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Morphometric Comparison of Mandibles Excavated from the Prehistoric Sites of Sri Lanka with Modern Sri Lankan Mandibles

Comparación Morfométrica de Mandíbulas Excavadas en Sitios Prehistóricos de Sri Lanka con Mandíbulas Modernas de Sri Lanka

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SUMMARY: Comparison of ancient and modern mandibles is important to understand the evolutionary trends and to identify affinities between ancient and modern populations. Many studies have been conducted around the globe to compare ancient and modern mandibles, but there are no recorded studies in Sri Lanka. Therefore, the objective of this study was to compare the morphometry of mandibles excavated at prehistoric sites in Sri Lanka with modern Sri Lankan mandibles. Eleven prehistoric human mandibles were included in this study. They were selected from different prehistoric sites in Sri Lanka namely Batadombalena, Belilena, Bellan-Bandi Palassa, Pallemallala, and Potana dating back to 4500 and 10,000 YBP. A total of 59 modern mandibles from the Department of Anatomy, Faculty of Medicine, Wayamba University of Sri Lanka, and from the Department of Anatomy, University of Peradeniya were included in this study. A total of six mandibular measurements were taken from each mandible. Mean measurements were calculated according to gender using the SPSS 23 version. Comparison of means was done with independent samples t-test to determine the significant differences. According to the study, all the mean measurements of modern mandibles were lesser than ancient mandibles with reference to gender and some measurements had a significant difference. The mandible has become smaller in size with time in the Sri Lankan population which is compatible with the evolutionary trend of most populations around the globe. This may be mainly due to the change in food habits of people with time, as suggested by world literature.

KEY WORDS: Human mandibles; Morphometry; Prehistory; Present population.

INTRODUCTION

The human mandible is one of the facial bones, vital for creating facial architecture. The craniofacial morphology of humans has undergone considerable morphological and morphometric changes as they evolved (Humphrey *et al*., 1999). Therefore, comparing ancient and modern human mandibles will distinguish human evolutionary trends and reveal morphological and morphometrical variations of mandibles in people living during different eras. In addition, this would discover the affinities between ancient and modern populations by the presence of ambiguous traits.

The mandible has a structural tendency to change in response to genetics, environmental factors, and physical stress brought on by dietary consistency and habits of eating (von Cramon-Taubadel, 2011). The food consistency and food habits changed from the hunter-gatherer nomadic way of life of the prehistoric era to agricultural life of the megalithic and historic era. The extremely primitive way of food preparation used by hunter-gatherers resulted in either raw or partially processed food for their consumption. The introduction of agriculture in the megalithic era and the historic era produced a more processed diet for their consumption (Stansfield *et al*., 2018). Biomechanical and finite element studies demonstrated that mandibular shape was heavily affected by the orientation and magnitude of masticatory forces (Stansfield *et al*., 2018).

Prehistoric humans consumed a greater variety of hard, raw, unprocessed, or partially processed foods. Consequently, prehistoric people used their jaws vigorously to force the meal into their mouth and for chewing. Because of this, their mandibles had a large, robust structure that allowed them to exert powerful pressures when manipulating food in the mouth and chewing (Stansfield *et al*., 2018).

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When fire and food processing methods were developed during the course of human evolution, food became less tough and required less force from the jaws to be ingested and chewed. As a result, the mandible reduced in its size and robusticity. This was proven by numerous research investigations that compared the historic and prehistoric mandibles of the world with the mandibles of modern humans (Moore *et al*., 1968; Humphrey *et al*., 1999; Stansfield *et al*., 2018).

The prehistory of Sri Lanka dates back to about 125,000 YBP (years before the present) and possibly goes even as further as 500,000 YBP covering the Palaeolithic, Mesolithic, and early Iron Age (Deraniyagala, 1992). The chronology of prehistoric human skeletal remains of Sri Lanka ranges around 40,000 YBP, and prehistoric human skeletal remains of around 34,000 YBP onwards stand in a more complete form providing better and more informative evidence. The prehistoric human skeletal record of the country is much more complete and represents the best human skeletal record sequence present in South Asia (Kennedy *et al*., 1987). Prehistoric sites which are located in various climate zones of the country yield human skeletal remains along with human mandibles. This includes; Fa Hien Lena (37,000 BP), Batadombalena (31,000 BP, 28,500 BP, and 16,000 BP), Belilena-Kithulgala (12,000 BP & 2700 BC), Belilena-Athula (27,000 BP-3,000 BP), Alu lena (10,500 BP), Bellan-bandi Palassa (6,500 BP), Potana (5,500 BP) and Miniatheliya (3,600 BP) (Kennedy *et al*., 1987; Deraniyagala, 1992; Kulatilake, 2016).

