ANTHROPOLOGICAL REVIEW

WYDAWNICTWO
UNIWERSYTETU
ŁÓDZKIEGO

ANTHROPOLOGICAL REVIEW

The Official Publication of
the Polish Anthropological Society

Volume 85/2022
Issue 4

POLSKIE TOWARZYSTWO ANTROPOLOGICZNE

WYDAWNICTWO UNIWERSYTETU ŁÓDZKIEGO
Łódź 2022

Published by Łódź University Press
Publisher's sheets 12.0; printing sheets 9.625
W.10945.22.0.C
ISSN 1898-6773
e-ISSN 2083-4594

Contents

Anthropological Review • Vol. 85(4), 1–13 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.4.01

A morphological comparison between a death mask of the American Prophet Joseph Smith and a photograph likely to depict him

Teghan Lucas[1,2], Debra Hatfield[3], Maciej Henneberg[4,5]

[1] School of Medical Sciences, Anatomy, University of New South Wales, Sydney, Australia
[2] Department of Archaeology, Flinders University, Adelaide, Australia
[3] History, Brigham Young University-Idaho, USA
[4] Biological Anthropology and Comparative Anatomy Research Unit, School of Biomedicine, University of Adelaide, Australia
[5] Institute of Evolutionary Medicine, University of Zurich, Winterthurerstr. 190, 8057 Zurich, Switzerland

Abstract: Application of forensic identification methods to establish authenticity of a historical photograph is made. Joseph Smith Junior was the Prophet and founder of The Church of Jesus Christ of Latter-day Saints, often referred to as Mormons. In 1844 Joseph and his brother Hyrum were shot and killed by a mob of angry men who opposed his church and its followers. Shortly after death, Joseph's face was moulded, and a death mask was made. Photography was invented during the life of Joseph Smith Jnr and there are reports that he had a daguerreotype (photograph) taken, but no image has been verified to be of him.

A photographic image of an Illinois man from the 1840s is linked by circumstantial evidence, such as similar clothing, to Joseph Smith Jnr and the photographer's studio being close to where Joseph Smith III was at the time the photograph has been produced. A morphological comparison is made between the death mask and the photograph in order to establish the likelihood that the man in the photograph is the prophet. Sixteen points of anatomical similarity were found between the death mask and the photograph, the most compelling of which is asymmetry of the face and a possible scar in the area of the left eyebrow. Superimposition confirmed morphological similarity. Finding of close morphological similarity is not an ultimate proof of identification, but increases the probability that the photograph depicts Joseph Smith Junior. This is the first case of an anatomical comparison between a death mask and a photograph.

Key words: Joseph Smith, image analysis, morphology, death mask, anatomy.

Received: 4.11.2022; Revised: 1.12.2022; Accepted: 2.12.2022

Introduction

The testimony of Joseph Smith Junior recounts that on the evening of September 21st 1823, he was visited by a messenger of God who instructed him to find and translate golden plates to what is known as 'The book of Mormon' (The testimony of the prophet Joseph Smith, The Book of Mormon). In March 1830, 'The Book of Mormon, Another Testament of Jesus Christ' was published, and Joseph Smith Jr became known as a prophet. In April of the same year, the prophet Joseph Smith organised The Church of Jesus Christ of Latter-day Saints (LDS) and became its first president (Quinn 1976).

In 1839 the Church of Jesus Christ of Latter-Day Saints settled in Nauvoo, Illinois. Joseph Smith Jnr was elected the mayor of Nauvoo in 1842; in February 1844, he was nominated to run for President of the United States. Joseph Smith's presidential bid chose not to be affiliated with either major party and was seen as a political and religious threat. In June 1844, the Nauvoo Expositor accused Joseph Smith Jnr of immorality. This led to a political row involving the State Governor and surrounding towns that resulted in Joseph being fined $500, jailed and charged with causing riot and with treason (Taylor 2017).

On June 27th 1844, Joseph Smith Jnr was shot and killed after a mob ambushed the jail where he and his brother Hyrum were being held. After Joseph was shot, he fell through a second story window (Gayler 1957). This event has since been known as the 'Martyrdom of Joseph Smith' (McCarl 1962; Weber 2009).

On June 29th 1844 moulds were made of the brothers faces (Weber 2009) and masks were made from the moulds. It is reported that sometime after 1849 the masks came into possession of Philo Dibble (Weber 2009). This is the oldest known set of the death masks and they are currently located in the Museum of Church History and Art in Salt Lake City, commonly referred to as the 'Dibble Death Masks' (Weber 2009). These death masks are the most reliable representation of the face of Joseph Smith Jnr and his brother Hyrum to date.

There exists a lot of wonder surrounding the appearance of Joseph Smith Jnr as no photograph has been proven to be of the prophet and there is debate amongst scholars as to which historical records depicting his image are reliable. McCarl (1962) compiled a historical record of journal entries which reference the appearance of Joseph Smith Jnr by people who have claimed to have met him. These descriptions, while numerous, are somewhat contradictory and embellished to not describe his anatomical appearance but somehow derive his character from his features. Some describe him as having brown hair, while others claim it was a very light colour. His eyes received the greatest attention, some reported a blue colour, others hazel but the most intriguing descriptions were not anatomical but embellishments of personality, one person wrote of his eyes '*…seemed to dive down to the innermost thoughts with their sharp penetrating gaze, a striking countenance, and with manners at once majestic yet gentile, dignified yet exceedingly pleasant*' (McCarl 1962). Some descriptions are consistent between those who met him and describe in detail anatomical features such as: thin lips, prominent nose, oblong/oval face, large forehead without a furrow, retreating forehead, eyes set back in the head (McCarl 1962). It would seem that people's perception of him as a prophet and religious man, somewhat

biased their opinions and descriptions of him to embellish his status as a prophet. Thus, these descriptions are not considered entirely reliable.

During his life, Joseph Smith Jnr reported posing for a reproduction of his likeness on two occasions. On June 25th 1842, Joseph wrote that he '*sat for a drawing of my profile to be placed on a lithograph of the map of the city of Nauvoo*' (Smith 1842a). This image was the work of Sutcliffe Maudsley, known as the 'Maudsley print'. Joseph Smith Jnr also reports having his likeness painted by 'Brother Rogers' in September of 1842, referring to David Rogers (Smith 1842b). There are two paintings which have been assigned as being painted by David Rogers, a profile picture and an anterior facing picture. Unfortunately, paintings are an artist's interpretation of the person and are often touched up to eliminate any potential flaws. Therefore, the only proven, reliable representation of Joseph Smith is the death mask.

In 1910, Joseph Smith III wrote to the Salt Lake Tribune stating that the family was in possession of a daguerreotype of his father Joseph Smith Jnr (McCarl 1962). The daguerreotype he speaks of, was reportedly taken by Lucian Foster who had just returned from a mission in New York, for the Church of Jesus Christ (J. Smith, 2015). On April 29th 1844, Joseph Smith Jnr wrote in his journal '*At home received a visit from Lucian R Foster of New York who gave me a gold pencil case…*' (Smith 1844). Joseph Smith Jnr. died two months later. The daguerreotype was the most prominent form of photography between 1839 and 1860 (Švadlena 2014). Many people have come forth with daguerreotypes claiming to be the prophet, however, none have been conclusively proven to be Joseph Smith Jnr (McCarl 1962). The latest of these claims has been made in 2022 when Ronald Roming and Lachlan Mackay presented a picture found in the locket inherited from Joseph Smith III's son's wife. The origins of this image are still discussed, while the similarity of the person depicted on this image to Joseph Smith Jnr is not apparent (Roming and Mckay 2022).

DH who had an old photographic image of a man taken in Illinois in her possession and wanted a facial comparison between this image and images of the Dibble death mask of Joseph Smith Jnr contacted TL who undertook the analysis reported here.

According to Houlton and Steyn (2018) there are four methods of facial comparison: holistic, photographic video superimposition, photoanthropometry and morphological. The holistic method involves a fast visual comparison between a living person and a photograph, usually performed by police and customs officers to confirm or deny an individual's identity. Facial superimposition involves the overlay of two photos and assessment how well they fit over each other, often with animated image transitions which show various aspects of one photograph compared with the other (Houlton and Steyn 2018). Unfortunately, biases can be produced depending on the method used and quality of images. Photoanthropometry is the measurement of the face using dimensions and angles based on standardised anthropometric landmarks. Photoanthropometry and landmark precision has proved useful in identification, however, it requires calibration of images with surveying of the site for scale, and often expensive technology (Scoleri et al. 2014). In the absence of technology and site surveys (often not possible if it is not known where the image was taken or if there are no objects in the image) ratios will allow proportional

measurements to be taken. Lucas et al. (2016) concluded that ratios are not precise enough to differentiate between adult individuals and thus cannot be used in facial or body comparisons of forensic significance. It has also been suggested that proportional measurements are subject to image distortion (Moreton and Morley 2011). Given the potential for bias in facial superimposition, and the unreliability of photoanthropometry and the inappropriate use of the holistic approach for image to image comparisons where time to complete the task is irrelevant, morphological analysis is the preferred method for facial identification. Facial identification methods are usually applied in cases of forensic significance (Lucas and Henneberg 2015b; Houlton and Steyn 2018), although, they can be applied to any case where identification is questioned.

The aim of the current paper is to establish the degree of anatomical similarity between the death mask of Joseph Smith Jnr and the image of a man from Illinois. This facial comparison is the first case of a systematic forensic comparison between an image and a death mask.

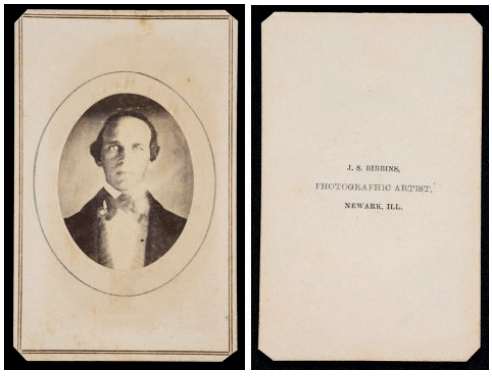

Fig. 1. Carte-de-visite photograph of an unknown man pictured from the anterior view (left), the back of the CDV, showing details of the photographer (right)

Materials and Method

Authentication of the Carte-de-visite photograph

Figure 1 is a Carte de visite (CDV) image of an unknown man pictured in the anterior view. The Carte-de-visite was the most popular form of copying photographs from the 1860s to the 1880s (Burstow 2016). On the back of the photograph is text which reads 'J.S Bibbins, Photographic Artist, Newark ILL'. This Carte-de-visite was examined by Gaiwan Weaver Art Conservation who produced a report stating that the image was an albumen print on CDV mount typical of the 1860s. The report says the image is a copy of an earlier photographic portrait, likely to be a daguerreotype or ambrotype.

In 1866 Joseph Smith III moved to Plano, Illinois, 10 miles away from Newark until his departure in 1881 (Smith 1979). J.S Bibbins (Joseph Slocum Bibbins) is recorded in the 1860s census as having the profession of 'Artist' (Bibbins 1860). It is entirely plausible that Joseph Smith III or a member of his family, had the CDV made from an earlier image of Joseph Smith. The advantage of having a CDV copied from a daguerreotype can be demonstrated by viewing an authenticated 1845 daguerreotype of Emma Smith (Joseph Smith's wife) and her son David Hyrum Smith (Joseph Smith's son) and a CDV (Figure 2). The daguerreotype has degraded to the point where the image is almost unrecognisable, this occurs due to the chemical nature of the daguerreotype with time and environmental conditions unfavourable to preservation (Švadlena 2014).

To further authenticate the date of the CDV and connections with Joseph Smith Jnr, the clothing was analysed. Only a few examples of clothing worn by

Joseph Smith Jnr have survived the past 176 years since his death. The Pioneer Memorial Museum in Utah is in possession of a collar and a vest belonging to Joseph Smith Jnr (Figure 3).

Fig. 2. A paper CDV copy of Emma and David Smith [left, courtesy of the Community of Christ] taken from the original 1845 daguerrotype [right, Collection of John Hajicek, Mormonism.com]

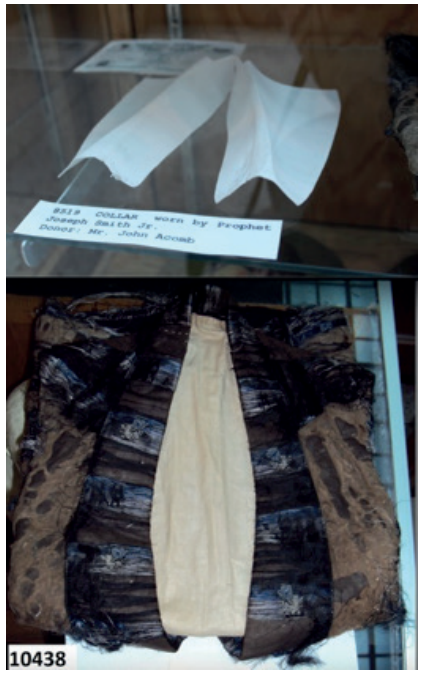

Fig. 3. Popped down collar (top) and vest with horizontal stripes (bottom) both belonging to Joseph Smith Jnr. Courtesy of the International Society of Daughters of Utah Pioneers

The collar is a 'popped down' collar, where the top of the collar is elongated and is folded down over a neck/bow tie, much like the one seen in the CDV of the unknown man. The vest has blue, black and white horizontal stripes on the front. The CDV shows a man wearing both a popped down collar and a vest with horizontal stripes visible under the lapels of his jacket. Colour cannot be determined as the photo is monochrome but it is obvious that there are different shades of stripes on the jacket pictured in the CDV. This is not evidence enough to show that the unknown man in the CDV and Joseph Smith Jnr are one and the same but it does provide further authentication of the man in the photograph as being from the 1840s due to the similar clothing styles. It also does not provide evidence against the possibility that Joseph Smith Jnr is the man in the CDV.

The Dibble death mask

As previously mentioned, the Dibble death mask (Figure 4) is considered the most reliable representation of the face of Joseph Smith Jnr. Weber (2009) confirms this by demonstrating the facial proportions of the death mask, matching the death mask with outline drawings of Joseph's facial profile drawn by Sutcliffe Maudsley in 1842 when they drew Joseph from life. Multiple images of the death mask were taken in person by DH showing all angles for facial comparison.

Facial comparisons

Images of the 'Dibble' death mask of Joseph Smith Jnr (Figure 4) and the CDV of a man (Figure 1) are compared using morphology and superimposition to establish any similarities or differences.

Morphological analysis is conducted using a set of standardised categorical scales to describe various anatomical features of the face and head. Scales were derived from Gabriel and Huckenbeck (2013) and Iscan and Steyn (2013). For each feature, a set of categories exists which can describe the shape, size, presence/absence, colour or position of anatomical traits. For example a person's face shape can be classified according to the following ten categories: ellipitical, round, oval, pentagonal, rhomboid, square, trapezoid, wedge shaped, double concave, asymmetrical. These scales use stardardised verbal descriptions and images of the categories to avoid miscategorisation/misinterpretation of anatomical traits. As well as categorising anatomical traits using standardised categories which capture morphology (size, shape etc.), unique identifiers and levels of symmetry/asymmetry are considered. The facial analysis was performed independently by two trained experts (MH and TL) in order to reduce potential bias. Analysis of the death mask was conducted by MH, while the analysis of the photograph was conducted by TL. After all descriptions/categorisations of traits were performed, the findings of MH and TL were compared. The features that could not be reliably compared between the CDV and the death mask were excluded, for example the death mask was photographed from various angles which allowed more features to be seen, however the CDV only presents the anterior view where some features could not be assessed. It is standard when conducting a facial comparison that if any anatomical differences are found between the two subjects then it must be concluded that they are not the same person. These differences do not include those that can be explained by lighting, camera angle and environmental differences which could alter anatomy between images eg. the effects of aging over time.

Fig. 4. 'Dibble' death mask of Joseph Smith, on display at the Museum of Church History and Art in Salt Lake City. © D.Hatfield

Morphology is the primary method used in this case as it was the most appropriate method for the types of images the authors had access to. However, as a secondary form of analysis a facial superimposition was conducted to show the alignment of anatomical points of the face between the man in the CDV and the death mask. As superimposition can result in bias (Houlton and Steyn 2018) it should only be considered a secondary source to further illustrate similarities or differences. The following standardised anatomical points (Martin and Saller 1957) were identified on both images and then the images were overlayed to show the alignments of these points: nasion (the deepest point of the root of the nose in the midline), subnasale (the point where the nasal septum meets the philtrum), stomion (the midpoint of the occlusal line between the lips), gnathion (the most inferior point on the body of the mandible in the midsagittal plane).

Results

The similarities between the death mask and the CDV were compiled after the independent analysis of each, conducted by MH and TL. Both experts agreed on 16 similarities and found 3 differences. Morphological points of comparison are presented in table 1 and figure 5.

Due to the long time it took for older cameras to capture the image of a person, people were often photographed with little facial expression, this allowed for better comparison as the neutral facial expressions of the man in the CDV and that of the death mask matched. Both the unknown man in the CDV and Joseph Smith Jnr. have a very high and broad forehead, this is further emphasised by the concave shape of the frontal hairline on the superior aspect of the head. Laterally, the hair moves more anteriorly to the temporal region. The superior border of the hairline can be seen in both the CDV and the death mask, however, lateral extent of the hair cannot be seen in the death mask. This is not to say that it was not present, but the mask was not moulded to the point where the hair is present on the image.

Table 1. Categories of facial traits showing similarities and differences between the man in the CDV and the death mask of Joseph Smith

	Similarities
1	Cheek bones: Prominent
2	Forehead height: High
3	Forehead width: Broad
4	Frontal hairline shape: Concave
5	Eyebrow shape: Straight, tapering on the left eye
6	Palpebral slit: Horizontal with the left eye drooping laterally
7	Nasion depression: Trace
8	Nose width: Medium
9	Nasal root: High
10	Septum tilt: Horizontal
11	Nostril position: Inferior
12	Lip thickness: Average
13	Relative lip size: Lower lip more prominent with thin upper lip
14	Upper lip shape: Flat
15	Lower lip shape :Flat
16	Chin shape: Round
	Differences
17	Face shape: rhomboid to wedge shape: there is little difference between these two face shapes, both are longer than they are wide. The rhomboid shape, has a slight protrusion laterally at the level of the cheek bones while the wedge shape does not.
18	Eyebrow thickness: the eyebrows on the death mask are thinner (possibly due to the casting process of the mask)
19	Philtrum prominence: the philtrum of the death mask is less prominent (possible due to casting process)
20	Mouth corners: the man in the CDV has straight mouth corners while the death mask has the left corner that is orientated downwards and a right that is orientated upwards (possibly due to gravity and the position of the body when the mould was taken)

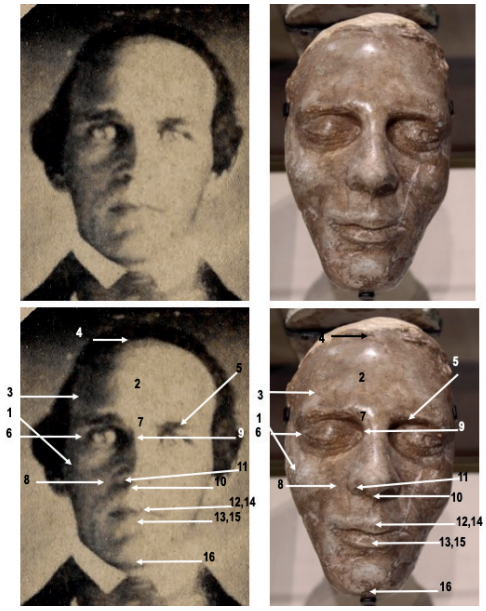

Fig. 5. Visual references for the similarities between the unknown man in the CDV and the death mask of Joseph Smith. Numbers like in Table 1

Although the similarities presented in Table 1 are in standardised categorical scales for facial features, there are some categories which cannot fully describe anatomical traits, especially unique identifying features and asymmetry of the face, therefore, these are discussed in addition to standard morphology. The eyebrow shape is straight, however, the left eyebrow of the man in the CDV is shorter than the right brow and it tapers laterally. As well as this, the left eye lid slopes laterally partially closing the eye, while the upper lid of the right eye is consistently widely open. Thus, the entire left eye and its brow are asymmetrical when compared to the right. The left eye is located slightly inferior compared to the right eye. The asymmetry of the eyes, the tapering of the left brow and the slope in the upper left eyelid are most likely a result of trauma to the left temple. The death mask shows both the tapering of the left eyebrow and the asymmetry in the position of the eyes, however, the sloping of the left upper eyelid cannot be compared as the eyes are closed. Although there is a high brightness of the photographic image on the left side of the man in the CDV, the authors are confident that the missing lateral aspect of the eyebrow is not a consequence of photo-exposure. The asymmetry of the position of the eyes on the CDV cannot be questioned.

Both faces have similarities in their descriptions, namely, they are both longer than they are wide, with the width of the face reducing inferiorly. The difference between the rhomboid and wedge shapes is that the widest part of the face in the rhomboid is the zygomatic width (cheek bones) whereas the wedge shape has a wider gonial region (angle of the mandible). Both authors agreed that the cheek bones were prominent. The mask does not reach back far enough to include gonions, hence a possible difference in observation. Thus the differences in face shape are considered insignificant. The eyebrows on the death mask are thinner than those of the man in the CDV, this could be due to the moulding process whereby only the thickest parts of the eyebrows were captured in the mould. The hair on the outline of the eyebrows may not have been captured in the mould as these hairs are often thinner than in the middle. The philtrum on the death mask is less prominent ie. less concave, this could be due to the post-mortem change in the skin of the face (sagging and flattening). The man in the CDV has straight corners of the mouth while the death mask has a left corner pointing downwards and the right corner pointing upwards. Joseph Smith Jnr would have

been in the prone position when the death mask mould was taken and the effects of gravity may have acted differently upon the mouth corners depending on the evenness of the surface that the table was on or exact position of his head.

Fig. 6. Superimposition of CDV and the images of the death mask belonging to Joseph Smith Jnr

Figure 6 shows the superimposition of the CDV and the image of the death mask with the anatomical points identified. The anatomical points align with each other and there are no significant differences between points. As there are no differences in the alignment of points and the findings of the morphological analysis, the man in the CDV cannot be ruled out as potentially being Joseph Smith Junior.

Discussion

Joseph Smith Jnr kept a personal journal throughout his life and wrote many letters to his family and friends. In his writings, he details multiple instances where he was subject to trauma, any one of these incidents could have resulted in the trauma to the left side of the face that was described from the photograph and potentially captured in the death mask. The most traumatic incident described by Joseph Smith Jnr occurred between the 25th and 26th March 1832. Joseph was badly beaten and tarred, fearing for his life he later wrote '*I learned that they had concluded not to kill me, but pound and scratch me, well tear off my shirt and drawer and leave me naked*' (Smith 1805–1834). He goes on to describe how the men who attacked him had tarred up his face and body. Another significant experience is dated circa 18th December 1835 when Joseph Smith Jnr wrote a letter to his brother William Smith, describing a physical altercation between the two men, Joseph wrote '*… abuse, anger, malice, hatred, and rage, are heaped upon me, by a brother; and with marks of violence upon my body, with a lame side, I left your habitation bruised and wounded…*' (Smith 1835). These are just two examples of physical abuse that Joseph had endured in his lifetime and as mentioned previously, could have lead to the trauma on the left side of the face which is responsible for the asymmetry of the eye region and missing lateral aspect of the left eyebrow. Ptosis is a condition that occurs when the muscles which raise the eyelid, or their nerve supply, are damaged, namely the *levator palpebrae superioris* or the superior tarsal muscle (Srinath et al. 2012). Both of these muscles function to elevate the upper eyelid, thus, any damage would cause the eyelid to fall. Ptosis can have different levels of severity, in the extreme the eyelid can cover the pupil, in the less severe cases, only minor drooping of the eyelid is seen (Finsterer 2003). The man in the CDV has minor ptosis as the entire pupil is visible. The missing lateral aspect of the left eyebrow may also be a result of trauma, namely, scarring which leads to the loss of hair over the scar site. However, this cannot be confirmed as the CDV has a high brightness (overexposure) on the left side, which does not allow fine details such as scars to be seen. There is a sign

of trauma (a scar) on the death mask at the site of the tapering eyebrow, the substance used to create the mask is roughened at the lateral part of the left eyebrow. This can either be from scarring in real life, or a consequence of the moulding process or damage to the mask itself.

As previously discussed, many of the historical descriptions of Joseph Smith's appearance are considered unreliable as many are contradictory and do not focus on anatomy. However, there were some anatomical details that were consistent in the historical record, these include: thin lips, prominent nose, oblong/oval face, large forehead without a furrow, retreating hairline, eyes set back in the head (McCarl 1962). This list of features was investigated after the authors conducted their analysis, both MH and TL agree that the man in the CDV and the death mask of Joseph Smith have a large and retreating forehead without a furrow. The 'retreating' forehead refers to the hairline being set back more superoposteriorly, which is further emphasised by the concave shape (not described in the historical records). Unfortunately, the nasal profile could not be compared as the CDV is taken in anterior view. According to our analysis, the lip thickness of both men is medium. The eye position in the head was not analysed as part of the standard classification system used but both MH and TL agree that the eyes are 'set back' in the head in both men.

Although the authors disagreed on the face shape between the man in CDV and the death mask, both the rhomboid and wedge shape allocated by the authors share similarities with the oval/oblong face shape in that they are both longer than they are wide, giving the appearance of elongation. It needs to be considered that the death mask did not encompass the entire extent of the face, just its anterior part, while the CDV, by the obvious nature of the antero-posterior projection of the entire head and face of an individual, depicted the full extent of the most lateral parts of the face.

There were some limitations in the current analysis. Unfortunately, the CDV is singular and only shows the man from the anterior view. This limited some morphological analyses, namely those that can be observed best from the lateral view, ie. nose projection. The death mask was photographed from multiple angles, including anterior, lateral and superior views which allowed analysis of more features, however, without comparison with the CDV, these were of little use.

Porter and Doran (2000) discuss the usefulness of facial comparisons in the positive identification of individuals, they suggest a holistic approach which includes analysis of the following, unique identifiers (scars, moles etc), morphology (form, size and shape of facial characteristics), facial symmetry (or asymmetry) and anthropometric analysis. Porter (2009) claims that without any evidence of unique identifying features, a positive identification would be most inappropriate. All methods in the holistic approach proposed by Porter and Doran (2000) have been considered in this case except for anthropometry for reasons already discussed, namely, its unreliability in the absence of a scale on the photograph (Houlton and Steyn 2018). In this case, there were morphological similarities, a degree of unique facial asymmetry and a unique identifier in the lateral aspect of the eyebrow (a scar). However, the scarring could not be confirmed due to image quality and inconclusive appearance of

trauma on the death mask. There were no moles, other scars or other unique identifiers on either the man in the CDV or the death mask, the absence of which neither confirms nor denies identification. The differences that were present were minor and could be explained by casting/photographic methods. The superimposition showed no significant differences between the man in the CDV and the death mask.

It is not known how many times the actual Joseph Smith Jnr. was photographed. The CDV we have analysed is undoubtedly a technical copy of a daguerreotype of a person whose imperfections, especially related to the left eye and the left brow, were uncorrected by touch up. These are present in the death mask. There are some full face painted portraits claiming to be Joseph Smith Jnr which are free hand artistic reproductions of some unknown image of the person (McCarl 1962) and as such are likely to be biased towards perfect symmetry and the lack of any disfigurement, especially when and if the artists tried to depict an idealised religious leader.

In conclusion, the authors suggest that there is a high degree of anatomical similarity between the man in the CDV and the death mask of Joseph Smith Jnr, however, without an unquestionable unique identifier or authentication of the original daguerreotype, the results of this analysis remain inconclusive, without, however, ruling out the possibility of this being a photograph of Joseph Smith Jnr the American prophet.

Data Availability Statement

No specific data, beyond images included in the paper were used, thus nothing that can be made available exists.

Conflict of interest

The two authors who conducted the facial analysis (TL and MH) would like to declare that they are not affiliated with the LDS faith and thus had no vested interest beyond scientific inquiry in the results and conclusions of this paper.

Authors' contributions

DH formulated the hypothesis and provided historical information, TL designed and conducted morphological comparison and drafted the text, MH helped with morphological comparison and conducted superimposition. All authors edited the text.

Data availability

Data for this study consist of the photograph analysed and photographic images of the face mask. Copies of both are presented as figures in this paper. Historical information can be obtained from DH debiann25@gmail.com.

Corresponding author

Maciej Henneberg, Anatomy and Pathology, School of Biomedicine, The University of Adelaide, Adelaide SA 5005; e-mail: maciej.henneberg@adelaide.edu.au

References

Bibbins JS. 1860. United States Federal Census [database on-line]. Big Grove, Kendall, Illinois; Page: 73; Family History Library Film: 803194. Retrieved from https://www.ancestry.com/discoveryuicontent/view/37536705:7667?tid=&pid=&queryId=fc42271eb2a9bb13e3813239ce17546b&_phsrc=jSI7&_phstart=successSource [Accessed 1 July 2021].

Burstow S. 2016. The Carte de Visite and Domestic Digital Photography. Photographies 9(3):287–305, https://doi.org/10.1080/17540763.2016.1202309

Finsterer J. 2003. Ptosis: Causes, Presentation, and Management. Aesth Plast Surg 27:193–204, https://doi.org/10.1007/s00266-003-0127-5

Gabriel P, Huckenbeck W. 2013. Identification of the living. In: Encyclopedia of forensic sciences (2nd edition). Eds. Siegel, JA, Saukko, PJ, Houck, MM. Academic press. 97–105.

Gayler GR. 1957. Governor Ford and the death of Joseph and Hyrum Smith. JISHS 50(4):391–411.

HoultonTMR, Steyn M. 2018. Finding Makhubu: a morphological forensic facial comparison. Forensic Sci Int 285:13–20.

Iscan MY, Steyn M. 2013. The Human Skeleton in Forensic Medicine. Charles C Thomas. Springfiled, IL.

Lucas T, Henneberg M. 2015. Are human faces unique? A metric approach to finding single individuals without duplicates in large samples. Forensic Sci Int 257:514-e1–514e6.

Lucas T, Kumaratilake J, Henneberg M. 2016. Metric identification of the same people from images – how reliable is it? J Anthropol 2016:1–10.

Martin R, Saller K. 1957. Lehrbuch der Antropologie, Gustav Fischer, Stuttgart, Germany.

McCarl WB. 1962. The Visual image of Joseph Smith. (Dissertation, Brigham Young University).

Moreton R, Morley J. 2011. Investigation into the use oof photoanthropometry in facial image comparison. Forensic Sci Int 212:231–237.

Porter G. 2009. CCTV images as evidence. Aust J Forensic Sci 41(1):11–25.

Porter G, Doran G. 2000. An anatomical and photographic technique for forensic facial identification. Forensic Sci Int 114(2):97–105.

Quinn DM. 1976. The Mormon succession crisis of 1844. BYU studies quarterly 16(2):187–233.

Romig R, Macay L. 2022. Hidden things shall come to light: the visual image of Joseph Smith Jr. John Whitmer Historical Association 42(1), https://www.jwha.info [Accessed 1 July 2021].

Scoleri T, Lucas T, Henneberg M. 2014. Effect of garments on photoanthropometry of body parts: Application of stature estimation. Forensic Sci Int 237:1–12.

Smith J. 1835. Letter to William Smith. The Joseph Smith Papers, Church History Library, Salt Lake City, UT, United States, https://www.josephsmithpapers.org/paper-summary/letter-to-william-smith-circa-18-december-1835/5 [Accessed 18 January 2021].

Smith J. 1842a. 2nd November 1838-31st July 1842. The Joseph Smith Papers, Journal, Church History Library, Salt Lake City, UT, United States. https://www.josephsmithpapers.org/paper-summary/history-1838-1856-volume-c-1-2-november-1838-31-july-1842/522 [Accessed 1 July 2021].

Smith J. 1842b. Journal, December 1841-December 1842. The Joseph Smith Papers , Church History Library, Salt Lake City, UT, United States. https://www.josephsmithpapers.org/paper-summary/journal-december-1841-december-1842/82#XB7538EB9-FC09-4743-8FA3-B2226C784F11 [Accessed 1 July 2021].

Smith J. 1844. Journal, December 1842–1844; March-June 1844. The Joseph Smith Papers, Church History Library, Salt Lake City, UT, United States. https://www.josephsmithpapers.org/paper-summary/journal-december-1842-june-1844-book-4-1-march-22-june-1844/106 [Accessed 3 July 2021].

Smith J. 1979. The memoirs of Joseph Smith III (1832–1914). Herald Publishing House, Independence, Missouri.

Smith J. 2015, The Joseph Smith Papers, Journals, V.3, May 1843-June 1844. Church Historian's Press, p. 238. https://www.josephsmithpapers.org/paper-summary/journal-december-1842-june-1844-book-4-1-march-22-june-1844/103 [Accessed 3 July 2021].

Srinath N, Balaji R, Basha MS. 2012. Ptosis correction: a challenge following complex orbital injuries. J Maxillofac Oral Surg 11(2):195–199, https://doi.org/10.1007/s12663-011-0300-3

Svadlena J. 2014. Daguerrotype – the first ever practically used photographic technique Daguerrotype – the first ever practically used photographic technique. Koroze a Ochrana Materiálu 58(2):59–64.

Taylor J. 2017. Witness to the Martyrdom: John Taylor's Personal account of the last days of the Prophet Joseph Smith. 2nd Edn. Deseret Book. Salt Lake City, Utah.

The Diary of Joseph Smith (1805–1834) [diary] 1832 March, p. 205–207 in The Joseph Smith Papers, https://www.josephsmithpapers.org/paper-summary/history-1838-1856-volume-a-1-23-december-1805-30-august-1834/213 [Accessed 18 January 2021].

The Saints Herald (1879), Volume 26, pg. 254 Plano, Illinois. August 15th, 1879. https://archive.org/details/TheSaintsHerald_Volume_26_1879/page/n253/mode/2up [Accessed 18 January 2021].

Weber CG. 2009. Skull and crossed bones: A forensic study of the remains of Joseph and Hyrum Smith. Mormon Historical Studies, Salt Lake City, Utah.

Anthropological Review • Vol. 85(4), 15–30 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.4.02

A violent structure. Southern perspective on the practice of forensic anthropology as a public service

Katarzyna Górka

Department of Anthropology, Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, Wrocław, Poland

Abstract: Global South perspective rarely reaches the academic vanguard. While they represent over 80% of the world population, the voices from less developed regions often are ignored in academic debate. This fact produces an important disequilibrium in relation to the dissemination of knowledge, sharing of experiences and exchange of thoughts and, consequently, undermines and hinders the development of scientific disciplines. Forensic anthropology is no exception in this trend.

The present article brings up the subject of the context of forensic anthropology in Brazil to demonstrate the interconnection of the professional situation of this discipline, its structural and bureaucratic limitations and their effect on the perpetuation of human rights violation. Various aspects of daily practice of forensic anthropology in a context devoid of basic resources generate a setting that affects both the victims and their families. Despite an outstanding performance and dedication of professionals, structural limitations often substantially affect the effectiveness of their service. The present article discusses these aspects in a conceptual framework of the relation between the practice of forensic anthropology and human rights violation. In this research, Brazil serves as a case-study, an intensively studied subject that brings interpretations that can be applied in a broader context.

The article aims at opening a broader, international debate that would increase the visibility of the relationship between the practice of forensic anthropology and the structure generating and/or maintaining violence in a specific economic and legislative context especially present in the countries of the so-called global South.

Key words: forensic anthropology, human rights, Global South, Brazil, infrastructure, violence, structural violence, theory.

Received: 16.09.2022; Revised: 26.10.2022; Accepted: 30.11.2022

Introduction

The so-called Global North and Global South represent contrasting contexts in terms of economy, technological advancement, political stability and population growth, among others (Odeth 2010). When it comes to knowledge production and exchange, Global South perspectives are rarely given voice and often pass unnoticed in international academic debate. This creates an important disequilibrium in relation to the dissemination of knowledge, sharing of experiences and exchange of thoughts and, consequently, undermines and hinders the development of scientific disciplines, as these are factors that strongly contribute to the advancement of science (Peters 2006; King 2011; Collyer 2018).

Forensic anthropology (FA) is an applied field of sciences which is often, yet not exclusively, linked to death. Forensic anthropologists focus their efforts on establishing the identity of unknown human remains found either skeletonized or in an advanced stage of decay. For this purpose, a set of internationally validated and recognized methodologies is used in order to estimate the biological profile of an individual (sex, age at death, stature and sometimes ancestry/biological affinity) with the aim of narrowing down the number of possible suspects. Additionally, possible trauma, pathological lesions, and other individualizing characteristics that can facilitate the process of identification are observed. Forensic anthropologists may also assist in establishing the cause of death, should any death marks/indicators be visible on skeletal material (Cunha and Cattaneo 2006).

The fact that forensic anthropologists often focus their professional activity on dead individuals brings an important set of issues related to human rights and ethical aspects of their work. Both the treatment of the dead and the rights and feelings of the living constitute aspects that must be taken into account when considering the ethical dimension of the service of forensic anthropologists. While the sole act of death can be a result of a violent action that critically affects the right to life of the victim, death and the subsequent treatment of the dead body can constitute important factors related to unnecessary physical and/or mental suffering of the living relatives and friends (Squires and Garcia-Mancuso 2021). Forensic anthropology, by definition, should mitigate this process by providing answers and information that can be helpful in the course of obtaining justice, by delivering a set of data that can facilitate the identification of an individual who might have been sought for, sometimes for an extensive period of time, by his/her relatives. However, this process may sometimes be challenged by factors that are independent of, yet strongly influence and affect the performance of forensic anthropologists. Adequate working conditions and access to necessary means and tools are extremely important for a specialist to be able to complete the process of an anthropological analysis of skeletal remains in a forensic context, that is, to deliver a positive identification of the victim. Similarly, administrative, legislative and structural limitations, often existing in forensic anthropology contexts, highly impact the possibility of conducting efficient expertise.

Theoretical research in forensic anthropology is rather scarce. This fact has been recently brought up and the importance of theoretical approaches within this discipline has been emphasized (Clifford Boyd and Boyd 2011, 2018). Concep-

tualization of ideas and interpretations brings a wider perspective and better understanding of processes that form a part of a given contextual dimension. Moreover, the possibility of impartial studying, documenting and reporting on realities that are somehow disregarded helps to bring visibility, broadens our perspectives and opens up a space for a dialogue. The present theoretical-philosophical reflection focuses on a subject that has been greatly overlooked in studies regarding forensic anthropology. With a reference to the situation of this discipline in Brazil as a case study, the present article aims at proposing a debate on how structural factors and political decisions influence the perpetuation of violence towards the victims and their families in a setting which, by definition, should be working against violence and its consequences. This paper is aimed at presenting reflections upon the existence of a relationship between (infra)structural, legislative and bureaucratic factors that may be affecting the service of forensic anthropology and a simultaneous context in which basic human rights are being violated.

Human Rights in Forensic Context

The Universal Declaration of Human Rights, proclaimed in 1948 by the General Assembly of the United Nations, introduces the concept of a basic equality among people. It covers the rights inherent to each person, regardless of skin colour, sex, nationality, ethnicity, religion or any other aspect of identity that could, in any circumstance, be used as a means for justification of differentiation and discrimination between people (UN 2020).

