) - the outermost point of the curve made by the auricle towards the back, and Preaurale (Pra) - the point located at the level of helix attachment to the head and the front part of the ear, the sizes of the auricles were calculated bilaterally by measuring distances between points. The regions for which measurements between landmark points would be taken are detailed below.

Figure 5 illustrates the distances labeled G and L, representing the distances of the auricles to the head.

As shown in Figure 4, photographs obtained with lateral auricle images in the Frankfurt plane, and the front and back photographs depicted in Figure 5 were used to calculate the 14 distances described below.

The obtained data were used to calculate two indices for each ear, namely the Ear Index and the Lobule Index. Prior to statistical analysis, a power analysis was conducted, and with an effect size of 0.5, an a error probability (primary error) of 0.05, and a b error probability (secondary error) of 0.95, a minimum of 88 participants per group was determined. Descriptive statistics (mean, standard deviation) were calculated for the data obtained in the statistical analysis. The Kolmogorov-Smirnov test was employed to assess the normal distribution of the data. For normally distributed data, independent samples t-tests were used for intergroup comparisons, and for non-normally distributed data, the Mann-Whitney U test was applied.

Auricles measured with the indirect measurement technique of a digital camera, including their shape, size, and attachment distances to the head, are presented in the table below.

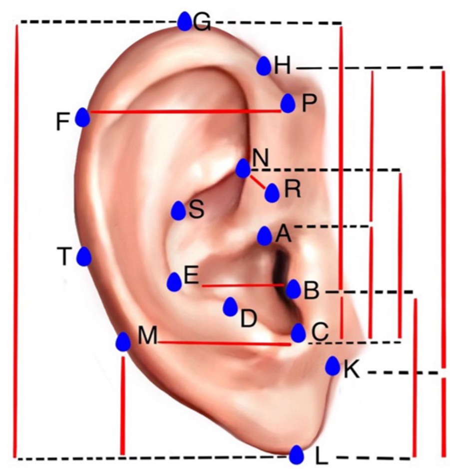

Fig. 4. Photometric measurement points on the ear.
(G-L) Height of auricle - Total ear length
(E-B) Width of concha
(C-M) Width of lobule (Earlobe)
(H-K) Attachment height of auricle to the head
(A-C) Height of cavum conchae
(M-L) Height of lobulus auricularis (Earlobe)
(B-C) Height of tragus
(L-K) Height of lobule (Earlobe)

(A-H) Distance between cymba conchae anterior and cavum conchae superior
(N-C) Height of concha
(F-P) Width of ear
(N-R) Height of cymba conchae
(G-B) Height above tragus to auricle
(B-L) Height below tragus to auricle

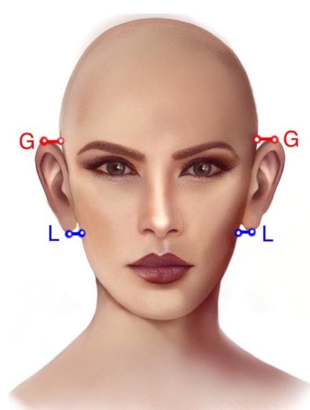

Fig. 5. Distances of the upper and lower ends of the auricle to the head (G: Auricle Distance to head (Upper); L:Auricle Distance to Head (Lower)).

RESULTS

The statistical analyses of the data obtained for the left ear are presented in Table I. In the left ear, auricle width, auricle height, auricle length, cymba conchae height, showed significantly lower averages in the courier group compared to the control group ($p<0.001$). The attachment height of the auricle to the head, lobule auricle height, and ear width measurements had significantly higher averages in the courier group ($p<0.01$). The measurements of the distances of the lower and upper points of the ear to the head had significantly lower averages in the control group compared to the courier group ($p<0.001$).

Table I. Data for the left ear.