Bellan-bandi Palassa reported as an open-air prehistoric site is located in Rathnapura district, Sabaragamuwa province in the wet climatic zone of Sri Lanka, and 10 mandibular fragments have been found from the site (Kanthilatha *et al*., 2012). Pallemalala reported as shell midden prehistoric site is located in Hambantota district, southern province in the dry climatic zone of the country and 3 mandibular fragments have been found from the excavation (Ranaweera & Adikari, 2022). Belilena Kithulgala is reported as a prehistoric cave site, located in the Kegalle district, Sabaragamuwa province in the wet zone of the country, and one mandibular fragment was found at this site (Kennedy *et al*., 1987). Batadombalena Kuruwita reported as a prehistoric cave site is located in Rathnapura district, Sabaragamuwa province in the wet zone of the country, and 2 mandibular fragments were found from this site (Kennedy *et al*., 1987) Potana, Sigiriya reported as prehistoric cave site located in Matale district, Central province in the intermediate zone of the country, and 3 mandibular fragments were found from this site (Chandimal *et al*., 2019) (Fig. 1).

Several morphological and morphometrical studies have been conducted to determine the sex, age at death, stature, way of life, and pathology of the human skeletal remains excavated from these prehistoric sites Batadombalena, Belilena, Bellan-bandi Palassa, Pellemalala, and Potana by Kennedy *et al*. (1987), Der (1992), Kanthilatha *et al*. (2012) and Chandimal *et al*. (2019), respectively. However, the morphometry of mandibles of prehistoric skeletal remains in Sri aniyagala, Lanka have not been fully studied and documented. Morphology and morphometry of prehistoric human mandibles and modern human mandibles have been extensively compared globally (Luther, 1993; Humphrey *et al*., 1999; von Cramon-Taubadel, 2011; Stansfield *et al*., 2018; Akbulut *et al*., 2020; Xu *et al*., 2022). However, there is no reported evidence to determine the mandibular morphological and morphometrical variations between prehistory and present-day humans in Sri Lanka. Thus, the objective of this study was to compare the morphology and morphometry of the prehistoric mandibles discovered at prehistoric sites of Batadombalena, Belilena, Bellan-bandi Palassa, Pellemalala, and Potana Sri Lanka, which date back between 4500 and 10,000 YBP, with the mandibles of the present-day mandibles.

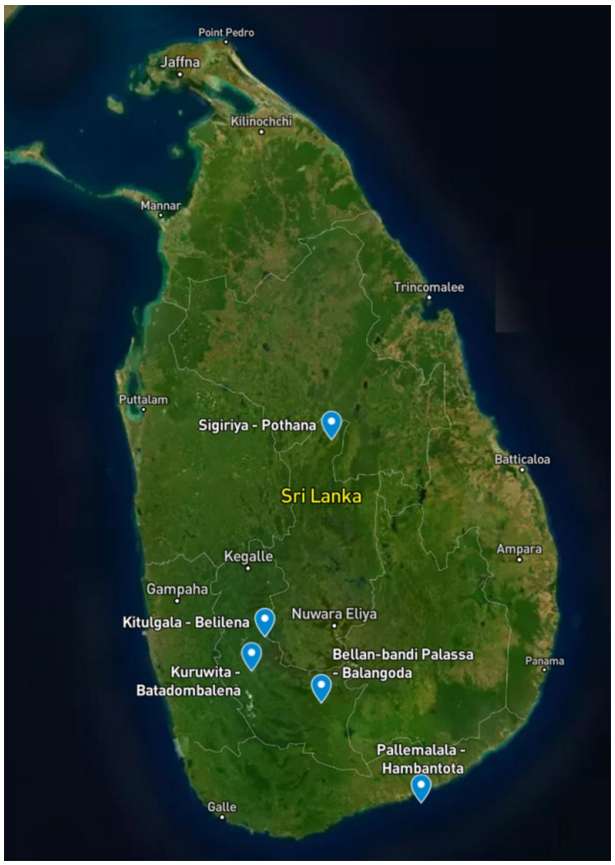

Fig. 1. Prehistoric sites – Kuruwita Batadombalena, Kithulagala Belilena, Bellan-bandi Palassa, Pellamalala, and Sigiriya Potana in Sri Lanka.