A violation of human rights is a situation that evidently affects its direct victim(s) – a person(s) who has suffered injustice, discrimination or even death due to the violation of some of their basic and universal rights. Nevertheless, our social nature often implies that injustice or violence suffered by one individual transfers to a broader circle of subjects – people close to the victim, their immediate family, friends and more distant family members. The International Commission of Missing Persons indicates that human rights, apart from the right to life and liberty, the right to freedom of opinion and expression, and the right to work and education, also includes issues far less frequently automatically considered as such, for example, the right to recognition of the victim as a person under the law, the right to effective investigation, the right to due process of law, or even the rights of surviving relatives to know what happened to their family member(s), or the right to burial and dignified farewell to a loved one (ICMP 2020). These aspects involve equally the direct victim(s), but also their families and friends. In case of a disappearance of a person, especially a forced one, or in case of dead victim(s) whose identity is initially unknown, and in situations in which the process of identification is deficient, ineffective or for any reason cannot be completed, various of those rights are put at risk of being abused or even violated.

Violation of human rights is a constant and daily aspect present in the service of Medico-Legal Institutes (IMLs), where medical examinations on living and dead victims are performed for legal purposes. When a case involves skeletonized, severely mutilated or heavily decomposed corpse, or in a case in which for any other reason traditional methods of forensic medicine cannot be applied, the service of forensic anthropology is usually requested. Anthropological analysis of the

skeletal material permits the estimation of a biological profile of the victim (probable: sex, age, height and biological affinity) and this way narrowing down the number of people that can be considered possible victims. A subsequent comparative analysis of the skeletal remains with available antemortem data (e.g. medical records, dental records, photographs) allows for further positive identification of the victim and a certain closure of their circle of life. It is pertinent to acknowledge here that the concept of ancestry or biological/population affinity raises important debates and its use in the context of forensic anthropology has been recently extensively contested (Smay and Armelagos 2000; Albanese and Saunders 2006; Bethard and DiGiangi 2020; Cunha and Ubelaker 2020; Dunn et al. 2020; DiGiangi and Bethard 2021; Ross and Pilloud 2021; Ross and Williams 2021). This issue is even more relevant in the Brazilian context, as the extremely high miscegenation of the population creates a biological space that strongly supports the concept of the groundlessness and inutility of categorization of people into certain geographic groups based on *a priori* defined sets of morphological variables (either metric or macroscopic).

Under ideal circumstances, in which working conditions are adequate and the specialist has full access to all necessary comparative data, the application of anthropological methods would permit the solution of practically every case involving sufficiently preserved skeletal material. Nevertheless, this is rarely the case. Administrative, bureaucratic and legislative limitations together with the lack of access to necessary means and tools required for an effective expertise represent a frequent reality of many forensic anthropology services (Górka and Plens 2021). It is relevant to mention that these circumstances are not exclusive to Brazilian context and similar limitations affect the work of many forensic anthropologists around the world. Such situations leave the affected professionals in an institutionalized limbo which significantly disturbs and hinders their potential of identifying the deceased person. As a result, the circle of life of these people (the victims) does not close, and they often remain marked as N/N in the IMLs records, with their bones kept in an ossuary and which, in the best scenario, can still serve as teaching or research material. In such circumstances, often independent of practitioners' will and efforts, the role that forensic anthropology plays in the context of violence prevention and crime solving transforms into another factor that maintains and perpetuates the abuse and violation of human rights of both the victims and their relatives.

Material and Methods

In the present article Brazil serves as a case study in order to bring broader, generalized reflection on the subject that could be applied in other local contexts. The text is based on extensive field research conducted by the author in Brazil in 2018. It consisted of in-person visits to nine Medico-Legal Institutes across Brazil, covering all five geographic regions of the country (North, Northeast, Centre-west, Southeast, South) and a total of 33% of Brazilian states. A series of personal interviews were conducted with 16 professionals acting in the field of forensic anthropology in Brazil following an a priori prepared semi-structured questionnaire. This number accounts for about 32% of specialists actively working on anthropological cases in this country,

however, no official statistics on their number are publicly available. The approximate number of professionals was obtained from the private records of Dr. Trindade Filho through personal communication on 29th of May 2018.

The main aim of that research was to "report the information gathered directly from professionals acting in the field, their opinions, concerns, and difficulties encountered in their daily practice, with the aim of highlighting the challenges of the discipline and this way contribute to the advancement and development of forensic anthropology in Brazil" (Górka and Plens 2021). Detailed results of the above mentioned research have already been published (Górka and Plens 2021), yet they do not focus on issues addressed herein. In an attempt to avoid an unnecessary repetition of information, interested readers are directed to the source publication. However, in order to conceptualize the context of forensic anthropology in Brazil for the purpose of the present paper, where necessary, certain aspects will be presented in a summarized manner with an adequate reference to the original work.

Results

Medico-Legal Institutes and forensic anthropology in Brazil

With the area of over 8.5 million square kilometres and the population size above 213 million (IBGE 2020), Brazil is the world's fifth-largest country and the sixth most populous. The country is divided into five geographic regions and its federal administration is composed of 27 units (26 states and one Federal District). The states are entities with semi-autonomous governments and relative financial independence.

Medico-Legal Institutes (IMLs) are public offices, in majority under the administration of the State Secretary for Public Security or the Civil Police. They deliver specialized expertise for legal purposes in various areas (necropsies, toxicology, body injuries, sexual violence, mental health, age verification, etc.). In Brazil, there are currently 381 such entities (SENASP 2012). The service of forensic anthropology falls under state governance as it is performed within the Medico-Legal Institutes' realm. This type of administrative organization results in a series of important consequences for the performance of work by professionals in the area of forensic anthropology, as well as in other specialties. The lack of a joint and central administration makes each state of the Union apply different policies and distribution of resources to the Medico-Legal Institutes under their management. This type of administrative organization of the country gives the states the autonomy to decide on various aspects of their policies, but at the same time makes it difficult to develop homogeneous strategies across the country in areas of national public interest, such as forensic anthropology.

Furthermore, in the whole country, there are only 15 locations distributed within 13 of the 27 administrative units, where a more or less formally structured FA service exists (Trindade Filho 2018). In most cases, there is a single forensic anthropology sector (Department, Section) in the IML of the state's capital (Bahia, Ceará, Distrito Federal, Goiás, Minas Gerais, Paraiba, Parana, Pernambuco, Rio de Janeiro, Rio Grande do Sul, Roraima, Santa Catarina), with São Paulo being the only exception (there are two other forensic anthropology centres, one in Ribeirão Preto and one in São José do

Rio Preto). Such a small number of entities specialized in forensic anthropology, in a country where the rate of violent deaths is one of the highest in the world (UNODC 2019) and the brutality of homicides together with unfavourable climatic conditions accelerate the decomposition of bodies is far from being sufficient for the existing demand. This varies greatly from state to state and oscillates within the range ~12 - 1000 cases per year (Górka and Plens 2021).

A very limited number of specialists is another urgent issue affecting the service of forensic anthropology in Brazil. There are no official data available regarding the number of professionals working in the field of forensic anthropology in Brazil. Their approximate number oscillates around 50 for the whole country (Trindade Filho 2018). Due to mainly historical circumstances (Gaspar Neto 2017), biological anthropology, which is internationally considered as a basic discipline for further specialization in forensic anthropology (Christensen et al. 2019) is practically not being taught in Brazil (Gaspar Neto 2017). As a consequence, if we consider as an anthropologist a person with academic background in anthropology, Brazil does not have any practicing forensic anthropologists[1] and their tasks are usually taken over by either odontologists or medical practitioners, as according to the current legislation, only these professionals can act as such (Górka and Plens 2021). By no means does this fact diminish the competence of professionals working in this field, yet, as they state themselves, it greatly hampers the beginnings of their career as they generally enter the field without proper theoretical and practical training and often spend a long time "learning by doing". Such circumstances also undermine the search for potential future personnel, as professionals with adequate initial qualifications are rare.

All this leads to a situation where citizens of the same country cannot expect to receive the same quality of service from the same public agencies in different states. This fact represents a highly detrimental context to the society and, in the case of forensic anthropology, can be considered a violation of human rights (Baraybar and Blackwell 2014). It also constitutes an important obstacle for the development of a democratic society through institutions that are trustworthy, effective, accountable and fair (ICMP 2020).

Forensic Anthropology and Human Rights

The first measurements taken on human skeletal material were recorded in the eighteenth-century France, and the application of forensic anthropology in a legal context goes back to the mid-nineteenth and early twentieth century, within the area of physical anthropology in the United States (Klepinger 2006). However, the use of forensic anthropology in the situations of human rights violations is a much more recent event. The creation of the Argentine Forensic Anthropology Team (EAAF) in the 1984 to investigate crimes committed by the State during the period of the Military Dictatorship (1976–1983) is usually considered as a pioneer application of anthropological methods in such context. The Balkan War (1992–1995), especially the atrocities committed against the Muslim population in this region and the Rwanda genocide of the Tutsi population in

[1] As of December 2022 there are two professionals certified by the FASE (Forensic Anthroppology Society of Europe).

1994 generated a large demand to identify the thousands of victims found in mass graves, bringing more visibility to the field of forensic anthropology (Ferlini 1999). Currently, all over the world, in (post)conflict zones, several forensic anthropology groups work with the aim to denounce human rights abuses using anthropological methods (Hughes 2001).

Such cases represent clear examples of State-committed crimes during turbulent times, in which forensic anthropology could contribute significantly. However, the application of forensic anthropology in the context of human rights abuses is not solely limited to scenarios of war or mass atrocities. Every death resulting from a violent action constitutes an act of violation of the most basic right of every human being – the right to life. What is more, multiple human rights abuses happen in cases when the victim had been kidnapped and/or tortured before his/her death, which often occurs, for example, in the context of organized crime. As a consequence, the experts at Medico-Legal Institutes are immersed in a context of human rights violations on a daily basis and do not need to travel to places of armed conflicts for their work to be of equal importance.

Crimes involving a person's disappearance, especially a forced one, constitute cases in which various human rights, both of the victim and his/her family, are being violated (e.g. the right to safety, freedom, dignity, life and not to be subjected to torture or ill-treatment, the right of the victim's families to know what happened to their relative) (ICMP 2020). Moreover, an inadequate and deficient response of the authorities responsible for resolving the case may lead to subsequent human rights abuses (for example, the right to due process or recognition of the victim as a person before the law), especially in the absence of an official, effective, transparent and independent investigation or some other form of omission on the part of the State and its agencies. The Universal Declaration of Human Rights states that national and local governments and law enforcement bodies should cooperate in a joint effort to locate and identify missing persons in any case of disappearance and violent death, so that the investigation is effective and brings the necessary answers to families and society (UN 2020).

Forensic Anthropology and the Violation of Human Rights

Participation in a crime solving framework constitutes a part of forensic anthropologist's service. At the same time, the inability of delivering an effective outcome of the work resulting from e.g. (infra)structural limitations creates a context in which unintentional violation of human rights may occur.

In order to complete the process of anthropological analysis in forensic context a professional should dispose of adequate working conditions and access to necessary comparative material and relevant information from the police investigation. This, by default, implies their existence (in the case of comparative material), and secondly, a cooperation between different branches of law enforcement agencies, as well as between different IMLs and even between various departments of the same IML. Insufficient infrastructure and scarceness of equipment have a significant impact on the work effectiveness. Working conditions deficient in these matters provide a framework in which effective performance of forensic anthropology service is hampered. As a result, the positive contribution of this

discipline to criminal cases is seriously weakened. This automatically transfers to the failure of forensic anthropology to fulfil its potential related to the respect of human rights of both the victims and their families, and consequently creates a context in which these rights are not respected, and hence abused/violated. It is important to emphasize that these circumstances are independent of the abilities, knowledge and potential of professionals working in this area. Nevertheless, they are inseparably linked to the outcomes of their work.

What is also quite relevant to this discussion is the fact that the field-work performed by Górka and Plens (2021) was conducted in IMLs in nine state capital cities. The 366 remaining Medico-Legal Institutes across the whole country do not have a formal forensic anthropology unit in their structure, neither they have trained specialist in this area. Considering the fact that capital cities usually dispose of a relatively higher budget than the cities in the interior parts of a state, together with the fact the above mentioned research was mainly performed in wealthier states and the authors encountered a set of challenges and difficulties in those localities, it becomes relevant to question how forensic anthropology cases are handled in the remaining locations. Whether anthropological examinations are performed at all? If so, are they performed properly? What are the working conditions in which the anthropological examinations are performed? Are they adequate for this type of expertise? Do the professionals have access to adequate tools and resources? Are they properly trained to conduct this kind of examination? Does the population have access to forensic anthropology service? Is its quality adequate?

Knowing the answers it would be possible to more precisely assess the level of human rights violations in relation to forensic anthropology in Brazil. What we know is that important challenges and limitations are present even in the wealthiest and most developed locations (Górka and Plens 2021). As a result, it is relevant to contemplate the possibility that the situation of forensic anthropology is probably even more challenging in the remaining regions, especially those with lower incomes and higher levels of violence. In such context, the systemic deficiency of forensic anthropology transfers and directly affects the citizens and families that require such service in order to find and identify their disappeared or dead relative(s). The inability of a state to provide an adequate service for such specialized cases forms a context of systemic and systematic violation of basic human rights of the citizens, and these include both, direct victims and their families and relatives. Although this situation does not have easy and quick solution, it should not be ignored and viewed as non-existent.

In order to improve the situation, coordinated and institutionalized actions should be implemented. The work of professionals, however adequate and well-intentioned, is insufficient to change the reality of forensic anthropology in Brazil, which is immersed in a historical lack of attention and institutional interest on the part of the State in different fields.

Discussion

The Role of the State and Violence by Omission

Violence is a multidimensional phenomenon affecting every human being at some point in one way or another. Hu-

man rights violations constitute a particular form of violence that is directed towards both individuals, but also whole groups and societies. By default, we usually assume that human rights violations happen in extreme situations, such as wars, tortures, etc., and considering any act of violence, we usually think of an aggressor who, through a direct action, causes some kind of harm to the victim. Nevertheless, a single act of violence can have more dimensions than a simple direct action with harmful consequences. The most common form of violence is a direct violence – when someone does something. But violence also happens when someone does not do something – violence by omission (Bufacci 2007). This form of violence is way less obvious, perceptible and can occur in different forms, e.g. abandonment, negligence or simply lack of knowledge or disregard for situations that can generate a context of violence.

Situations, in which a State performs direct acts of violence towards its own citizens are known and often highly publicized. Nevertheless, States, quite often operate, intentionally or unintentionally, causing violence directed at its citizens through omission. This type of violence is defined by Galtung (1969) as structural violence – a deliberate disengagement of basic human needs by power actors, which involves failure to take action that could improve the lives of citizens or prevent the violation of their basic rights. Because of the nature of such violence, the detection of a direct correlation between the perpetrator and the victim in such situation is often more difficult compared to direct violence. This results in a fact that violence by omission often goes unnoticed, ignored and/or disregarded. However, unlike direct violence, violence by omission often follows a continuous pattern perpetuating systemic structures of oppression (Bufacci 2007). It is much easier for governments to act in favour of maintaining the status quo – even if this may generate a context that somehow violates the population's basic rights – than to take a proactive attitude to change it.

Such circumstances create a double role of a State in relation to human rights. On the one hand, the State plays a crucial part in combating the violation of human rights. On the other hand, it can and often does act, more or less intentionally, in parallel, violating the same rights.

By default, government authorities and officials at each level of the administration should, and often do act in favour of promotion and help in reducing human rights abuses. Nevertheless, the systemic ignorance or disregard of issues related to human rights abuses, legislative omission and unwillingness to solve problems that can be solved solely through administrative decision, together with insufficient distribution of resources to areas directly related to work against such situations create a context in which human rights are being systemically and systematically violated. This can happen even without any intentional involvement of anyone in this regard.

When applying such an approach to the analysis of the current situation of forensic anthropology in Brazil, the impact of a State induced violence by omission on the Brazilian population can be easily perceptible. The most noticeable aspect of human rights violation in relation to forensic anthropology in Brazilian context is the enormous inequality among citizens when it comes to access to the

service. Only 4% of the 381 Medico-Legal Institutes across the country have a structured, more or less formal, forensic anthropology department, section or unit (Górka and Plens 2021). Locations without designated forensic anthropology sections in the IML structure and those without experts properly trained in this area often either leave anthropological cases unanalysed or perform only a simple registration of the collected material without actual anthropological examination (Górka and Plens 2021). Considering that such circumstances characterize the majority of the Brazilian IMLs, the availability of service for the populations remains extremely scarce and precarious. This issue has been already raised by the Brazilian Medical Federation who indicated in its report in 2016 that: "A high amount of IMLs does not mean that services are available to the population" (FMB 2020). The National Secretary for Public Safety (SENASP) recognizes that the service of the IMLs is: "… fundamental for the protection of human rights and for the strengthening of the evidential framework and the consequent reduction of impunity" (SENASP 2012). The same quality and type of service should be available to the entire population of a country, if public institutions of such importance in solving crimes, reducing impunity and improving public safety aim at fulfilling its mission.

In complex anthropological cases that require specialized knowledge and training, together with adequate physical condition and equipment of a laboratory this is particularly important. The lack of comparable access to such service for the entire population produces a context of a significant inequality that greatly hampers the fulfilment of basic human rights (right to effective investigation, right to recognition as a person before the law, due process, rights of surviving relatives at burial and dignified farewell of a loved one, etc.).

The administrative structure of the country, together with state differences in the management of public funds and the management of the IMLs appear as the main contributing factors of this situation. Linked to the National Secretary of Public Security or the Civil Police of each state, Medico-Legal Institutes work within the political context of each one. The federal organization of the country gives the states the autonomy of resource distribution and organization of legislative, economic and social priorities according to their particular political interest and the decisions of their governors. In such context, changes that would imply benefits for the entire population of the country would require centralized, coordinated, institutionalized and universal actions and creation of national strategies in areas of high public interest, such as forensic anthropology. Only this way, universal access to the same quality of service for every citizen could be guaranteed.

When experts work in settings without proper, or sometimes even minimal physical and/or technical conditions (FMB 2020; Górka and Plens 2021), the verification and validation of the evidence is put at risk and, together with an effective investigation, can be compromised. Unsolved cases accumulate, and new ones arriving daily already surpass the processing possibilities of the experts. This situation creates yet another problem. The accumulation of unsolved, not analysed and/or not claimed material demands adequate and dignified storage space that many IMLs have difficulty to designate due to their limited physical capacity (Górka and Plens 2021).

The lack of a national database of missing persons, despite the existence of several local and unintegrated registries, creates another major problem in Brazilian forensic anthropology (Calmon 2019). The importance of a forensic anthropologist work lies in the possibility and ability to conduct a comparative analysis of unidentified skeletal remains with antemortem data from a suspect of identity in order to confirm or reject a possible match. For a person to be considered the subject of an analysis, it is necessary to have information about his/her disappearance. Experts working in the field of forensic anthropology are able to perfectly reconstruct the biological profile of the victim (sex, height, age). They also have the ability to recover some individualizing information about that person from the skeletal material (fractures or previous surgeries, pathological lesions, dental treatment or other individuality of denture or skeleton, etc.). These, compared with medical and/or dental records or even simple smile photographs (Silva et al. 2008, 2016; Miranda et al. 2016; Mazur et al. 2021) may be sufficient to confirm the individual's identity.

A high level of internal migration in Brazil (de Lima Amaral 2013) constitutes a factor which often determines that a disappearance of a person is notified to the relevant authorities in the state of the victim's origin and not always in the state where the person disappeared or was translated to after a forced disappearance. The continental dimension of the country and the context of economic vulnerability of a great part of internal migrants frequently contribute to this fact. At the same time, the relevant authorities of the administrative unit where the victim's body is found will work on the case and possibly will not have access to the information about the victim's disappearance if this record was made in another state. This is because the existing local databases of missing persons are managed by the states and are not integrated at a national level. Additionally, the data introduced within the state databases is not always consistent with each other, which significantly hinders and undermines effective investigations (Calmon 2019).

Until 2017, Brazil did not have any integrated national policy or tool for the management of missing persons' records. In 2017, the National System for Locating and Identifying Missing Persons (SINALID) was created, with the purpose of fostering the cooperation of various agencies and public institutions working with missing persons. As of the date of writing (October 2022), over 85.000 cases from 20 states are registered in the database, however the system is not yet fully operational in all federative units (SINALID 2022). In 2019, the law nº 13.812/2019 was established, creating the National Policy for the Search of Missing Persons and launching the National Registry of Missing Persons, yet the system is still under construction (Ministério de Justiça e Segurança 2021a). In 2021, a week-long national campaign for the collection of biological material (DNA) from the relatives of missing persons was launched with the aim of creating the National Bank of Genetic Profiles (Ministério de Justiça e Segurança 2021b).

Nevertheless, these are only very recent initiatives. The long-term omission and lack of initiative by the federal authorities, relevant agencies and the legislative powers, regarding the creation of a national and functional database of missing persons falls under another form

of human rights violation by the State against the Brazilian population. Access to such registries is a fundamental factor in the process of solving crimes and combating impunity. The existence of such a tool is also crucial within the field of forensic anthropology and opens up space for better and more effective work by specialists in this area as the process of positive identification is incomplete without comparative material from possible suspects of identity. In fact, this factor was commented by professionals as one of the main reasons why the majority of forensic anthropology cases in Brazil remain unsolved/unidentified (Górka and Plens 2021). Therefore, mentioned initiatives are extremely important steps in the direction of providing the Brazilian population with tools that would facilitate the service of public and law enforcement agencies that work within the context of missing persons.

All from the above indicated problems arise as an effect of administrative decisions within the structure of a country, state and of an IML itself. The omission of those responsible for addressing these issues in order to improve the situation and create adequate spaces for carrying out anthropological examinations is an important factor in perpetuating the context of violation of basic rights of the population.

The potential and future of forensic anthropology in a global perspective

Forensic anthropology is gaining a lot of attention and recognition within both forensic sciences and popular consciousness. Over the years, the field has undergone an important developmental shift from a pure application of anthropological methods in a legal context to a highly independent field of science (Dirkmaat et al. 2008; Cunha 2010; Passalacqua et al. 2021). Recent advances created a certain theoretical void (Adovasio 2011) that began to be addressed over the past years (Clifford Boyd and Boyd 2011, 2018; Winburn and Clemmons 2021). However, there are still certain theoretical aspects related to the practice of forensic anthropology that have not received much attention and which, nevertheless, significantly affect the performance of specialists in some regions.

For the field of forensic anthropology to fully contribute in the defence of human rights, without creating context of their violation, it must be ensured that its entire potential is used in forensic cases. This can be achieved only if a sufficient number of properly trained experts is available for the existing demand and their distribution is coherent with the needs of the entire population. Appropriate working conditions and a national database of missing people are essential factors for effective forensic investigations that would guarantee due process of law of a case. Such context would allow us to consider that the system in which the field of forensic anthropology operates does not violate the rights of the population. The characteristics of the structural violence inflicted by the State in relation to the practice of forensic anthropology must be addressed in a coordinated, institutional and urgent manner.

The progress and development of forensic anthropology needs a coherent, universal, well-structured and national plan, which can be applied to all units destined to perform anthropological expertise. When creating strategies, it is important to remember not to start building the house from the roof. Solid professional and academic foundations of the discipline are crucial for the rest of the field to begin forming a stable structure.

The outstanding performance and efforts of the professional community in this field need the support of authorities at all levels of the country's administration. It is through this that proposals and initiatives that arise from those who know the field and its challenges first-hand can be materialized and, thus, promote the advancement of this discipline that can directly contribute for the basic rights of the Brazilian population to be respected.

It is important to acknowledge that the circumstances, as presented here, may not be true for every forensic anthropology unit around the world, yet, quite likely they are also not exclusive to the Brazilian context only. As scientists, even though it may not affect us personally, we cannot turn a blind eye on the fact that professional realities differ, and they differ greatly between geographic regions, often due to important social, political and economic disequilibrium existing among the countries of the so-called Global North and South. This imbalance directly affects multiple aspects of various areas of life, including the practice of forensic anthropology. As Sabzalieva et al. (2020) state: "…global asymmetries in the production of science shape mechanisms of recognition." Despite being a leader in scientific production in the region, Brazil continues as a peripheral actor in global science (Martinez and Sá 2020). Consequently, as Brazilian perspective rarely reaches the international academic vanguard, the issues affecting various fields of science that are being raised by national researchers and practitioners remain at a rather local level. Highlighting difficulties and challenges faced by professionals from academically marginalized regions to a broader audience helps break the bubble of "North-centric" perspectives by presenting realities that are distant yet real. It broadens the possibility for exchanging knowledge and experience and opens up space for international collaborations that ultimately can lead to an improvement of the situation by creating joint proposals, applicable strategies and actuation plans based on contrasting experiences.

Conflict of interests

Author declares no conflict of interests.

Corresponding author

Katarzyna Górka; e-mail: katarzyna.gorka@hirszfeld.pl

References

Adovasio JM. 2011. An "outsider" look at forensic anthropology. In: Dirkmaat DC, editor. A Companion to Forensic Anthropology. Chichester, UK: Wiley & Blackwell, 683–689.

Albanese J, Saunders SR. 2006. Is It Possible to Escape Racial Typology in Forensic Identification? In: Schmitt A, Cunha E, Pinheiro J, editors. Forensic anthropology and forensic medicine: Complementary sciences from recovery to cause of death. Totowa (NJ): Humana Press, 281–316.

Baraybar JP, Blackwell R. 2014. Where are they? Missing forensics and memory. Ann Anthropol Pract 38(1):22–42.

Bethard JD, DiGangi EA. 2020. Letter to the Editor–Moving Beyond a Lost Cause: Forensic Anthropology and Ancestry Estimates in the United States. Forensic Sci Int 65(5):1791–1792.

Bufacci V. 2007. Violence by omission. In: Bufacci V, editor. Violence and social justice. Cork, UK: University College, 48–65.

Calmon M. 2019. Forensic anthropology and missing persons: A Brazilian perspective. Forensic Sci Int 298:425.e1-425.e6.

Christensen AM, Passalacqua NV, Bartelink EJ. 2019. Forensic Anthropology: Current Methods and Practice, 2nd ed. San Diego (CA): Elsevier.

Clifford Boyd C, Boyd CD. 2018. Forensic Anthropology: Theoretical Framework and Scientific Basis. Hoboken (NJ): Wiley.

Clifford Boyd C, Boyd CD. 2011. Theory and the Scientific Basis for Forensic Anthropology. J Forensic Sci 56(6):1407–1415.

Collyer FM. 2018. Global patterns in the publishing of academic knowledge: Global North, Global South. Curr Sociol 66(1):56–73.

Cunha E, Cattaneo C. 2006. Forensic anthropology: The state of the art. In: Schmitt A, Cunha E, Pinheiro J, editors. Forensic anthropology and forensic medicine: Complementary sciences from recovery to cause of death. Totowa (NJ): Humana Press, 39–56.

Cunha E, Ubelaker DH. 2020. Evaluation of ancestry from human skeletal remains: a concise review. Forensic Sci Res 5(2):89–97.

Cunha E. 2010. Some reflections on the popularity of forensic anthropology today. Bull Mém Soc Anthropol 22:190–193.

Davilla J. 2013. Dictatorships in Latin America. Chichester, West Sussex, UK: Wiley-Blackwell.

de Lima Amaral EF. 2013. Brazil: internal migration. In: Ness I, editor. The Encyclopedia of Global Human Migration; Hoboken – NJ, United States: Wiley-Blackwell, 1–7.

DiGangi EA, Bethard JD. 2021. Uncloaking a Lost Cause: Decolonizing ancestry estimation in the United States. Am J Phys Anthropol 175:422–436.

Dirkmaat DC, Cabo LL, Ousley SD, et al. 2008. New perspectives in forensic anthropology. Am J Phys Anthropol 137(S47):33–52.

Dunn RR, Spiros MC, Kamnikar KR, et al. 2020. Ancestry estimation in forensic anthropology: A review. WIREs Forensic Sci 2:e1369.

Ferllini R. 1999. The role of forensic anthropology in human rights issues. In: Fargrieve S, editor. Forensic osteological analysis: A book of case studies. Springfield: Charles C. Thomas, 287–301.

FMB. 2020. Institutos médico-legais: Segundo CFM, Brasil apresenta discrepâncias de acesso. Federação Médica Brasileira. Available at: http://portalfmb.org.br/2016/10/19/institutos-medico-legais-segundo-cfm-brasil-apresenta-discrepancias-de-acesso-so/ [Accessed 31 October 2021].

Galtung J. 1969. Violence, peace, and peace research. J Peace Res. 6(3):167–191.

Gaspar Neto VV. 2017. Biological anthropology in Brazil: A preliminary overview. Vibrant – (Brasília) 14(3):e14303.

Górka K, Plens CR. 2021. In search of identity – the field of forensic anthropology in Brazil. J Forensic Sci 66(1):44–55.

Górka K, Plens CR. 2020. Na fronteira Brasil – Polônia: cooperação acadêmica em Antropologia Forense a serviço dos Direitos Humanos. Revista Historia Debates e Tendências Passo Fundo 20(3):14–27.

Hughes SC. 2001. The Involvement of the Forensic Anthropologist in Human Rights Issues. Master's thesis, University of Tennessee, Knoxville, USA. Available at: https://trace.tennessee.edu/utk_gradthes/4136 [Accessed 13 September 2021].

IBGE. 2020. IBGE divulga estimativa da população dos municípios para 2020. Instituto Brasileiro de Geografia e Estadística. Available at: https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/28668-ibge-divulga-estimativa-da-populacao-dos-municipios-para-2020 [Accessed 5 November 2020].

ICMP. 2020. Legal Frameworks and Rights. International Commission for Missing Persons. Available at: https://www.icmp.int/the-missing/legal-frameworks-and-rights/ [Accessed 25 May 2020].

IPEA. 2019. Atlas da violência. Instituto de Pesquisa Económica Aplicada. Available at: https://www.ipea.gov.br/atlasviolencia/dados-series/20 [Accessed 17 November 2021].

King R. 2011. Power and Networks in Worldwide Knowledge Coordination: The Case of Global Science. High Educ Policy 24:359–376.

Klepinger LL. 2006. Fundamentals of Forensic Anthropology. Hoboken (NJ): John Wiley & Sons, Inc.

Legarin M. 2010. Brazil must investigate and punish crimes committed under military dictatorship. Available at: https://cejil.org/comunicado-de-prensa/brazil-must-investigate-and-punish-crimes-committed-under-military-dictatorship/ [Accessed 20 October 2021].

Loveman BE. 2018. Military Government in Latin America, 1959–1990. In: Vinson B, editor. Oxford Bibliographies in "Latin American Studies". New York: Oxford University Press. Available at: https://www.oxfordbibliographies.com/view/document/obo-9780199766581/obo-9780199766581-0015.xml [Accessed 20 October 2021].

Martinez M, Sá C. 2020. Highly Cited in the South: International Collaboration and Research Recognition Among Brazil's Highly Cited Researchers. J Stud Int Educ 24(1):39–58.

Mazur M, Górka K, Alemán Aguilera I. 2022. Smile photograph analysis and its connection with focal length as one of identification methods in forensic anthropology and odontology. Forensic Sci Int 335:111285.

Ministério da Justiça e Segurança Pública. 2021a. Available at: https://www.gov.br/mj/pt-br/acesso-a-informacao/acoes-e-programas/desaparecidos/cadastro-nacional [Accessed 6 October 2021].

Ministério da Justiça e Segurança Pública. 2021b. Available at: https://www.gov.br/mj/pt-br/assuntos/noticias/ministerio-da-justica-e-seguranca-publica-lanca-campanha-de-coleta-de-dna-para-auxiliar-familias-na-busca-de-pessoas-desaparecidas [Accessed 6 October 2022].

Miranda GE, Freitas SG, Maia LVA, et al. 2016. An unusual method of forensic human identification: use of selfie photographs. Forensic Sci Int 263:14–17.

Odeth LE. 2010. A comparative analysis of Global North and Global South economies. J Sustain Dev Afr 12(3):338–348.

Passalacqua NV, Pilloud MA, Congram D. 2021. Forensic Anthropology as a Discipline. Biology 10:691.

Peters MA. 2006. The rise of global science and the emerging political economy of international research collaborations. Eur J Educ 41(2):225–244.

Potter H. 2018. A Lei da Anistia e o esquecimento dos crimes da ditadura militar. Available at: https://www.dw.com/pt-br/a-lei-da-anistia-e-o-esquecimento-dos-crimes-da-ditadura-militar/a-45082182 [Accessed 20 October 2021].

Ross AH, Pilloud M. 2021. The need to incorporate human variation and evolutionary theory in forensic anthropology: A call for reform. Am J Phys Anthropol 176(4):672–683.

Ross AH, Williams SE. 2021. Ancestry Studies in Forensic Anthropology: Back on the Frontier of Racism. Biology 10:602.

Sabzalieva E, Martinez M, Sá C. 2020. Moving Beyond "North" and "South": Global Perspectives on International Research Collaborations. J Stud Int Edu 24(1):3–8.

SENASP. 2012. Diagnostico da Perícia Criminal no Brasil. [pdf]. Ministério da Justiça, Secretaria Nacional de Segurança Pública. Available at: https://www.mpma.mp.br/arquivos/CAOPCEAP/Diagn%C3%B3stico%20Per%C3%ADcia%20Criminal%20no%20Brasil.pdf [Accessed 8 September 2021].

Silva RF, Franco A, Seixas JR, et al. 2016. Positive identification of a decomposed human body through forensic anthropology and smile photographs a case report. Eur J Forensic Sci 3(4):1–4.

Silva RF, Pereira SD, Prado FB, et al. 2008. Forensic odontology identification using smile photograph analysis-case reports. J Forensic Odontostomatol 26(1):12–7. PMID: 22689352.

SINALID. 2022. Conselho Nacional do Ministério Público. Available at: https://www.cnmp.mp.br/portal/institucional/comissoes/comissao-de-defesa-dos-direitos-fundamentais/sinalid/informacoes-sobre-o-sistema [Accessed 2 October 2022].

Smay D, Armelagos G. 2000. Galileo Wept: A critical assessment of the use of race in Forensic Anthropology. Transform Anthropol 9(2):19–29.

Squires K, García-Mancuso R. 2021. Ethical challenges associated with the study and treatment of human remains in anthropological sciences in the 21st century. Revista Argentina de Antropologia Biológica 23(2):1–22.

Trindade Filho, A. 2018. Instituto de Pesquisa de DNA Forense, Polícia Civil do Distrito Federal, Brasília, Distrito Federal, Brasil. Personal communication, 29.05.2018.

UN. 2020. Universal Declaration of Human Rights. United Nations. Available at: https://www.un.org/en/about-us/universal-declaration-of-human-rights [Accessed 15 September 2021].

UNIFESP. 2021. Grupo de Trabalho Perus identifica segundo desaparecido político. Boletim da Universidade Federal de São Paulo. Available at: https://www.unifesp.br/boletins-anteriores/item/3642-grupo-de-trabalho-perus-identifica-segundo-desaparecido-politico [Accessed 17 November 2021].

UNODC. 2019. Global Study on Homicide: Homicide trends, patterns and criminal justice response [pdf]. United Nations Office on Drugs and Crimes. Vienna. Available at: https://www.unodc.org/documents/data-and-analysis/gsh/Booklet2.pdf [Accessed 13 November 2020].

Winburn AP, Clemmons CMJ. 2021. Objectivity is a myth that harms the practice and diversity of forensic science. Forensic Sci Int Synergy 3:100196.

Anthropological Review • Vol. 85(4), 31–42 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.4.03

Anthropometric characteristic and body composition of female students involved in volleyball training

Tetiana Kutseryb, Myroslava Hrynkiv, Lyubomyr Vovkanych, Fedir Muzyka, Valeryi Melnyk

Department of Anatomy and Physiology, Ivan Bobersky Lviv State University of Physical Culture

Abstract: There have been only few studies investigating the anthropometric characteristics of female volleyball players. These studies have revealed a positive influence of volleyball training on the physical development and fitness level among girls and women. The aim of the study was to assess the anthropometric profile of young female volleyball players.

Our sample consisted of twelve female volleyball players aged between 18-21 years with at least 5 years of training experience. The body height and mass, the thickness of skinfolds, longitudinal dimensions of the body, girth and breadths were measured. The body composition was determined using anthropometric and bioimpedance methods. Somatotype was determined according to the calculating method of J. E. L. Carter.

The body height of the volleyball players was estimated as high, and the body mass – higher than average. Middle shoulders, narrow pelvis and prevailing of longitudinal dimensions were the most distinctive features of the body proportions of the female volleyball players. Although their thorax was narrow, the respiratory muscles were well developed. The male type of proportions was typical for players exhibiting a theinoid scheme (middle shoulders, long legs) according to V.V. Bunak. Our data showed high development of the muscular component of the body of volleyball players, comparable to females professionally involved in sport . Index of muscle development, based on the excursion of the shoulder muscles, was typical for female athletes – 9,92 ± 2,98 cm. We also found that the relative mass of the fat component was within the normal range for elite volleyball players. The central somatotype was found to be typical for the female volleyball players: endomorphy – 3,98 ± 0,58, mesomorphy – 3,38 ± 1,01, and ectomorphy – 3,67 ± 0,76.

The obtained results describe the morphological profile of female volleyball players and can be used for the monitoring of their fitness level.

Key words: anthropometry, female players, playing positions, bioelectrical impedance, body proportions, Heath-Carter somatotype.

Received: 26.10.2022; Revised: 05.12.2022; Accepted: 05.12.2022

Introduction

Volleyball is considered as one of the most popular sports and plays both the role of recreational activity and a professional sport. Anthropometry studies can provide important information regarding the influence of volleyball activities on the physical development of the younger population as well as asses sport selection processes and adaptation of professional volleyball players. Such studies have also the potential to determine the anthropometric characteristics of professional athletes, as well as estimate an influence of volleyball training on the physical development and fitness level of girls and women. Importantly, such studies can provide data that could be compared to anthropometric characteristics of other female athletes, such as those described in our previous research (Kutseryb et al. 2017; 2018; 2019; Hrynkiv et al. 2018).

Unfortunately, to our knowledge, there have been only few studies comparing anthropometric characteristics, such as somatotype and body composition, between female volleyball players and untrained students or young women (Tsunawake et al. 2003; Pietraszewska et al. 2015; Pastuszak et al. 2016; Sarafyniuk et al. 2018). These studies have revealed that, compared to students not actively involved in sport activities, volleyball players tended to be taller, while their circumferences of the arm and crus, most of the chest dimensions, body density, and lean body mass exhibited higher values. The above changes in physical development and fitness levels may be caused by volleyball training, resulting in the overall increase in shoulder width, circumferences of the chest and tensed shoulder, thigh and calf in young female volleyball players during one year training period (Sarafyniuk et al. 2020). The influence of the volleyball activities on anthropometric characteristics appears to be greater compared to other game sports. For example, young female handball players tended to be taller, had thinner skinfolds, lower body mass index and percentage of body fat compared to handball players (Konstantinos et al. 2019).