	Helmeted Courier	Control Group	p
Auricle width (F-H)	2.35 ± 0.31	2.53 ± 0.26	**0.000**
Auricle height (G-L)	4.47 ± 0.54	4.78 ± 0.50	**0.000**
Concha width (E-B)	1.38 ± 0.22	1.39 ± 0.18	0.59
Lobule auricle width (C-M)	2.07 ± 0.29	2.13 ± 0.19	0.131
Auricle attachment height to head (H-K)	3.39 ± 0.41	3.57 ± 0.44	**0.003**
Cavum conchae height (A-C)	1.33 ± 0.22	1.33 ± 0.16	0.992
Lobule auricle height (M-L)	2.13 ± 0.37	2.28 ± 0.27	**0.002**
Auricle length - Total ear length (G-L)	4.99 ± 0.54	5.30 ± 0.50	**0.000**
Distance between cymba conchae anterior and cavum conchae superior (A-H)	1.66 ± 0.25	1.82 ± 0.25	**0.000**
Concha height (N-C)	1.91 ± 0.28	1.97 ± 0.21	0.105
Ear width (F-P)	2.54 ± 0.30	2.68 ± 0.27	**0.001**
Cymba conchalis height (N-R)	0.58 ± 0.11	0.67 ± 0.10	**0.000**
Auricle distance to head (Upper) (G)	0.78 ± 0.20	0.69 ± 0.19	**0.000**
Auricle distance to head (Lower) (L)	0.51 ± 0.16	0.44 ± 0.13	**0.000**
Height above tragus to auricle (GB)	3.03 ± 0.31	2.96± 0.28	0.078
Height below tragus to auricle (BL)	2.07 ± 0.29	2.10 ± 0.28	0.917
Height of tragus (BC)	0.65 ± 0.12	0.56 ± 0.09	**0.001**
Height of lobule (Ear lobe) (LK)	1.35 ± 0.21	1.19 ± 0.19	**0.001**

Table II. Data for the right ear.

	Helmeted Courier	Control Group	p
Auricle width (F-H)	2.40 ± 0.27	2.57 ± 0.25	**0.000**
Auricle height (G-L)	4.34 ± 0.46	4.69 ± 0.49	**0.000**
Concha width (E-B)	1.38 ± 0.23	1.41 ± 0.18	0.33
Lobule auricle width (C-M)	2.13 ± 0.30	2.18 ± 0.22	0.155
Auricle attachment height to head (H-K)	3.33 ± 0.42	3.65 ± 0.40	**0.000**
Cavum conchae height (A-C)	1.28 ± 0.19	1.34 ± 0.17	**0.033**
Lobule auricle height (M-L)	2.18 ± 0.35	2.32 ± 0.25	**0.026**
Auricle length - Total ear length (G-L)	4.92 ± 0.53	5.22 ± 0.48	**0.000**
Cymba conchae anterior to cavum conchae superior distance (A-H)	1.59 ± 0.21	1.72 ± 0.32	**0.001**
Concha height (N-C)	1.86 ± 0.24	1.99 ± 0.23	**0.000**
Ear width (F-P)	2.57 ± 0.28	2.73 ± 0.24	**0.000**
Cymba conchalis height (N-R)	0.57 ± 0.11	0.67 ± 0.09	**0.000**
Auricle distance to head (Upper) (G)	0.78 ± 0.19	0.71 ± 0.20	**0.007**
Auricle distance to head (Lower) (L)	0.51 ± 0.16	0.45 ± 0.14	**0.002**
Height above tragus to auricle (GB)	2.98 ± 0.29	3.05 ± 0.29	0.127
Height below tragus to auricle (BL)	2.03 ± 0.25	2.03 ± 0.26	0.985
Height of tragus (BC)	0.65 ± 0.1	0.54 ± 0.08	**0.001**
Height of lobule (Ear lobe) (LK)	1.37 ± 0.15	1.29 ± 0.2	**0.002**

In the right ear; auricle width, auricle height, attachment height of the auricle to the head, auricle length, cavum conchae height, ear width, and cymba conchae height measurements showed significantly lower averages in the courier group compared to the control group ($p<0.001$) (Table II).

Cymba conchae anterior to cavum conchae superior distance (A-H), cavum conchae height (A-C), and lobule auricle height (M-L) measurements showed significantly lower averages in couriers ($p<0.01$, $p<0.05$, $p<0.05$, respectively). However, in the measurements of the distances of the lower and upper points of the ear to the head, the control group's averages were significantly lower than the courier group ($p<0.01$).

In both ear measurements, overall, the average measurements of couriers with helmets were found to be lower. However, in the distances between the head and the ear, the opposite was observed, with the control group having lower values (Table III). This is thought to be due to the rigid structure of the helmet, which may alter the morphological structure of the ear.