MATERIAL AND METHOD

A total of 59 dry modern mandibles including 34 male mandibles and 25 female mandibles from the Department of Anatomy, Faculty of Medicine Wayamba University Sri Lanka, and from the Department of Anatomy, Faculty of Medicine, University of Peradeniya were used in this study. Mandibles with pathological abnormalities were excluded. The sex of the modern mandibles was determined according to standard guidelines in Bass (2005) and White & Folkens (2005). Eleven dry adult prehistoric mandibles including 5 male mandibles and 6 female mandibles were taken in this study which dated back between 4500 and 10000 YBP. Two mandibles discovered from the prehistoric site Batadombalena, one mandible discovered from Belilena, and five mandibles discovered from Bellan-bandi Palassa presently available at the National Museum were included in the study. One mandible discovered from Pallemalala and two mandibles discovered from Potana, currently available at the Osteology gallery, Postgraduate Institute of Archaeology, and National Museum Sigiriya respectively were included in the study. The pre-determined sex of each prehistoric mandible was confirmed again by comparing the morphological characteristics of the mandibles included in the study with published standard sex-determining morphological characteristics of male and female mandibles including the shape of the chin, gonion morphology, and mandibular angle as described in Bass (2005) and White & Folkens (2005).

As the prehistoric mandibles were fragmented, mandibular measurements were limited to five measurements. The following five measurements in Figure 2 were taken from each prehistoric and modern mandible using the digital vernier calliper and the mandibular meter.

A single observer performed all measurements, each measurement was taken three times, and the mean values were taken for analysis. The measurements of the prehistoric mandibles were compared with the corresponding measurements of the modern mandibles according to sex, by using SPSS 23.0 version. Means were calculated and the comparisons were done using the independent samples t-test.

RESULTS

Analyzed results showed that the most of the studied measurements of the modern mandibles including the mandibular length of males and females, bicondylar breadth of males and females, bigonial breadth of males and females, breadth of the mandibular body of males and females, minimum mandibular ramus breadth of males and females, and mean height of the mandibular body of females are lesser than that of the ancient mandibles belonging to male and female respectively except the mean mandibular height of modern male mandibles that was higher than that of the ancient male mandibles (Figs. 3 and 4).

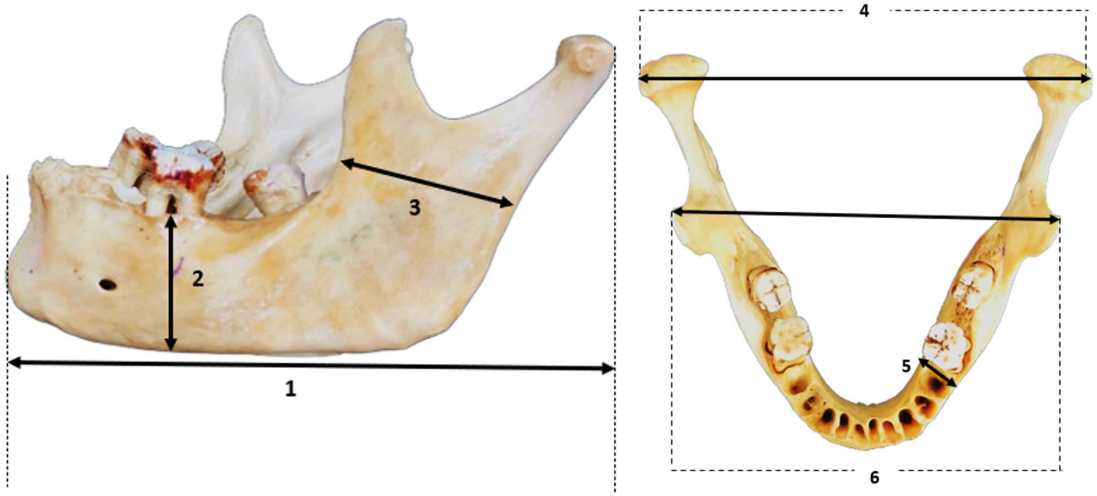

Fig. 2. Mandibular measurements. 1. mandibular length - linear distance between the head of the condyle and the mandibular symphysis 2. height of mandibular body - maximum height in the plane of first molar tooth perpendicular to the longitudinal axis of the body. 3. minimum mandibular ramus breadth - minimum distance between the anterior and posterior borders of the ascending ramus. 4. bicondylar breadth - the maximum distance between the lateral surfaces of the condyles 5. breadth of mandibular body - maximum thickness in the plane of mental foramen perpendicular to the longitudinal axis of the body. 6. bigonial breadth - the maximum distance between the external surfaces of the gonial angles.