In the previously mentioned studies, the possible differences in the anthropometric profiles of the players of different positions were not considered. Such differences, possibly caused by variance in physical demands during a volleyball game (Fomin et al. 2012), were found for professional players by a number of studies (Zaccagni 2001; Malousaris et al. 2008; Carvajal et al. 2012; Gualdi-Russo & Martín-Matillas et al. 2014; Pietraszewska et al. 2015; Milić et al. 2017). In general, centers (middle blockers) and opposites (opposite heaters) are the tallest players with the largest ectomorphic component, while the liberos had the smallest body height and exhibited the highest mesomorphy. Differences in some somatotype categories influence the efficiency of young volleyball players (Grgantov Z. 2017). Although professional players have been found to exhibit significant differences in the anthropometric profiles, corresponding differences have not been investigated among college students. Therefore, the need for the creating an anthropometric model of college-level female athletes has been suggested, which would reflect the specificity of their sports activities. To address this issue, the present study aimed to examine the anthropometric profile of young female volleyball players.

Materials and methods

Study participants

We have examined 12 female athletes aged 18–21 years with sports experience of at least 5 years, players of Ivan Bobersky Lviv State University of Physical Culture (LSUPhC) volleyball team. A detailed description of the subjects is provided in Table 1. Informed consent was obtained before the study. All studies were provided with the ethical standards declared in the state documents and the internal regulations of the organizations responsible for the study with the participation of a human, as well as the principles of the declaration of the World Medical Association of Helsinki.

Data collection and statistical analysis

The following anthropometric characteristics were measured: body height (by anthropometer) and body mass (by Tanita BC 601), thickness of skinfolds (by Skinfold Caliper Baseline), longitudinal dimensions of the total body and the segments (trunk, lower and upper extremities), girths (circumferences) and breadths (diameters) (Martirosov 1982; Łaskia-Mierzejewska 2008). Chest girth (CG) was measured at rest, and at maximal inspiration and expiration (Martirosov 1982; Carter 1990; Malinowski & Bozitow 1997). Arm girth was measured in relaxed and tensed position.

Table 1. Main anthropometric characteristics of female volleyball players (n = 12)

Playing positions	Sport experience, years	Age, years	Body height, cm	Body mass, kg	CG, cm	CE, cm	BMI	IMD	BI
MB	7	19	182.0	70.5	85.0	7.0	18.7	6.3	49.1
MB	5	20	182.5	74.5	92.5	7.5	22.4	10.0	50.7
MB	8	21	181.7	76.8	85.1	6.0	19.8	7.7	46.8
OpH	13	20	180.1	76.6	87.2	7.9	20.0	11.5	48.2
OpH	8	18	179.9	65.9	86.8	7.0	20.5	8.1	48.5
OpH	8	18	179.9	65.9	85.1	7.0	20.4	11.5	47.5
S	6	19	178.2	68.0	87.0	4.5	19.8	11.5	48.7
S	8	18	177.1	69.1	88.0	8.3	20.7	8.0	48.9
OH	7	20	176.1	68.5	89.0	12.0	22.3	7.5	50.6
OH	5	20	175.2	69.1	95.0	5.0	21.7	7.1	54.3
L	10	20	172.4	59.4	97.0	7.0	23.7	10.0	56.4
L	5	20	170.1	61.00	82.5	10	20.0	9.8	47.9
Mean ± SEM	7.5±0.67	19.4 ±0.29	177.9 ±1.13	68.8 ±1.57	88.4 ±1.26	7.4 ±0.59	20.8 ±0.41	9.1 ±0.54	49.8 ±0.83

Notes: MB – middle blocker; OpH – opposite hitter; S – setter; OH – outside hitter; L – libero; CG – chest girth (at rest); CE – chest excursion; BMI – body mass index; IMD – index of muscles development; BI – Brugsch index.

Body composition was determined by both anthropometric and bioimpedance (Tanita BC 601) methods (Martirosov 1982; Martirosov et al. 2006), while physical development and body proportions were estimated by the index method. The Heath-Carter somatotype of athletes was determined by the calculation method of J. E. L. Carter (Carter 1990; 2002). Data were analyzed in Microsoft Excel 2010. All values are presented with arithmetic mean with standard error of the mean (SEM), in some cases the standard error (SE) of the data is shown.

Results

Body height of the study participants (see Table 1) was very high and exceeded the 97th percentile of 2000 CDC growth charts for healthy untrained subjects, while their body mass was higher than average (75th–90th percentiles). The tallest players were middle blockers (182.0 ± 3.30 cm) and the opposite hitters (180.1 ± 2.36 cm), while the smallest were liberos (172.4 ± 2.39 cm), which also had the lowest body mass. The mean value of body mass index (BMI) of volleyball players was 20.83 ± 1.41 kg/m^2, which is within 25th–50th percentile range for healthy untrained girls aged 18–20 years (2000 CDC growth charts 2002; Kuczmarski 2002). The values of chest girth (at rest, at maximal inspiration and expiration), Brugsch index, and chest excursion (see Table 1) indicated a good chest development of study participants.

The dimensions of the trunk and extremities of the players, such as lengths, breadths (diameters), and girths (circumferences) are presented in Table 2.

Table 2. Partial dimensions of the body of female volleyball players (n=12)

Dimensions, cm	Mean ± SEM
Trunk length	51.89±1.96
Arm length	79.38±2.59
Leg length	97.62±2.95
Biacromial breadth (diameter)	39.58±1.65
Transverse chest breadth	26.19±0.96
Anterior-posterior chest breadth	17.95±1.29
Biiliocristal breadth	28.08±1.49
Hand breadth	6.33±0.69
Wrist breadth	5.07±0.43
Femur breadth	9.46±0.64
Ankle breadth	6.39±0.80
Arm girth (circumference) (flexed and tensed)	29.23±2.45
Arm girth (relaxed)	26.58±1.95
Arm excursion	2.67±0.23
Forearm girth	24.27±1.58
Thigh girth	54.91±2.40
Leg girth	35.35±1.62

A comparison between athletes with different playing positions showed that middle blockers and the opposite hitters had the largest length of the trunk, upper extremities and lower extremities, with slightly lower values exhibited by setters and outside hitters, and the lowest values of the liberos. Thus, players of the attack line had larger values of the longitudal dimensions of the body's parts compared to players of the defensive line. We did not find any relationship between the playing role and the chest girth and chest excursion.

The index of lower extremities length (Sergienko 2004) and Manouvrier's skelic index (MSI, Łaskia-Mierzejewska 2008) showed that the examined players had long legs, combined with average shoulders width (by the index of shoulders width). The paratheinoid type of the body type with middle shoulders and long legs was found to be representative for the players (Martirosov 1982). The ratio of the biacromial to biiliocristal breadths of the subjects was 71.05 ± 1.29%, which clearly indicates a "male" type of body proportions.

The body composition of the athletes was determined by the anthropometric method and bioimpedance analysis (Table 3).

It should be noted that the bioimpedance analysis aims to show the mass of all human muscles (including smooth muscle and myocardium) and the mass of dry bone (Nikolaev et al. 2009). Due to this, the mean value of muscle component in our sample (47.00 ± 1.06 kg) was higher than the one obtained by the anthropometric method (29.49 ± 0.47 kg) and the dry bone mass – only 2.62 ± 0.09 kg. The fat component, determined by the bioimpedance method, was slightly higher (19.85 ± 2.34%), than obtained by the anthropometric one (16.39 ± 1.01%).

The thickness of subcutaneous fat layer on different body parts was analyzed by the skinfolds measurements and could be compared to the results of segmental bioimpedance analysis (Table 4). The average thickness of the subscapular skinfold was 12.58 ± 2.54 mm, abdominal – 18.25 ± 4.65 mm, suprailiac – 19.25 ± 4.63 mm. The triceps skinfold reached 13.50 ± 2.61 mm, biceps – 9.08 ± 2.91 mm, and the forearm one – 7.08 ± 2.50 mm. The thickness of the thigh skinfold was 15.25 ± 2.01 mm, and the medial calf one – 13.75 ± 2.86 mm. No significant difference was found between the players holding different volleyball positions, although there was a tendency towards slightly larger suprailiac, forearm skinfolds along with smaller subscapular skinfold for outside hitters and liberos.

Table 3. Body composition of female volleyball players (n = 12), determined by anthropometric and bioimpedance methods (Mean ± SEM)

Method	Bioimpedance method			
	Total muscles, kg	Bone mass, kg	Body fat, %	Visceral fat, %
Bioimpedance	47.00 ± 1.06	2.62 ± 0.09*	19.85 ± 2.34	1.67 ± 0.21
Anthropometric	29.49 ± 0.47**	9.94 ± 0.41	16.39 ± 1.01	–

Notes: * – dry bone mass; ** – skeletal muscles only.

Table 4. Results of segmental bioimpedance analysis (n=12, mean ± SEM)

Index	Total muscles, kg				
	Trunk	Right hand	Right leg	Left hand	Left leg
Total muscles, kg	26.76 ±0.74	2.71 ±0.20	8.97 ±0.26	2.73 ±0.16	8.87 ±0.25
Body fat, %	22.39 ±1.38	19.66 ±2.20	26.25 ±1.57	19.06 ±1.45	25.97 ±1.57

Both the results of segmental bioimpedance analysis and anthropometric data showed a high development of the lower extremity muscles of the examined players that was confirmed by high girths of thigh and calf (see Table 2), small thickness of relevant skinfolds (see above), and a high mass of leg muscles (see Table 4). As expected, there was no significant bilateral asymmetry in the muscle and fat components of the extremities.

The analysis of the Heath-Carter somatotype of players (Carter 1990) revealed significant individual differences in the values of some components (Fig. 1) which might be related the specific demands of different playing positions, though a larger data set is needed for these results to be conclusive. For example, the somatotype of both liberos was ectomorphic endomorph, and outside hitters – mesomorph-endomorph. Other players were generally more ectomorphic, especially the middle blockers and opposite hitters.

We found the following average values for somatotype components of the

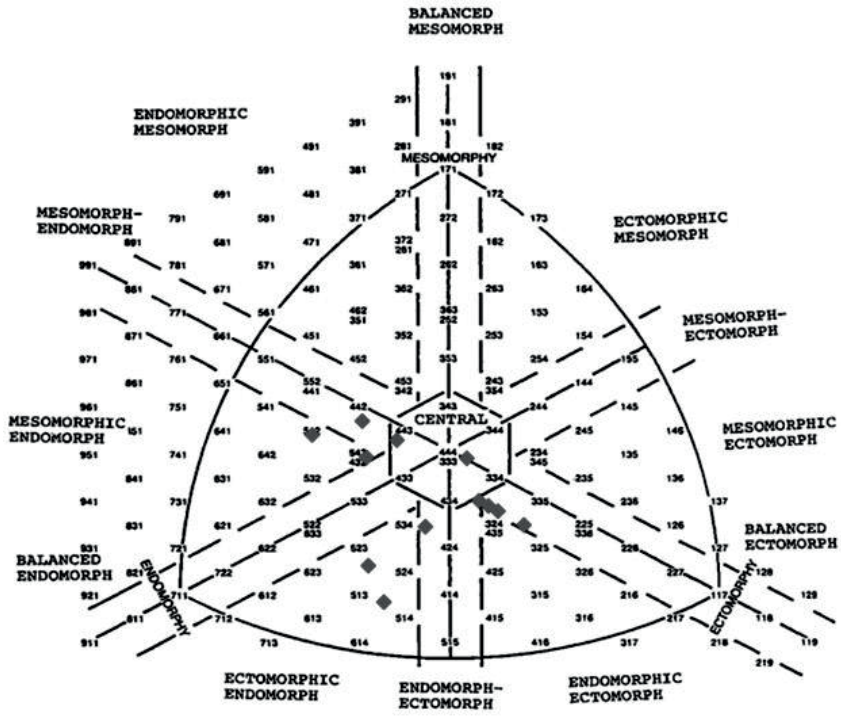

Fig. 1. Individual somatotypes of female volleyball players according to Heath-Carter

players: endomorphy – 3,98 ± 0,58, mesomorphy – 3,38 ± 1,01, and ectomorphy – 3,67 ± 0,76. As all somatotype components are close to average levels, and the difference between them does not exceed 1 point, it indicates the central type of constitution. The obtained values of ectomorphic and endomorphic components are caused by a combination of large height and long legs of players with the average body mass and average thigh girth.

Discussion

The body height and mass of study participants of our study are similar to those reported in other studies. For instance, the body height of female volleyball players was reported to range from 169.2 to 187.1 cm (Carvajal et al. 2012; D'Anastasio 2019) and body mass – from 79.0 to 60.7 kg (Carvajal et al. 2012; D'Anastasio 2019). The elite players tend to be higher – from 177.1 to 187.1 cm (Malousaris et al. 2008; Carvajal et al. 2012) in comparison to non-professional athletes (168.7–177.9 cm) (Tsunawake et al. 2003; Buśko 2012). Consequently, the height of participant in our study falls within the upper range for college players, and the lower level for top-level athletes. The body mass of the elite players (63.7–79.0 kg) is also higher compared to players of college teams (59.7–71.3 kg) (Tsunawake 2003; Buśko 2012; Bozo and Lleshi 2012; Carvajal et al. 2012). Therefore, body mass observed among study participants corresponds to average values of top-level athletes and above average values of college players. The BMI of study participants (20.83) is comparable to those of other college players (20.0–22.5) and lower than BMI of elite players (22.0–23.2) (Bozo and Lleshi 2012; Buśko 2012; Carvajal et al. 2012, 2015). The larger values of BMI of the top-level players could be the result of higher development of skeletal muscles.

There have been plenty of studies looking at the variance in the height and body mass between the professional players of different positions (Malousaris et al. 2008; Carvajal et al. 2012; Martín-Matillas et al. 2014; Pietraszewska et al. 2015; D'Anastasio 2019). In support of their findings, we have found that middle blockers (181.7–182.0 cm) are the tallest players, while the opposite hitters, setters and outside hitters are slightly smaller, and the smallest height is exhibited by liberos (170.1–172.4 cm). Liberos also have the lowest body mass (59.4–61.0 kg), as compared to athletes of the other playing positions (65.9–76.8 kg). The differences in the total sizes of the athlete's body can be explained by the peculiarities of the activity of each playing position. Our results suggest that the pronounced morphological adaptation of the players to the demands of different playing positions might be detected even at the level of college (university) teams.

The chest girth of our subjects (88.35 ± 4.36 cm) highly exceeds the data presented by Tsunawake et al. (2003) – 82.8 cm, and appears to be comparable to chest girth of elite players (89.1–90.5) (Carvajal et al. 2015). A pronounced chest development of study participants is also indicated by Brugsch index, which is high (49.80 ± 2.86) and similar to the normal level for men (50–55 units). Chest excursion (7.43 ± 2.04 cm) appears to be within the normal range for female athletes. The anterior-posterior chest breadth (26.2 cm) is comparable to top-level athletes (26.3–26.5 cm; Carvajal et al. 2012).

The average arm length of the examined volleyball players (79.4 cm) is comparable to results reported by other researchers (Sarafyniuk et al. 2020), and larger compared to basketball players (Hrynkiv 2018). The width of the shoulders (39.6 cm) and pelvis (28.1 cm) of study participants is rather average compared to elite players reported by other studies (39.2–40.9 cm and 27.6–33.1 respectively; Papadopoulou 2003; Carvajal et al. 2015). Examined players have paratheinoid type of body, the "male" type of body proportions (larger biacromial than the biiliocristal breadth), and highly developed legs' muscles. These features indicate an optimal adaptation to vertical jumps, which is incredibly important in the volleyball.

The breadth of the hand (6.33 cm), wrist (5.07 cm), femur (9.46 cm), and ankle (6.39 cm) of examined players in most cases are slightly lower compared to the corresponding values of top-level players (6.2–7.1; 5.3–5.4; 9.6–9.9; 6.8–7.4 cm respectively) (Papadopoulou 2003; Carvajal et al. 2012; 2015; Pietraszewska et al. 2015), suggesting that the adaptive changes in the skeletal system are less pronounced at the level of college players in comparison to the elite athletes.

The circumferential dimensions of some body parts (i.e., girth of the forearm, thigh, and leg), the girth of flexed and tensed arm, the strength index and index of muscle development can be used as an indicator of skeletal muscles development. This is supported by the findings of other studies (Papadopoulou 2002, 2003; Carvajal et al. 2012; 2015; Martín-Matillas et al. 2014) showing that the highest values of circumferences of arm (relaxed – 28.5, flexed – 30.5 cm), forearm (25.9 cm), thigh (60.1 cm), and leg (37.7) of the elite female volleyball players exceed the corresponding values of the college teams' players (26.6–29.2; 24.3; 54.9; 36.5 cm respectively). It also indicates the importance of high muscles development necessary to enhance volleyball performance. The circumferential dimensions of the examined players appear to fall within the lower part of the range for the elite athletes, while the difference in the girth of flexed and tensed arm of our subjects (2.67 cm) exceeds the maximal level of top players (2.1 cm, Carvajal et al. 2015). We found that the strength index of the examined volleyball players (48.99 ± 3.68%) lies within the range for female athletes (50–60%). The index of muscle development of study participants is 9.92 ± 2.98%, while for the basketball players it is considerably lower – 5.38 ± 1.13%, exhibiting typical values for female athletes are 5–12% (Malinowski and Bozitow 1997; Łaska-Mierzejewska 2008; Hrynkiv et al. 2018; Kutseryb et al. 2019). Our results suggest that development of the skeletal muscles of our subjects is comparable to the top-level players.

The fat component of our study participants (16.4%), determined by the skinfold measurements, is close to the lowest values, reported both for the high-skilled (14.9–28.9%) and college-level (13.99–25.6%) female players (Bozo and Lleshi 2012; Carvajal et al. 2012; Buśko 2012). The thickness of skinfolds might indicate differences regarding the development of subcutaneous fat layer for examined players compared to highly qualified athletes. Similar values are found for the number of skinfolds: subscapular (12.1 mm compared to 9.5–12.3 mm), triceps (13.5 and 9.6–19.3 mm), thigh (15.25 and 10.0–19.0 mm), and medial (13.75 and 7.6–17.4) (Papadopoulou

2002; Malousaris et al. 2008; Carvajal et al. 2012; 2015). However, some other skinfolds, such as abdominal (18.25 compared to 10.6–12.6 mm), suprailiac (19.25 and 6–10.9 mm), and biceps (9.08 compared to 4.5–5.9 mm) are thicker in the participants of this study.

A higher level of relative fat mass (19.85 ± 8.09%) is observed among study participants using the bioimpedance method. It includes 1.67 ± 0.73% of visceral fat, a sufficient amount of which could play an important role in terms of the fitness and health of female athletes. It is widely assumed that visceral adipose tissue in omentums and adipose capsule of the kidneys ensures proper fixation of internal organs and cushioning of the mechanical shocks during the run and jump performance.

The relative mass of the bone component (15.13%), showed in our study using the athropometric method, is higher compared to high-skilled female players (8.9–9.5%, Carvajal et al. 2012). The bioimpedance analysis reveals a dry bone mass of 2.62 kg. Given that the average body mass of the study participants is 65.66 kg, these values of the bone component are within a normal range (Nikolaev et al. 2009).

The muscular component of examined volleyball players reaches 44.93% of body mass, while in other studies it was reported to vary from 37.8% (Martín-Matillas et al. 2014) to 45.9% (Carvajal et al. 2012) for the elite female players, supporting the results of our study regarding the high development of the skeletal muscles.

The average somatotype of our study participants is the central one (endomorphy – 3.98 ± 0.58, mesomorphy – 3.38 ± 1.01, and ectomorphy – 3.67 ± 0.76). The endomorphy level of elite female volleyball players ranges between 2.4 and 3.4 (Carvajal et al. 2015; Malousaris et al. 2008), and in one case it reaches 4.25 (Papadopoulou 2002). The mesomorphy of elite athletes was found to vary from 2.2 to 3.5 (Papadopoulou 2002; Carvajal et al. 2015), and ectomorphy – from 2.9 to 3.2 (Malousaris et al. 2008; Carvajal et al. 2012; 2015). The average somatotype of top-level female players, calculated as the mean of the data of other authors (Papadopoulou 2002; Malousaris et al. 2008; Carvajal et al. 2012, 2015; Martín-Matillas et al. 2014), is estimated to be 2.91–3.24–2.96 (endomorphy – 2.91 ± 0.16, mesomorphy – 3.24 ± 0.13, and ectomorphy – 2.96 ± 0.08). It shows that top-level female players also have central somatotype, although our study participants have larger endomorphy and smaller ectomorphy levels.

In summary, the results of our study reveal a significant influence of the training activities on the female physique, though not as large as professional sport activities. Our study participants are much taller and exhibit higher body mass and BMI compared to untrained persons, and these features to a great extent depend on playing position. however, the above differences in body physique are less pronounced than in professional athletes. Still, the examined players exhibit well-developed chest and shoulders, parathenoid type of body proportions and the "male" body type. Development of the skeletal muscles among study participants is comparable to the top-level players. The muscular component of their body composition is high (44.93 ± 1.52%), while the fat component (16.4%) is close to the lowest values of volleyball players. The average somatotype of examined volleyball players is central type (3.98–3.38–3.67), although significant

individual differences in the values of the three components of the constitution have been found.

We suggest that the obtained data allow us to recommend volleyball training for the improvement of the physical development of women. The knowledge of the morphological profile of the female volleyball players, described in our study, will facilitate the selection of the players for the volleyball teams and will improve the individual approach to athletes' training during regular, pre-competitive and main competition periods.

Acknowledgements

The research was carried out with the financial support of Ivan Bobersky Lviv State University of Physical Culture.

Conflict of interests

The authors confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Authors' contributions

TK, MH, FM – conceived and designed the analysis, collected the data, performed the analysis and wrote the manuscript; LV – performed the analysis and wrote the manuscript; VM – collected the data and wrote the manuscript. All authors discussed the results and contributed to the final manuscript.

Financial support disclosure

Research was financed by Ivan Bobersky Lviv State University of Physical Culture in the form of salary payment.

Correspondent author

Lyubomyr Vovkanych, 11, Kostiushka Str., Lviv, Ukraine, 79000; tel. +38(097)3342187, fax. +38(032)2553208; e-mail: lsvovkanych@gmail.com

References

Bozo D, Lleshi E. 2012. Comparison of Albanian female volleyball players with anthropometric, performance and haematological parameters. J Hum Sport Exercise 7(1):41–50.

Buśko K, Lipińska M. 2012. A comparative analysis of the anthropometric method and bioelectrical impedance analysis on changes in body composition of female volleyball players during the 2010/2011 season. Human Movement 13(2), https://doi.org/10.2478/v10038-012-0013-6

Carter JEL. 1990. Somatotyping-development and applications. Cambridge University Press.

Carter J. 2002. The Heath-Carter Anthropometric Somatotype – Instruction Manual. Surrey TeP and ROSSCRAFT.

Carvajal W, Betancourt H, León S, Deturnel Y, Martínez M, Echevarría I. et al. 2012. Kinanthropometric profile of Cuban women olympic volleyball champions. MEDICC Rev 14(2):16, https://doi.org/10.37757/mr2012v14.n2.6

Carvajal VW, León PS, González RME, Echevarría GIY, Martínez AM. 2015. Morphological changes of elite Cuban female volleyball players, 1984-2008. Rev Esp Antrop Fís 36:33–44.

D'Anastasio R, Milivojevic A, Cilli J, Icaro I, Viciano J. 2019. Anthropometric Profiles and Somatotypes of Female Volleyball and Beach Volleyball Players. Int J Morphol 37(4):1480–5.

Fomin EV, Bulykina LV, Sukhanov AV. 2012. Techno-tactical training of volleyball players: manual [in Russian]. Moscow: VFV.

Grgantov Z, Padulo J, Milić M, Ardigò LP, Erceg M, Cular D. 2017. Intra-positional and inter-positional differences in somatotype components and proportions of particular somatotype categories in youth volleyball players. Ann Appl Sport Sci 5(2):37–49.

Gualdi-Russo E, Zaccagni L. 2001. Somatotype, role and performance in elite volleyball players. J Sports Med Phys Fitness 41(2):256–62.

Hrynkiv M, Kutseryb T, Vovkanych L, Muzyka F. 2018. Influence of basketball training on the physical development of female athletes [in Ukrainian]. Sport Sci Ukraine 84(2):9–13.

Konstantinos NS, Panagiotis MG, Ioannis BA. 2019. Morphological characteristics of adolescent elite female handball and volleyball players. J Phys Educ Sport 19(4):1502–07.

Kuczmarski RJ. 2002. 2000 CDC growth charts for the United States: Methods and development. Hyattsville, MD: Dept. of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.

Kutseryb T, Hrynkiv M, Vovkanych L, Muzyka F. 2018. Body proportions and somatotype of female basketball players [in Ukrainian]. Sport Sci Ukraine 87(5):20–4.

Kutseryb T, Hrynkiv M, Vovkanych L, Muzyka, F. 2019. Influence of basketball training on the features of women's physique. J Phys Educ Sport 19(4):2384–9.

Kutseryb T, Vovkanych L, Hrynkiv M, Majevska S., Muzyka F. 2017. Peculiarities of the somatotype of athletes with different directions of the training process. J Phys Educ Sport 17(1):431–5.

Łaska-Mierzejewska T. 2008. Ćwiczenia z antropologii. Warszawa.

Malinowski A, Bożiłow W. 1997. Podstawy antropometrii. Metody, techniki, normy. Warszawa: PWN.

Malousaris GG, Bergeles NK, Barzouka KG, Bayios IA, Nassis GP, Koskolou MD. 2008. Somatotype, size and body composition of competitive female volleyball players. J Sci Med Sport 11(3):337–44, https://doi.org/10.1016/j.jsams.2006.11.008

Martín-Matillas M, Valadés D, Hernández-Hernández E, Olea-Serrano F, Sjöström M, Delgado-Fernández M, et al. 2013. Anthropometric, body composition and somatotype characteristics of elite female volleyball players from the highest Spanish League. J Sports Sci 32(2):137–48, https://doi.org/10.1080/02640414.2013.809472

Martirosov EG, Nikolaev DV, Rudnev SG. 2006. Technologies and methods for determining the composition of the human body [in Russian]. Moscow: Nauka.

Martirosov EG. 1982. Research methods in sport anthropology [in Russian]. Moscow: Physical Culture and Sport.

Milić M, Grgantov Z, Chamari K, Ardigò LP, Bianco A, Padulo J. 2017. Anthropometric and physical characteristics allow differentiation of young female volleyball players according to playing position and level of expertise. Biol Sport 1:19–26, https://doi.org/10.5114/biolsport.2017.63382

Nikolaev DV, Smirnov AV, Bobrinskaya IG, Rudnev SG. 2009. Bioelectric impedance analysis of human body composition [in Russian]. Moscow: Nauka.

Papadopoulou S. 2003. Anthropometric characteristics and body composition of Greek elite women volleyball players. In: H Ridder and T. Olds, editors. Kinanthropometry 7th edition. Potchefstroom, RSA: Potchefstroom University for Christian Higher Education 93–110.

Pastuszak A, Buśko K, Kalka E. 2016. Somatotype and body composition of volleyball players and untrained female students – reference group for comparison in Sport. Anthropol Rev 79(4):461–70, https://doi.org/10.1515/anre-2016-0033

Pietraszewska J, Burdukiewicz A, Stachoń A, Andrzejewska J, Pietraszewski B. 2015. Anthropometric characteristics and lower limb power of professional female volleyball players. S Afr J Res Sport Phys Educ Recreat 37(1):99–111.

Sarafyniuk LA, Khapitska OP, Sarafyniuk PV, Koliadenko SV, Cherkasova LA. 2020. Change of anthropometric indicators in qualified young women volleyball players during the annual training macrocycle. Rep Morphol 26(1):14–18.

Sarafyniuk LA, Pivtorak VI, Khavtur VO, Fedoniuk LI, Khapitska OP. 2018. Peculiarities of the chest's size in female volleyball players of different constitutional types. Biomed Biosoci Anthrop 33:47–52, https://doi.org/10.31393/bba33-2018-8

Sergienko LP. The basics of Sport Genetics [in Russian]. Kyiv: Vuscha Shkola. 2004.

Tsunawake N, Tahara Y, Moji K, Muraki S, Minowa K, Yukawa K. 2003. Body composition and physical fitness of female volleyball and basketball players of the Japan inter-high school championship teams. J Physiol Anthropol Appl Human Sci 22(4):195–201, https://doi.org/10.2114/jpa.22.195

Anthropological Review • Vol. 85(4), 43–60 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.4.04

Assessment of the obesity based on voice perception

Łukasz Pawelec, Karolina Kierczak, Anna Lipowicz

Division of Anthropology, Institute of Environmental Biology, Faculty of Biology and Animal Science, Wroclaw University of Environmental and Life Sciences

Abstract: Human voice is an extremely important biological signal which contains information about sex, age, emotional state, health and physical features of a speaker. Estimating a physical appearance from a vocal cue can be an important asset for sciences including forensics and dietetics. Although there have been several studies focused on the relationships between vocal parameters and ratings of height, weight, age and musculature of a speaker, to our knowledge, there has not been a study examining the assessment of one's BMI based on voice alone.

The purpose of the current study was to determine the ability of female "Judges" to evaluate speakers' (men and women) obesity and body fat distribution from their vocal cues. It has also been checked which voice parameters are key vocal cues in this assessment.

The study material consisted of 12 adult speakers' (6 women) voice recordings assessed by 87 "Judges" based on a 5-point graphic scale presenting body fat level and distribution (separately for men and women). For each speaker body height, weight, BMI, Visceral Fat Level (VFL, InBody 270) and acoustic parameters were measured. In addition, the accuracy of BMI category was verified. This study also aimed to determine which vocal parameters were cues for the assessment for men and women. To achieve it, two independent experiments were conducted: I: "Judges" had to choose one (obese) speaker from 3 voices (in 4 series); II: they were asked to rate body fat level of the same 12 speakers based on 5-point graphic scale.

Obese speakers (i.e., BMI above 30) were selected correctly with the accuracy greater than predicted by chance (experiment I). By using a graphic scale, our study found that speakers exhibiting higher BMI were rated as fatter (experiment II). For male speakers the most important vocal predictors of the BMI were harmonics-to-noise ratio (*HNR*) and formant dispersion (*Df*); for women: formant spacing (*Pf*) and intensity (loudness).

Human voice contains information about one's increased BMI level which are hidden in some vocal cues.

Key words: body composition, formant dispersion, fundamental frequency, formant position, obesity, fat distribution, body shape.

Received: 26.10.2022; Revised: 9.12.2022; Accepted: 9.12.2022

Introduction

Voice is an extremely important biological signal for almost all living organisms, including humans. Human voice can convey a relevant information, such as sex (Wolfe et al. 1990), age (Tarafder et al. 2012), emotions (Raine et al. 2019; Sondhi et al. 2015), stimulants used (Byeon and Cha 2020; Moreira et al. 2015), body size/shape (Evans et al. 2006; Pawelec et al. 2022a; Pisanski et al. 2014; 2016; Rendall et al. 2005; 2007) and body composition (Hamdan et al. 2012; 2013b). There have been plenty of studies aiming to determine the listeners' ability to correctly estimate biological traits of a speaker. One of the most cited studies was conducted by Collins (2000). She found that men whose voices exhibited a low harmonic component (lower formant frequencies and smaller differences between them) were judged as more attractive, taller, heavier, older, more likely to have chest hair and more muscular bodies. Moreover, the assessment of body weight was accurate. Similar results were obtained by Brueckert et al. (2006), who not only found a significant correlation between estimated and actual weight of the male speakers but also that the age of the participants was correctly judged based on their voice. Although these two studies only looked at male speakers, there have been also studies that were focused on both sexes. One of such studies has been conducted by Hughes et al. (2002), aiming to determine whether the audience was able to assess speaker's attractiveness assessed based on the voice and the extent to which voice cues correspond to the level of their fluctuating asymmetry (FA). This study revealed that there was a significant relationship between voice attractiveness and overall, FA of the speakers. In addition, Lass and Davis (1976) found that judges were capable of identifying the height of male and female speakers and body mass of men from their voices with better than chance accuracy. Another finding of the same author revealed a similar trend of assessment accuracy of male and female speakers (Lass et al. 1980). These studies suggest that cues regarding a body size / shape of the speakers are included in the speakers' voice parameters. For example, Pisanski and Rendall (2011) found that speakers of both sexes with lower values of fundamental frequency (*F0*) and mean formant frequency (*Fn*) are rated by male and female listeners as larger and more masculine. Moreover, a manipulation of these parameters (lower *F0* and *Fn*) resulted in speakers of both sexes were judged as larger and more masculine (Pisanski and Rendall 2011). The tendency to accurately assess biological parameters of a body from vocal cues has been suggested to have evolutionary roots. Indeed, one study found that even congenitally blind listeners are able to correctly estimate the speaker's height from the voice alone (Pisanski et al. 2016).

All of the discussed above studies have focused on the physical characteristics of the speakers, such as height and weight, age, muscularity, physical strength and body hair. However, there has not been, to our knowledge, a study examining the assessment of relative body weight (body fat / body mass index [BMI]) based on vocal cues and the only one work that vaguely oscillates around the topic investigated the relationship between voice parameters and BMI in patients using the algorithms of artificial intelligence (Lee et al. 2013). Nevertheless, there has been a study on the effect of blood glucose levels on voice quality showing that the effect of glucose levels

on the elastic properties of the vocal fold tissues (Sidorova et al. 2020). This study found an association of hypoglycemia with a sense of anxiety causing faster speech or hyperglycemia affecting slower and slurred speech (Sidorova et al. 2020). Therefore, since the glucose level is related to voice quality and obesity, it can be expected that people with a higher body fat content should have different voice characteristics compared to people with a normal BMI.

Human voice provides a lot of information about the body structure (Pawelec et al. 2022a; Pisanski et al. 2014), and it is also a very important biological signal that plays an important role in male-male competition and sexual selection (Collins 2000; Gregory 1994; Oguchi & Kikuchi 1997; Puts et al. 2006), as well as it contains information about the individual's health (Arnocky et al. 2018; Barties et al. 2013; Sidorova et al. 2020). Therefore, as the excessive content of adipose tissue in the body (obesity) deteriorates the biological quality of an individual and an evolutionary importance of recognizing biological quality (*fitness*) of healthy or sick person, the question arises whether it is possible to correctly subjectively assess obesity level of an individual based only on the voice. The first objective of the study was to determine whether "Judges" could correctly identify the speaker as an obese person based on his/her voice. The second aim of the study was to determine whether "Judges" were able to rate obese speakers higher on the 5-point scale of body silhouettes exhibiting varied BMI. Finally, the third goal was to compare ratings according to 5-point scale of adiposity mentioned above and actual parameters of the speakers' voices in order to see which of them influenced this rating.

Material and methods

Speakers

a) Procedure for speaker's selection

Material of the study consisted of 12 adult's speakers (including 6 women) aged 24–48 years. Each participant was asked to fill a short questionnaire containing basic questions (about sex, age, domicile) and questions about any factors that could potentially affect voice quality (head or neck trauma/surgery, speech impediment, malocclusion, hearing impairment, the use of the stimulants i.e. cigarettes, drinking an alcohol the day before examination, taking hormonal drugs, being ill in the time of the study, transition of COVID-19 disease in the last year or using the voice as the work tool or hobby i.e. working as a teacher/lecturer, sales representatives, film reader, radio operator, singer etc.). None of the participants declared any factors that could have a negative impact on the quality of their voice. No speaker abused his/her voice (neither professionally nor as a hobby). All speakers used Polish as their mother tongue (no dialects). All participants agreed to participate in the study free of charge.

Each of the speakers was subjected to body height measurement (in cm) using an anthropometer and body composition analysis using the InBody 270 analyser. The total absolute body weight (in kg), and Visceral Fat Level (VFL) was selected from the InBody 270 analyser results. The InBody composition analyser gives a range of visceral fat between 1 and 59. A rating between 1 and 12 indicates a healthy level of visceral fat. A rating between 13 and 59 indicates an excessive level of visceral fat. Visceral fat is a fatty tissue that accumulates around the internal organs in the abdominal region.

It means that, the amount of visceral fat (VFL) reflects the distribution of fat in this area and thus affects body shape (i.e., silhouette expressed by the waist-to-hip ratio, *WHR*). Subsequently, based on body height and body weight values, body mass index (BMI; kg/m^2) was calculated.

The 12 speakers of this study were chosen from the larger group of 80 volunteers (40 women) based on specific inclusion criteria. Four out of 12 subjects were obese (2 men and 2 women): BMI value above 30.0 kg/m^2 (according to the WHO classification) and Visceral Fat Level (VFL) above 18. level. The remaining 8 participants (including 4 women) were selected as a control group on the basis of similar age to obese speakers.

The 12 participants were divided into 4 equal groups (triads) – 1 subject obese and 2 subjects of normal weight in each triad. Two triads consisted of women; 2 groups consisted of male triads. The median age in the first female triad was 24 y. (years: 24, 24, 26), second female triad – 47 y. (years: 43, 47, 48), first male triad – 35 y. (years: 29, 35, 35), second male triad 27 y. (years: 25, 27, 31).