Lobule Index comparison between groups revealed significantly higher averages in both the left and right ears in the courier group ($p<0.01$, $p<0.05$, respectively). However, in the Ear Index analysis, no significant difference was found between the groups ($p>0.05$). The Ear Index represents the ratio of ear width to length, while the Lobule Index represents the ratio of lobule auricle height to ear height. When examining lobule auricle height and ear length individually, the courier group was found to have lower

Table III. Comparison of ear index and lobule index.

	Helmeted Courier	Control Group	p
Left ear index	47.01 ± 4.47	47.67 ± 4.44	0.3
Right ear index	48.86 ± 5.12	49.46 ± 4.47	0.381
Left lobule index	98.39± 12.21	94.11 ± 9.02	**0.007**
Right lobule index	98.49 ± 11.19	94.82 ± 9.94	**0.016**

averages. However, when looking at the ratio between these two measurements, couriers were observed to have a higher proportion (Table III). This is believed to be due to the helmet significantly reducing ear length due to pressure, consequently elevating the Lobule Index value.

DISCUSSION

The auricle is the part of the ear responsible for collecting and transmitting sound to the middle ear. The possibility of its differentiation based on external factors, which has been a frequent subject of forensic anthropology for identity identification studies in recent years, serves as the starting point for our research. Our study is designed to investigate the potential changes in the auricle due to increased hours of helmet use by motorcycle couriers during the pandemic, corresponding to their extended working hours.

Evaluation of the auricle is crucially important in understanding prenatal and postnatal development. The average length and normal dimensions of the auricle, especially in cases with congenital malformations, play a significant role in planning the timing of surgical interventions (Kalcioglu *et al*., 2003; Alexander *et al.*, 2011). Auricular development continues postnatally, and the age at which this development is complete varies between different societies. Knowledge of these variations is essential for the accuracy of assessments.

For example, German newborns have the largest auricles at birth, with Turkish infants ranking second (Kalcioglu *et al*., 2003; Niemitz *et al*., 2007). Newborns with the smallest auricles are born in South India (Lakshminarayana *et al*., 1991). Understanding these developmental differences is crucial for accurate assessments and planning interventions, particularly in cases involving surgical procedures on the auricle.

The auricle is considered an important parameter in forensic anthropological evaluations because it does not change with facial expressions (Farkas *et al*., 2007; Boesoirie *et al*., 2022).

Ethnic origin also plays a role in auricular developmental morphometrics, with studies in the literature indicating variations in external ear development patterns associated with ethnic backgrounds (Bozkir *et al*., 2006; Johnson & Ekanem, 2019). A study evaluating auricular anthropometric measurements in individuals under 18 years of age in the Turkish population, it was indicated that the total length of the auricle completes at the age of 11 in females and 12 in males. Furthermore, concha width completes at 6 months in females and 1 year in males (Sclafani & Mashkevich, 2006). Total ear length serves as an indicator in determining some congenital anomalies (Farkas, 1978; Chou *et al*., 2002). Additionally, the earlobe, like a fingerprint, is unique to each individual. Studies involving twins confirm this information, suggesting that earlobes may be similar but not identical (Wahab *et al*., 2012). Therefore, earlobe analysis has become a subject of interest in forensic studies related to individual analysis. Considering the impact of external factors on the shape of the ear, our study provides substantial evidence that prolonged helmet use leads to significant changes in auricular morphometrics.

Another study investigating the variations in ear development based on ethnic origin compared the auricles of Turkish and African individuals. In females, the total length of both ears was found to be higher in Africans compared to Turks, while in males, concha width and distances between tragus and helix were lower in Turks for both ears (Acar *et al*., 2017). The reasons for such intercultural differences are associated with age, nutrition, genetic factors, and the environment (Deopa *et al*., 2013). In our study, by comparing the ear measurements of couriers of the same sex within the same population with a control group, we identified that external pressure, as an environmental factor, has an impact on ear anthropometrics.

In numerous studies comparing ear morphometrics between sexes in the literature, it has been consistently observed that men exhibit significantly higher auricle width and height compared to women (Barut & Aktunc, 2006; Kent *et al*., 2021). In our study, to ensure that these sex differences do not influence our research findings, we conducted our study exclusively within one sex. Additionally, studies suggest that besides sex, age and chronic diseases such as hypertension and diabetes can also alter the shape of the auricle (Nunes *et al*., 2021).