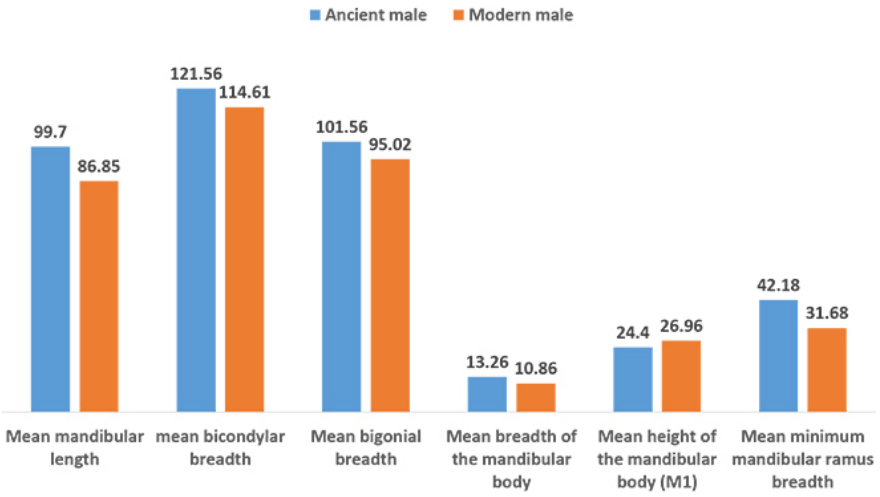

Fig. 3. Mean mandibular measurements of ancient and modern male mandibles

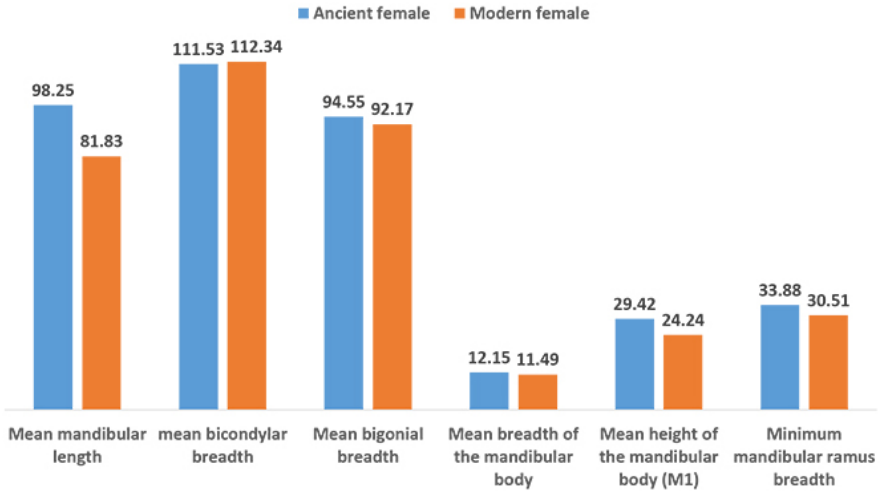

Fig. 4. Mean mandibular measurements of ancient and modern female mandibles.

The mean mandibular length (p=0.016), mean bicondylar breadth (p=0.037), mean breadth of the mandibular body (p=0.041), and the mean mandibular ramus breadth (p=0.000) of modern males are significantly smaller than that of prehistoric males. The mean mandibular length (P=0.000), mean minimum mandibular ramus breadth (p=0.000), mean height of the mandibular body (P=0.006) of modern female are significantly smaller than that of ancient female mandibles (Table I).

DISCUSSION

The study of the morphometry of the mandibles is important in identifying evolutionary changes as well as sexual dimorphisms (Humphrey *et al*., 1999). According to the present study, it is evident that most of the measurements of the modern mandibles including the mandibular length, bicondylar breadth, bigonial breadth, breadth of the mandibular body, minimum mandibular ramus breadth of both males and females and height of the mandibular body of females, are lesser than that of the ancient mandibles except the height of the mandibular body which was higher in modern males than the ancient males.