Table 1. Speakers' descriptive data (N=12)

Speakers' parameters	Mean	SD	Median	Min	Max
Male speakers (N=6)					
A1. normal weight individuals (n=4)					
Body height [cm]	180.88	5.57	182.25	173.00	186.00
Weight [kg]	77.68	7.46	78.00	68.70	86.00
BMI [kg/m ^ 2]	23.78	2.45	24.25	20.50	26.10
VFL (level)	3.75	3.10	3.00	1.00	8.00
Intensity [dB]	79.51	5.18	81.48	71.93	83.15
F0 [Hz]	123.73	14.35	127.74	103.14	136.28
Jitter [%]	2.98	0.81	2.98	2.19	3.79
Shimmer [%]	8.70	1.68	8.65	7.09	10.41
HNR [dB]	8.50	1.63	8.60	6.74	10.05
Fn [Hz]	2445.72	71.68	2464.37	2504.17	71.68
Pf [Z]	0.56	1.45	0.94	1.74	1.45
Df [Hz]	1117.27	43.48	1126.69	1153.87	43.48
ΔF [Hz]	1279.10	51.06	1278.21	1337.47	51.06
A2. obese individuals (n=2)					
Body height [cm]	183.50	7.07	183.50	178.50	188.50
Weight [kg]	141.10	33.38	141.10	117.50	164.70
BMI [kg/m^2]	41.65	6.72	41.65	36.90	46.40
VFL (level)	19.50	0.71	19.50	19.00	20.00
Intensity [dB]	76.92	7.05	76.92	71.93	81.90
F0 [Hz]	97.81	6.82	97.81	92.98	102.63
Jitter [%]	3.05	0.09	3.05	2.99	3.12

Speakers' parameters	Mean	SD	Median	Min	Max
A2. obese individuals (n=2)					
Shimmer [%]	10.31	1.19	10.31	9.48	11.15
HNR [dB]	7.95	0.06	7.95	7.91	8.00
Fn [Hz]	2442.39	31.01	2442.39	2420.46	2464.32
Pf [Z]	0.50	0.63	0.50	0.05	0.94
Df [Hz]	1138.77	52.40	1138.77	1101.72	1175.83
ΔF [Hz]	1270.22	32.59	1270.22	1247.18	1293.27
Female speakers (N=6)					
B1. normal weight individuals (n=4)					
Body height [cm]	162.80	4.20	162.60	158.70	167.30
Weight [kg]	56.18	9.96	53.60	47.50	70.00
BMI [kg/m^2]	21.10	2.70	20.25	18.90	25.00
VFL (level)	5.75	1.26	6.00	4.00	7.00
Intensity [dB]	73.32	7.43	73.70	65.22	80.65
F0 [Hz]	203.08	10.11	198.90	196.59	217.92
Jitter [%]	2.15	0.28	2.19	1.77	2.45
Shimmer [%]	10.08	2.04	9.99	8.01	12.34
HNR [dB]	11.54	1.68	11.29	10.02	13.54
Fn [Hz]	2393.01	24.11	2396.95	2361.55	2416.60
Pf [Z]	-0.50	0.49	-0.42	-1.13	-0.02
Df [Hz]	1136.28	13.93	1133.45	1123.50	1154.72
ΔF [Hz]	1239.68	19.62	1248.59	1210.31	1251.21
B2. obese individuals (n=2)					
Body height [cm]	168.85	4.45	168.85	165.70	172.00
Weight [kg]	97.50	26.16	97.50	79.00	116.00
BMI [kg/m^2]	34.10	7.50	34.10	28.80	39.40
VFL (level)	19.50	0.71	19.50	19.00	20.00
Intensity [dB]	76.89	9.76	76.89	69.98	83.79
F0 [Hz]	230.42	17.45	230.42	218.08	242.76
Jitter [%]	1.86	0.40	1.86	1.57	2.14
Shimmer [%]	7.93	1.10	7.93	7.15	8.71
HNR [dB]	13.33	1.70	13.33	12.13	14.53
Fn [Hz]	2386.74	13.11	2386.74	2377.47	2396.02
Pf [Z]	-0.63	0.26	-0.63	-0.81	-0.44
Df [Hz]	1145.97	56.23	1145.97	1106.21	1185.72
ΔF [Hz]	1226.50	19.39	1226.50	1212.79	1240.21

b) Voice recording procedure

All speakers' voices were recorded using dynamic cardioid microphone Shure SM 58 SE connected to an amplifier IMG Stageline MPA-202 and, subsequently, to the sound card of the computer Dell Latitude E6400. The microphone was situated on the tripod at the eye level of each participant at 20 cm from the tip of the mouth. All voices were recorded under the same acoustic conditions: a silent room with an acoustic cabin Mozos Mshield on the top of the tripod (microphone inside), a time of the day (9–12 am), an equal acoustic background for all recordings (~39 dB). Each speaker was asked to say aloud (in Polish language) the following: "*Głos jest falą akustyczną, powstającą w głośni* (english translation: *Voice is a soundwave that arises in the glottis*)" with comfortable pitch and loudness. All sound files were recorded with equal sampling frequency (44.1 kHz, 16-bit resolution) as uncompressed format mono files (.wav). The similar procedure was previously described in Pawelec et al. (2022a; 2022b).

c) Acoustic analysis of speakers' voices

Acoustic analysis of speakers' voices was performed in Praat software v 3.9.2. (Boersma & Weenink 2019). The acoustic analysis was made based on the entire recording (sentence: *"Głos jest falą akustyczną…"*). Based on the recorded sample, the following acoustic parameters of the voice were determined:

– intensity (loudness; sound pressure level, *SPL*) of the voice [dB];
– fundamental frequency (*F0*) perceived as vocal pitch [Hz];
– voice instability (perturbation) parameters:
  • *shimmer* – degree of the amplitude of the acoustic wave variation from period to period, perceived as voice hoarseness [%],
  • *jitter* – degree of variation in the frequency of sound wave from period to period, perceived as voice roughness [%],
  • *harmonic-to-noise ratio* (*HNR*) – indicator of the relation of harmonics to noises in the voice - the lower *HNR* the higher voice instability [dB] (Texeira et al. 2014);
– formant frequencies (formants) *F1-F4* [Hz] – harmonic frequencies produced during passage of a laryngeal tone (*F0*, *the source*) through successive elements of the supralaryngeal vocal tract (*the filter*; Armstrong et al. 2018; Fant 1960);
– derivatives formants-based parameters: mean formant frequency (*Fn*, [Hz]) and standardized formant frequency (formant position, *Pf*, [Z-scale values]), formant dispersion (*Df*, [Hz]), formant spacing (*ΔF*, [Hz]), (Pisanski et al. 2014);
– maximum phonation time (*MPT*) [s].

For fundamental frequency pitch floor was set to 75 Hz and pitch ceiling to 300 Hz for male and 100–500 Hz for female speakers. Formant ceiling was 5000 Hz for men and 5500 Hz for women.

"Judges"

a) Competent judges selection criteria

A group of competent "Judges" was selected from female students of the Faculty of Biology and Animal Science at the Wroclaw University of Environmental and Life Sciences. Volunteers were asked to complete a questionnaire regarding their sex, age, sexual orientation, whether they had a hearing impairment as well as information regarding the current phase of the menstrual cycle (the first day of the last

menstruation and the average length of the menstrual cycle and menstrual bleeding) or taking hormonal agents (e.g. hormonal contraception). Study participants with hearing impairments and women with an irregular length of the monthly cycle, were excluded from the group of "Judges". Finally, 87 competent judges were selected for the experiment procedure. The median age of "Judges" was 22 years old. All study participants agreed to participate in the study free of charge and on a voluntary basis.

b) Speaker's fatness assessment procedure

The assessment procedure was carried out among 6 student's groups, each of about 15–16 individuals in the same room (classroom) with equal acoustic condition. A JBL Go2 loudspeaker was used to play back the voice recordings, connected to a laptop Acer Aspire 5 via an AUX cable. Voices were played at the same (maximum) volume level. There were two independent experiments:

Experiment I

In the first experiment "Judges" were asked to listen to 4 series of 3 voices within each one (4 triads). First and second triads consisted of only female voices, third and fourth triads of male voices only. In each triad one per three voices belonged to the obese speaker (BMI>30; VFL>18); the other two voices were from people of normal weight (BMI<25, VFL<9). Each triad comprised of people of comparable age. "Judges" had to choose only one out of 3 voices within each triad, which in their opinion belongs to an obese individual. An estimation of how many judges indicated a given voice as belonging to the obese individual was then conducted. The chosen voice within each triad was considered to be the modal value (dominant), i.e., the voice that was selected the most times during the 4 weeks of the experiment (women assessed the voices 4 times – once a week for a month, in each of the 4 phases of the menstrual cycle). Accurate typing was considered when the speaker within each triad was selected by over 33.3% of all "Judges" (a greater percentage of typing than the probability would suggest).

Experiment II

In the experiment II, "Judges" were asked to listen to 12 subsequent voices (the same that in experiment I: 4 triads * 3 voices) and indicate the silhouette (Fig. 1) that best suits, in their opinion, the appearance of the speaker, based on voice alone. Model silhouettes presented on a 5-point scale were performed using a website http://modelmydiet.com (access: 2. July 2022) and have been classified according to the following classification: 1 – underweight, 2 – normal weight, 3 – overweight, 4 – 1st degree obesity, 5 – 3rd degree obesity. Male models with a body height of 170 cm were given the following body weight values: 50 kg (BMI = 17.3), 67 kg (BMI = 23.2), 79 kg (BMI = 27.3), 95 kg (BMI = 32.9), 130 kg (BMI = 45.0). Female models with a body height of 165 cm the following body weights were given: 45 kg (BMI = 16.5), 57 kg (BMI = 20.9), 75 kg (BMI = 27.5), 90 kg (BMI = 33.1) and 120 kg (BMI = 44.1). Manipulation of the body weight of the silhouettes caused visual changes in the level of adipose tissue (especially abdominal fat and fat around the neck and face of male and female figures). Those 5 silhouettes reflected actual speaker fatness – figures from 1 to 2 could be compared with normal weight speakers (BMI<25; VFL<9; demonstrated in Table 1., headings A1 and B1); figures 3–5 may be perceived as obese speakers (BMI>25; VFL>9; demonstrated in Table 1., headings A2 and B2). Furthermore, some previ-

ous research showed that BMI and percentage body fat are highly positively correlated (Janjić et al. 2016; Ramel et al. 2013).

The assessment was performed 4 times (for 4 consecutive weeks, once in each phase of the menstrual cycle). Due to the lack of differences in the assessment of the silhouette (Fig. 1) depending on the phase of the menstrual cycle, sexual orientation, and the use/absence of hormonal contraception (data not shown), the ratings made by women "Judges" were averaged using the modal value (or the median in the case of multiple dominant).

The "Judges" were not informed about the identity of the speakers and, thus, none of the judges was able to identify the ID of any of the speakers.

Statistical methods

The basic parameters of the speakers and judges were provided using descriptive statistics, i.e., mean, standard deviation, min-max range.

To analyse the results from the Experiment I, univariate *chi-square* test was used independently for each triad. The test value was then compared with the critical value of the *chi-square* test for 2 degrees of freedom ($df = 3$ speakers $- 1 = 2$) to derive the significance level (p-value) using the probability calculator in Statistica software.

For Experiment II judicial compliance was assessed both within each of the 6 groups as well as between these groups. Within-group compliance was performed using Kendall's W coefficient of concordance. The test results were categorized using the intervals specified in the Garbaniuk (2016) study. Intergroup compatibility was performed using Kruskal-Wallis H test due to ordinal scale of dependent variable (silhouette assessment). Subsequently, an assessment of the accuracy of judges rating was performed. To compare ratings based on graphic scale (Fig. 1) between obese and normal weight speakers U Mann-Whitney test was applied, because of ordinal scale of dependent variable. Finally, the relationship between acoustic parameters of speakers' voices and silhouette ratings (I–V) was calculated using Spearman rank correlation (R). In addition, the multiple regression stepwise backward model was performed.

All statistical analyses were performed using the Statistica 13. software (1984–2017 TIBCO Software Inc, Palo Alto, California, USA). P-values below 0.05 were considered statistically significant.

Results

Descriptive statistics

Descriptive data of all 12 speakers including body build and voice parameters were shown in Table 1. The mean age of the judges was 22 years (SD = 1.3 y.; range: 19–27 y.). Most of the respondents did not take hormonal drugs, 22.7% of women used hormonal contraception. The largest percentage of judges were heterosexuals.

Experiment I

The accuracy of assignment was assessed separately for each of the 4 triads and results are presented in Table 2. Within each of the subgroups the obese speakers are marked in gray. In 3 out of 4 subgroups, the judges correctly typed speakers who were obese.

Regarding the correct identification of obese speakers, the difference in accuracy was performed. The differences were insignificant only for the third triad ($\chi^2 = 2.14$, $p = 0.3430$); for the remaining triads, the results were statistically significant ($p < 0.05$).

Table 2. Assignment accuracy of voice belonging to a person with obesity in each triad by female "Judges". Obese people are marked in gray. (Experiment I)

Triad		Female "judges" (n = 87)		
		n	%	*Chi-square* test
1 (female speakers' voices)	Speaker 1	5	5.7	**$\chi 2 = 57.38$ $p < 0.001$**
	Speaker 2	61	70.1	
	Speaker 3	21	24.2	
2 (female speakers' voices)	Speaker 4	3	3.4	**$\chi 2 = 43.31$ $p < 0.001$**
	Speaker 5	31	35.6	
	Speaker 6	53	60.9	
3 (male speakers' voices)	Speaker 7	35	40.2	$\chi 2 = 2.14$ $p = 0.3430$
	Speaker 8	24	27.6	
	Speaker 9	28	32.2	
4 (male speakers' voices)	Speaker 10	17	19.5	**$\chi 2 = 8.07$ $p = 0.0177$**
	Speaker 11	38	43.7	
	Speaker 12	32	36.8	

Experiment II

a) Judge compliance assessment

Within-group compliance. In 5 out of 6 examined groups of "Judges" a moderate agreement range of judicial compliance ($0.4 < W < 0.59$) was estimated (Table 3).

Intergroup compliance. Kruskal-Wallis test revealed no significant differences between ratings of 6 judges groups for 10 out of 12 speakers' voices (Table 4).

Due to the fact that the level of judicial compliance within each group was at a satisfactory level and differences in assessment between all groups were not significant, the responses of "Judges" from all groups were combined for the purposes of further analyses of the accuracy of the speaker's fatness assessments and the relationships between the speaker's voice parameters and the fatness level rating.

Table 3. Within-group compliance of "judges" ratings. Kendall's coefficient of concordance. (Experiment II)

"Judges" group	"Judges" compliance values		Assessment of the degree of judicial compliance
Group 1	$\chi 2$	74.31	moderate
	W	0.46	
	p	**<0.001**	
Group 2	$\chi 2$	91.11	moderate
	W	0.50	
	p	**<0.001**	
Group 3	$\chi 2$	80.23	moderate
	W	0.46	
	p	**<0.001**	
Group 4	$\chi 2$	71.16	moderate
	W	0.43	
	p	**<0.001**	
Group 5	$\chi 2$	66.53	fair
	W	0.34	
	p	**<0.001**	
Group 6	$\chi 2$	58.32	moderate
	W	0.44	
	p	**<0.001**	

Table 4. Inter-group compliance of "judges" ratings. Kruskal-Wallis *H* test. (Experiment II)

Speakers' voices	Sex	Kruskal-Wallis test (*H*)	*p*-value
Speaker 1	F	8.51	0.2025
Speaker 2	F	9.05	0.1600
Speaker 3	F	14.10	**0.0265**
Speaker 4	F	4.89	0.5820
Speaker 5	F	4.96	0.5444
Speaker 6	F	14.34	**0.0267**
Speaker 7	M	2.08	0.9145
Speaker 8	M	5.59	0.5089
Speaker 9	M	2.34	0.8991
Speaker 10	M	2.44	0.8750
Speaker 11	M	2.34	0.8732
Speaker 12	M	4.76	0.5601

c) Accuracy of speakers' BMI assessment

An assessment of whether obese speakers received, on average, higher grades of BMI from the judges using the silhouette scale (Fig. 1) than subjects with normal body weight was then performed. For comparison, the scores of all "Judges" from all 6 groups were considered in the analysis- 696 scores of speakers of normal body weight and 348 scores of obese speakers were obtained. Obese speakers were rated as higher (the higher the rate, the greater BMI category; Fig.1) than individuals of normal weight (Table 5). In the case of normal weight speakers, the most common rate was 3 and for obese participants – 4.

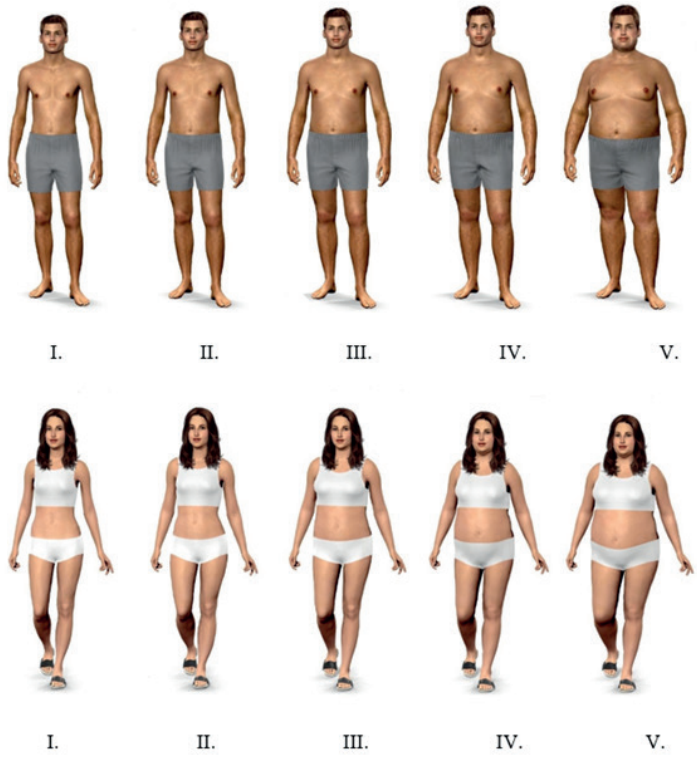

Fig. 1. Male (top) and female (bottom) silhouettes of different types of fatness

Table 5. Normal weight and obese speakers assessment. Mann-Whitney test. (Experiment II)

	Speakers' fatness type (n-number of ratings in total from 6 groups)								Mann-Whitney *U* test		
	Normal weight (n = 696)				Obese (n = 348)						
	Mean rank	*Me*	*Q*	*Mo*	*Mean rank*	*Me*	*Q*	*Mo*	*U*	*Z*	*p*
Silhouette rating (I-V)	498.27	3	1	3	570.95	3	1	4	104243.00	-3.67	**<0.001**

Me – median value, *Mo* – modal value, *Q* – quartile deviation.

c) BMI assessment and speakers' acoustic parameters

Due to a high correlation between some acoustic parameters values among men and women, not all of them were used in the regression model. For example in male speakers *jitter* was highly correlated with *HNR* (r = -0.98), *Pf* (r = 0.91), *ΔF* (r = 0.92); *Pf* was correlated with *Fn* (r = 1.00); intensity and *shimmer* (r = -0.82). Therefore, the following parameters were included in the stepwise regression model analysis: *F0, shimmer, HNR, Df, Pf* while the redundant parameters (*Fn, jitter,* intensity) were excluded.

In female speakers *HNR* and *shimmer* were highly correlated (r = -0.90); *Pf* and *Fn* (r = 1.00); *ΔF* (r = -0.99). Therefore, the following acoustic parameters were included in the model: *F0, shimmer*, intensity, *Df, Pf* as predictors while the redundant parameters (*HNR, Fn*) were discarded.

Male speakers with lower *HNR*/the higher formant dispersion (*Df*) received higher ratings on the BMI silhouette scale (i.e., these speakers were perceived as more obese). Female speakers with lower formant position (*Pf*) and higher intensity (loudness) received higher ratings on the BMI silhouette scale (Table 6).

Table 6. Relationships between silhouette BMI rating (dependent variable) and voice acoustic parameters (predictors). Zero order correlations and multiple stepwise backward regression models

Acoustic parameter	*r*	r_s	*β*	*t*	*p*	R^2 and *F* statistic
Male speakers' voices (n = 522 rates)						
-First model-						$R^2_{adj.}$ = 16.39
F0	**-0.21*****	**-0.24*****	0.17	2.42	**0.0158**	
Shimmer	-0.004	-0.02	0.05	1.12	0.2628	
HNR	**-0.37*****	**-0.33*****	-0.70	-5.85	**<0.001**	*F*=21.44; *p*<0.001
Df	**0.21*****	**0.27*****	0.15	3.29	**0.0011**	
Pf	**0.28*****	**0.24*****	-0.29	-2.97	**0.0031**	
-Final model-						$R^2_{adj.}$ = 14.83
HNR	**-0.37*****	**-0.33*****	-0.34	-8.06	**<0.001**	*F*=46.34; *p*<0.001
Df	**0.21*****	**0.27*****	0.13	3.04	**0.0027**	

Table 6 (cont.)

Acoustic parameter	r	r_s	β	t	p	R^2 and F statistic
Female speakers' voices (n = 522 rates)						
-First model-						
F0	-0.05	**0.15*****	-0.11	-2.02	**0.0441**	$R^2_{adj.}$ = 43.56
Shimmer	0.06	**-0.09***	-0.05	-1.34	0.1823	
Df	**-0.55****	**-0.58*****	0.03	0.38	0.7040	F=81.43; p<0.001
Pf	**-0.32*****	**-0.36*****	-0.13	-3.20	**0.0015**	
Intensity	**0.64****	**0.63*****	0.65	8.17	**<0.001**	
-Final model-						$R^2_{adj.}$ = 43.00
Pf	**-0.32*****	**-0.36*****	-0.17	-5.04	**<0.001**	F=197.53; p<0.001
Intensity	**0.64****	**0.63*****	0.59	17.41	**<0.001**	

r – zero order Pearson's correlation; r_s – zero order Spearman's correlation; β – beta regression coefficient; t, p – t-statistic and significance level of β; $R^2_{adj.}$ – adjusted R-squared of a model; *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

Discussion

The accuracy of the speaker's BMI assessment was found in both experiments; female "Judges" accurately chose obese speakers and gave higher ratings for silhouettes' BMI category (Fig. 1) to speakers who were obese. Furthermore, within- and inter-group judges' agreement regarding speakers' BMI evaluation was high.

There have not been, to our knowledge, any studies looking at BMI assessment based on vocal cues which makes it rather difficult to discuss the results of our findings within the context of similar research. Still, several studies have investigated the accuracy of the speakers' physical parameters assessment (i.e., body height and weight) from the voice alone. For example, some of these studies found that estimated and actual body weight of the speakers were significantly corelated (Brueckert et al. 2006; Collins 2000; Krauss et al. 2002; Lass and Davis 1976; Lass et al. 1978). However, these studies did not assess BMI level (fatness/obesity) but, instead, absolute body weight of the speakers. The only work, to our knowledge, on the assessment of the speaker's obesity (based on BMI) was conducted by Lee et al. (2013) showing that, by using artificial intelligence (machine learning methods), the researchers were able to assess the BMI category of patients (normal, overweight, obese) solely based on the analysis of voice parameters.

There have been some studies showing the relationship between a speaker's fatness and his/her voice characteristics. For instance, some researchers found a significant positive correlation between trunk visceral fat/absolute fat mass and vocal parameters, such as *shimmer* and formant dispersion (*Df*; Hamdan et al. 2012; 2013b). Moreover, Da Cunha et al. (2009) found that obese individuals had greater values of both perturbation parameters (*jitter, shimmer*) and voice noises as well as reduced maximum phonation time (*MPT*) compared to those with normal weight. Similarly, other studies revealed that obese people exhibited lower value of fundamental frequency (*F0*; Barties et al. 2013; Souza and Santos 2018) and shorter *MPT* compared to participants with

body mass index within a normal range (Celebi et al. 2013; Santos 2014; Souza and Santos 2018). Interestingly, one study found differences in subjective voice quality between obese and normal weight individuals. Specifically, Celebi et al. (2013) found that there was a significant difference in GRBAS scores (perceptual evaluation of Grade-Roughness-Breathiness-Asthenia-Strain using a scale of 0–3) – mean value for obese subjects was 1 and for control group: 0.2 (scale values meaning: 0 – normal, 1 – mild, 2 – moderate, 3 – severe voice disorders). This study suggests that obese individuals tend to have significantly different voice characteristics (objective and subjective) than those with normal body weight. These differences can be caused by abnormal fat deposits in obese individuals localized on the uvula, pharyngeal walls, tongue, and soft palate (Da Cunha et al. 2009). Alternatively, glucose-related changes in voice may contribute to this relationship (Hamdan et al. 2013a; Pyniopodjanard et al. 2021; Sidorova et al. 2020). Since obese people often have metabolic disorders of glucose, hyperglycemia may influence changes in the elastic properties of the biological tissues that build the larynx and the cords (Wang et al. 2015). Other diabetic complications affecting quality of voice, such as neuropathy (laryngeal sensory neuropathy is more common in patients with type 2 diabetes mellitus than in controls; Hamdan et al. 2014; Ravi and Gunjawate 2019) and gastro-oesophageal reflux disorder (Lechein et al. 2017) also cannot be discarded. Since there are such large differences in voice quality of obese people, "Judges" should be able to identify people with normal body weight and obese people solely on the basis of their voices, and our study shows that. Firstly, "Judges" indentify obese speakers with a high accuracy (probability greater than a chance, > 33.3%). Secondly, we showed that obese speakers got higher rank in 5-point scale (Fig. 1; obese: *Mo* = 4, normal weight: *Mo* = 3), which means that their silhouettes were rated as having greater BMI (possibly, but not necessarily, resulting from more fat deposits). Lastly, "Judges" were consistent in their judgments both within and between each of the six groups suggesting that the differences in ratings are not artifacts, but, rather, reflect specific trends in assessing the BMI level based on voice perception.

The results of our study show that "Judges" during their assessment were guided by specific voice parameters. For example, male speakers with lower harmonics-to-noise ratio (*HNR*) and higher formant dispersion (*Df*) were judged to be fatter. It means that men with more unstable voices (less harmonics, more noises) and higher dispersion of formant frequencies were perceived as being more obese. *HNR* has been suggested to be a measure of voice aging as its lower values were observed in elderly individuals (Ferrand 2002). Furthermore, men with higher *Df* were rated as having greater BMI. In contrast, other studies show that larger individuals (taller, heavier) have lower spread of formant values (Evans et al. 2006; González 2004; Pawelec et al. 2022a; Pisanski et al. 2014). In addition, Collins (2000) found that men with lower formants were assessed as taller, heavier, and more muscular, while Sell et al. (2006) found that men with lower *Df* are perceived as physically stronger. In the light of the above studies, the results of our study are rather puzzling. Perhaps, lower formant dispersion, which is strongly negatively related to body size (Fitch 1997) and physical and social dominance (Puts et al. 2007), could be perceived by

women as a signal of health and masculinity (male *fitness*). Therefore, judges may assess men with higher value of *Df* as having worse biological condition and health (e.g., obese).

Our study shows that formant position (*Pf*) of female speakers was associated negatively and voice *intensity* (loudness) was correlated positively with silhouette ratings. Therefore, female speakers with lower *Pf* and higher intensity were rated as having greater BMI. Formant position is a parameter proposed by Puts et al. (2012) as a better alternative to formant dispersion (*Df*). This vocal characteristic was found to be negatively correlated in men with salivary IgA – a marker of immunocompetence (Arnocky et al. 2018). *Pf* was also found to be negatively associated with body height but not with adiposity among peripubertal Bolivian Tsimane women (Hodges-Simeon et al. 2014). Interestingly, in our study "Judges" rated women with lower *Pf* as more obese, i.e., in worse biological condition. The results of our study regarding loudness and the silhouette assessment could be more comparable with findings of other studies. For example, Barties et al. (2013) found that obese women had significantly louder (higher voice intensity [dB]) voices compared to women of underweight or normal weight. The authors of the study suggest that: "OB [obese] subjects have greater diaphragmatic motion and weight, and therefore have higher respiratory muscle motion" (Barties et al. 2013: 316). Similarly, Kantarci et al. (2004) showed that individuals with BMI above 30 kg/m^2 and waist circumference longer than 100 cm had greater diaphragmatic motion. To sum up, we found that vocal parameters describing formants, harmonics/noises and voice intensity level were critical factors while assessing the speakers' BMI.

Limitations and future directions

The sample size was quite small – only 12 speakers (including 6 women) four of whom (2 men and 2 women) were obese. Therefore, our sample of obese individuals (n = 4) may not be representative of the entire obese population in terms of voice parameters. A larger sample of obese study participants would better reflect the actual trends in assessing the degree of obesity based on voice perception.

A rather unclear relationships, e.g., assessing women with lower *Pf* and men with higher *Df* as more obese, may, to some extent, result from the adopted methodology in our study. Judges were asked to choose one among 5 silhouettes which differed in BMI values. Together with adiposity (BMI) changes (different absolute body weight [kg] values for equal body height), body proportions also changed. For male and female silhouettes, the relation between waist and hip circumferences (*WHR*) have changed. Perhaps "Judges" considered this ratio variation when listening to speakers' voices, more than absolute BMI level. The possible solution to this problem could be the use of a slightly different graphic scale of the speakers' silhouettes, similar to the one used in the research of Singh (1993; 1995), where the author presented the gradation of the *WHR* separately for different BMI values.

Conclusions

This study revealed that human voice provides a meaningful information regarding BMI level (degree of obesity). "Judges" within- as well as inter-group compliance of speaker's BMI were quite

consistent in terms of the accuracy of fat silhouette assessment. Higher rates of obesity level on average were given to speakers who really were obese. In women, some acoustic parameters, such as *HNR* and *Df* in men and *Pf* and Intensity, were associated with speakers' BMI assessment. To the best of our knowledge, this is the first study assessing BMI of speakers (their obesity or lack of it) based on their voices, which makes it difficult to relate the results of our study to other studies and draw consistent conclusions. Our findings might also suggest that, in near future, commercially available mobile apps could be used to measure BMI. Although our study demonstrates the potential of assessing BMI based on voice cues, a development of effective method for estimating the degree of BMI based on the voice is needed. Potentially, this technology could be used in sciences, such as dietetics or criminology, to determine the degree of obesity of a patient remotely (or using a mobile application) or to identify a perpetrator of a crime in situations when law enforcement authorities rely solely on a voice recording of a suspect (e.g., from a telephone conversation with a blackmailer). However, in order to fully appreciate the potential of our study, further research is needed on the role of human voice in BMI assessment.

Acknowledgements

We would like to express our gratitude to all the participants who gave their time and took part in our study and helped with our research. Either those who judged the voice and those who have given their voice as well as anthropometric measurements for evaluation.

Without their participation, the entire study could not have taken place.

Funding

The material for this study was collected thanks to funding under the project N020 – Fundusz Wsparcia Badań Naukowych – Bon Doktoranta Szkoły Doktorskiej, number N020/0008/20 granted by Wroclaw University of Environmental and Life Sciences, Poland.

Corresponding author

Łukasz Pawelec, Kożuchowska 5, 51-631 Wrocław, Poland, 694 971 438; e-mail: lukasz.pawelec@upwr.edu.pl

References

Armstrong MM, Lee AJ, Feinberg DR. 2019. A house of cards: bias in perception of body size mediates the relationship between voice pitch and perceptions of dominance. Anim Behav 147:43–51, https://doi.org/10.1016/j.anbehav.2018.11.005

Arnocky S, Hodges-Simeon CR, Ouellette D, Albert G. 2018. Do men with more masculine voices have better immunocompetence? Evol Hum Behav 39(6):602–10, https://doi.org/10.1016/j.evolhumbehav.2018.06.003

Barsties B, Verfaillie R, Roy N, Maryn Y. 2013. Do body mass index and fat volume influence vocal quality, phonatory range, and aerodynamics in females? CoDAS 25(4):310–318, https://doi.org/10.1590/s2317-17822013000400003

Boersma P, Weenink D. 2019. Praat: doing phonetics by computer [Computer program]. Version 6.0.56; http://www.praat.org/ [Accessed 20 June 2019].

Byeon H, Cha S. 2020. Evaluating the effects of smoking on the voice and subjective voice problems using a meta-analysis approach. Sci Rep 10(1):1–8, https://doi.org/10.1038/s41598-020-61565-3

Celebi S, Yelken K, Develioglu ON, Topak M, Celik O, Ipek HD, Kulekci M. 2013. Acoustic, perceptual and aerodynamic voice evaluation in an obese population. J Laryngol Otol 127(10):987–90, https://doi.org/10.1017/S0022215113001916

Collins SA. 2000. Men's voices and women's choices. Anim behav 60(6):773–780, https://doi.org/10.1006/anbe.2000.1523

Da Cunha MGB, Passerotti GH, Weber R, Zilberstein B, Cecconello I. 2009. Voice feature characteristic in morbid obese population. Obes Surg 21(3):340–4, https://doi.org/10.1007/s11695-009-9959-7

Evans S, Neave N, Wakelin D. 2006. Relationships between vocal characteristics and body size and shape in human males: An evolutionary explanation for a deep male voice. Biol Psychol 72(2):160–3, https://doi.org/10.1016/j.biopsycho.2005.09.003

Fant G. 1970. Acoustic theory of speech production (No. 2). Walter de Gruyter. https://doi.org/10.1515/9783110873429.13

Ferrand CT. 2002. Harmonics-to-noise ratio: An index of vocal aging. J Voice 16(4):480–7, https://doi.org/10.1016/S0892-1997(02)00123-6

Fitch WT. 1997. Vocal tract length and formant frequency dispersion correlate with body size in rhesus macaques. J Acoust Soc Am 102(2):1213–22, https://doi.org/10.1121/1.421048

Garbaniuk O. 2016. Wykorzystywanie procedury sędziów kompetentnych w naukach społecznych i możliwości jej oceny psychometrycznej za pomocą narzędzi dostępnych w Statistica. Uniwersytet Zielonogórski i Katolicki Uniwersytet Lubelski Jana Pawła II. https://doi.org/10.33141/po.2020.12.02

González J. 2004. Formant frequencies and body size of speaker: A weak relationship in adult humans. J Phon Academic Press 32(2):277–87, https://doi.org/10.1016/S0095-4470(03)00049-4

Gregory SW. 1994. Sounds of power and deference: acoustic analysis of macro social constraints on micro interaction. Sociol Perspect 37:497–526, https://doi.org/10.2307/1389277

Hamdan ALH, Al-Barazi R, Tabri D, Saade R, Kutkut I, Sinno S, Nassar J. 2012. Relationship between acoustic parameters and body mass analysis in young males. J Voice 26(2):144–7, https://doi.org/10.1016/j.jvoice.2011.01.011

Hamdan ALH, Jabbour J, Nassar J, Dahouk I, Azar ST. 2013a. Vocal characteristics in patients with type 2 diabetes mellitus. Eur Arch Oto-Rhino-L 269(5):1489–95, https://doi.org/10.1016/j.jvoice.2012.09.005

Hamdan ALH, Al Barazi R, Khneizer G, Turfe Z, Sinno S, Ashkar J, Tabri D. 2013b. Formant frequency in relation to body mass composition. J Voice 27(5):567–71, https://doi.org/10.1016/j.jvoice.2012.09.005

Hamdan ALH, Dowli A, Barazi R, Jabbour J, Azar S. 2014. Laryngeal sensory neuropathy in patients with diabetes mellitus. J Laryngol Otol 128(8):725–9, https://doi.org/10.1017/S002221511400139X

Hodges-Simeon CR, Gurven M, Puts DA, Gaulin SJC. 2014. Vocal fundamental and formant frequencies are honest signals of threat potential in peripubertal males. Behav Ecol 25(4):984–8, https://doi.org/10.1093/beheco/aru081

Hughes SM, Harrison MA, Gallup Jr GG. 2002. The sound of symmetry: Voice as a marker of developmental instability. Evol Hum Behav 23(3):173–80, https://doi.org/10.1016/S1090-5138(01)00099-X

Janjić J, Baltić MŽ, Glišić M, Ivanović J, Bošković M, Popović M, Lovrenović M. 2016. Relationship between body mass index and body fat percentage among adolescents from Serbian Republic Child Obes 1(2):9, https://doi.org/10.21767/2572-5394.10009

Kantarci F, Mihmanli I, Demirel MK, Harmanci K, Akman C, Aydogan F, Mihmanli A, Uysal O. 2004. Normal Diaphragmatic Motion and the Effects of Body Composition: Determination with M-Mode Sonography. J Ultrasound Med 23(2):255–60, https://doi.org/10.7863/jum.2004.23.2.255

Lass NJ, Davis M. 1976. An investigation of speaker height and weight identification. J Acoust Soc Am 60(3):700–3, https://doi.org/10.1121/1.381142

Lass NJ, Brong GW, Ciccolella SA, Walters SC, Maxwell EL. 1980. An investigation of speaker height and Weight Discriminations by means of paired comparison judgments. J Phon 8(2):205–12, https://doi.org/10.1016/S0095-4470(19)31465-2

Lechien JR, Finck C, Costa de Araujo P, Huet K, Delvaux V, Piccaluga M, Harmegnies B, Saussez S. 2017. Voice outcomes of laryngopharyngeal reflux treatment: a systematic review of 1483 patients. Eur Arch Oto-Rhino-L 274(1):1–23, https://doi.org/10.1007/s00405-016-3984-7

Moreira TDC, Gadenz C, Figueiró LR, Capobianco DM, Cunha K, Ferigolo M, Barros HMT, Cassol M. 2015. Substance use, voice changes and quality of life in licit and illicit drug users. Revista CEFAC 17:374–384, https://doi.org/10.1590/1982-021620156714

Oguchi T, Kikuchi H. 1997. Voice and interpersonal attraction. Jpn Psychol Res 39:56–61, https://doi.org/10.1111/1468-5884.00037

Pawelec ŁP, Graja K, Lipowicz A. 2022a. Vocal Indicators of Size, Shape and Body Composition in Polish Men. J Voice 36(6):878.e9-878.22, https://doi.org/10.1016/j.jvoice.2020.09.011

Pawelec ŁP, Lipowicz A, Czak M, Mitas AW. 2022b. The Microphone Type and Voice Acoustic Parameters Values–A Comparative Study. In International Conference on Information Technologies in Biomedicine (pp. 421–431). Springer, Cham. https://doi.org/10.1007/978-3-031-09135-3_35

Pisanski K, Rendall D. 2011. The prioritization of voice fundamental frequency or formants in listeners' assessments of speaker size, masculinity, and attractiveness. J Acoust Soc Am 129(4):2201–12, https://doi.org/10.1121/1.3552866

Pisański K, Fraccaro PJ, Tigue CC, O'Connor JJM, Röder S, Andrews PW, Fink B, DeBruine LM, Jones BC, Feinberg DR. 2014. Vocal indicators of body size in men and women: a meta-analysis. Anim Behav 95:89–99, https://doi.org/10.1016/j.anbehav.2014.06.011

Pisanski K, Jones BC, Fink B, O'Connor JJM, DeBruine LM, Röder S, Feinberg DR. 2016. Voice parameters predict sex-specific body morphology in men and women. Anim Behav 112:13–22, https://doi.org/10.1016/j.anbehav.2015.11.008

Pisanski K, Oleszkiewicz A, Sorokowska A. 2016. Can blind persons accurately assess body size from the voice? Biol Lett 12(4), https://doi.org/10.1098/rsbl.2016.0063

Puts DA, Gaulin SJC, Verdolini K. 2006. Dominance and the evolution of sexual dimorphism in human voice pitch. Evol Hum Behav 27:283–296, https://doi.org/10.1016/j.evolhumbehav.2005.11.003

Puts DA, Hodges CR, Cárdenas RA, Gaulin SJ. 2007. Men's voices as dominance signals: vocal fundamental and formant frequencies influence dominance attributions among men. Evol Hum Behav 28(5):340–4, https://doi.org/10.1016/j.evolhum behav.2007.05.002

Puts DA, Apicella CL, Cárdenas RA. 2012. Masculine voices signal men's threat potential in forager and industrial societies. Proc Royal Soc B 279(1728):601–9, https://doi.org/10.1098/rspb.2011.0829

Raine J, Pisanski K, Simner J, Reby D. 2019. Vocal communication of simulated pain. Bioacoustics 28(5):404–26, https://doi.org/10.1080/09524622.2018.1463295

Ramel A, Halldorsson TI, Tryggvadottir EA, Martinez JA, Kiely M, Bandarra NM, Thorsdottir I. 2013. Relationship between BMI and body fatness in three European countries. Eur J Clin Nutr, 67(3):254–8, https://doi.org/10.1038/ejcn.2013.6

Ravi R, Gunjawate DR. 2019. Effect of diabetes mellitus on voice: a systematic review. Pract Diabetes 36(5):177–80, https://doi.org/10.1002/pdi.2240

Rendall D, Kollias S, Ney C, Lloyd P. 2005. Pitch (F0) and formant profiles of human vowels and vowel-like baboon grunts: The role of vocalizer body size and voice-acoustic allometry. J Acoust Soc Am 117(2):944–55, https://doi.org/10.1121/1.1848011

Rendall D, Vokey JR, Nemeth C. 2007. Lifting the Curtain on the Wizard of Oz: Biased Voice-Based Impressions of Speaker Size. J Exp Psychol Hum Percept Perform 33(5):1208–19, https://doi.org/10.1037/0096-1523.33.5.1208

Souza LB, Pereira RM, Santos MM, Godoy CM. 2014. Fundamental frequency, phonation maximum time and vocal complaints in morbidly obese women. Arq Bras Cir Dig 27(1):43–6, https://doi.org/10.1590/S0102-67202014000100011

Sell A, Bryant GA, Cosmides L, Tooby J, Sznycer D, Von Rueden C, Krauss A, Gurven M. 2010. Adaptations in humans for assessing physical strength from the voice. Proc Royal Soc B 277(1699):3509–18, https://doi.org/10.1098/rspb.2010.0769

Sidorova J, Carbonell P, Čukić M. 2020. Blood glucose estimation from voice: first review of successes and challenges. J Voice. Epub ahead of print, https://doi.org/10.1016/j.jvoice.2020.08.034

Singh D. 1993. Adaptive significance of female physical attractiveness: role of waist-to-hip ratio. J Pers Soc Psychol 65(2):293–307, https://doi.org/10.1037//0022-3514.65.2.293

Singh D. 1995. Female judgment of male attractiveness and desirability for relationships: role of waist-to-hip ratio and financial status. J Pers Soc Psychol 69(6):1089–101, https://doi.org/10.1037//0022-3514.69.6.1089

Pinyopodjanard S, Suppakitjanusant P, Lomprew P, Kasemkosin N, Chailurkit L, Ongphiphadhanakul B. 2021. Instrumental acoustic voice characteristics in adults with type 2 diabetes. J Voice 35(1):116–21, https://doi.org/10.1016/j.jvoice.2019.07.003

Sondhi S, Khan M, Vijay R, Salhan AK. 2015. Vocal indicators of emotional stress. Int J Comput Appl 122(15):38–43, https://doi.org/10.5120/21780-5056

Souza LBR, Santos MM. 2018. Body mass index and acoustic voice parameters: is there a relationship? Braz J Otorhinolaryngol 84(4):410–15, https://doi.org/10.1016/j.bjorl.2017.04.003

Tarafder KH, Datta PG, Tariq A. 2012. The aging voice. BSSMU 5(1):83–86, https://doi.org/10.3329/BSMMUJ.V5I1.11033

Teixeira JP, Fernandes PO. 2014. Jitter, shimmer and HNR classification within gender, tones and vowels in healthy voices. Proc Technol 16:1228–1237, https://doi.org/10.1016/j.protcy.2014.10.138

Wang Y, Zeinali-Davarani S, Davis EC, Zhang Y. 2015. Effect of glucose on the biomechanical function of arterial elastin. J Mech Behav Biomed Mater 49:244–54, https://doi.org/10.1016/j.jmbbm.2015.04.025

Wolfe VI, Ratusnik DL, Smith FH, Northrop G. 1990. Intonation and fundamental frequency in male-to-female transsexuals. J Speech Hear Dis 55(1):43–50, https://doi.org/10.1044/jshd.5501.43

Anthropological Review • Vol. 85(4), 61–81 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.4.05

Maternal risk factors associated with term low birth weight in India: A review

Harsh Vats[1], Ruchi Saxena[2], Mohinder P. Sachdeva[1], Gagandeep K. Walia[3], Vipin Gupta[1]

[1] Department of Anthropology, University of Delhi, Delhi
[2] Department of Obstetrics and Gynaecology, Sardar Patel Medical College, Bikaner, Rajasthan, India
[3] Public Health Foundation of India, Gurugram, Haryana, India

Abstract: Low birth weight is one of the leading factors for infant morbidity and mortality. To a large extent affect, various maternal risk factors are associated with pregnancy outcomes by increasing odds of delivering an infant with low birth weight. Despite this association, understanding the maternal risk factors affecting term low birth weight has been a challenging task. To date, limited studies have been conducted in India that exert independent magnitude of these effects on term low birth weight. The aim of this review is to examine the current knowledge of maternal risk factors that contribute to term low birth weight in the Indian population. In order to identify the potentially relevant articles, an extensive literature search was conducted using PubMed, Goggle Scholar and IndMed databases (1993 – Dec 2020). Our results indicate that maternal age, educational status, socio-economic status, ethnicity, parity, pre-pregnancy weight, maternal stature, maternal body mass index, obstetric history, maternal anaemia, gestational weight gain, short pregnancy outcome, hypertension during pregnancy, infection, antepartum haemorrhage, tobacco consumption, maternal occupation, maternal psychological stress, alcohol consumption, antenatal care and mid-upper arm circumference have all independent effects on term low birth weight in the Indian population. Further, we argue that exploration for various other dimensions of maternal factors and underlying pathways can be useful for a better understanding of how it exerts independent association on term low birth weight in the Indian sub-continent.