According to a 2022 study evaluating ear morphometrics in the Marmara region population, an increase in auricle protrusion values was observed post-pandemic, and this was correlated with mask usage. This phenomenon can be explained by the continuous pressure applied to the flexible form of the auricle. In the same study, musicians were compared with the control group, but no significant difference was found (Wróbel *et al*., 2023). Similarly, in our study, significant differences were detected in the parameters of the right and left ears between the values of motorcycle couriers and the control group, related to the pressure applied to the auricles of motorcycle couriers. In conclusion, based on the obtained data, we can say that the auricle width, earlobe width, conchae height, and ear width of motorcycle couriers tend to decrease compared to the control group.

Auricle morphology is noteworthy in studies related to human identification. The morphological features of the auricle can vary based on ethnic origin and sex (Petekkaya *et al*., 2020; Angelakopoulos *et al*., 2023). Additionally, differences are often observed between the right and left auricles of the same individuals (Cameriere *et al*., 2011). In the determination of criminals using security camera footage, side profile images of individuals are commonly captured by cameras instead of their full faces. In recent years, ear morphometrics have become a subject of frequent research for person analysis based on these images (Yaman *et al*., 2022). In a study conducted in 2023, Sezgin & Ersoy (2023) emphasized that ear measurements are an effective method for predicting sex.

According to a study conducted on primates in 2004, it has been established that the shape of the auricle affects hearing. It is noted that prosimians with larger and wider auricles perceive both low and high-frequency sounds better (Coleman & Ross, 2004). Building on these findings, we can hypothesize that the shape of the auricle has an impact on hearing.

CONCLUSION

As a result, the evaluation of professions or groups of people who work with accessories that can affect the auricle, in terms of hearing loss, is crucial. The results of our study are significant in guiding craniofacial anthropometric and biometric auricle studies, including hearing tests with groups of different ethnicities, who spend extended periods wearing accessories that may exert pressure on the external ear.

Ethics approval statements. This study was approved by the Kocaeli University Research Ethics Committee (approval no. E-80418770-020-171926 and project number 2021/378) on 17/01/2022.

ERDOGAN, M.; COLAK, T.; COLAK, S.; SIVRI, I. & KAYGIN, E. Evaluación de la morfología auricular de mensajeros en motocicleta basada en el uso de casco mediante métodos fotogramétricos. *Int. J. Morphol., 42(5)*:1416-1422, 2024.

RESUMEN: En los últimos años, el avance de la tecnología y la búsqueda de la eficiencia del tiempo han aumentado el interés de las personas por las compras online. Los motociclistas prefieren varios modelos de cascos, incluidos aquellos que cubren completamente la cabeza, solo cubren la barbilla o cubren media cara. Sin embargo, una característica común en todos los modelos es que los lóbulos de las orejas permanecen dentro del casco. Anatómicamente, considerando la posibilidad de cambios en la estructura del pabellón auricular debido al uso del casco y el potencial impacto en la transmisión del sonido al oído medio, nuestro estudio está diseñado para identificar alteraciones que puedan ocurrir en los lóbulos de las orejas de los mensajeros en motocicleta como resultado del uso del casco. Los participantes en nuestro estudio fueron seleccionados entre personas que trabajaban como mensajeros. Se incluyó un total de 200 participantes, que comprendían 100 personas que usaban cascos regularmente y 100 personas que no usaban cascos, según la participación voluntaria. Se excluyeron del estudio las personas con antecedentes de cirugía del lóbulo de la oreja o anomalías auriculares. Los criterios de selección para los mensajeros con casco incluían un mínimo de cinco años de uso del casco. Las mediciones morfométricas se realizaron mediante un método fotométrico utilizando una cámara digital, que es una técnica de medición indirecta. La distancia entre los puntos de referencia marcados en la oreja y la distancia de unión de la oreja a la cabeza se calcularon utilizando el programa MB Ruler. Según el análisis estadístico de los datos morfométricos obtenidos, se observó que la altura de la concha de la oreja, así como el ancho y alto de la oreja, fueron significativamente menores tanto en el lado derecho como en el izquierdo de los mensajeros. Como resultado, se puede considerar que el uso prolongado del casco puede afectar la estructura cartilaginosa de la oreja, alterando así los valores de distancia entre puntos de referencia.

PALABRAS CLAVE: Oreja externa; Aurícula; Cartílago de la oreja; Pabellón auricular.

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