In comparison to prehistoric males, modern males have significantly reduced mean mandibular length (p=0.016), mean bicondylar breadth (p=0.037), mean mandibular body breadth (p=0.041), and mean mandibular ramus breadth (p=0.000). Table I shows that the modern female mandibles are significantly smaller than the ancient female mandibles in terms of mean mandibular length (P=0.000), mean minimum mandibular ramus breadth (p=0.000), and mean height of the mandibular body (P=0.006).

The results of this study were compared with similar studies conducted around the world.

Table I. Mandibular measurements of ancient and modern male and female mandibles and their P values.

Measurement	Ancient male	Modern male	P value	Ancient female	Modern female	P value
Mean mandibular length (mm)	99.70± 6.45	86.85±8.54	P=0.016	98.25±6.01	81.83±5.37	P=0.000
mean bicondylar breadth (mm)	121.56±11.56	114.61±4.69	P=0.037	111.53	112.34±6.75	P=0.907
Mean bigonial breadth (mm)	101.56±5.75	95.02±6.14	P=0.085	94.55±6.29	92.17±7.39	P=0.418
Mean breadth of the mandibular body (mm)	13.26±0.80	10.86±1.91	P=0.041	12.15±1.36	11.49±2.21	P=0.577
Mean height of the mandibular body (M1) (mm)	24.40±4.24	26.96±4.94	P=0.330	29.42±2.32	24.24±3.26	P=0.006
Mean minimum mandibular ramus breadth (mm)	42.18±5.08	31.68±2.32	P=0.000	33.88 ±3.70	30.51±3.04	P=0.027

Humprey and his colleagues have compared the mandibular size of three great apes' families and modern humans. They showed that the morphometric dimensions of modern mandibles were lesser in comparison to the great apes. This study further confirmed the fact that the human mandible has become smaller through evolution (Humphrey *et al*., 1999). This study result findings also showed the same reduction of size of the mandibles from prehistoric males and females to modern males and females.

The study conducted on British mandibles belonging to Neolithic, Bronze Age, Romano-British, Anglo-Saxon, Mediaeval, 17th and 19th century periods reported that the dimensions of the mandible have reduced over time, which is compatible with the present study on Sri Lankan populations which showed the same reduction. It was suggested that these morphometric changes of British mandibles in different era occurred due to the physical consistency of the foods in different eras, for example modern populations started to use wheat in bread making instead of rye flour (Moore *et al*., 1968).

The modern mandibles were found to be significantly smaller than the ancient mandibles in a study comparing the cephalometric measurements of Anatolian populations, and there was a significant difference between the measurements of mandibular length ($p<0.001$) and mandibular body length ($p<0.001$) (12). These results are consistent with those of the present study, which shows that mandibular body length ($p<0.001$) and mandibular length ($p<0.001$) measurements are also significantly greater than those of prehistoric mandibles.

Another study comparing Neolithic Chinese mandibles with modern populations using CT scan data revealed that Neolithic mandibles without considering the sex were significantly larger compared to modern populations (Xu *et al*., 2022). Their findings agree with the present study, which also found that the mandibles of males and females from the prehistoric era are larger than those of their respective sexes of modern mandibles.

Luther (1993) has compared the medieval skulls with the modern population. According to the study, it was found that all the mandibular indices were higher in the medieval population in comparison to the modern population. These findings are compatible with the present study. Stansfield *et al*. (2018) compared the morphology and morphometry of modern mandibles with Palaeolithic and Mesolithic mandibles from Ukraine, Russia and Romania using CT scans. It was revealed that the modern mandibles are much smaller than the ancient mandibles and specifically mandibular body has become shorter. Their findings agree with the present study, which also found that the mandibles of males and females from the prehistoric era are larger than those of their respective sexes of modern mandibles. They have also compared the mandibular morphology and morphometry with the mastication performance of the pre-historic hunter-gatherers, ancient populations that started agriculture, and modern populations. They have concluded that due to the change in food texture and food preparation methods, the force and effort required for mastication has been reduced over time which is the main reason for changes in mandibular morphology and morphometry (Stansfield *et al*., 2018). As the Sri Lankan hunter gatherer consumed mostly burnt partially processed meat and plant foods such yams and seeds the force and effort required for mastication has been increased (Deraniyagala, 1992). As a result, their mandibles grossly large, robust, strong and muscle attachments sites over the mandible are well developed. Modern Sri Lankans consume well processed soft diet and the force and effort required for mastication has been reduced. As a result, their mandibles become small and muscle attachments sites over the mandible are less prominent.