Key words: anaemia, gestational weight gain, hypertension, India, Low Birth Weight, maternal age, maternal Body Mass Index, maternal risk factors, obstetric history.

Received: 04.02.2022; Revised: 05.12.2022; Accepted: 05.12.2022

Introduction

The birth weight of the newborn is a prime demographic indicator of the health status of a given society. The decrease and the increase in the mean birth weight of the population are directly linked to the quality of maternity care and living condition of the mothers (Barker 2004). Birth weight also plays a pivotal role in infant and childhood mortality (McCormick 1985).

The birth weight of less than 2500 grams is defined as the Low Birth Weight (LBW), regardless of gestational age (WHO 2004). The LBW can be distinguished into three categories. 1) Premature or Pre-Term LBW (born before 37 completed weeks of gestation or with fewer than 259 days of gestation); 2) Term LBW (born between 37 and 42 completed week of gestation, or between 259 and 293 days of gestation); 3) Post-Term LBW (born after 42 week or 294 days of gestation) (WHO 2004).

LBW can be either caused by a short gestation period or retarded intra-uterine growth, as well as by a combination of both these pathophysiologic conditions (Kramer 1987). Importantly, term LBW and intra-uterine growth restriction do not necessarily reflect the same clinical situation. For example, some new-borns, normally formed and perfectly healthy, are born weighing less than the 10th percentile for their gestational age (Resnik 2002), while others whose birth weight is higher than the 10th percentile may show signs of growth restriction if they come from a uterine environment that thwart the foetus from reaching its full potential for growth (Wollmann 1998).

On average, an infant with LBW has 40 times greater mortality risk than normal weight new-borns (Alexander et al. 2007), while Very Low Birth Weight (<1500 gram), might increase mortality risk up to 100 times (Mayor 2016). LBW infants are also more prone to developing iron deficiency anaemia potentially leading to longer and impaired neurodevelopmental disorders (Long et al. 2012). In addition, several research studies have shown that the impaired growth at birth is linked to an increased risk of developing certain types of chronic disorders at an older age (Sallout et al. 2003), such as diabetes, obesity (Kuhle et al. 2017), endothelial dysfunction (Visentin et al. 2014), non-alcoholic fatty liver diseases (Newton et al. 2017), cardiovascular diseases (Kuhle et al. 2017), asthma (Wjst et al. 1998), hypothermia (Erekia Ebrahim 2015) and chronic kidney disease (Hirano et al. 2016).

Globally, LBW was estimated to comprise 12.4–17.1% of all births (WHO 2019). The prevalence of LBW in Low- and Middle-Income Countries (LMIC) was 91% of the world's LBW. There were notable global and regional variations in LBW rates. An estimated 14% of neonates exhibited LBW in Sub-Sahara Africa, 12.2% in North Africa, 5.3% in East Asia, 5.4% in Southeast Asia, 9.9% in Western Asia, 8.7% in Latin America and 26.4% in South Asia. Up to one-fourth of all born LBW infants were born in South Asia (Blencowe et al. 2019). In South Asia itself, India heads the list with 18.2% of the infant with LBW as per the National Family Health survey 4 statistics (IIPS and ICF 2017). Compared to prematurity in developed countries, the observed LBW in developing countries, such as India, can be largely attributed to Intra-uterine growth restriction (Saili 2008).

The major problem in the field of public health is to determine factors

influencing LBW and to institute therapeutic measures (Velankar 2009). The aetiology of LBW is complex and mainly influences fetal growth, although these factors can be categorised into several different categories on the basis of the locus of their impact: the placenta, the pregnant woman herself, the fetus and finally, factors produced from the interaction of these factors (Institute of Medicine 1985). Although the progress in obstetrical and neonatal care has improved the prognosis for LBW neonates, the best strategy to reduce it is primary prevention by identifying and avoiding the risk factors that led to LBW. This review aims to update the current knowledge and understanding of the maternal risk factors affecting Term LBW in the Indian population.

Materials and Methods

Search strategy

This comprehensive literature review was conducted using PubMed, Goggle Scholar and IndMed databases from 1993 to December 2021 to identify the relevant articles. The search strategy was developed using combination of medical subject heading (MeSH) terms and words in Title/abstract- ("maternal risk factor" [Title/Abstract] OR "maternal risk factors" [All Fields] OR "risk factor" [All Fields] OR "risk factors" [MeSH Terms]) AND ("infant, low birth weight" [MeSH Terms] OR "infant, low birth weight" [MeSH Terms] OR "low birth weight" [Title/Abstract]). Full text articles that were written in English and relevant to the topic were included in the study. The references of those selected articles were then utilised in a cascade search to obtain more relevant citations.

Selection strategy

Inclusion criteria are followed as:

1) Studies published in English 2) Studies related to human 3) Original research articles 4) Natural conception 5) Singleton pregnancy 6) No history of visceral diseases 7) Studies done on Indian population

Exclusion criteria are followed as:

1) Review studies and 2) Systematic review and meta-analysis

Initial search identified 10900 articles for inclusion. After deleting articles not related to humans, 10329 articles were left for consideration. Assessment based on titles and abstracts were carried out to determine the objectives and relevance of the studies, which resulted in exclusion of 9835 studies. The full texts of remaining 494 papers were included for consideration in the study and those articles that neither met the inclusion nor the exclusion criteria were removed from consideration. At this stage of the search process 46 articles were retained while 9 more articles were identified from the references of searched articles and added for final consideration. In total, 55 studies that met all the inclusion and exclusion criteria. The identifying information (such as research objectives, study design, sample size, risk factor, results, and effect size) of those 55 studies are presented in supplementary table 1.

Results and Discussion

Demographic risk factors

Maternal age

A large number of epidemiological studies in India have shown an increased risk of LBW in extreme reproductive age, i.e., less than 20 years of age (Amin et al.

1993; Fraser et al. 1995; Deshmukh et al. 1998; Agarwal et al. 2005; Joshi et al. 2005; Chen et al. 2007; Dharmalingam et al. 2010; Roy et. al. 2009; Epstein et al. 2013; Raje et al. 2015; Patel et al. 2018; Kumar et al. 2020), and above 30 years of age or both (Cnattingius et al. 1992; Malik et al. 1997; Mondal 2000; Nair et al. 2000; Jha et al. 2009; Ganesh Kumar et al. 2010; Deshpande Jayant et al. 2011; Borah et al. 2016; Patel et al. 2018). The main cause of early conception is a well-established custom of child marriage in India (27% according to NFHS-4 (IIPS and ICF 2017), which is magnified due to the poverty and ignorance (Seth et al. 2018). The devastating effects of early conception also led to an increased risk of stillbirth, abortion, and premature delivery (Rao et al. 2010; Igwegbe et al. 2001). It is generally accepted that women of advanced age (>30 years) exhibit some latent factors that can cause complications in pregnancy, including LBW (Shan et al. 2018; Goisis et al. 2017; Tabcharoen et al. 2009). These latent factors might include an impaired function of the myometrium (Nelson et al. 2013) or a large number of chronic diseases at older ages (Sheen et al. 2018).

Education level

Many research studies have demonstrated a direct association between mother's education level and fetal birth weight. For example, the risk of LBW decreases with an increase in mother's education level. It might suggest that women with higher levels of education were less prone to neglect health care, have high socio-economic status (SES) (Deshpande Jayant et al. 2011; Mathew et al. 2014), and better decision making regarding health care as well as family planning (Mavalankar et al. 1992; Hirve et al. 1994; Biswas et al. 2008; Subramanyam et al. 2010; Sreeramareddy et al. 2011; Chakraborty et al. 2011; Metgud et al. 2012; Epstein et al. 2013; Kader et al. 2014; Patel et al. 2018; Kumar et al. 2020).

Socio-economic status

Studies have shown that low SES was associated with high prevalence (11–50%) of LBW (Deshmukh et al. 1998; Nair et al. 2000; Radhakrishnan et al. 2000; Jha et al. 2009; Roy et al. 2009; Chakraborty et al. 2011; Deshpande Jayant et al. 2011; Khattar et al. 2013; Bellad et al. 2012; Kader et al. 2014; Mathew et al. 2014; Kumar et al. 2020). However, the association between SES and LBW should be interpreted in the light of other factors related to SES, such as maternal age, education level, tobacco consumption, gestational weight gain and maternal height (Deshmukh et al. 1998; Roy et al. 2009). In addition, some studies have also reported that low SES can lead to low health consciousness, lower nutritional status and low antenatal attendance, leading to the increased risk of LBW (Nair et al. 2000; Jha et al. 2009; Deshpande Jayant et al. 2011; Mumbare et al. 2012; Chakraborty et al. 2011; Kumar et al. 2020). Moreover, many studies have also found a significant association between SES and birth weight of neonates (Hirve et al. 1994; Deshmukh et al. 1998).

Ethnicity

India harbours more genetic diversity compared to other comparable global regions (Majumder 1998). Epidemiological studies have reported large disparities in the prevalence rates of LBW in different racial and ethnic groups (James 1993; Branum et al. 2002) as well as regions

(Chakraborty et al. 2011; Epstein et al. 2013). For example, the prevalence of LBW was reported to be the highest in the north India compared to other regions of India (Chakraborty et al. 2011; Epstein et al. 2013). One study reported a significant influence of religion on the prevalence of LBW (i.e. Hindus have more prevalence of LBW compared to Muslims) (Mavalankar et al. 1992). Similarly, the NFHS-4 (National Fertility Health Survey) data also showed that Hindus (18.5%) have more prevalence of LBW than Muslims (17.3%) (IIPS and ICF 2017).

Medical risk before pregnancy

Parity

Maternal Parity is defined as the number of pregnancies reaching viable gestational age (>20 weeks), including live birth and still births. The parity is a well-recognised potential indicator for LBW (Shah 2010). LBW has been reported to be significantly high in nulliparous, decrease significantly in multiparous (parity 2–4) and significantly increase in grand multiparous (parity 5–8) (Amin et al. 1993; Mavalankar et al. 1992; Hirve et al. 1994; Malik et al. 1997; Deshmukh et al. 1998; Anand et al. 2000; Nair et al. 2000; Mondal 2000; Chhabra et al. 2004; Joshi et al. 2005; Negi et al. 2006; Roy et al. 2009; Epstein et al. 2013; Patel et al. 2018). The biological mechanisms regarding how parity influences birth weight has not not clearly understood (Shah 2010). It has been hypothesised that the first pregnancy primes the body and led each subsequent pregnancy to be more efficient (Khong et al. 2003). A lower birth weight in nulliparous may be a direct consequence of multiple health factors, such as the overall health, higher rate of smoking before/during pregnancy, low gestational weight gain, higher age, low pre-pregnancy weight, chronic hypertension, and placental vascular disorder (Ego et al. 2008). In contrast, the increase in the incidence of LBW among grand multiparous (Mesleh 1986; Ozumba et al. 1992; Seidman et al. 1991), could be due to chronic hypertension (Alsibai et al. 1987), loss of elasticity and hyalinisation of blood vessels for uterine rupture (Nelson et al. 2013), uterine atony for post-partum hemorrhage (Israel et al. 1965), atrophy of the endometrium for placenta previa (Evaldson 1990), hyperlordosis, and placenta previa for fetal malpositioning (Tanbo et al. 1987).

Pre-pregnancy weight

Pre-pregnancy weight and BMI are closely linked to pregnancy outcomes. The weight is influenced by both genetic and environmental factors (Kramer 1987). Theoretically, genetic factors determine body weight by controlling adiposity or influencing body mass among infants (O'Rahilly et al. 2006). However, even in the absence of such genetic influences, maternal weight or BMI prior to conception replicates the nutritional reserves that are available for intrauterine growth of the fetus (Kramer 1987). The large meta-analysis of 111,000 births worldwide demonstrated that pre-pregnancy weight has the highest odds ratio for detecting LBW (OR:2.3, 95% CI:2.1–2.5) (Kelly et al. 1996). Young et al. (2015) (Young et al. 2015) showed that one standard deviation increase in pre-pregnancy weight independently associated with 250 grams increase in infant birth weight, which also led to approximately 10% reduction in the risk of delivering LBW infant. Studies conducted in India have shown similar associations in

which weight lower than 45 kgs and BMI lower than 20kg/m^2 increases the risk for LBW (Hirve et al. 1994; Ganesh Kumar et al. 2010; Singh et al. 2009; Deshpande Jayant et al. 2011).

Maternal stature

Maternal stature has been argued to predispose the neonate to LBW and preterm birth (Chan et al. 2009). Studies have also reported that short maternal stature is associated with LBW (Britto et al. 2013; Inoue et al. 2016). Studies conducted in India have shown similar associations (Deshmukh et al. 1998; Malik et al. 1997; Jha et al. 2009; Sen et al. 2009; Kumar et al. 2010; Mumbare et al. 2012; Deshpande Jayant et al. 2011; Kader et al. 2014; Mathew et al. 2014; Tellapragada et al. 2016; Shivakumar et al. 2018). A WHO collaborative study (1995) (Kelly et al. 1996) showed that a maternal height cut off range of 146–157 cm (OR:1.7, 95% CI:1.6–1.8) is associated with a higher risk for LBW. Higher risk of LBW among shorter mothers can be related to a narrow pelvis, which results in limited space, consequently led to intrauterine growth restriction (IUGR) (Zhang et al. 2007). On the other hand, a study reported a significant association between taller women with cut off ≥170 cm and LBW (Kheirouri et al. 2017). There can be other factors, such as paternal height or other paternal characteristics, that could play an important role in influencing the neonatal size (Veena et al. 2004).

Maternal BMI

For many decades BMI of mothers has been used as an epidemiological factor predictive of fetal growth (Kramer 1987). A low BMI indicates chronic energy depletion and has been used as an important parameter for assessing nutritional risk in women during the reproductive years (Wynn et al. 1991). It also indicates a wasting of both fat and lean tissue (Allen et al. 1994). Some large epidemiological studies showed that the maternal BMI for gestational age is associated with LBW (Kelly et al. 1996; Brewster et al. 2015). In the same vein, two meta-analyses reported that low BMI among mothers increases the risk of having an LBW infant (Han et al. 2011; Vats et al. 2021) while Indian studies have also shown a similar trend of low maternal BMI (<18.5kg/m2) (Amin et al. 1993; Dharmalingam et al. 2010; Sreeramareddy et al. 2011; Chakraborty et al. 2011; Kader et al. 2014; Raje et al. 2015; Patel et al. 2018). Interestingly, the above-described trend is evenly distributed all over India (i.e., 13 out of 17 states), showing that mothers with low maternal pregnancy BMI are at approximately 30% higher risk of giving birth to a LBW infant with a substantial variation between the states. This variation could be due to the interaction between the proximate factors, such as human development index, antenatal visits, and maternal anaemia (Dharmalingam et al. 2010).

Obstetric history

Antecedences of abortion, both induced abortion and miscarriages, have been associated with LBW (Kramer 1987). Some studies have shown that among women with a history of previous miscarriage and induced abortion the risk of LBW is increased more than fourfold (Anand et al. 2000; Negi et al. 2006). However, most of the Indian studies did not differentiate between induced abortion and miscarriages and the biological mechanisms of these two factors regarding their influence on LBW might be different. In

induced abortions, for instance, cervical insufficiency from dilation and curettage and uterine adhesions result from a post-abortion complication (Hooker et al. 2016). On the other hand, the cervical incompetence has been found to be a major predictor of miscarriages, along with genetic, immunological and uterine abnormalities (Jeve et al. 2014).

A history of LBW in previous pregnancy increases the risk of LBW in the current pregnancy, and this risk continues even after controlling for the socio-demographic and obstetric factors (Anand et al. 2000; Idris et al. 2000; Negi et al. 2006; Roy et al. 2009; Singh et al. 2009; Deshpande Jayant et al. 2011; Metgud et al. 2012; Khattar et al. 2013).

Medical risk during the current pregnancy

Maternal anaemia

Anaemia during pregnancy is a major public health concern that affects almost two-third of pregnant women in developing countries and contributes to maternal morbidity and LBW infant (Figueiredo et al. 2018). A large cohort study from China showed that the risk of anaemia increases more than twofold from 13th week to 32nd week of pregnancy (Zhang et al. 2009). According to NFHS-4 statistics (IIPS and ICF 2017), the prevalence of anaemia was estimated to be 50.3% in India. Anaemia during pregnancy is a well-known and established physiological fact. The haemoglobin (Hb) and haematocrit concentration typically decreases during the first 13 weeks and reach the lowest level at the end of 28th week of pregnancy, and increases again during the third trimester (Laflamme 2010). The physiological drop in Hb and haematocrit concentration is attributed to an increase in plasma volume which, in turn, results in a decrease in blood viscosity (Carlin et al. 2008) leading to a better circulation in the placenta (Tan et al. 2013). When the Hb concentration levels were reduced to <11g/dL, changes in placental angiogenesis were observed, limiting the availability of oxygen to the fetus and consequently causing potential restriction of intrauterine growth and LBW (Stangret et al. 2017). Studies conducted in India have suggested a similar pattern showing that maternal Hb levels below 11g/dL were at increased risk of having LBW compared to healthy pregnant women (Mavalankar et al. 1992; Deshmukh et al. 1998; Idris et al. 2000; Anand et al. 2000; Dharmalingam et al. 2010; Ganesh Kumar et al. 2010; Deshpande Jayant et al. 2011; Khattar et al. 2013; Borah et al. 2016; Ahankari et al. 2017; Patel et al. 2018; Shankar et al. 2019).

Gestational weight gain

The weight of women increases during the pregnancy which, in turn, affects the inter-uterine growth (Hector et al. 2013). Weight gain during pregnancy is divided into four components 1) Increase plasma volume 2) growth of breast and uterine tissues 3) laying down the fat stores, and 4) growth of the placenta, amniotic fluid and fetus (Kramer 1987). The first three components serve as an energy source to the growing fetus, and a decline in those will result in a decrease in the overall birth weight (Kramer 1987). Thus, weight gain is a factor that affects the size of the fetus (Hector et al. 2013). In 2009, the Institute of Medicine (IOM), USA, published (Rasmussen and Yaktine 2009) the revised Gestational weight gain (GWG) guidelines that are based on pre-pregnancy ranges for underweight, normal weight,

overweight and obese women to gain 12.5–18 kg, 11.5–16 kg, 7–11.5 kg, and 5–9 kg respectively. Although these recommendations have been widely accepted (Davies et al. n.d.), they were based on parameters of American women (Kelly et al. 1996), and Asian women parameters, whose BMI classification differs for the one used in the west (WHO 2000), were not considered. Therefore, the applicability of such guidelines to Asian countries is debated [81]. In addition, there is also no such GWG recommendation available for Asian women. As there are not enough publications based on use of IOM guidelines among the Indians and other Asian women (Arora et al. 2019). However, in the absence of India specific GWG guidelines, it was observed that the weight gain of less than 5 kg increases more than six-fold chance of being LBW (Roy et al. 2009; Metgud et al. 2012; Hanumant Dandekar et al. 2014).

Short pregnancy interval

Birth spacing contributes to adverse birth outcomes (Kramer 1987). The short interval between the pregnancies increased the risk of LBW and other obstetric complications (Gibbs et al. 2012; Kozuki et al. 2013; Allis 1983). Indian studies have found a similar significant association between pregnancy interval of less than 24 months and obstetrical complication (Deshpande Jayant et al. 2011; Metgud et al. 2012). While other studies have mentioned that the increased risk of LBW when the pregnancy interval is shorter than 12 months (Negi et al. 2006; Roy et al. 2009) or 18 months (Borah et al. 2016). The biological mechanism behind this is not yet clearly understood, but it is likely that pregnancies that occur before the restoration of energy balance, maternal hormones and repletion of maternal resources can lead to health complications in subsequent pregnancies (Conde-Agudelo et al. 2012).

Hypertension during pregnancy

Hypertension during pregnancy is classified as gestational hypertension, pre-eclampsia, severe pre-eclampsia, or eclampsia (Mammaro et al. 2009). Gestational hypertension is diagnosed when the blood pressure equals to or is greater than 140/90mmHg without proteinuria after 20 weeks of gestation (Mammaro et al. 2009). Hypertension associated with the symptoms of proteinuria, seizure or both can indicate the presence of pre-eclampsia and eclampsia (Visintin et al. 2010). As per the prevailing hypothesis of the "ischemic model", hypertension decreases uteroplacental perfusion by reducing placental blood flow (van Beek et al. 1997) which, in turn, results in the decreased fetal growth with an increased risk of pre-term birth and LBW (Misra 1996). Studies in India also showed a significant association between increased risks of LBW with pregnancy induced hypertension (Metgud et al. 2012; Deshpande Jayant et al. 2011) or Pre-eclampsia and Eclampsia (Idris et al. 2000; Singh et al. 2009).

Infection

Bacterial, viral and parasite infections experienced during pregnancy can affect placental development and function, which can lead to IUGR (Adams Waldorf et al. 2013). Infections, such as Treponema pallidum (syphilis) (De Santis et al. 2012), HIV (Xiao et al. 2015), Plasmodium falciparum or Plasmodium vivax (Rijken et al. 2012), Trypanosoma cruzi (Chagas') (Cevallos et al. 2014) have been shown to be associated with LBW. In contrast, only two Indian studies

that have covered a very broad spectrum for infections have been reported (Tellapragada et al. 2016; Idris et al. 2000) and there has been a paucity of studies related to infections during pregnancy in India to support the above-mentioned associations with various pathogens.

Other widely reported infection in pregnancy, also in India, has been a periodontal infection that also has been regarded as a potential risk factor for LBW (Offenbacher et al. 1996) (Deshpande Jayant et al. 2011; Mathew et al. 2014; Basha et al. 2015; Tellapragada et al. 2016).

Antepartum haemorrhage

Antepartum haemorrhage (APH) is a bleeding from or into the genital tract, usually occurring from 24th week of pregnancy onwards and prior to the birth of the fetus (WHO 2011). It is an important predictor of pregnancy outcomes (Bener et al. 2012). It has been estimated that 70% of women who bleed in the last half of the pregnancy have an equal chance of exhibiting either placenta previa , or abruption placentae while in the remaining 30% five out of six cases is unexplained due to indeterminate site of bleeding and one out of six cases is caused by extra placental factors (Konar 2014). Several worldwide studies showed an increased risk of LBW for bleeding in the late pregnancy (Bener et al. 2012) and studies in India support (OR:3.2, $P<0.01$) the above-mentioned observation (Idris et al. 2000).

Behaviour and Environmental risks

Tobacco consumption

Tobacco smoking by women of childbearing age has long been suggested to be one of the most critical factors associated with maternal-fetal health. Tobacco consumption affects the intrauterine environment through several mechanisms (Scholl et al. 1986; Kramer 1987) of which the most commonly reported involve mediators, such as carbon monoxide and nicotine. Carbon monoxide decreases the oxygen-carrying capacity and increases carboxy-hemoglobin, which leads to less release of oxygen to the fetal tissues (Longo 1977). Nicotine, on the other hand, works as an appetite suppressant and results in a rapid increase of catecholamines consequent to uterine vasoconstriction (Quigley et al. 1979). Further, the cyanide compound present in smoke leads to mediated inferences with fetal oxidative metabolism (Andrews 1973). Large epidemiological studies have shown a significant association between tobacco consumption and LBW, even after controlling for confounding factors (Coutinho et al. 2009; Dietz et al. 2010). Similar findings have also been also reported from India (Deshmukh et al. 1998; Deshpande Jayant et al. 2011).

Active smoking directly affects maternal-child health, but studies show that passive smoking also affects maternal-child health through inhaled air pathways (Ward et al. 2007; Pogodina et al. 2009). Compered to men, females are more exposed to the ill effects of tobacco smoke due to passive smoking in their homes or outside as environmental conditions, such as overcrowding and poor ventilation at home (Khattar et al. 2013). Studies conducted in developed countries have shown an association between maternal environment tobacco smoke (ETS) exposure and LBW with increased odds from 1.0 to 2.2 (Ward et al. 2007; Pogodina et al. 2009). Most of the Indian studies also shown a stronger association between ETS exposure and LBW neonate (Gupta et al. 2004; Khattar et al. 2013; Metgud et al. 2012).

Maternal occupation

Many studies confirm a significant association between maternal occupation and LBW worldwide (Meyer et al. 2008; Casas et al. 2015). One study showed that a moderate to vigorous activity throughout pregnancy may enhance birth weight while severe activity may lead to lighter offspring (Pivarnik 1998). Choudhary et al. (2013) showed that in India daily calorie, mother occupation, and the daytime rest taken were inter-related and significantly associated with LBW. This study also reported that daily calorie was less than 2000 kcal, daytime rest of less than 1 hour and worked as labourer increases the risk of LBW (Choudhary et al. 2013). Moreover, several studies have also shown that mothers who were unemployed, farm labourers during pregnancy have a higher risk of LBW compared to employed (professional/clerical services et al. 2011; Epstein et al. 2013; Kumar et al. 2020).

Maternal psychological stress

Maternal psychological stress factors include stressful life changing events, anxiety, mental illness, abuse, and unwanted pregnancy. These factors have been shown to be associated with LBW, prematurity and IUGR (Rondó et al. 2003; Chhabra 2007; Sarkar 2008). The reason behind this may be related to the release of catecholamines or corticosteroids, which increases the vulnerability to infectious diseases (like chorioamnionitis) due to a higher degree of neuromuscular reactivity and the secretion of oxytocin. These factors might induce the placental hypotension and consequent restriction of oxygen and nutrient to the fetus, leading to growth impairment or precipitation of pre-term delivery (Omer 1986; Copper et al. 1996). Stressed women have been reported to more often smoke cigarettes or use a substance such as alcohol and caffeine (McAnarney et al. 1990). Rondo et al. (2003), in their study, observed that maternal distress was associated with LBW and prematurity and also reported an interaction between distress and smoking (Rondó et al. 2003). In India, only one study showed an association between local crime involving a harassment of women and girls with LBW (Baker et al. 2018), although no other major study has investigated this association.

Alcohol consumption

A systematic review and meta-analysis revealed that, compared to abstainers (i.e., those who consume less than 19-gram pure alcohol per day) a heavy alcohol consumption during pregnancy increases the risk of LBW, pre-term birth and small for gestational age, whereas light to moderate alcohol consumption showed no effect (although no data from Asia was included in this review (Patra et al. 2011). Another study from Asia revealed that maternal alcohol consumption of more than 1 gram per day during pregnancy was significantly associated with a risk of pre-term birth, but not with LBW and small for gestational age (Miyake et al. 2014). However, the results of this study might not be representative of all Asian countries as the study did not cover the whole of Asia. In India, no study reported the association between alcohol consumption and LBW. One reason can be its low prevalence of 5.8% in India as reported by the Gender, Alcohol, and Culture: An International Study (GENACIS) project (WHO 2005).

Health care risks

Antenatal care

Studies in developing countries have provided evidence that improvement in Antenatal Care (ANC) can significantly reduce the incidence of LBW (Mahumud et al. 2017; Zhou et al. 2019). Quality of ANC, as recommended by WHO, includes at least four standard qualities ANC visits, comprising interventions, such as tetanus toxoid vaccination, screening as well as treatment for infections and identification of warning signs during pregnancy (WHO 2016). These recommendations vary worldwide; in India, for instance, an adequate ANC was considered when the pregnant women were registered at any time during pregnancy, had at least three ANC check-ups, was adequately vaccinated against tetanus, had consumed at least 100 tablets of iron and folic acid, was not involved in hard work and had taken adequate rest during pregnancy (minimum 2 hours sleep during day and 8 hours sleep during the night) (Mumbare et al. 2012). Several studies in India have established a significant relationship between these factors and LBW (Deshpande Jayant et al. 2011; Metgud et al. 2012; Epstein et al. 2013; Choudhary et al. 2013; Negandhi et al. 2014; Mumbare et al. 2012). Other studies have reported a more significant link when registration with ANC was late (Negi et al. 2006; Singh et al. 2009) or a number of ANC visits was lower (Malik et al. 1997; Idris et al. 2000; Agarwal et al. 2005; Dharmalingam et al. 2010; Jha et al. 2009; Khattar et al. 2013; Kader et al. 2014; Mathew et al. 2014). Another study showed a lower incidence of LBW among mothers who received average quality ANC (18.5%), and good quality ANC (13.5%) (OR=1.45, 95% CI: 1.13–1.87, $p < 0.05$) (Nair et al. 2000). To summarise the above studies, adequate ANC care prevents LBW, regardless of the presence of possible confounding factors.

Evolving concepts of risks

Mid-upper arm circumference

Mid-upper arm circumference (MUAC) is a good indicator for identifying chronic energy deficiency in the body (James et al. 1994) and plays an important role in the determinant of LBW. A WHO collaborative study (1995) (Kelly et al. 1996) showed that MUAC cut-off values of <21–23 cm (OR: 1.9, 95% CI: 1.7–2.1) were at higher risk for LBW. In another study, Mohanty et al. (2006) reported MUAC of 395 pregnant women in the first trimester and found that MUAC ≤22.5 cm was the best cut off value to predict LBW (Mohanty et al. 2006). Several other studies conducted in different parts of India showed a significant association between the birth weight of neonates and MUAC. According to those studies, MUAC was the best surrogate measure for LBW (Sen et al. 2009; Shrivastava et al. 2016) as MUAC was insensitive to the changes experienced during the pregnancy (Katz et al. 2010).

Conclusions

Low birth weight has been known to cause numerous adverse effects among neonates and infants. This literature review suggests that maternal age, educational status, socio-economic status, ethnicity, parity, pre-pregnancy weight, maternal stature, maternal body mass index, obstetric history, maternal anaemia, gestational weight gain, short pregnancy outcome, hypertension during

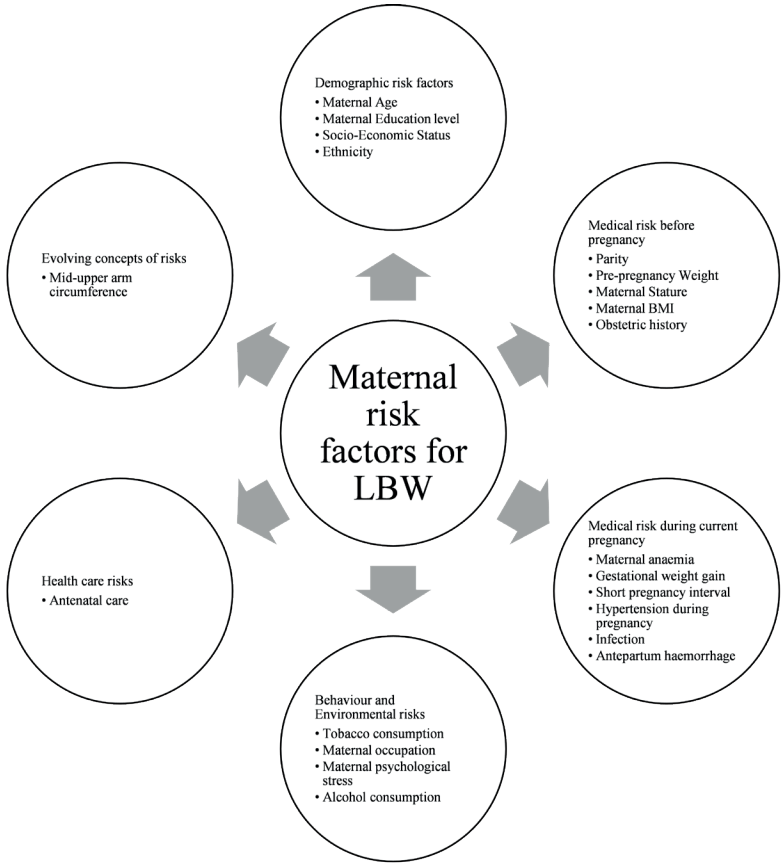

Fig. 1. Summary of Maternal risk factors for LBW in Indian population

pregnancy, infection, antepartum haemorrhage, tobacco consumption, maternal occupation, maternal psychological stress, alcohol consumption, antenatal care and mid-upper arm circumference are independently associated with term LBW in the Indian population. The awareness about the various aspect of maternal risk factors during pregnancy and understanding general pathways underlying Term LBW can be potentially very beneficial for the healthcare providers to apply the preventive measures and the necessary interventions. The prenatal screening should be started so the high-risk pregnant women will be clearly marked and given a plan for pregnancy with regular advice. A suggested summary for maternal risk factors for low birth weight is depicted in figure 1.

Conflict of interest

The authors report no conflict of interest.

Ethical approval

The manuscript is a narrative review paper and did not require any clinical trials registration.

Authors' contributions

The topic was conceived by HV, RS and VG. The literature review was performed by HV and VG who also constructed the project outline and drafted the manuscript. The figure was developed by HV. The critical review of manuscript was done by MPS, GKW, VG.

Funding

This study has been supported by Wellcome/DBT India Alliance,Hyderabad, India, Intermediate fellowship award to Vipin Gupta(grant reference: IA/CPHI/16/1/502623) and Institute of Eminence, Delhi University, India.

Corresponding author

Vipin Gupta, Department of Anthropology, University of Delhi, India; e-mail: drvipiing@gmail.com

References

Adams Waldorf KM, McAdams RM. 2013. Influence of infection during pregnancy on fetal development. Reproduction 146(5):151.

Agarwal N, Reddaiah VP. 2005. Factors affecting birth weight in a sub-urban community: A study in a secondary level hospital in Delhi. Health and Population: Perspectives and Issues 28(4):189–96.

Ahankari AS, Myles PR, Dixit J V, Tata LJ, & Fogarty AW. 2017. Risk factors for maternal anaemia and low birth weight in pregnant women living in rural India: a prospective cohort study. Pub Health 151:63–73.

Al-sibai MH, Rahman MS, Rahman J. 1987. Obstetric problems in the grand multipara: a clinical study of 1330 cases. J Obstet Gynaecol 8(2)135–8.

Alexander GR, Wingate MS, Mor J, Boulet S. 2007. Birth outcomes of Asian-Indian-Americans. Int J Obstet Gynaecol 97(3):215–20.

Allen LH, Lung'aho MS, Shaheen A, Harrison GG, Neumann C, Kirksey A. 1994. Maternal body mass index and pregnancy outcome in the Nutrition Collaborative Research Support Program. Eur J Clin Nutr 48S:68–76.

Allis PA. 1983. Low birth weight deliveries-management of the subsequent pregnancy. J Obstet Gynaecol 3(3):161–62.

Amin N, Abel R, Sampathkumar V. 1993. Maternal risk factors associated with low birth weight. Indian J Pediatr 60(2):269–74.

Anand K, Garg BS. 2000. A Study of Factors Affecting LBW. Indian J Community Med 25(2):57–61.

Andrews J. 1973. Thiocyanate and smoking in pregnancy. BJOG: An Int J Obstet Gynaecol 80(9):810–14.

International Institute for Population Sciences (IIPS) and ICF. 2017. National Family Health Survey (NFHS-4), 2015–16: India. Mumbai: IIPS.

UNICEF-WHO. 2019. UNICEF-WHO Low birthweight estimates: Levels and trends 2000–2015 | UNICEF.

Arora P, Tamber Aeri B. 2019. Gestational Weight Gain among Healthy Pregnant Women from Asia in Comparison with Institute of Medicine (IOM) Guidelines-2009: A Systematic Review. J Pregnan 2019.

Baker KK, Story WT, Walser-Kuntz E, Zimmerman MB. 2018. Impact of social capital, harassment of women and girls, and water and sanitation access on premature birth and low infant birth weight in India. PLoS ONE 13(10):1–18.

Barker D. 2004. Developmental origins of adult health and disease. J Epidemiol Community Health 58(2):114–5.

Basha S, Swamy HS, Mohamed RN. 2015. Maternal periodontitis as a possible risk factor for preterm birth and low birth weight – A prospective study. Oral Health Prev Dent 13(6):537–44.

World Haalth Organisation. 2000. The Asia-Pacific perspective : redefining obesity and its treatment.

van Beek E, Peeters LL. 1997. The pathogenesis of preeclampsia. Nederlands tijdschrift voor geneeskunde 141(28):1379–84.

Bellad M et al. 2012. Consanguinity, prematurity, birth weight and pregnancy loss: a prospective cohort study at four primary health center areas of Karnataka, India. J Perinatol 32:431–7.

Bener A, Salameh KMK, Yousafzai MT, Saleh NM. 2012. Pattern of Maternal Complications and Low Birth Weight: Associated Risk Factors among Highly Endogamous Women. ISRN Obstet Gynecol 2012:540495.

Biswas R, Dasgupta A, Sinha RN, Chaudhuri RN. 2008. An epidemiological study of low birth weight newborns in the district of Puruliya, West Bengal. Indian J. Public Health 52(2):65–71.

Blencowe H, Krasevec J, de Onis M, Black RE, Xiaoyi A, Stevens GA et al. 2019. National, regional, and worldwide estimates of low birthweight in 2015, with trends from 2000: a systematic analysis. The Lancet Global Health 7(7):e849–e60.

Borah M, Agarwalla R. 2016. Maternal and socio-demographic determinants of low birth weight (LBW): A community-based study in a rural block of Assam. J Postgrad Med 62(3):178–81.

Branum AM, Schoendorf KC. 2002. Changing patterns of low birthweight and preterm birth in the United States, 1981–98. Paediatr Perinat Epidemiol 16(1):8–15.

Brewster AJ, Hardock V, Bhattacharya S. 2015. Exploring the relationship between maternal body mass index and offspring birth weight: Analysis of routinely collected data from 1967 to 2010 in Aberdeen, Scotland. J Obstet Gynaecol 35(8):810–6.

Britto RPDA et al. 2013. Influence of maternal height and weight on low birth weight: A cross-sectional study in poor communities of northeastern Brazil. PLoS ONE 8(11): e80159.

Carlin A, Alfirevic Z. 2008. Physiological changes of pregnancy and monitoring. Best Pract Res Clin Obstet Gynaecol 22(5):801–23.

Casas M, Cordier S, Martinez D, Barros H, Bonde JP, Burdorf A, et al. 2015. Maternal occupation during pregnancy, birth weight, and length of gestation: combined analysis of 13 European birth cohorts. Scand J Work Environ Health 41(4):384–96.

Cevallos AM, Hernández R. 2014. Chagas' disease: Pregnancy and congenital transmission. Biomed Res Int 2014:401864.

Chakraborty P, Anderson AK. 2011. Maternal autonomy and low birth weight in India. J Womens Health 20(9):1373–82.

Chan BCP, & Lao TTH. 2009. The impact of maternal height on intrapartum operative delivery: A reappraisal. J Obstet Gynaecol Res 35(2):307–14.

Chen X-K, Wen SW, Fleming N, Demissie K, Rhoads GG, Walker M. 2007. Teenage pregnancy and adverse birth outcomes: a large population based retrospective cohort study. Int J Epidemiol 36(2):368–73.

Chhabra P, Sharma AK, Grover VL, Aggarwal OP. 2004. Prevalence of low birth weight and its determinants in an urban resettlement area of Delhi. Asia Pac J Public Health 16(2):95–8.

Chhabra S. 2007. Physical violence during pregnancy. J Obstet Gynaecol 27(5):460–3.

Choudhary AK, Choudhary A, Tiwari SC, Dwivedi R. 2013. Factors associated with low birth weight among newborns in an urban slum community in Bhopal. Indian J Public Health 57(1):20–3.

Cnattingius S, Forman MR, Berendes HW, Isotalo L. 1992. Delayed Childbearing and Risk of Adverse Perinatal Outcome: A Population-Based Study. JAMA 268(7):886–90.

Conde-Agudelo A, Rosas-Bermudez A, Castaño F, Norton MH. 2012. Effects of Birth Spacing on Maternal, Perinatal, Infant, and Child Health: A Systematic Review of Causal Mechanisms. Stud Fam Plann 43(2):93–114.

Copper RL, Goldenberg RL, Das A, Elder N, Swain M, Norman G, et al. 1996. The preterm prediction study: maternal stress is associated with spontaneous preterm birth at less than thirty-five weeks' gestation. National Institute of Child Health and Human Development Maternal-Fetal Medicine Units Network. Am J Obstet Gynecol 175(5):1286–92.

Coutinho PR, Cecatti JG, Surita FG., de Souza JP, de Morais SS. 2009. Fatores associados a baixo peso ao nascer em uma série histórica de partos em Campinas, Brazil. Revista da Associacao Medica Brasileira 55(6):692–9.

Davies G, Maxwell C, McLeod L, Gagnon R, Basso M, Bos H, et al. 2010. SOGC Clinical Practice Guidelines: Obesity in pregnancy. No. 239, February 2010. Int J Gynaecol Obstet 110(2):167–73.

Deshmukh JS, Motghare DD, Zodpey SP, Wadhva SK. 1998. Low birth weight and associated maternal factors in an urban area. Indian Pediatrics 35(1):33–6.

Deshpande Jayant D, Phalke DB, Bangal VB, D Peeyuusha BS. 2011. Maternal Risk Factors for Low Birth Weight Neonates : a Hospital Based Case-Control Study in Rural Area of Western Maharashtra. Indian J Community Med 2(3):394–8.

Dharmalingam A, Navaneetham K, Krishnakumar CS. 2010. Nutritional status of mothers and low birth weight in India. Matern Child Health J 14(2):290–8.

Dietz PM, England LJ, Shapiro-Mendoza CK, Tong VT, Farr SL, Callagham WM. 2010. Infant morbidity and mortality attributable to prenatal smoking in the U.S. Am J Prev Med 39(1):45–52.

Ego A, Subtil D, Grange G, Thiebaugeorges O, Senat M-V, Vayssiere C, Zeitlin J. 2008. Should parity be included in customised fetal weight standards for identifying small-for-gestational-age babies? Results from a French multicentre study. BJOG 115(10):1256–64.

Epstein MB, Bates MN, Arora NK, Balakrishnan K, Jack DW, Smith KR. 2013. Household fuels, low birth weight, and neonatal death in India: The separate impacts of biomass, kerosene, and coal. Int J Hyg Environ Health 216(5):523–32.

Erekia Ebrahim TS. 2015. Proportion of Neonatal Hypothermia and Associated Factors among New-borns at Gondar University Teaching and Refferal Hospital, Northwest Ethiopia: A Hospital Based Cross Sectional Study. General Medicine 3(04):1–7.

Evaldson GR. 1990. The grand multipara in modern obstetrics. Gynecol Obstet Investig 30(4):17–23.

Figueiredo ACMG, Gomes-Filho IS, Silva RB, Pereira PSP, Da Mata FAF, Lyrio AO, Souza ES et al. 2018. Maternal anemia and low birth weight: A systematic review and meta-analysis. Nutrients 10(5):601.

Fraser AM, Brockert JE, Ward RH. 1995. Association of Young Maternal Age with Adverse Reproductive Outcomes. N Engl J Med 332(17):1113–8.

Ganesh Kumar S, Harsha Kumar HN, Jayaram S, Kotian MS. 2010. Determinants of low birth weight: A case control study in a district hospital in Karnataka. Indian J Pediatr 77(1):87–9.

Gibbs CM, Wendt A, Peters S, Hogue CJ. 2012. The impact of early age at first

childbirth on maternal and infant health. Paediatr Perinat Epidemiol 26S:259–84.

Goisis A, Remes H, Barclay K, Martikainen P, Myrskylä M. 2017. Advanced Maternal Age and the Risk of Low Birth Weight and Preterm Delivery: a Within-Family Analysis Using Finnish Population Registers. Am j Epidemiol 186(11):1219–26.

Gupta PC, Sreevidya S. 2004. Smokeless tobacco use, birth weight, and gestational age: Population based, prospective cohort study of 1217 women in Mumbai, India. BMJ 328(7455):1538–40.

Han Z, Mulla S, Beyene J, Liao G, McDonald SD. 2011. Maternal underweight and the risk of preterm birth and low birth weight: A systematic review and meta-analyses. Int J Epidemiol 40(1):65–101.

Hanumant Dandekar R, Shafee M, Sinha SP. 2014. Prevalence and risk factors affecting low birth weight in a district hospital at Perambalur, Tamilnadu. Int J Community Med Public Health 3(2).

Hector D, Hebden L. 2013. Prevention of excessive gestational weight gain: An evidence review to inform policy and practice.

Hirano D, Ishikura K, Uemura O, Ito S, Wada N, Hattori M, Ohashi Y, Hamasaki Y, Tanaka R, Nakanishi K, Kaneko T, Honda M; Pediatric CKD Study Group in Japan in conjunction with the Committee of Measures for Pediatric CKD of the Japanese Society of Pediatric Nephrology. 2016. Association between low birth weight and childhood-onset chronic kidney disease in Japan: a combined analysis of a nationwide survey for paediatric chronic kidney disease and the National Vital Statistics Report. Nephrol Dial Transplant 31(11):1895–1900.

Hirve SS, Ganatra BR. 1994. Determinants of low birth weight: a community based prospective cohort study. Indian pediatr 31(10):1221–1225.

Hooker A, Fraenk D, Brölmann H, Huirne J. 2016. Prevalence of intrauterine adhesions after termination of pregnancy: a systematic review. Eur J Contracept Reprod Health Care 21(4):329–335.

Idris MZ, Gupta A, Mohan U, Srivastava AK, Das V. 2000. Maternal Health and Low Birth Weight Among Institutional Deliveries. Indian J Community Med XXV(4):156–160.

Igwegbe AO, Udigwe GO. 2001. Teenage pregnancy: Still an obstetric risk. J Obstet Gynaecol 21(5):478–481.

Inoue S, Naruse H, Yorifuji T, Kato T, Murakoshi T, Doi H, Subramanian SV. 2016. Association between Short Maternal Height and Low Birth Weight: a Hospital-based Study in Japan. J Korean Med Sci. 31(3):353–9.

Institute of Medicine. 1985. Preventing Low Birthweight. Washington, DC: The National Academies Press.

James SA. 1993. Racial and ethnic differences in infant mortality and low birth weight. A psychosocial critique. Ann Epidemiol 3(2):130–136.

James WP, Mascie-Taylor GC, Norgan NG, Bistrian BR, Shetty PS, Ferro-Luzzi A. 1994. The value of arm circumference measurements in assessing chronic energy deficiency in Third World adults. Eur J Clin Nutr 48(12):883–94.

Jeve YB, Davies W. 2014. Evidence-based management of recurrent miscarriages. J Hum Reprod Sci 7(3):159–169.

Jha SK, Misra CP, Hussain MA. 2009. Determinants of low birth weight: findings from a community based study in a rural area of Varanasi. Indian J Community Health 21(1):18–22.

Joshi HS, Subba SH, Dabral1 SB, Dwivedi S, Kumar D, Singh S. 2005. Risk Factors Associated with Low Birth Weight in Newborns. Indian J Community Med 30(4):142–143.

Kader M. Perera NKP. 2014. Socio-economic and nutritional determinants of low birth weight in India. N Am J Med Sci 6(7):302–308.

Katz J, Khatry SK, LeClerq SC, West KP, Christian P. 2010. The post-partum mid-upper arm circumference of adolescents is reduced by pregnancy in rural Nepal. Matern Child Nutr 6(3):287–295.

Kelly A, Kevany J, De Onis M, Shah PM. 1996. A WHO Collaborative Study of Maternal Anthropometry and Pregnancy Outcomes. Int J Gynaecol Obstet 53(3):219–233.

Khattar D, Awasthi S, Das V. 2013. Residential environmental tobacco smoke exposure during pregnancy and low birth weight of neonates: Case control study in a public hospital in Lucknow, India. Indian Pediatr 50(1):134–138.

Kheirouri S, Alizadeh M. 2017. Impact of prenatal maternal factors and birth order on the anthropometric status of newborns in Iran. J Biosoc Sci 49(2):251–264.

Khong TY, Adema ED, Erwich JJHM. 2003. On an anatomical basis for the increase in birth weight in second and subsequent born children. Placenta 24(4):348–353.

Konar H. 2014. DC Dutta's Textbook of Obstetrics. Jaypee Brothers Medical Publishers Pvt. Limited.

Kozuki N, Lee AC, Silveira MF, Victora CG, Adair L, Humphrey J, Ntozini R, Black RE, Katz J; Child Health Epidemiology Reference Group Small-for-Gestational-Age-Preterm Birth Working Group. The associations of birth intervals with small-for-gestational-age, preterm, and neonatal and infant mortality: a meta-analysis. BMC Public Health. 2013;13 Suppl 3(Suppl 3):S3.

Kramer MS. 1987. Determinants of low birth weight: Methodological assessment and meta-analysis. Bull. World Health Organ 65(5):663–737.

Kuhle S, Maguire B, Ata N, MacInnis N, Dodds L. 2017. Birth Weight for Gestational Age, Anthropometric Measures, and Cardiovascular Disease Markers in Children. J Pediatr 182:99–106.

Kumar A, Chaudhary K, Prasad S. 2010. Maternal indicators and obstetric outcome in the north Indian population: A hospital-based study. J Postgrad Med 56(3):192–195.

Kumar SN, Raisuddin S, Singh KJ, Bastia B, Borgohain D, Teron L, Sharma SK, Jain AK. 2020. Association of maternal determinants with low birth weight babies in tea garden workers of Assam. J Obstet Gynaecol Res 46(5):715–726.

Laflamme EM. 2010. Maternal hemoglobin concentration and pregnancy outcome: A study of the effects of elevation in EL alto, Bolivia. Mcgill J Med 13(1):47–55.

Long H, Yi JM, Hu PL, Li ZB, Qiu WY, Wang F, Zhu S. 2012. Benefits of iron supplementation for low birth weight infants: a systematic review. BMC Pediatr 16;12:99.

Longo LD. 1977. The biological effects of carbon monoxide on the pregnant woman, fetus, and newborn infant. AJOG 129(1):69–103.

Mahumud RA, Sultana M, Sarker AR. 2017. Distribution and determinants of low birth weight in developing countries. JPMPH 50(1):18–28.

Majumder PP. 1998. People of India: Biological diversity and affinities. Evol Anthropol 6(3):100–110.

Malik S, Ghidiyal RG, Udani R, Waingankar P. 1997. Maternal Biosocial Factors Affecting Low Birth Weight. Indian J. Pediatr 64(3):373–377.

Mammaro A, Carrara S, Cavaliere A, Ermito S, Dinatale A, Pappalardo EM, Militello M, Pedata R. 2009. Hypertensive disorders of pregnancy. J Prenat Med 3(1):1–5.

Mathew RJ, Bose A, Prasad JH, Muliyil JP, Singh D. 2014. Maternal periodontal

disease as a significant risk factor for low birth weight in pregnant women attending a secondary care hospital in South India: A Case-control study. Indian J Dent Res 25(6):742–747.

Mavalankar DV, Gray RH, Trivedi CR. 1992. Risk factors for preterm and term low birthweight in Ahmedabad, India. Int J Epidemiol 21(2):263–272.

Mayor S. 2016. Low birth weight is associated with increased deaths in infancy and adolescence, shows study. BMJ 353:i2682.

McAnarney ER, Stevens-Simon C. 1990. Maternal Psychological Stress/Depression and Low Birth Weight: Is There a Relationship? Am J Dis Child 144(7):789–792.

McCormick MC. 1985. The Contribution of Low Birth Weight to Infant Mortality and Childhood Morbidity. N Engl J Med 312(2):82–90.

Mesleh R. 1986. The grand multipara-still an obstetric problem. J Obstet Gynaecol 7(2):84–87.

Metgud CS, Naik VA, Mallapur MD. 2012. Factors affecting birth weight of a newborn – a community based study in rural Karnataka, India. PLoS ONE 7(7).

Meyer JD, Nichols GH, Warren N, Reisine S. 2008. Maternal occupation and risk for low birth weight delivery: assessment using state birth registry data. J Occup Environ Med 50(3):306–15.

Misra DP. 1996. The effect of the pregnancy-induced hypertension on fetal growth: a review of the literature. Paediatr Perinat Epidemiol 10(3):244–63.

Miyake Y, Tanaka K, Okubo H, Sasaki S, Arakawa M. 2014. Alcohol consumption during pregnancy and birth outcomes: The Kyushu Okinawa Maternal and Child Health Study. BMC Pregnancy Childbirth 14(79).

Mohanty C, Prasad R, Srikanth Reddy A, Ghosh JK, Singh TB, Das BK. 2006. Maternal anthropometry as predictors of low birth weight. J Trop Pediatr 52(1):24–9.

Mondal B. 2000. Risk factors for low birth weight in Nepali infants. Indian J Pediatr 67(7):477–482.

Mumbare SS, Maindarkar G, Darade R, Yenge S, Tolani MK, Patole K. 2012. Maternal risk factors associated with term low birth weight neonates: a matched-pair case control study. Indian Pediatr 49(1):25–8.

Nair S, Rao RSP, Chandrashekar S, Acharya D, Bhat HV. 2000. Socio-demographic and maternal determinants of low birth weight: A multivariate approach. Indian J Pediatr 67(1):9–14.

Negandhi PH, Negandhi HN., Zodpey SP, Ughade SN, Biranjan JR. 2014. Risk factors for low birth weight in an Indian urban setting: A nested case control study. Asia Pac J Public Health 26(5):461–469.

Negi KS, Kandpal SD, Kukreti M. 2006. Epidemiological factors affecting low birth weight. JK Science 8(1):31–34.

Nelson SM, Telfer EE, Anderson RA. 2013. The ageing ovary and uterus: New biological insights. Human Reproduction Update 19(1):67–83.

Newton KP, Feldman HS, Chambers CD, Wilson L, Behling C, Clark JM, Molleston JP, Chalasani N, Sanyal AJ, Fishbein MH, Lavine JE, Schwimmer JB; Nonalcoholic Steatohepatitis Clinical Research Network (NASH CRN). 2017. Low and High Birth Weights Are Risk Factors for Nonalcoholic Fatty Liver Disease in Children. J Pediatr 187:141–146.e1.

O'Rahilly S, Farooqi IS. 2006. Genetics of obesity. Philosophical Transactions of the Royal Society B: Biol Sci 361(1471):1095–1105.

Offenbacher S, Katz V, Fertik G, Collins J, Boyd D, Maynor G, McKaig R, Beck J. 1996. Periodontal infection as a possible risk factor for preterm low birth weight. J Periodontol 67(10 Suppl):1103–13.

Omer H. 1986. Possible psychophysiologic mechanisms in premature labor. Psychosomatics 27(8):580–4.

Ozumba BC, Igwegbe AO. 1992. The challenge of grandmultiparity in Nigerian obstetric practice. J Obstet Gynaecol 37(4):259–264.

Patel A, Prakash AA, Das PK, Gupta S, Pusdekar YV, Hibberd PL. 2018. Maternal anemia and underweight as determinants of pregnancy outcomes: cohort study in eastern rural Maharashtra, India. BMJ Open 8:e021623

Patra J, Bakker R, Irving H, Jaddoe VW, Malini S, Rehm J. 2011. Dose-response relationship between alcohol consumption before and during pregnancy and the risks of low birthweight, preterm birth and small for gestational age (SGA)-a systematic review and meta-analyses. BJOG 118(12):1411–21.

Pivarnik JM. 1998. Potential effects of maternal physical activity on birth weight: Brief review. Med Sci Sports Exerc 30(3):400–406.

Pogodina C, Brunner Huber LR, Racine EF, Platonova E. 2009. Smoke-free homes for smoke-free babies: The role of residential environmental tobacco smoke on low birth weight. J Community Health 34(5):376–382.

Quigley ME, Sheehan KL., Wilkes MM, Yen SSC. 1979. Effects of maternal smoking on circulating catecholamine levels and fetal heart rates. J Obstet Gynaecol 133(6):685–690.

Radhakrishnan T, Thankappan KR, Vasan RS, Sarma PS. 2000. Socioeconomic and demographic factors associated with birth weight: a community based study in Kerala. Indian pediatr 37(8):872–6.

Raje S, Rao S. 2015. Maternal Food Consumption Patterns and Risk of Low Birth Weight in Rural Maharashtra. Indian J Nutr Diet 52(2):153–165.

Rao S, Gokhale M, Joshi S, Kanade A. 2010. Early life undernutrition and adolescent pregnancy outcome in rural India. Ann Hum Biol 37(4):475–87.

Rasmussen KM, Yaktine AL editors. 2009. Weight Gain During Pregnancy: Reexamining the Guidelines. Washington (DC): National Academies Press (US).

Resnik R. 2002. Intrauterine growth restriction. J Obstet Gynecol 99(3):490–496.

Rijken MJ, McGready R, Boel ME, Poespoprodjo R, Singh N, Syafruddin D, Rogerson S, Nosten F. 2012. Malaria in pregnancy in the Asia-Pacific region. Lancet Infect Dis 12(1):75–88.

Rondó PH, Ferreira RF, Nogueira F, Ribeiro MC, Lobert H, Artes R. 2003. Maternal psychological stress and distress as predictors of low birth weight, prematurity and intrauterine growth retardation. Eur J Clin Nutr 57(2):266–72.

Roy S, Motghare DD, Ferreira AM, Vas FS, Kulkarni MS. 2009. Maternal determinants of low birth weight at a tertiary care. J Fam Welf 55(1):79–83.

Saili A. 2008. Essential care of low birth weight neonates. Indian pediatr 45(1):13–5.

Sallout B, Walker M. 2003. The fetal origin of adult diseases. J Obstet Gynaecol 23(5):555–560.

De Santis M, De Luca C, Mappa I, Spagnuolo T, Licameli A, Straface G, Scambia G. 2012. Syphilis Infection during pregnancy: fetal risks and clinical management. Infect Dis Obstet Gynecol 2012:430585.

Sarkar NN. 2008. The impact of intimate partner violence on women's reproductive health and pregnancy outcome. J Obstet Gynaecol 28(3):266–271.

Scholl TO, Salmon W, Miller LK. 1986. Smoking and adolescent pregnancy outcome. J Adolesc Health Care 7(6):390–4.

Seidman DS., Dollberg S, Stevenson DK, Gale R. 1991. The effects of high parity and socioeconomic status on obstetric and neonatal outcome. Arch Gynecol Obstet 249(3):119–127.

Sen J, Roy A, Mondal N. 2009. Association of maternal nutritional status, body

composition and socio-economic variables with low birth weight in India. J Trop Pediatr 56(4):254–259.

Seth R, Bose V, Qaiyum Y, Chandrashekhar R, Kansal S, Taneja I, Seth T. 2018. Social Determinants of Child Marriage in Rural India. Ochsner J 18(4):390–394.

Shah PS. 2010. Parity and low birth weight and preterm birth: A systematic review and meta-analyses. Acta Obstet Gynecol Scand 89(7):862–875.

Shan D, Qiu PY, Wu YX, Chen Q, Li AL, Ramadoss S, Wang RR, Hu YY. 2018. Pregnancy Outcomes in Women of Advanced Maternal Age: a Retrospective Cohort Study from China. Sci Rep 16;8(1):12239.

Shankar H, Kumar N, Sandhir R, Singh MP, Mittal S, Adhikari T, Tarique M, Kaur P, Radhika MS, Kumar A, Rao DN. 2019. Association of dietary intake below recommendations and micronutrient deficiencies during pregnancy and low birthweight. J Perinat Med 25;47(7):724–731.

Sheen JJ, Wright JD, Goffman D, Kern-Goldberger AR, Booker W, Siddiq Z, D'Alton ME, Friedman AM. 2018. Maternal age and risk for adverse outcomes. Am J Obstet Gynecol 219(4):390.e1-390.e15.

Shivakumar N, Dwarkanath P, Bosch R, Duggan C, Kurpad AV, Thomas T. 2018. Influence of gestational weight gain on low birth weight in short-statured South Indian pregnant women. Eur J Clin Nutr 72(5):752–760.

Shrivastava J, Agrawal A, Giri A. 2016. Maternal anthropometry in relation to birth weight of newborn: A prospective hospital based study. Indian J Child Health 03(01):59–63.

Singh G, Chouhan R, Sidhu K. 2009. Maternal factors for low birth weight babies. Med J. Armed Forces India 65(1):10–12.

Sreeramareddy CT., Shidhaye RR, Sathiakumar N. 2011. Association between biomass fuel use and maternal report of child size at birth – An analysis of 2005-06 India Demographic Health Survey data. BMC Public Health 11(1):1–10.

Stangret A, Skoda M, Wnuk A, Pyzlak M, Szukiewicz D. 2017. Mild anemia during pregnancy upregulates placental vascularity development. Med Hypotheses 102:37–40.

Subramanyam MA, Ackerson LK, Subramanian SV. 2010. Patterning in birthweight in India: Analysis of maternal recall and health card data. PLoS ONE 5(7):p.e11424.

Tabcharoen C, Pinjaroen S, Suwanrath C, Krisanapan O. 2009. Pregnancy outcome after age 40 and risk of low birth weight. J Obstet Gynecol 29(5):378–383.

Tan EK, Tan EL. 2013. Alterations in physiology and anatomy during pregnancy. Best Pract Res Clin Obstet Gynaecol 27(6):791–802.

Tanbo TG, Bungum L. 1987. The grand multipara-maternal and neonatal complications. Acta Obstet Gynecol Scand 66(1):53–6.

Tellapragada C, Eshwara VK, Bhat P, Acharya S, Kamath A, Bhat S, Rao C, Nayak S, Mukhopadhyay C. 2016. Risk Factors for Preterm Birth and Low Birth Weight Among Pregnant Indian Women: A Hospital-based Prospective Study. J Prev Med Public Health 49(3):165–75.

Vats H, Saxena R, Sachdeva MP, Walia GK, Gupta V. 2021. Impact of maternal pre-pregnancy body mass index on maternal, fetal and neonatal adverse outcomes in the worldwide populations: A systematic review and meta-analysis. Obes Res Clin Pract 15(6):536–545.

Veena SR, Kumaran K, Swarnagowri MN, Jayakumar MN, Leary SD, Stein CE, Cox VA, Fall CH. 2004. Intergenerational effects on size at birth in South India. Paediatr Perinat Epidemiol 18(5):361–70.

Velankar DH. 2009. Maternal Factors Contributing to Low Birth Weight Babies in an Urban Slum Community of Greater Mumbai. Bombay Hosp J 51(1):26–35.

Visentin S, Grumolato F, Nardelli GB, Di Camillo B, Grisan E, Cosmi E. 2014. Early origins of adult disease: low birth weight and vascular remodeling. Atherosclerosis 237(2):391–9.

Visintin C, Mugglestone MA, Almerie MQ, Nherera LM, James D, Walkinshaw S; Guideline Development Group. 2010. Management of hypertensive disorders during pregnancy: summary of NICE guidance. BMJ 25;341:c2207.

Ward C, Lewis S, Coleman T. 2007. Prevalence of maternal smoking and environmental tobacco smoke exposure during pregnancy and impact on birth weight: retrospective study using Millennium Cohort. BMC Public Health 16,7:81.

Wjst M, Popescu M, Trepka MJ, Heinrich J, Wichmann HE. 1998. Pulmonary function in children with initial low birth weight. Pediatr Allergy Immunol 9(2):80–90.

Wollmann HA. 1998. Intrauterine growth restriction: Definition and etiology. Horm Res 49(2 SUPPL.)1–6.

World Health Organisation. 2004. ICD-10 : international statistical classification of diseases and related health problems : tenth revision. 2nd ed. World Health Organisation.

World Health Organization. 2005. Alcohol, gender and drinking problems in low and middle income countries. World Health Organization.

World Health Organisation. 2011. Antepartum Haemorrhage Green-top Guideline No. 63.

World Health Organisation. 2016. Recommendations on antenatal care for a positive pregnancy experience.

Wynn AHA, Crawford MA, Doyle W, Wynn SW. 1991. Nutrition of Women in Anticipation of Pregnancy. Nutr Health 7(2):69–88.

Xiao PL, Zhou YB, Chen Y, Yang MX, Song XX, Shi Y, Jiang QW. 2015. Association between maternal HIV infection and low birth weight and prematurity: a meta-analysis of cohort studies. BMC Pregnancy Childbirth 8;15:246.

Young MF, Nguyen PH, Addo OY, Hao W, Nguyen H, Pham H, Martorell R, Ramakrishnan U. 2015. The relative influence of maternal nutritional status before and during pregnancy on birth outcomes in Vietnam. Eur J Obstet Gynecol Reprod Biol 194:223–7.

Zhang Q, Li Z, Ananth CV. 2009. Prevalence and risk factors for anaemia in pregnant women: A population-based prospective cohort study in China. Paediatr Perinat Epidemiol 23(4):282–291.

Zhang X, Platt RW, Cnattingius S, Joseph KS, Kramer MS. 2007. The use of customised versus population-based birthweight standards in predicting perinatal mortality. BJOG: Int. J. Obstet. Gynaecol 114(4):474–477.

Zhou Y, Li H, Zhang Y, Zhang L, Liu J, Liu J. 2019. Association of Maternal Obesity in Early Pregnancy with Adverse Pregnancy Outcomes: A Chinese Prospective Cohort Analysis. Obesity (Silver Spring) 27(6):1030–1036.

Anthropological Review • Vol. 85(4), 83–94 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.4.06

Level of oxytocin prior to rugby and handball matches: An exploratory study among groups of Polish players

Marek Kociuba[1], Zofia Ignasiak[2], Andrzej Rokita[2], Ireneusz Cichy[2], Andrzej Dudkowski[2], Marcin Ściślak[2], Katarzyna Kochan[2], Anna Sebastjan[2], Anna Spinek[3], Daria Lorek[4], Barry Bogin[5], Raja Chakraborty[6], Sławomir Kozieł[3]

[1] Department of Physical Education, Military University of Technology, Warsaw, Poland
[2] Faculty of Physical Education, University School of Physical Education in Wroclaw, Wroclaw, Poland
[3] Department of Anthropology, Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, Wroclaw, Poland
[4] Laboratory of Reproductive Immunology, Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, Wroclaw, Poland
[5] School of Sport, Exercise and Health Sciences, Loughborough University, Loughborough
[6] Department of Anthropology and Tribal Studies, Sidho-Kanho-Birsha University, Purulia, West Bengal, India

Abstract: The aim of the present exploratory study was to assess the changes in urinary oxytocin (OT) concentration during the period between five days before, and on the day of match, among rugby and handball players. Nine male rugby players with a mean age of 27.62 years (SD = 4.21) and 18 male handball players with a mean age of 17.03 years (SD = 0.57) participated. Urinary oxytocin level was measured by ELISA immunoassay as a ratio to the concentration of creatinine [mg/ml] measured through colorimetric detection. The relative level of OT to creatinine (OT/CRE) significantly differed between the type of player (rugby or handball) but not between times of measurements. Significant differences were only between OT/CRE level in a day of match in rugby players and in 5 days before match in handball players ($p<0.05$). There was no change in oxytocin levels during the time periods between five days before and on the day of a match, in either of the two kinds of players. The change in oxytocin might be traceable during the match but not before a match and this perhaps depends on a more subtle context of competition, but not on the assumption of competition. Further studies are needed based on more homogenous group with higher number of matches.

Key words: oxytocin, sports, rugby, handball, competition.

Original article

Received: 28.10.2022; Revised: 12.12.2022; Accepted: 13.12.2022

Introduction

Oxytocin (OT), the endogenous neuropeptide performing peripheral role as a hormone, is mostly known for facilitating uterine contractions during labour, facilitating maternal behaviour (Rilling et al. 2012), and also for initiating parenting behaviour (Gordon et al. 2010). However, OT has a broader role exerting modifying effects on human social cognition and behaviour (Bartz et al. 2011) that increase benefits of social interaction and promote social approach and affiliation (Heinrichs and Domes 2008; Gilbert and Basran 2019), empathy (Geng et al. 2018), build trust (Kosfeld et al. 2005), attachment (Donaldson and Young 2008) and group cohesion (De dreu et al. 2010; 2011) in humans and non-human animals (Rilling et al. 2012; Bartz et al. 2011; Chang et al. 2013; Neumann and Slattery 2016). The critical and intricate role of oxytocin has been implicated in the formation and maintenance of social groups by modifying several behaviours and human cooperative traits that are important in effectively functioning in a group (De Dreu 2012; Choi and Bowles 2007; Bowles 2009). However, there are recent reports that administration of oxytocin increased aggressive behaviour (Ne'eman et al. 2016) and that OT receptor gene polymorphism has association with aggression (Butovskaya et al. 2020) that might be important in combat with outgroup enemies. According to a theoretical framework, OT modulates social behavior by means of increasing the salience of social stimuli and perhaps promotes a wide range of emotions and behaviors and not merely the positive and affiliative ones (Shamay-Tsoory and Abu-Akel 2016). Therefore, if indeed OT increases the salience of social agents, a plausible assumption is that it will increase aggressive reactions in competitive situations involving aggressive provocations (Ne'eman et al. 2016). In a study of intergroup conflict in wild chimpanzees Samuni et al. (2016) reported that OT levels were elevated immediately before and during intergroup conflict compared with controls.

Human inter-group conflicts are part of our evolutionary history and success in such conflicts depends upon several adaptive mechanisms. Sports and games sometimes posit on humans a challenge situation that mimics inter-group conflict, as well as intra-group coordination to win over the opponent (Muñoz-Reyes et al. 2020). Sporting activities are very often chosen as a proxy to human combative situations. The sport competition model may involve several adaptive mechanisms, including aggression, and this model has been used in studies related to endocrine response or prenatal hormone exposure (Bogin et al. 2016; Longman et al. 2011). OT has been linked with human prosocial behaviour (Romney et al. 2019). On the other hand, there is evidence for prosocial behavior in enhancing team performance in sport (Moll et al. 2010). In a review, after considering several previous evidences, it was proposed that OT could be the bridging link between certain kinds of empathy as well as emotion transfer and enhanced group performance in team sports (for detailed review see: Pepping and Timmermans 2012).

Success in sports has been often linked with motivation and positive emotions (McCarthy 2011). Prosocial behaviours, such as the high-five, the fist-pump, and the group hug, during a game, remain staple elements of success in sporting life (Kraus et al. 2010). These behaviours may enhance OT (Uvnäs-Moberg et al. 2015). But it is not known if such increase also oc-

curs as a preparatory mechanism for a motivational adaptation among elite sports persons before a match. Pre-match elevation of OT might be important for soothing of stress and enhancing empathy and greater receptivity for collective emotions for teammates or rivalry against opponents.

With such background information, the present exploratory study was conducted with the aim to observe if some change occurred in urinary OT concentration between two ocasions, 5 days before, and on the match-day, among the selected groups of rugby and handball players in Wroclaw, Poland. The primary objective was to test if OT level would increase before the match or not, as the increase would be indicative of some change in oxytocinergic system. For this primary exploration, the present study chose rugby and handball matches as these are known to regularly generate high level of competitive excitement both among the players and the spectators. Rugby involves high level of contact, aggressive interactions, and hence high prevalence of injuries; handball on the other hand requires specialized team coordination (Uvnäs-Moberg et al. 2015). In this study, these two kinds of sports were chosen to proxy high aggressive competition and sociability, respectively. Although the study was a preliminary exploration, the findings were expected to set a direction towards further research on the adaptive response to a forthcoming challenge situation and building a capacity for enhanced team cooperation through a biological pathway of oxytocinergic response.

Materials and Methods

This preliminary exploratory study followed a repeated measures design of the outcome variable (OT) at two subsequent points of time. Nine male rugby league players with a mean age of 27.62 years (SD = 4.21), participating in games of regional rugby league (Lower Silesia), and 18 male handball players with a mean age of 17.03 years (SD = 0.57), taking part in games of academic league, were included in the study. All participants provided informed consent before participation. The rugby players were included in the study in a competition season during the matches of Second Polish League of Rugby. At this time, the player-participants were undertaking two trainings per week. The handball player-participants were attending the Junior Sport Championship School in Wroclaw, undertaking five training sessions a week, and at least, 10 hours per week of physical education lessons in school. Their handball teams were ranked 3rd–4th among 10 teams in the Third Senior League in Poland. Thus it was assumed that the participants were all potentially dedicated and whole time players.

The urine samples for study were collected by the participants on their own at their respective homes. They collected the morning samples of urine in two ocasions, 5 days before and on the day of match. For this purpose, sterile plastic containers (100 ml) were distributed to each participant before the day of collecting sample. They were asked to collect the samples of the first urine in one sterile container after waking up in the morning. After collection of these containers from the participants on the same day, each sample was stored in two sterile plastic tubes (30 ml) at minus 20^{o} Celsius temperature till the laboratory analyses were conducted. The rugby players were followed for 3 matches (during April and May 2017), whereas handball players for 2 matches (during October 2017). Together, the 112 urine samples were

collected, 51 from rugby and 61 from handball players.

After thawing, the samples were centrifuged at 1500 x g for 10 minutes at 4° Celsius temperature and supernatants were collected. OT concentration was estimated by ELISA immunoassay (Catalog #: ADI-901-153A; Enzo Life Science, USA). Creatinine (Cr) concentration was measured with the Creatinine Colorimetric Detection Kit (Catalog #: ADI-907-030A; Enzo Life Science, USA). Both analyses were conducted according to the assay procedures described in provided manuals. All standards and samples in both assays were run in duplicate. We calculated intra-class correlations (ICCs) of methods of estimating oxytocin ($r=0.92$ $r^2=0.84$) and creatinine ($r=0.997$, $r^2=0.995$). Relatively high values of ICCs showed confirmed the high precision of estimation. OT concentration in urine samples was expressed as a ratio of OT to creatinine: OT pg/ creatinine mg (OT/CRE) and used in further calculations. Analyses were conducted in a laboratory of Institute of Immunology and Experimental Therapy, Polish Academy of Sciences by two trained members of the institute (AS, DL).