Similarly in a study done to compare the mandibular variation between ancient hunter gatherer populations from Greenland, Alaska, Australia, San, Biaka and ancient populations involved in agriculture from Italy, Japan, China, Mongolia, Ibo and Hawikuh, it was concluded that in comparison to the other parts of cranium where morphological and morphometric changes were mainly determined by genetics through evolution, the mandibular morphology and morphometry was mainly determined by the subsistence economy and the food patterns(von Cramon-Taubadel, 2011).

Hila *et al*., have compared the morphometry of mandibles belonging to three ancient populations of Israel with modern mandibles. According to the study, it was revealed that some of the mandibular measurements have increased, some have reduced, and some have remained static through evolution. The morphometric parameter that have increased include the height of the mandibular body at the molar region, parameters that have reduced include mandibular angle width, ramus width, body length, and chin height, and the measurement that remained static included the body heights at premolar regions (May *et al*., 2018). In our study the height of the mandibular body at molar region was higher in modern male mandibles than the ancient mandibles. This finding is compatible with this study. This study has challenged most of the other studies and signifies the need to conduct further studies on the evolutionary trends of the mandibular body.

CONCLUSION

This study has proven the fact that there is a reduction in the general size of the mandible from ancient populations to the modern population of Sri Lanka, which is compatible with the studies done on the evolution of the mandible among different populations around the globe.The morphology and morphometry mandible result from the jaw structure adapted to the force and effort involved in ingestion and chewing. As humans have evolved, food preparation has advanced. Modern humans consume a soft, well-processed diet, requiring less force and effort to masticate. Their mandibles thus have become smaller than the prehistoric mandible.

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KATUPELELLA, C.; KONARA, W.; EDIRISINGHE, S.; DISSANAYAKE, H. & YASAWARDENE, S. Comparación morfométrica de mandíbulas excavadas en sitios prehistóricos de Sri Lanka con mandíbulas modernas de Sri Lanka. *Int. J. Morphol., 43(1)*:110-115, 2025.

RESUMEN: La comparación de mandíbulas antiguas y modernas es importante para comprender las tendencias evolutivas e identificar afinidades entre poblaciones antiguas y modernas. Se han realizado estudios en todo el mundo para comparar mandíbulas antiguas y modernas, pero no hay estudios registrados en Sri Lanka. Por lo tanto, el objetivo de este estudio fue comparar la morfometría de mandíbulas excavadas en sitios prehistóricos de Sri Lanka con mandíbulas modernas de Sri Lanka. En este estudio se incluyeron once mandíbulas humanas prehistóricas. Se seleccionaron de diferentes sitios prehistóricos en Sri Lanka, a saber, Batadombalena, Belilena, Bellan-Bandi Palassa, Palemallala y Pothana que datan de 4500 y 10 000 años antes del presente. Se incluyeron en este estudio un total de 59 mandíbulas modernas del Departamento de Anatomía, Facultad de Medicina, Universidad Wayamba de Sri Lanka, y del Departamento de Anatomía, Universidad de Peradeniya. Se tomaron un total de seis medidas mandibulares de cada mandíbula. Las medidas medias se calcularon según el sexo utilizando la versión 23 de SPSS. La comparación de medias se realizó con una prueba t de muestras independientes para determinar las diferencias significativas. Según el estudio, todas las medidas medias de las mandíbulas modernas fueron menores que las mandíbulas antiguas xon respecto al sexo y, algunas mediciones, tuvieron una diferencia significativa. La mandíbula se ha vuelto más pequeña con el tiempo en la población de Sri Lanka, lo que es compatible con la tendencia evolutiva de la mayoría de las poblaciones de todo el mundo. Esto puede deberse, principalmente, al cambio en los hábitos alimentarios de las personas a lo largo del tiempo, como lo sugiere la literatura mundial.

PALABRAS CLAVE: Mandíbulas humanas; Morfometría; Prehistoria; Población actual.

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