Statistics of mean, standard deviation (SD), median, maximum-, and minimum values were used to describe the measures of anthropometry as well as OT/CRE level. There was not any significant correlation between age and OT level, neither in rugby players not in handball players. Differences in ratios of OT, between 5 days before and a day of match, were assessed by ANOVA with repeated measurements, where appropriate team and repeated estimation of OT were factors. Post hoc comparison was done of the means of Tukey's Test for unequal sample size. All calculations were done using STATISTICA 13.1.

The study protocol has been approved by the Senate Ethical Committee Scientific Research of the University School of Physical Education in Wroclaw. Although the study used non-invasive measures, the ethical guidelines as laid down by the Helsinki Declaration were sincerely adhered to (Goodyear et al. 2007).

Results

Table 1 shows the mean age, height, weight and BMI in Rugby and Handball players and the difference in these measures between these two groups of players as assessed by student t test. There were significant differences in age ($p<0.001$) and BMI ($p<0.05$), but not in height and weight. The rugby players were older and had higher BMI than the handball players.

Table 2 presents the descriptive statistics of the ratio of oxytocin-to-creatinine levels [OT/CRE, pg/mg] for each subject. For each rugby player six estimations were done, whereas for handball players only four.

Table 1. Descriptive statistics of age and body dimensions of the players

		Age		Height		Weight		BMI	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Rugby	9	27.6	4.2	181.3	6.4	90.0	7.6	27.3	1.2
Handball	18	17.8	0.60	183.3	6.1	83.4	12.8	24.7	3.0
t-test		$t=10.11$; $p<0.001$		$t=0.83$; $p>0.05$		$t=1.49$; $p>0.05$		$t=2.63$; $p<0.05$	

Table 2. Descriptive statistics of the ratio of oxytocin-to-creatinine [pg/mg] of urine samples of all individual players collected at all occasions

Players' ID	N-urine samples	Mean	SD
Rugby (N = 52 samples)			
2	6	437.6	188.9
3	6	608.6	162.6
5	6	684.9	176.0
7	6	648.0	262.5
8	6	665.7	108.0
9	6	663.6	58.7
10	6	864.0	143.6
11	6	724.8	172.7
12	4	514.0	78.1
All rugby players	52	650.7	189.4
Handball (N = 61 samples)			
1	2	902.2	14.9
2	3	760.7	28.3
3	3	629.5	125.9
4	3	839.5	96.7
6	4	597.8	106.2
7	4	703.7	62.1
8	4	614.9	112.3
9	4	777.9	171.3
10	4	565.7	130.9
11	3	637.0	121.4
12	4	737.0	113.0
13	2	687.3	3.2
14	2	918.4	271.0
15	4	857.6	313.1
16	4	941.5	204.6
17	4	891.0	120.3
18	3	773.4	93.5
21	4	747.5	167.5
All handball players	61	748.8	172.5

Results of ANOVA revealed that only the type of player (rugby or handball) significantly differentiated OT/CRE levels, but no effect of repeated measurements were found (Table 3). Tukey's post-hoc tests showed only differences between OT/CRE level in a day of match in rugby players and OT/CRE level in 5 days before match in handball players ($p<0.05$).

Table 3. Results of ANOVA with repeated measurements of the oxytocin-to-creatinine ratio [pg OT/mg CRE] in 5 days and in a day of match among rugby and handball players (Size effect was expressed by partial eta square)

	5 days before		In a day of match	
	Mean	SD	Mean	SD
Rugby	672.21	196.52	625.78	171.13
Handball	754.74	194.16	743.21	167.73

	F	*p*	Partial η^2
Players	6.63	<0.05	0.11
Repeated measurements	1.17	=0.285	0.02
Interaction	0.26	=0.610	0.005

Figure 1 demonstrates the changes in the OT/CRE levels in each player between the two ocasions, five days before match and on the day of match. In this graph no definite pattern or regularity was observed indicating any difference in ratios 5 days before and on a day of match.

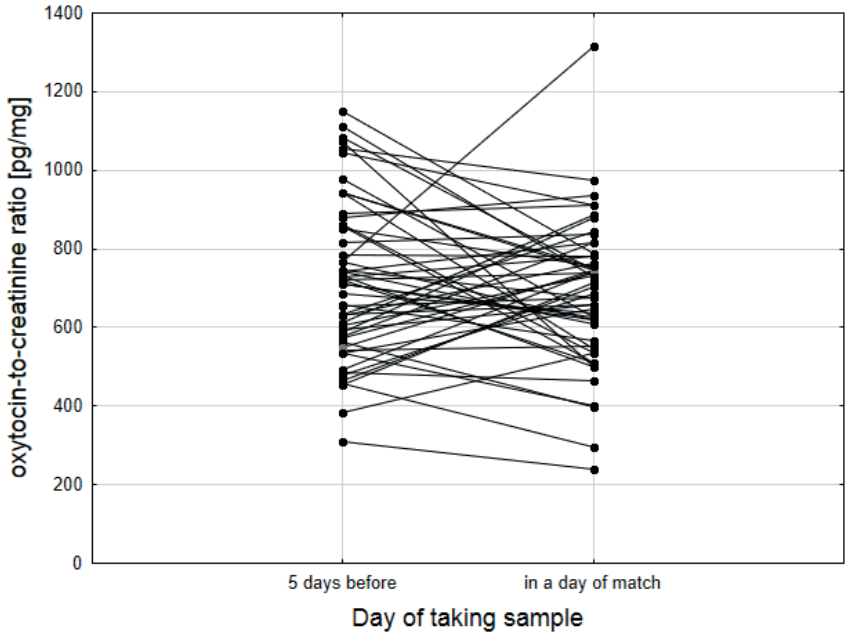

Fig.1. Changes of individual level of oxytocin-to-creatinine ratio [pg/mg] in all players estimated 5 days before and in a day of the match

Discussion

The effects of OT on adaptive social behaviour have been the topic of increasing scientific interest in recent years, both in animal and human studies. In the present study, we investigated whether urinary OT level among the players would rise up on the day, as compared to five days, before highly competitive rugby and handball matches. Results of the present study showed that the OT level differed between rugby and handball players. However, it did not differ between two time points, in either group or when participants from both sports were clumped together. There was no indication of any difference in OT between five days before and on a day of match.

Most previous research evidence was obtained in laboratory settings using intergroup social-dilemma games and focused on human male participants. Only a handful of studies have studied intergroup contexts in captive or wild non-human animals. In a study among wild chimpanzees, during intergroup conflicts in natural habitat, a significantly higher urinary OT level was recorded in both sexes immediately before and during the intergroup conflicts (compared to controls). Both anticipatory response to, and participation in the intergroup conflicts involved high urinary OT levels compared to control conditions (Samuni et al. 2016, 2018). The present exploratory research, however, could not measure OT concentration just before or after a match. But it at least, does provide a preliminary database up to a certain stage before competitive situation.

During intergroup conflict, elevated levels of both cortisol and OT are expected to have adaptive importance. Whereas the former facilitates rapid production of energy required for combat or flight (McEwen 2007; Samuni et al. 2016), the latter may promote the essential ingroup cohesion leading to cooperative responses (De Dreu et al. 2010, Samuni et al. 2016). Studies on both humans and chimpanzees indicate an oxytocinergic system involvement during intergroup conflict (De Dreu et al. 2010, Samuni et al. 2016). It is widely believed that sports and games could closely imitate a real-life inter-group conflict and intra-group cohesion among humans (Muñoz-Reyes et al. 2020). It was therefore hypothesized that similar effect could also be visible shortly before participation in highly competitive games. In Poland, rugby is played by a very few teams and the handball players selected for this study were relatively top ranking. Since the participants were dedicated players, it was possible that they had developed ability to perform at high level of sports by several years of practice and adjustment to the specific requirements of the game. Based on the theoretical framework, we tried to explore whether they might show elevated OT a few days before a game, as a physiological response, that might support them in performance. However, the results of the present study did not provide supportive evidence. It showed no definite pattern or regularity of changes in OT level from five days before and on a day of match. In both types of games there were no significant differences between those two time points. The result was identical even when data for all players in two games were analyzed together.

There are several probable scientific reasons for the 'negative' result. With growing number of investigations on the effects of OT on behavior, cognition, and neuropsychiatry, it is becoming clear that its functions are far more complex than

initially was presumed (Bartz et al. 2011; Chang et al. 2013). OT release during intergroup conflict as observed by Samuni et al. (Samuni et al. 2016) was postulated to be triggered by the social context that was linked with the stressor rather than the stressor itself (Samuni et al. 2019). Accumulated evidence from several studies indicates that social contexts and individual factors, such as sex, early experience, or health, influence oxytocinergic effects (Bartz et al. 2011; Rilling et al. 2012). Perhaps, the context before actual commencement of the matches, or during the mathes, such as, physical-aggressive contact during the match, would raise OT levels. Unfortunately, we could not measure OT/CRE ratios during or after the game.

Several studies, e.g., Striepens et al. (2011), suggested that OT mediates behaviors which are mainly prosocial. Nonetheless, other studies from animal research contradicted this by showing that OT can also enhance anxiety (Guzmán et al. 2013). Similarly, among humans, recent studies demonstrated its effects that might promote conflict rather than cohesion. For example, OT was found to increase envy and gloating (Shamay-Tsoory 2009), decrease trust and the inclination to cooperate in individuals with borderline personality disorder (Bartz et al. 2011), and facilitate out-group derogation (De Dreu et al. 2011). Thus, although OT is widely viewed as a prosocial compound, it may also promote antisocial responses, thus suggesting a context-dependent effect (Goodson and Thompson 2010). Thus, it seemed that OT level is not raised, at least, at this stage (before a few hours of match), but maybe just before game or during game. Instead, prosocial behaviors, such as mutual touching and hugging among teammates during the game (context) might increase the OT level (Kraus et al. 2010; Uvnäs-Moberg 2015). Although sports and games could be suitable proxies for real-life competitions (Longman et al. 2011), there are certain differences between sport, game, and real-life challenges. It would be ideal to measure OT in soldiers at war, as was done for fighting chimpanzees. The present study, however, showed that although some oxytocinergic response during preparatory period of a competitive sport was assumed, it might not have been activated even a few hours before the match. The social context immediately before a conflict to protect territory among the chimpanzee is expected to be very different from that of a human sports person before playing in a match. The game was only a part of their life but for chimpanzees the fights are to protect their entire world. Studies on animal models have also demonstrated that social context might modify the regulating effect of OT on social play (Bredewold et al. 2014).

Several limitations of the present study should also be worth discussing. First, this study was an exploratory attempt with limited resources. The sample sizes were small. Secondly, we compared players from different sports disciplines that might have different effects. The two teams also had different popularity and ranking scores, and perhaps, not exactly comparable. Third, we could not collect reliable data on the extent of training, how often the players worked in group, the immediate social conditions, the exact activities during a certain period before sample collection, etc. These factors including individual characteristics could have confounding effects (Bartz et al. 2011). Fourth, the players of handball and rugby were followed in different seasons of the year. Thus, potential seasonal variation in OT also could be responsible

for lack of relationship and differences between sport groups. Fifth, the differences in OT between two groups also could be age related since there was also significant age difference. Despite these inherent limitations, this study, with its purely exploratory objectives, provided the first preliminary information on the topic. Future research might best be conducted on several teams of a single discipline, assess OT before, during and after several games, precisely control for confounders, such as, age, nature of training, seasonal effect, and also include more aggressive games, such as, martial arts.

Conclusion

The present exploratory study showed that the OT level in professional sportspersons did not increase with the nearing of a match. Perhaps the increase might be noted in a more critical context, such as, during the game. Further studies are needed based on more homogenous group with higher number of matches.

Acknowledgments

The authors are especially grateful to all rugby and handball players for their participation in the study. The experiments comply with the current laws of the country of study.

Conflict of interests

The authors do not have any conflict of interests.

Authors' contributions

MK – collected the urine samples, prepared samples for analysis, build the database, ZI, AR, IC, AD, MŚ, KK, AS – recruited and instructed participants, conducted measurements and prepare database, prepare first draft; AS, DL – carried out biochemical analysis, prepared part of the draft, checked final draft; RC, BB – prepared and edited the final draft, collected literature, corrected statistical analysis; SK – designed the study, made the analysis and prepared the draft and checked the final version.

Corresponding author

Raja Chakraborty, Department of Anthropology and Tribal Studies, Sidho-Kanho-Birsha University, Purulia, West Bengal 723 104, India; e-mail: rajanth2003@yahoo.co.uk

References

Bartz J, Simeon D, Hamilton H, Kim S, Crystal S, Braun A, Vicens V, Hollander E. 2011. Oxytocin can hinder trust and cooperation in borderline personality disorder. Soc Cogn Affect Neurosci 6(5):556–563, https://doi.org/10.1093/scan/nsq085

Bartz JA, Zaki J, Bolger N, Ochsner KN. 2011. Social effects of oxytocin in humans: context and person matter. Trends Cogn Sci 15(7):301–309, https://doi.org/10.1016/j.tics.2011.05.002

Bogin B, Hermanussen M, Blum WF, Aßmann C. 2016. Sex Sport IGF-1 and the community effect in height hypothesis. Int J Env Res Public Health 12(5):4816–4832, https://doi.org/10.3390/ijerph120504816

Bowles S. 2009. Did warfare among ancestral hunter-gatherers affect the evolution of human social behaviors? Science 324(5932):1293–1298, https://doi.org/10.1126/science.1168112

Bredewold R, Smith CJ, Dumais KM, Veenema AH. 2014. Sex-specific modulation of juvenile social play behavior by

vasopressin and depends on social context. Front Behav Neurosci 8:216. Available at: http://hdl.handle.net/2345/bc-ir:103603 [Accessed 14 December 2022].

Butovskaya M, Rostovtseva V, Butovskaya P, Burkova V, Dronova D, Filatova V, Sukhodolskaya E, Vasiliy V, Mesa T, Rosa A, Lazebny O. 2020. Oxytocin receptor gene polymorphism (rs53576) and digit ratio associates with aggression: comparison in seven ethnic groups. J Physiol Anthropol 39(1):20, https://doi.org/10.1186/s40101-020-00232-y

Chang SWC, Brent LJN, Adams GK, Klein JT, Pearson JM, Watson KK, Platt ML. 2013. Neuroethology of primate social behaviour. Proc Natl Acad Sci USA 110 Suppl 2(Suppl 2):10387–10394, https://doi.org/10.1073/pnas.1301213110

Choi J-K, Bowles S. 2007. The coevolution of parochial altruism and war. Science 318(5850):636–640, https://doi.org/101126/science.1144237

Cummins C, Orr R. 2015. Analysis of physical collisions in elite national rugby league match play. Intl J Sports Physiol Perform 10(6):732–9, https://doi.org/10.1123/ijspp.2014-054

De Dreu CKW. 2012. Oxytocin modulates cooperation within and competition between groups: An integrative review and research agenda. Horm Behav 61(3):419–428, https://doi.org/10.1016/j.yhbeh.2011.12.009

De Dreu CKW, Greer LL, Handgraaf MJJ, Shalvi S, Van Kleef GA, Baas M, Velden FST, Dijk EV, Feith SWW. 2010. The neuropeptide oxytocin regulates parochial altruism in intergroup conflict among humans. Science 328(5984):1408–1411, https://doi.org/10.1126/science.1189047

De Dreu CKW, Greer LL, Van Kleef GA, Shalvi S, Handgraaf MJJ. 2011. Oxytocin promotes human ethnocentrism. Proc Natl Acad Sci USA 108(4):1262–1266, https://doi.org/10.1073/pnas.1015316108

Donaldson ZR, Young LJ. 2008. Oxytocin vasopressin and the neurogenetics of sociality. Science 322:900–4, https://doi.org/10.1126/science.1158668

Geng Y, Zhao W, Zhou F, Ma X, Yao S, Hurlemann R, Becker B, Kendrick K M. 2018. Oxytocin enhancement of emotional empathy: generalization across cultures and effects on amygdala activity. Front Neurosci 12:512, https://doi.org/10.3389/fnins.2018.00512

Gilbert P, Basran J. 2019. The evolution of prosocial and antisocial competitive behavior and the emergence of prosocial and antisocial leadership styles. Front Psychol 10:610, https://doi.org/10.3389/fpsyg.2019.00610

Goodson JL, Thompson RR. 2010. Nonapeptide mechanisms of social cognition behaviour and species-specific social systems. Curr Opin Neurobiol 20(6):784–794, https://doi.org/10.1016/j.conb.2010.08.020

Goodyear MDE, Krleza-Jeric K, Lemmens T. 2007. The Declaration of Helsinki. BMJ 335(7621):624–625, https://doi.org/10.1136/bmj.39339.610000.BE

Gordon I, Zagoory-Sharon O, Leckman J, and Feldman R. 2010. Oxytocin and the development of parenting in humans. Biol Psychiatry 68(4):377–382, https://doi.org/10.1016/j.biopsych.2010.02.005

Guzmán YF, Tronson NC, Jovasevic V, Sato K, Guedea AL, Mizukami H, NIsimori K, Radulovic J. 2013. Fear-enhancing effects of septal oxytocin receptors. Nat Neurosci 16(9):1185–1187, https://doi.org/10.1038/nn.3465

Heinrichs M, Domes G. 2008. Neuropeptides and social behaviour: effects of and vasopressin in humans. Prog Brain Res 170:337–350, https://doi.org/10.1016/S0079-6123(08)00428-7

Kosfeld M, Heinrichs M, Zak PJ, Fischbacher U, Fehr E. 2005. Oxytocin increases trust in humans. Nature 435:673–676, https://doi.org/10.1038/nature03701

Kraus MW, Huang C, Keltner D. 2010. Tactile communication cooperation and performance: an ethological study of the NBA. Emotion 10(5):745–749, https://doi.org/10.1037/a0019382

Longman D, Stock JT, Wells JCK. 2011. Digit ratio (2D:4D) and rowing ergometer performance in males and females. Am J Phys Anthropol 144(3):337–341, https://doi.org/10.1002/ajpa.21407

McCarthy PJ. 2011. Positive emotion in sport performance: current status and future directions. Intl Rev Sport Exercise Psychol 4(1):50–69, https://doi.org/10.1080/1750984X.2011.560955

McEwen BS. 2007. Physiology and neurobiology of stress and adaptation: central role of the brain. Physiol Rev 87(3):873–904, https://doi.org/10.1038/s42003-018-0142-3

Moll T, Jordet G, Pepping G. 2010. Emotional contagion in soccer penalty shootouts: celebration of individual success is associated with ultimate team success. J Sports Sci 28(9):983–992, https://doi.org/10.1080/02640414.2010.484068

Muñoz-Reyes JA, Polo P, Valenzuela N. 2020. The male warrior hypothesis: testosterone-related cooperation and aggression in the context of intergroup conflict. Sci Rep 10:375, https://doi.org/10.1038/s41598-019-57259-0

Ne'eman R, Perach-Barzilay N, Fischer-Shofty M, Atias A, Shamay-Tsoory SG. 2016. Intranasal administration of increases human aggressive behaviour. Horm Behav 80:125–130, https://doi.org/10.1016/j.yhbeh.2016.01.015

Neumann ID, Slattery DA. 2016. Oxytocin in general anxiety and social fear: a translational approach. Biol Psychiatry 79(3):213–221, https://doi.org/10.1016/j.biopsych.2015.06.004

Pepping G, Timmermans EJ. 2012. Oxytocin and the Biopsychology of Performance in Team Sports. Sci World J 567363, https://doi.org/10.1100/2012/567363

Rilling JK, DeMarco AC, Hackett PD, Thompson R, Ditzen B, Patel R, Pagnoni G. 2012. Effects of intranasal oxytocin and vasopressin on cooperative behavior and associated brain activity in men. Psychoneuroendocrinol 37:447–461, https://doi.org/10.1016/j.psyneuen.2011.07.013

Romney C, Hahn-Holbrook J, Norman G, Moore A, Holt-Lunstad J. 2019. Where is the love? A double-blind randomized study of the effects of intranasal oxytocin on stress regulation and aggression. Intl J Psychophysiol 136:15–21, https://doi.org/10.1016/j.ijpsycho.2018.08.010

Samuni L, Preis A, Deschner T, Crockford C. 2019. Cortisol and show independent activity during chimpanzee intergroup conflict. Psychoneuroendocrinol 104:165–173, https://doi.org/10.1016/j.psyneuen.2019.02.007

Samuni L, Preis A, Deschner T, Crockford C, Wittig RM. 2018. Reward of labor coordination and hunting success in wild chimpanzees. Commun Biol 1:138, https://doi.org/10.1038/s42003-018-0142-3

Samuni L, Preis A, Mundry R, Deschner T, Catherine C, Wittig RM. 2016. Oxytocin reactivity during intergroup conflict in wild chimpanzees. Proc Natl Acad Sci 114(2):268–273, https://doi.org/10.1073/pnas.1616812114

Shamay-Tsoory SG, Abu-Akel A. 2016. The social salience hypothesis of oxytocin. Biol Psychiatry 79(3):864–870, https://doi.org/10.1016/j.biopsych.2015.07.020

Shamay-Tsoory SG, Fischer M, Dvash J. 2009. Intranasal administration of increases envy and schadenfreude (gloating). Biol Psychiatry 66(9):864–870, https://doi.org/10.1016/j.biopsych.2009.06.009

Striepens N, Kendrick KM, Maier W, Hurlemann R. 2011. Prosocial effects of oxytocin and clinical evidence for its therapeutic potential. Front Neuroendocrinol

32(4):426–450, https://doi.org/10.1016/j.yfrne.2011.07.001

Uvnäs-Moberg K, Handlin L, Petersson M. 2015. Self-soothing behaviors with particular reference to oxytocin release induced by non-noxious sensory stimulation. Front Psychol 5:1529, https://doi.org/10.3389/fpsyg.2014.01529

Anthropological Review • Vol. 85(4), 95–121 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.4.07

Prevalence of wormian bones worldwide: a critical review

Agata Bisiecka[1], *Rafael Romero-Reverón*[2]

[1] Division of Anthropology, Institute of Environmental Biology, Wrocław University of Environmental and Life Sciences, Wrocław, Poland
[2] Human Anatomy Department, J.M. Vargas Medical School, Faculty of Medicine, Universidad Central de Venezuela, Caracas, Venezuela

Abstract: Wormian bones (WB) are the irregular bone structures developed from additional centers of ossification. Although they are commonly found in healthy individuals, under certain conditions (number >10, mosaic pattern, large size), they can indicate pathology. While their coexistence with numerous diseases is well-documented, and various studies have reported their prevalence in populations of various geographic regions, no qualitative critical review of such studies has been conducted. The aim of this paper is to perform a critical review of research studies on the presence of Wormian bones in populations worldwide, with a particular emphasis on the methodology used and the selection of the samples studied.

A sample of 44 original research articles was selected via PubMed and Google Scholar databases. Four criteria were assessed: 1) number of individuals in each group, 2) known sex of individuals, 3) selection criteria of individuals, and 4) implementation of the statistical analysis. The origin of the research sample was determined as well as the method of the WB calculation, and data on the WB prevalence worldwide was collected in tabular form.

The reported size of the research samples varies from 22 to 628 individuals, derived from both contemporary and archaeological populations. Four major formulas were used in order to provide the frequency of WB. The sex of individuals was known in 18 (40.9%) articles. Most of the articles focused on Asian samples.

The difficulties in comparing data on the Wormian bones are caused by considerable inconsistency in the methodology used to research this phenomenon. Therefore, the interpopulation comparisons currently made may not be correctly estimated. Our study highlights the need for using more comprehensive and consistent data collection as well as processing protocol suitable for populational research on sutural bones.

Key words: cranium, skull, suture, sutural bone, Wormian bone.

Received: 17.11.2022; Revised: 12.12.2022; Accepted: 12.12.2022

Introduction

The human skull consists of two developmentally and functionally distinct groups of bones: viscerocranium and neurocranium (Reicher and Łasiński 2010). The number of skull bones is generally constant, but in some cases, the number might increase due to the presence of so-called Wormian bones (WB) which are also known as 'intrasutural bones', 'sutural bones', 'skull accessory ossicles', 'supernumerary ossicles', 'intercalated bones', 'accidental bones', 'intercalary ossicles', '*Schaltknochen*', '*ossa Wormiana*', '*ossa suturalia*' (Goyal et al. 2019; Nowak et al. 2018; Rajni et al. 2018; Murlimanju et al. 2011). In particular cases – when the bones occur in the position fontanelles (Natsis et al. 2019; Nikolova et al. 2016) – they have specific names such as 'bregmatic bone' and 'Kerckring bone' (in bregma, Nikolova et al. 2016; Vishali et al. 2012), or 'pterion ossicles' and 'epipteric bone' (in pterion, Standring 2016). There is also a large bone on the posterior part of the skull (upper area of the occipital squama) referred to as the 'Inca bone' (Cirpan et al. 2014) or 'interparietal bone'.

Wormian bones are irregular, diversiform bone structures developed from the additional centers of ossification (Nowak et al. 2018; Bellary et al. 2013) and interjected in the cranial sutures. They are present not only in modern humans but also in the archeological context (Nikolova et al. 2014; Panzer et al. 2014), in Neanderthals (Bruner 2004), and animals (Zambrano et al. 2021; Smith et al. 1977).

The size of a single accessory bone can vary from less than 1 mm x 1mm up to more than 5 cm x 9 cm in width and length (Sreekanth and Samala 2016). In addition, these bones have multiple shapes: oval, round, oblong, quadrilateral, and irregular (Parker 1905, as cited in Murlimanju et al. 2011). Wormian bones are generally a feature of the neurocranium and occur mostly in the lambdoid suture, especially on the right side (Nowak et al. 2018; Bellary et al. 2013). Other frequent localizations are coronal suture, bregma, lambda, pterion, and asterion. However, WB may, although rarely, occur in the sutures connecting the craniofacial bones – for example in the frontonasal suture (Edwards et al. 2017) or in the orbital cavity between the frontal, lacrimal and ethmoid bone (Rizvi et al. 2018). The anatomical denomination of Wormian bones is still debated (Romero-Reverón 2020) while the etiology of sutural bone formation still remains unclear. It has been hypothetised that WB might indicate genetic factors (Finkel 1975; Bennett 1965), mechanical pressure on the skull bones in early stages of ontogenetic development, such as artificial cranial deformations (Sanchez-Lara et al. 2007; O'Loughlin 2004; El-Najjar and Dawson 1977), metabolic disorders (Hess 1946, as cited in Jeanty et al. 2000), as well as environmental factors (Barberini et al. 2008; Sanchez-Lara et al. 2007). Currently, more holistic interpretations are adopted that recognize the influence of all the aforementioned factors in WB development (Di Ieva et al. 2013; Barberini et al. 2008). Some studies suggest that the presence of sutural bones might indicate developmental instability (Di Ieva et al. 2013; Vishali et al. 2012; Barberini et al. 2008).

The Wormian bones have been reported to commonly occur in healthy populations, and their presence typically is not associated with any pathological conditions (Natsis et al. 2019; Andrade et al. 2018; Johal et al. 2017; Walulkar et

al. 2012); however, their significant number (above 10), size (more than 6 mm x 4 mm), or characteristic mosaic pattern are clinically considered as indicators of several congenital diseases, mostly osteogenesis imperfecta (Cremin et al. 1982) exhibited by abnormally numerous Wormian bones (Semler et al. 2010). Other diseases are also frequently associated with WB, such as hypophosphatasia, craniosynostosis, hypothyroidism, cleidocranial dysostosis, rickets, pyknodysostosis (osteopetrosis acro-osteolytica), pachydermoperiostosis, congenital hypothyroidism, hydrocephalus, otopalatodigital syndrome, Hajdu-Cheney syndrome, Menkes syndrome (Ratnaningrum 2020; Saylisoy 2020; Basnet et al. 2019; Romero-Reverón and Arráez-Aybar 2019; Kumar and Ratna Prabha 2016; Marti et al. 2013). Many of them are congenital disorders or CNS (central nervous system) anomalies. Studies have shown that Wormian bones can help in diagnosis and treatment of those conditions (Goyal et al. 2019; Romero-Reverón and Arráez-Aybar 2019; Jeanty et al. 2000). As Wormian bones are developed prenatally (Jeanty et al. 2000), they can be detected during the routine USG examination, and used as the prenatal diagnosis of severe or lethal conditions (Tonni et al. 2013).

Wormian bones can be also considered as important from the medicolegal perspective as their characteristic pattern, can be used for identification of an individual (Kuharić et al. 2011; Jayprakash 1997); moreover, due to their association with abnormal bone brittleness, WB can prove critical in the diagnosis of the children's bone trauma in order to exclude the possibility of physical abuse (Johal et al. 2017; Govsa et al. 2014; Marti et al. 2013). During X-Ray examination of the head, Wormian bones can also be mistaken for fractures (Narayan et al. 2019; Romero-Reverón 2017). Radiologists and surgeons have been advised to take WB into account while planning surgical interventions to the head to avoid possible injury (Ratnaningrum 2020; Kumar and Ratna Prabha 2016).

Interest in Wormian bones in the last decade has been significantly growing (see fig. 1).

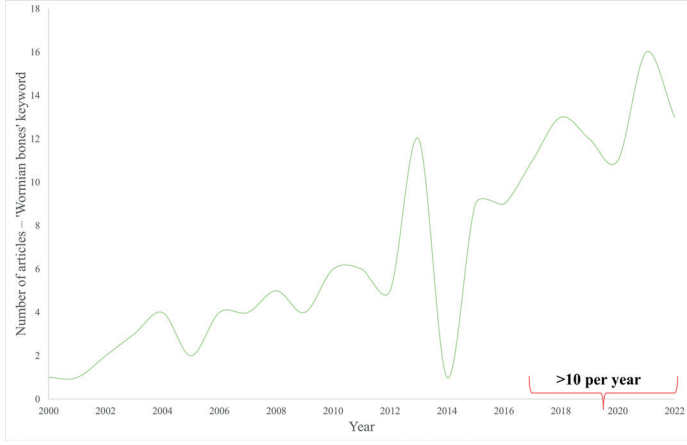

Fig. 1. Number of articles published between 2000 and 2022, found in PubMed by the 'Wormian bones' keyword (full texts only)

Some studies have discussed the association of WB with various diseases (case reports), while other have established the relationship between WB and biological phenomena, such as metopism (Li et al. 2022; Cirpan et al. 2016), individual genes or groups of genes that influence WB formation (Zimmerman et al. 2019; Kague et al. 2016), and variants of the skull morphology (Basnet et al. 2019). Since WB are considered as an anthropological marker of the interpopulation distance (Natsis et al. 2018; Gümüsburun et al. 1997; Pal and Routal 1986), some studies report the WB prevalence in human populations worldwide. In many cases, the data presented and juxtaposed therein are further cited by researchers; however, so far, no qualitative critical analysis of this group of articles has been carried out. Such a comprehensive review of the above studies, however, would be very useful for other researchers by providing an established basis for future research on Wormian bones.

The aim of this study is to review articles on the presence of Wormian bones in populations worldwide, with a particular emphasis on the methodology used and the selection of the study sample. In this study, the term 'Wormian bones' is used predominantly due to its common occurrence in the reviewed articles.

Material and Methods

This study is a semiqualitative review of literature. By using 'Wormian bones' as the keyword search term, 208 articles in the PubMed database were found. After adding the filter for 'full text', the total number was 169 (August 22, 2022).

In addition, in order to supplement the study material, the authors also used the Google Scholar database. Overall, the number of records found using the same 'Wormian bones' search term was 5870 (citations and patents were not taken into account). To limit the scope of the material, the following search criteria were used:

1. Published in the last 10 years (2012–2022)
2. 'Highest relevance' of the search filter selected

The total sum of records found using the above search criteria was 2600 (August 22, 2022). Since the search with the 'highest relevance' option was used, the further review was limited to the first five pages of Google Scholar results (50 articles), considering them to be the most relevant to the search criteria.

The total number of records obtained at this stage of search (preliminary database) was 219.

At the following stage, the articles were reviewed in terms of meeting the following selection criteria:

1. Research on Wormian bones (or their specific categories such as pteric bones, etc.) in any context (assessed by using the 'Wormian bone' or 'sutural bone' term in the title, keywords or abstract) conducted on human sample
2. Article available online
3. Full text of article available free (Open Access) or via institutional approach of authors' units
4. Article in English, Polish, German or Spanish.

After excluding duplicates (publications recorded both in PubMed and Google Scholar databases) the total number of articles was 176.

Such obtained material was then divided into six groups/categories: 1) case reports, 2) original articles on clinical approaches, 3) medicolegal approaches,

4) original articles on Wormian bones prevalence in populations worldwide, 5) reviews, 6) varia (i.e., articles directly or indirectly related to Wormian bones, which were not assigned to any of the above category). Only the fourth group (original articles on Wormian bones prevalence in populations worldwide) was selected as the subject of this research. An article was assigned to this group if it indicated the studied population in the title, introduction, or in the description of the research material. Articles that investigated the relationship between WB and skull deformities in various populations were excluded from the study. The preliminary number of articles included into the fourth group was 39.

In order to enrich the material, the authors checked the reference lists of these articles and selected additional publications regarding the WB prevalence in particular populations that were not included during the previous selection steps. Although such identified articles were only few, they report relevant results that are cited in further research as reference data. Because this study is, to our knowledge, the first attempt to propose a semiqualitative review of the WB issue, the chosen articles were not selected for peer review, citation score, impact factor, or other parameters. The final number of articles in the fourth group was 44 (see fig. 2), published between 1975 and 2022.

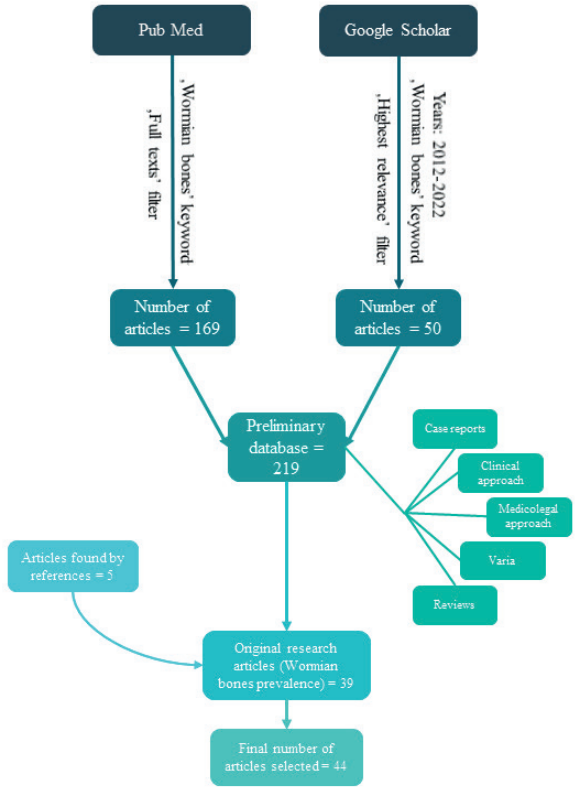

Fig. 2. Articles selection process

A scoring system, inspired in part by the Bradford-Hill criteria (Rothman and Greenland 2005), was proposed for the assessment of the evidential strength of the analyzed articles. Four benchmarks were selected, and one point was noted for each criterion:

1. ≥30 individuals in each examined group
2. Known sex of individuals
3. Statistical testing (regardless of the type of test selected)
4. Discussed selection criteria of the material

The data was tabulated according to the point category: 0–4 points. Central tendency measures were calculated using the STATISTICA 13.3 software (TIBCO; no. of license: JPZ007B482801A-RACD-9).

Results

Due to the scoring system implemented and discussed above, the division of the articles from the group of articles selected for review is as follows: 0 points – 1 article; 1 point – 11 articles; 2 points – 15 articles; 3 points – 12 articles; 4 points – 5 articles (table 1). The reported size of research samples varies from 22 to 628 individuals (*mean = 125, Me = 79, Mo = 50, Q1 = 50, Q3 = 155.5*). Research samples used in these studies were collected from contemporary institutions (e.g., post-sectional dry skulls, exhibits of medical museums with the number of articles of 36), or historical populations (e.g., from archaeological excavations or museums with a number of 5 articles), or mixed sources with only one article. In a few cases the origin of samples was unclear. Where possible, the authors determined the origin of the sample on the basis of the condition of the skulls visible in the photographs. In 18 studies (40.9%), the sex of the subjects was known. The age of individuals was known in 33 (75%) of all examined articles, although in most cases they were described simply as 'adults'. In two articles, the division of individuals into age categories was given as follows:

1. Natsis et al. 2019 – three age groups: 20–39 (n = 41), 40–59 (n=30), over 60 (n = 95).

2. Durge 2016 – four age groups: 20–30 (male n = 18, female n = 21, total n = 39), 30-45 (male n = 32, female n = 26, total n = 58), 45-60 (male n = 10, female n = 21, total n = 31), over 60 (male n = 12, female n = 20, total n = 32).

Some articles were thematically limited to selected points of the skull: asterion – 3 articles; – pterion – 7 articles; asterion and pterion – 1 article; preinterparietal/interparietal/Inca bones – 4 articles. In two cases, the preinterparietal/interparietal/Inca bones were excluded from the study.

The described research was conducted mainly in the area of South Asia (see fig. 3) with a high representation of data from India.

In 24 out of 44 articles (54.5%), a value of general prevalence of Wormian bones in a particular population was reported. This value varied from 4.7% in Rajasthan (Masih et al. 2013) to 88.8% in South India (Nayak and Shetty 2019). Moreover, the articles provide the WB frequency in particular skull sutures (table 2) revealing that the site of the most frequent occurrence of these structures was the lambdoid suture, which corresponds to other studies (El-Najjar and Dawson 1977; Romero Reverón 2017). The next most common locations for sutural bones were the asterion (79.7%

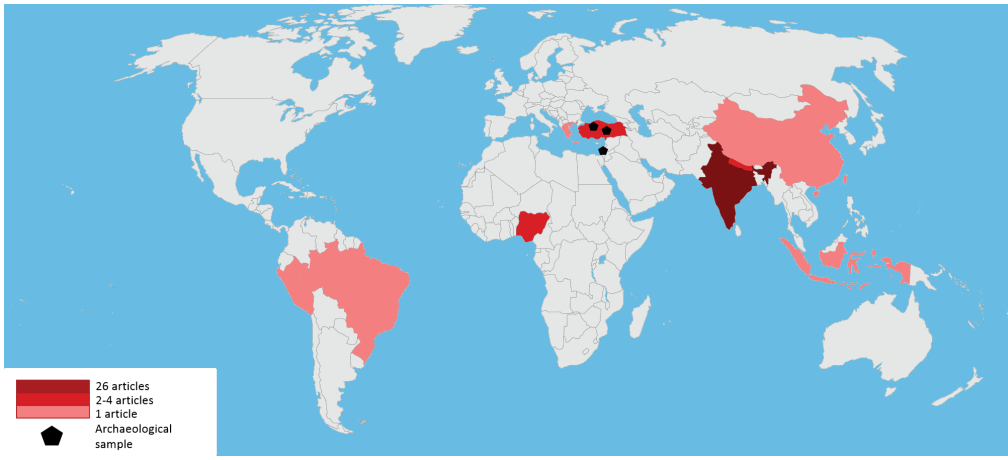

Fig. 3. Geographical distribution of research on Wormian bones (blank map by Ian Maphy, the authors' modification)

in South Indian population, Lekshmy et al. 2017), coronal suture (66.6% in South Indian population, Nayak and Shetty 2019), and the squamous suture (45.5%, also in South Indian population, Lekshmy et al. 2017) – the highest percentages recorded are given in this study. The prevalence of preinterparietal or interparietal or Inca bones occurrence varies from 1.3% in Central India (Marathe et al. 2010) to 13.3% in South India (Nagarajan and Ganesh 2017). All percentages listed indicate the number of individuals with a Wormian bone in specific cranial site (suture), relative to the entire study group.

26 articles (59.1% of reviewed sample) relate to the Indian population. Articles investigating populations from other areas of Asia taken into account included Nepal = 2, Indonesia = 1, Turkey (including Anatolia) = 6, China = 1, and Israel (Lachish) = 1. Data on Asian populations (including archaeological) account for over 84% of the sample. The remaining articles concern Greek (1 article), Nigerian (4 articles), Brazilian (1 article), Peruvian (1 article).

Discussion

The assessment of the variability in the occurrence of biological phenomena in a population is the first and indispensable step towards analyzing the etiology of any given phenomenon. The collected and available data on the variability of the phenomenon in other populations allow for comparative analyzes. Researchers investigating Wormian bone in the analyzed populations often refer to tabulated data from other studies (Li et al. 2022; Sah et al. 2017; Kalthur et al. 2017; Ghosh et al. 2017; Gümüsburun et al. 1997). In the above studies, the researchers refer to the global ranges of variability determined by the populations with the lowest and highest percentage of sutural bones – such as: "The reported incidence is variable, ranging from around 10% (in Caucasian skulls), through 40% (in Indian skulls), to 80% (in Chinese skulls)" (Khan et al. 2011).

This study reviews the original articles that reported the incidence of Wormian bones in populations from

different geographic regions in order to create an organized database; however, the difficulty in completing such a database results from the inconsistency of the methods used to assess the presence of the Wormian worldwide. The most considerable differences in the adopted methodology concern calculating the frequency (percentage) of a feature in the analyzed publications. Four dominant strategies were shown (table 2):

1. WB frequency as the quotient of the sum of all Wormian bones (in specific sites of the skull) counted in the study sample and the entire study group (WB-positive and WB-negative individuals, divided according to sex, if stated), multiplied by 100% This strategy has been used in 3 (6.8%) cases.
2. WB frequency as the quotient of the sum of all Wormian bones (in specific sites of the skull) counted in the sample and the number of WB-positive individuals (divided into sex groups, if distinguished), multiplied by 100%. This strategy has been used in 2 (4.6%) cases.
3. WB frequency as the quotient of the number of individuals with WB (in specific sites of the skull) and the entire study group (WB-positive and WB-negative individuals, divided into sex groups, if distinguished), multiplied by 100%. This strategy has been used predominantly, in 31 (70.5%) cases.
4. WB frequency as the quotient of the number of individuals with WB (in specific sites of the skull) and the group of WB-positive individuals (divided into sex groups, if distinguished), multiplied by 100%. This strategy has been used n 5 (11.4%) cases.

In 5 cases, either a different way of calculating attendance was used or it was not specified how the result was obtained. The inconsistency of the calculation methods in which the result is reduced to one value category – the percentage (%) – creates a risk that the data obtained and compiled with each other may be under- or overestimated. Inaccuracies also apply to the classification of the Wormian bones themselves; for example, (pre-)interparietal/Inca bones are treated as a separate category or included into the group of lambda bones or sagittal/lambdoid sutures.

Of the selected studies, 2 were conducted on archaeological samples: Lachish (Finkel 1975) and Anatolian (Gümüsburun et al. 1997). These two studies are relatively often quoted in tabular summaries, in which they are compared with contemporary samples (Li et al. 2022). However, this approach may raise concerns because genetic distances between historical populations may differ considerably compared to those derived from contemporary populations. Moreover, a direct comparison of modern trials with groups that are significantly distant in time, such as the Lachish population analyzed in the article by Finkel (1975) dated as the late bronze age, may omit some aspects of morphological changes related to the process of human microevolution. For this reason, a greater precision in the description of the tested sample is important. One of the included in this review articles focused on the occurrence of morphological variants of pterion in mixed archaeological (13-century Byzantine) and contemporary (20-century Turkish) sample (Illknur et al. 2009). This study states that the pteric bone occurs in 6.25% od Byzantine sample and in 3.6% of the modern population. How-

ever, the statistical significance of differences in these both frequencies was not tested, and the samples were relatively small (28 modern skulls and 16 Byzantine skulls), so the obtained results may be unreliable (Illknur et al. 2009).

In 16 studies included in this review, the origin of the sample was not specified. It is also worth noting is that in some studies osteological materials from anatomical museums at medical faculties were used. The origin of such materials should also be carefully explained because museums can store both prepared contemporary remains and historical bone material (i.e., those from archaeological excavations including modern, medieval, and even older remains) in their collections.

Modern samples may not only differ from archaeological samples in terms of genetic distance, but also be exposed to different environmental conditions, exhibit different health status which may, potentially, affect the incidence of Wormian bones and the high number of which is associated with numerous diseases. Furthermore, historical material from archaeological excavations or crypts is subject to taphonomic changes. For example, an excavated material may be damaged or dehydrated in such a way as to posthumously unseal the space of the cranial sutures. This poses a risk of accidentally losing Wormian bone post mortem. Such a risk is much smaller in comparison with contemporary post-sectional samples. In historical populations, the structure of sex and age is also different, which may distort the interpretation of data.

In 26 out of 44 (59.1%) analyzed articles, the researchers did not specify the sex of the examined remains. The omission of such information makes it difficult to undertake further works on the study of sexual dimorphism, on which there is no consensus in the literature (Natsis et al. 2019; Cirpan et al. 2016; Patil and Sheelavant 2012). Some authors argue that there are no differences in the prevalence of WB between sex groups. However, according to the 16 discussed articles in which the sex of individual was determined (research on male group only excluded), it may appear that the Wormian bones are more common in males (table 3). Note, however, that these results may represent non-statistical observations, not based on a significant difference testing result.

In the four included in this review articles (4 of the 44, 9.1%), the examined sample consisted less than 30 individuals, which are considered minimum that allows inference on quantitative data. None of these studies attempted to estimate the required sample size. The collection of research material depends on many substantive factors, such as the total amount of osteological material obtained through archaeological excavations, non-substantive factors such as funds, consent to share the material, and the duration of the study. In population studies, providing a sample size that allows for statistical analyzes, although critical, was implemented only in 23 out of the 44 (52.3%) evaluated articles. Statistical inference with respect to compiling numerical data from population studies is the only way to distinguish significant biological relationships from numerical randomness. Without which it is rather difficult, if not impossible, to properly estimate the differences in the occurrence of Wormian bones between sex groups.

Of the 44 original articles included in the analysis, more than a half (26 of the

44, 59.1%) relate to the Indian population. Nevertheless, there is no consensus on the reported frequency of suture bones in populations from the same areas; consider the following examples: in the East Indies reported from 29.7% (Yadav and Salam 2020) to 72.3% (Purohit and Yadav 2019), in North India – from 35.3% (Goyal et al. 2019) to 51% (Rajni et al. 2018). These discrepancies may result from the large diversity of the populations inhabiting the area of India but also from the methodology adopted in the assessment of the Wormian bones.

Studies regarding populations from Asia account for over 84% of the sample collected according to the proposed method partly based on indications and systematic reviews of publications in established scientific databases. In contrast, there is an insufficient number of studies on populations from Europe, Africa, Australia, Oceania as well as North and South America. The problem of older research on WB, published in print (not digitized) in languages other than those used internationally, also should be mentioned.The lack of digital and linguistic access for researchers who want to undertake reviews or comparative analyzes can create considerable gaps in the methodology and results. An example of such materials could be the publication of Česnys and Balčiūnienė (1988) on Lithuanian populations; therefore, it is important to enrich available databases of scientific articles with archival works on the subject. Translated non-English-language studies and English-language meta-analyzes published in native languages concerning the prevalence of Wormian bones, as well as other morphological and anatomical studies in local populations, should be made available to the worldwide scientific and scholarly community.

Due to the major inconsistency regarding research methods used to determine the frequency of Wormian bones, comparing archival data may not be reliable and therefore existing knowledge regarding this phenomenon may not reflect the actual biological regularities. Consequently, there is a need for clarity regarding the description of the data collection protocol which would allow conducting a more robust meta-analysis and further research on Wormian bones. In addition, there is a significant gap in the data on the presence of sutural bones in non-Asian populations which should encourage research on materials from these regions of the world.

Acknowledgments

This work was supported by the Wrocław University of Environmental and Life Sciences (Poland) as the Ph.D. research program "Bon Doktoranta UPWr" no. N020/0006/20.

Conflict of interests

The authors declare no conflict of interests

Authors' contributions

AB is the head of the research team, originator, main researcher, author of the working and final version of the paper, performer of statistical analyzes and interpretation of calculation results. RR-R is the co-creator of the draft and final version of the work and the substantive supervisor.

Corresponding author

Agata Bisiecka, Kożuchowska Street 5, 51-631 Wrocław, Poland; e-mail: agata.bisiecka@upwr.edu.pl

References

Ahad M, Thenmozhi MS. 2015. Study on Asterion and Presence of Sutural Bones in South Indian Dry Skull. J Pharm Sci and Res 7(6):390–92.

Andrade LS, Kalthur SG. 2018. Topography of Wormian Bones in Cadaveric Dry Skulls. The Online Journal of Health and Allied Sciences 17(3):6. Available at https://www.ojhas.org/issue67/2018-3-6.html [Accessed 14 December 2022].

Barberini F, Bruner E, Cartolari R, Franchitto G, Heyn R, Ricci F, Manzi G. 2008. An unusually-wide human bregmatic Wormian bone: anatomy, tomographic description, and possible significance. Surg Radiol Anat 30(8):683–87, https://doi.org/10.1007/s00276-008-0371-0

Basnet LM, Shrestha S, Sapkota S. 2019. Prevalence of Wormian bones in dried adult human skulls: an osteo-morphometric study in Nepal. Anat Sci Int 94:101–09, https://doi.org/10.1007/s12565-018-0454-x

Bellary SS, Steinberg A, Mirzayan N, Shirak M, Tubbs RS., Cohen-Gadol AA, Loukas M. 2013. Wormian bones: A review. Clin Anat 26:922–27, https://doi.org/10.1002/ca.22262

Bennett KA. 1965. The Etiology and Genetics of Wormian Bones. Am J Phys Anthropol 23(3):255–60, https://doi.org/10.1002/ajpa.1330230313

Bruner E. 2004. Geometric morphometrics and paleoneurology: brain shape evolution in the genus *Homo*. J Hum Evol 47:279e303, https://doi.org/10.1016/j.jhevol.2004.03.009

Cirpan S, Aksu F, Mas N. 2014. Inca Bone in Human Skulls of the West Anatolian Populatıon. Int J Morphol 32(1):275–78, https://doi.org/10.4067/S0717-95022014000100045

Cirpan S, Aksu F, Mas N, Magden AO. 2016. Coexistence of Wormian Bones with Metopism, and Vice Versa, in Adult Skulls. J Craniofac Surg 27(2):493–95, https://doi.org/10.1097/SCS.0000000000002370

Cremin B, Goodman H, Spranger J, Beighton P. 1982. Wormian Bones in Osteogenesis Imperfecta and Other Disorders. Skeletal Radiol 8:35–38, https://doi.org/10.1007/BF00361366

De Lucena JD, Freitas FOR, Limeira ÍS, de Araújo Sales TH, Sanders JVS, Cavalcante JB, Cerqueira GS. 2019. Incidence of sutural bones at asterion in dry human skulls in Northeast Brazil, Acta Sci Anat.1(3):178–83.

Česnys G, Balčiūnienė I. 1988. Senųjų Lietuvos gyventojų antropologija. Vilnius, Lithuania: Mokslas. 154–160.

Durge SV. 2016. Study of Wormian Bones on Dry human skull and its sexual dimorphism in the region of Andhra Pradesh. IP Indian J Anat Surg Head Neck Brain 2(3):79–82.

Durgesh V, Rani CHR, Vijayalakshmi K, Khin Myo Thu, Venugopala Rao B, Viswakanth B. 2015. Incidence of Wormian Bones in the North Coastal Andhra Pradesh. IOSR-JDMS 14(10):53–57, https://doi.org/10.9790/0853-141085357

Di Ieva A, Bruner E, Davidson J, Pisano P, Haider T, Stone SS, Cusimano MD, Tschabitscher M, Grizzi F. 2013. Cranial sutures: a multidisciplinary review. Childs Nerv Sys 29:893–905, https://doi.org/10.1007/s00381-013-2061-4

Eboh DEO, Obaroefe M. 2014. Morphometric Study of Pterion in Dry Human Skull Bones of Nigerians, Int J Morphol 32(1):208–13, https://doi.org/10.4067/S0717-95022014000100035

Edwards B, Wang JMH, Iwanaga J, Luviano J, Loukas M, Oskouian RJ, Tubbs RS. 2017. Hiding Within the Cracks: Case Report of Rare Sutural Bone Found at the Nasion. Cureus 9(6):e1333, https://doi.org/10.7759/cureus.1333

El-Najjar M, Dawson GL. 1977. The Effect of Artificial Cranial Deformation on the Incidence of Wormian Bones in the Lambdoidal Suture. Am J Phys Anthropol 46:155–60, https://doi.org/10.1002/ajpa.1330460119

Finkel DJ. 1975. Wormian Bone Formation in the Skeletal Population from Lachish. J Hum Evol 5(3):291–95, https://doi.org/10.1016/0047-2484(76)90032-4

Ghosh SK, Biswas S, Sharma S, Chakraborty S. 2017. An anatomical study of Wormian bones from the eastern part of India: is genetic influence a primary determinant of their morphogenesis? Anat Sci Int 92(3):373–82, https://doi.org/10.1007/s12565-016-0342-1

Govsa F, Ozer MA, Bayraktaroglu S, Aktas EO. 2014. Anatomoradiological Identification of Intrasutural Bones for Importance of Cranial Fracture. Turkish Neurosurgery 24(3):357–62, https://doi.org/10.5137/1019-5149.JTN.8380-13.2

Goyal N, Garg A, Kumar Y. 2019. Incidence and Medicolegal Significance of Wormian Bones in Human Skulls in North India Region. Int J Appl Basic Med Res 9(3):165–68, https://doi.org/10.4103/ijabmr.IJABMR_89_19

Gümüsburun E, Sevim A, Katkici U, Adigüzel E, Güleç E. 1997. A study of sutural bones in Anatolian-Ottoman Skulls. Int J Anthropol 12(2):43–48, https://doi.org/10.1007/BF02447895

Illknur A, Mustafa KI, Sinan B. 2009. A Comparative Study of Variation of the Pterion of Human Skulls from 13th and 20th Century Anatolia. Int J Morphol 27(4):1291–98.

Jeanty P, Silva SR, Turner C. 2000. Prenatal diagnosis of Wormian bones. J Ultrasound Med 19(12):863–69, https://doi.org/10.7863/jum.2000.19.12.863

Jayprakash PT. 1997. Skull sutures: radiographic contour of Wormian bone as an individualising epigenetic marker. Can Soc Forensic Sci 30(2):39–47, https://doi.org/10.1080/00085030.1997.10757085

Johal J, Iwanaga J, Loukas M, Tubbs RS. 2017. Anterior Fontanelle Wormian Bone/Fontanellar Bone: A Review of this Rare Anomaly with Case Illustration. Cureus 9(7):e1443, https://doi.org/10.7759/cureus.1443

Kague E, Roy P, Asselin G, Hu G, Simonet J, Stanley A, Albertson C, Fisher S. 2016. Osterix/Sp7 limits cranial bone initiation sites and is required for formation of sutures. Dev Biol 413(2):160–72, https://doi.org/10.1016/j.ydbio.2016.03.011

Kalthur SG, Vangara SV, Kiruba L, Dsouza AS, Gupta C. 2017. Metrical and non-metrical study of the pterion in South Indian adult dry skulls with notes on its clinical importance. Marmara Med J 30:30–39, https://doi.org/10.5472/marumj.299387

Khan AA, Asari MA, Hassan A. 2011. Unusual presence of Wormian (sutural) bones in human skulls. Folia Morphol 70(4):291–294.

Kuharić J, Kovacic N, Marusic P, Marusic A, Petrovecki V. 2011. Positive Identification by a Skull with Multiple Epigenetic Traits and Abnormal Structure of the Neurocranium, Viscerocranium, and the Skeleton. JFS 56(3):788–93, https://doi.org/10.1111/j.1556-4029.2011.01718.x

Kumar U, Ratna Prabha J. 2016. Wormian bones: study on dry human skulls in North Karnataka region. IJAR 4(1):1854–58, https://doi.org/10.16965/ijar.2015.351

Lekshmy VVG, Ramakrishna A, Meera J. 2017. Incidence of Wormian bones in dry human skulls in South Indian population. Int J Anat Res 5(3.3):4349–55, https://doi.org/10.16965/ijar.2017.331

Li J-H, Chen Z-J, Zhong W-X, Yang H, Liu D, Li Y-K. 2022. Anatomical characteristics and significance of the metopism and Wormian bones in dry adult-Chi-

nese skulls. Folia Morphol, https://doi.org/10.5603/FM.a2022.0006

Marathe RR, Yogesh AS, Pandit SV, Joshi M, Trivedi GN. 2010. Inca – interparietal bones in neurocranium of human skulls in central India 2010. JNRP 1(1):14–16, https://doi.org/10.4103/0976-3147.63094

Marti B, Sirinelli D, Maurin L, Carpentier E. 2013. Wormian bones in a general paediatric population. Diagn. Interv. Imaging 94(4):428–32, https://doi.org/10.1016/j.diii.2013.01.001

Masih WF, Gupta S, Chand AE, Jaiswal P, Saraswat PK. 2013. Incidence of Wormian bone in human skulls in Rajasthan. JEMDS 2(9):1001–04, https://doi.org/10.14260/jemds/370

Murlimanju BV, Prabhu LV, Ashraf CM, Kumar CG, Rai R, Maheshwari C. 2011. Morphological and topographical study of Wormian bones in cadaver dry skulls. J Morphol Sci 28(3):176–79.

Murrieta-Angulo S, Tejada-Valdivia CA, Arriola-Guillén LE. 2019. Morphological study of Pterion in skulls of corpses of the Institute of Legal Medicine and Forensic Sciences (Ditanfor), Lima – Peru 2018. Rev Mex Med Forense 4(2):12–23.

Nagarajan K, Ganesh MK. 2017. Variations in the Occurrence of "Os Inca" and its Cranial Deformities in South Indian Dry Skulls. J Pharm Sci and Res 9(2):167–69.

Natsis K, Piagkou M, Lazaridis N, Anastasopoulos N, Nousios G, Piagkos G, Loukas M. 2019. Incidence, number and topography of Wormian bones in Greek adult dry skulls. Folia Morphol 78(2):359–70.

Narayan RK, Kumari S, Verma M. 2019. Prevalence and variety of sutural bones in densely populated East Indian state of Bihar. Ann Acad Med Siles 73:174–81, https://doi.org/10.18794/aams/109153

Nayak SB, Shetty SD. 2019. High Incidence of Sutural Bones, Especially at the Asterion – A South Indian Study. Online J Health Allied Scs 18(8). Available at: https://www.ojhas.org/issue72/2019-4-8.html [Accessed 14 December 2022].

Nikolova SY, Toneva DH, Yordanov YA, Lazarov NE. 2014. Multiple Wormian bones and their relation with definite pathological conditions in a case of an adult cranium. Anthropol Anz 71(3):169–90, https://doi.org/10.1127/0003-5548/2014/0355

Nikolova S, Toneva D, Georgiev I, Yordanov Y, Lazarov N. 2016. Two cases of large bregmatic bone along with a persistent metopic suture from necropoles on the northern Black Sea coast of Bulgaria. Anthropol Sci 124(2):145–53, https://doi.org/10.1537/ase.160530

Nowak J, Pawlak S, Poniewierski W, Adamiec M, Iwańczyk B, Wojtowicz A. 2018. Kości Worma – anatomia czy patologia? Implants. International magazine of oral implantology 13(1):42–45.

O'Loughlin VD. 2004. Effects of Different Kinds of Cranial Deformation on the Incidence of Wormian Bones. Am J Phys Anthropol 123(2):146–55, https://doi.org/10.1002/ajpa.10304

Oguz Ö, Güraslan Şanli S, Bozkir MG, Soames RW. 2004. The pterion in Turkish male skulls. Surg Radiol Anat 26:220–24, https://doi.org/10.1007/s00276-003-0210-2

Pal GP, Routal RV. 1986. A study of sutural bones in different morphological forms of skulls. Anthropol Anz 44(2):169–73.

Panzer S, Peschel O, Haas-Gebhard B, Bachmeier BE, Pusch CM, Nerlich AG. 2014. Reconstructing the Life of an Unknown (ca. 500 Years-Old South American Inca) Mummy – Multidisciplinary Study of a Peruvian Inca Mummy Suggests Severe Chagas Disease and Ritual Homicide. PloS ONE 9(2): e89528, https://doi.org/10.1371/journal.pone.0089528

Patil M, Sheelavant S. 2012. Sexual dimorphism among the Wormian bones in adult human skulls. J Indian Acad Forensic Med 34:124–127.

Praba AMA, Venkatramaniah C. 2015. A study on the occurrence of Wormian bones among the male and female skulls of Tamil Nadu, India. IJAR 3(4):1700–03, http://doi.org/10.16965/ijar.2015.320

Purohit K, Yadav B. 2019. Sutural bones: A study on incidence, laterality and co-relation with cephalic index in dry crania of East Indian ethnicity. Int J Anat Res 7(3.3):6944–51, https://doi.org/10.16965/ijar.2019.265

Raja SK, Siva NRSS. 2016. Incidence of sutural bones at pterion in South Indian dried skulls, Int J Anat Res 4(1):2099–2101, http://doi.org/10.16965/ijar.2016.154

Rajni MG, Shalik RA, Hema N, Renu M, Swati Y. 2018. Incidence of Wormian bones in North India – a study on adult cadavers dried skull. Int J Curr Res 10(8):72372–74, https://doi.org/10.24941/ijcr.31882.08.2018

Ratnaningrum SF. 2020. Identification of sutural bones in Indonesian skulls. Transl Res Anat 18:100061, https://doi.org/10.1016/j.tria.2019.100061

Reicher M, Łasiński W. 2010. Uwagi wstępne (funkcja czaszki). In: Bochenek A, Reicher M, editors. Anatomia człowieka. Tom I. Anatomia ogólna. Kości, stawy i więzadła, mięśnie. Warszawa, Polska: Wydawnictwo Lekarskie PZWL. 299.

Rizvi A, Iwanaga J, Oskouian RJ, Loukas M, Tubbs RS. 2018. Wormian Bone of the Orbit: A Case Report. Cureus 10(8):e3117, https://doi.org/10.7759/cureus.3117

Romero-Reverón R. 2017. Anatomical classification of sutural bones. MOJAP 3(4):130–31, https://doi.org/10.15406/mojap.2017.03.00101

Romero-Reverón R. 2020. False Sutural Bones should have its Own Anatomical Denomination in International Anatomical Terminology? JMA 4(3):134, https://doi.org/10.37421/JMA.2020.4.134

Romero-Reverón R, Arráez-Aybar LA. 2019. Sutural bones: a literature review. Anatomy 13(1):61–65, https://doi.org/10.2399/ana.18.062

Rothman KJ, Greenland S. 2005. Hill's Criteria for Causality. In: Armitage P and Colton T, editors. Encyclopedia of Biostatistics. 2nd edition. John Wiley & Sons, Ltd. https://doi.org/10.1002/0470011815.b2a03072

Sah SK, Chaudhary D, Pandey N. 2017. Study of metopism and Wormian bones in dry skulls of human cadavers in Nepal. Int J Anat Res 5(1):3443–46, https://doi.org/10.16965/ijar.2016.499

Sanchez-Lara PA, Graham Jr JM, Hing AV, Lee J, Cunningham M. 2007. The Morphogenesis of Wormian Bones: A Study of Craniosynostosis and Purposeful Cranial Deformation. AJMG 143A:3243–51, https://doi.org/10.1002/ajmg.a.32073

Saylisoy S. 2020. Is There a Coexistence of Peritemporal Wormian Bones and Congenital Aural Atresia? JCAT 44:559–61, https://doi.org/10.1097/RCT.0000000000001047

Saxena SK, Chowdhary DS, Jain SP. 1986. Interparietal bones in Nigerian skulls. J Anat 144:235–237.

Semler O, Cheung MS, Glorieux FH, Rauch F. 2010. Wormian Bones in Osteogenesis Imperfecta: Correlation to Clinical Findings and Genotype. AJMG 152(A):1681–87, https://doi.org/10.1002/ajmg.a.33448

Shiv S, Hitesh C, Rajeev K, Ashish T, Bhushan V, Panchal J. 2020. Study of incidence of Wormian bones in southern Haryana – A prospective observational study. IJFCM 7(3):129–33, https://doi.org/10.18231/j.ijfcm.2020.028

Singh R. 2012. Incidence of Sutural Bones at Asterion in Adults Indians Skulls. Int J Morphol 30(3):1182–86.

Smith JD, Genoways HH, Jones Jr JK. 1977. Cranial and dental anomalies in three species of platyrrhine monkeys from Nicaragua. Folia Primatol. 28(1):1–42, https://doi.org/10.1159/000155796

Sreekanth T, Samala N. 2016. Morphological study of Wormian bones in dried adult human skulls in Telangana. IJAR 4(4):3257–62, https://doi.org/10.16965/ijar.2016.454

Standring S. 2016. External skull. In: Black S, editor. Gray's anatomy: the anatomical basis of clinical practice. USA, Philadelphia: Elsevier. 416–25.

Sudha R, Sridevi C, Ezhilarasi M. 2013. Anatomical variations in the formation of pterion and asterion in South Indian population. IJCRR 5(9):92–101.

Tonni G, Lituania M, Rosignoli L. 2013. Craniosynostosis with Wormian Bone, Bowing of the Long Bones, Unilateral Short Femur, and Focal Fibula Deficiency: A Prenatal Diagnostic Dilemma. JCU 41(7):448–52, https://doi.org/10.1002/jcu.22002

Uchewa OO, Egwu OA, Egwu AJ, Nwajagu GI. 2018. Incidence of Wormian bones in the dried skull of Nigerian males. Int J Anat Var 11(1):32–34, https://doi.org/10.37532/1308-4038.18.11.32

Ukoha U, Oranusi CK, Okafor JI, Udemezue OO, Anyabolu AE, Nwamarachi TC. 2013. Anatomic study of the pterion in Nigerian dry human skulls. Niger J Clin Pract 16(3):325–28, https://doi.org/10.4103/1119-3077.113455

Uday K, Ratna Prabha J. 2016. Wormian bones: Study on dry human skulls in North Karnataka region. Int J Anat Res 4(1):1854–58, http://doi.org/10.16965/ijar.2015.351

Yadav B, Salam R. 2020. A preliminary study on incidence of cranial sutural bones by 3D volume rendering of CT scan in current population in Eastern India. IJAR 8(1.3):7390–94, https://doi.org/10.16965/ijar.2020.110

Veeresh KTM, Kumar V, Yadav N. 2016. The occurrence of Wormian bones within the cranial sutures and their clinical significance. Int J Anat Res 4(4):3082–86, http://doi.org/10.16965/ijar.2016.408

Vishali N, Ebenraj TJ, Rojomon TC. 2012. A rare existence of significant number of wormian bones in the lambdoid suture. IJSR 3(8):671–677.

Walulkar S, Ksheersagar D, Walukar M. 2012. The study of Wormian bones in human skulls in Vidarbha region. PJMS 2(2):18–21.

Zambrano MLA, Kilroy D, Kumar A, Gilchrist MD, Nı´Annaidh A. 2021. The presence of Wormian bones increases the fracture resistance of equine cranial bone. PLoS ONE 16(4): e0249451, https://doi.org/10.1371/journal.pone.0249451

Zimmerman H, Yin Z, Zou F, Everett ET. 2019. Interfrontal Bone Among Inbred Strains of Mice and QTL Mapping. Frontiers in Genetics 10:291, https://doi.org/10.3389/fgene.2019.00291

Table 1. Research Characteristics

Article	Population	Sample	No. of Individuals	Known Sex and Age	Research Method	Comments
SCORING = 0						
Ahad and Thenmozhi, 2015	South Indian	cont?	25	A	Asterion bones counted and measured relative to cranial landmarks (bilaterally)	asterion only
SCORING = 1						
Saxena et al. 1986	Nigerian	cont?	40	A	Preinterpalietal bones counted	preinterpatietal bones only
Singh 2012	Indian	–	55	S, A	Number of WB in asterion noted (bilaterally)	asterion only
Masih et al. 2013	North Indian (Rajasthan)	cont	150	S, A	Presence of WB noted	–
Durgesh et al. 2015	Indian (Andhra Pradesh)	cont?	48	–	Occurrence of WB noted	WB present only in the lambdoid suture
Praba and Venkatramaniah 2015	Indian (Tamil Nadu)	cont?	50	S, A	WB counted in bregma, lambda, pterion and asterion (regardless of the side)	–
Raja and Siva 2016	South Indian	cont?	75	A	WB in pterion counted	pterion only
Veeresh et al. 2016	Indian	cont?	50	A	Number and location of WB noted (bilaterally); WB photographed	–
Sah et al. 2017	Nepalese	cont?	80	A	Presence and localization of WB noted	–
Uchewa et al. 2018	Nigerian	cont	22	S, A	WB counted and photographed; lateralization not included	–
Rajni et al. 2018	North Indian	cont/ cont (?)	55	A	Number and location of WB noted (bilaterally)	Material including cadaveric and museum samples
Ratnaningrum 2020	Indonesian	cont?	69	–	Presence, localization and variations in WB shapes noted (bilaterally)	–

SCORING = 2						
Illknur et al. 2009	Anatolia	cont/arch	44	S/–, A	Epipteric bones counted; measurements between pterion and several landmarks taken both in manual and digital way (on photographs)	pterion only; sex (male) assessed on archaeological sample only
Murlimanju et al. 2011	Indian	cont?	78	–	Incidence and topographical distribution of WB (bilaterally)	Interparietal and preinterparietal bones not considered as WB
Walulkar et al. 2012	Central Indian (Vidarbha)	cont	225	S, A	WB counted bilaterally, measured (max. width x max. length), incidence of various shapes of WB noted	–
Sudha et al. 2013	South Indian	cont	150	A	Epipteric and asterion bones noted bilaterally	pterion and asterion only
Eboh and Obaroefe 2014	Nigerian	–	50	–	Epipteric bones counted bilaterally; measurements between pterion and several cranial landmarks	pterion only
Ghosh et al. 2017	East Indian	cont	120	A	WB counted bilaterally; topographic distribution analysis, symmetry of WB occurrence analysis	–
Tallapaneni and Niveditha 2016	South-Eastern Indian (Telangana)	cont?	111	–	Presence of Wormian bones in respect to their location and number noted (bilaterally)	–
Uday and Ratna Prabha 2016	Indian (North Karnataka)	cont	200	–	Presence, localization and number of WB noted	–
Ukoha et al. 2013	Nigerian	cont	56	A	Frequency of pterion's types recorded according to Murphy (1956)	pterion only
Kalthur et al. 2017	South Indian (Karnataka)	cont?	50	S, A	Epipteric bones counted and measured relative to cranial landmarks (bilaterally)	pterion only

Article	Population	Sample	No. of Individuals	Known Sex and Age	Research Method	Comments
Lekshmy et al. 2017	South Indian	cont	200	A	WB counted (bilaterally); topographic distribution of WB	–
Nagarajan and Ganesh 2017	South Indian	cont	60	–	Presence and number of Inca bones; skulls with Inca bones photographed	Inca bones only
Narayan et al. 2019	Eastern Indian (Bihar)	cont?	30	A	Number of WB and their localization noted bilaterally; cranial index examined	–
Nayak and Shetty 2019	South Indian	–	27	S, A	WB noted (regardless of the side), photographs of skulls with WB	–
Yadav and Salam 2020	Eastern Indian	cont	64	S, A	WB counted (regardless of the side)	CT scans of head and neck
SCORING = 3						
Pal and Routal 1986	Indian (South Gujarat)	cont	117	–	WB noted bilaterally for each morphological type of skull; correlation with cephalic index examined	–
Gümüsburun et al. 1997	Anatolian-Ottoman	arch	302	S, A	WB counted bilaterally; examined correlation with the cephalic index (3 morphological forms)	–
Govsa et al. 2014	Turkish	cont	300	A	Presence, localization and number of WB noted bilaterally	3D reconstructions with volume rendering; preinterparietal bones treated separately
Oguz et al. 2004	Turkish	cont?	26	S (males only), A	Types of pterions (according to Murphy (1956)) noted; measurements between pterion and selected landmarks; bone thickness measurements	pterion only

Cirpan et al. 2014	West Anatolian	cont	151	A	Inca bones counted following the Hauser and De Stefano (1989) and Kadanoff and Mutafov (1968) classification	Inca bones only
Cirpan et al. 2016	West Anatolian	cont?	150	A	Presence, frequency and topographic distribution of WB assessed bilaterally; photography	–
Durge 2016	South-Easter Indian (Andhra Pradesh)	cont?	160	S, A	WB number and localization noted	–
Basnet et al. 2019	Nepalese	–	70	A	WB counted bilaterally; examined correlation with the cephalic index (3 morphological forms)	Inca bones treated separately
de Lucena et al. 2019	North-East Brazilian	cont	30	S, A	Numbers of WB in asterion noted; measurements between asterion and several skull landmarks	asterion only
Li et al. 2022	Chinese	cont	285	A	Width and length of WB measured, counted (bilaterally); types of WB shapes counted	Inca bones treated separately
Murrieta-Angulo et al. 2019	Peru	cont	90	S, A	Type of pterion bilaterally noted according to Murphy's classification (1956); measurements between the ossification center and zygomatic arch; photographs	pterion only
Shiv et al. 2020	Indian (Southern Haryana)	cont	130	S	Location of WB along the coronal, sagittal and lambdoid suture on ectocranial surface noted; photographs	–
SCORING = 4						
Finkel 1975	Lachish	arch	628	S	WB presence noted (in lambdoid, sagittal or coronal suture); skull metric differences in relation to WB presence/absence examined	Inca bones excluded

Article	Population	Sample	No. of Individuals	Known Sex and Age	Research Method	Comments
Goyal et al. 2019	North Indian (Haryana)	cont	147	–	Presence, number and topographic distribution of WB noted (regardless the side of the skull)	Interparietal and preinterparietal bones not considered as WB
Marathe et al. 2010	Central Indian	cont	380	A	Incidence of Inca bone noted; measurements of Inca bone	Inca bones only
Natsis et al. 2019	Greek	cont	166	S, A	WB presence noted bilaterally and both exo- and intracranially; WB presence on viscerocranium noted; side asymmetry analysis	Inca bone excluded from the study
Purohit and Yadav 2019	East Indian	–	180	S, A	Presence and location of WB noted bilaterally; photographs of WB taken; cephalic index included	Inca bones not counted as WB

Abbreviations: arch – archaeological sample, cont – contemporary sample; S – sex, A - age. 'Known age' was determined positively both when the exact age categories were given or when subjects were assigned the general 'adult' age category. 'Bilaterally' description in the table refers to the parts of the skull (sutures or landmarks) that appear paired.

Table 2. Wormian Bones Prevalence Among Various Populations Worldwide

Article	Presence	Total no.	WB in main sutures					WB in specific sites of the skull						
			C	S	Sq-R	Sq-L	L	B	LL	A-R	A-L	P-R	P-L	I
SCORING = 0														
Ahad and Thenmozhi 2015 ⁂	–	–	–	–	–	–	–	–	–	12%	20%	–	–	–
										Σ: 32%				
SCORING = 1														
Saxena et al. 1986 ⁂	–	–	–	–	–	–	–	–	–	–	–	–	–	*II* single: 1 (2.5%) *PI* single: 4 (10%) multi: 1 (2.5%)
Singh 2012 ⁂	–	–	–	–	–	–	–	–	–	♂: 25.0 % ♀: 14.8%	♂: 10.7 % ♀: 14.8%	–	–	–
Masih et al. 2013 ⁂	♂: 6 (4.1%) ♀: 1 (3.6%) Σ: 7 (4.7%)	–	–	–	–	–	–	–	–	–	–	–	–	–
Durgesh et al. 2015 ⁂	24.1%	–	–	–	–	–	14	–	–	–	–	–	–	–
Praba and Venkatramaniah 2015	–	♂: 56 ♀: 27	–	–	–	–	–	♂: 0 ♀: 0	♂: 13 ♀: 1	♂: 35 ♀: 19		♂: 8 ♀: 7		–
Raja and Siva 2016 ⁂	–	–	–	–	–	–	–	–	–	–	–	1	2	–
												Σ: 3 (4%)		

Article	Presence	Total no.	WB in main sutures						WB in specific sites of the skull					
			C	S	Sq-R	Sq-L	L	B	LL	A-R	A-L	P-R	P-L	I
Veeresh et al. 2016 ⁂	16 (32%)	–	–	0	–	–	R: 7 L: 15 Σ: 22 (44%)	0	3 (6%)	1	2 Σ: 3 (6%)	1	0 Σ: 1 (2%)	–
Sah et al. 2017 ⁂⁂	55 (68.7%)	–	0	2 (3.6%)	–	–	35 (63.6%)	0	–	11 (20%)		7 (12.7%)		–
Uchewa et al. 2018 ⁂	10 (45.5%)	–	0	0	–	–	8 (36.4%)	0	–	–	–	Σ: 2 (9.1%)		–
Rajni et al. 2018 *	28 (51%)	–	0	1 (2%)	2 Σ: 3 (5%)	1	6 Σ: 14 (26%)	8	4 (7%)	1	2 Σ: 3 (5%)	1	0 Σ: 1 (2%)	–
Ratnaningrum 2020 ⁂⁂	11 (15.9%)	–	–	–	–	–	8 (72.7%)	–	–	–	–	3 (27.3%)		1
SCORING = 2														
Illknur et al. 2009 ⁑	–	–	–	–	–	–	–	–	–	–	–	Archaeological sample: 1 (6.25%) Contemporary sample: 1 (3.5%)		–
Murlimanju et al. 2011 ⁂	57 (73.1%)	–	1 (1.3%)	1 (1.3%)	–	–	44 (56.4%)	0	–	Σ: 14 (17.9%)		Σ: 9 (11.%)		–
Walulkar et al. 2012 ⁂	♂: 63 (39.1%) ♀: 14 (21.9%) Σ: 77 (34.2%)	–	♂: 1 (1.3%) ♀: 0 Σ: 1 (1.3%)	♂: 4 (5.2%) ♀: 0 Σ: 4 (5.2%)	–	–	♂: 45 (71.4%) ♀: 12 (85.7%) Σ: 57 (74.2%)	0	♂: 7 (11.1%) ♀: 1 (7.1%) Σ: 8 (10.4%)	♂: 3 ♀: 1 Σ: 7 (9.1%)	♂: 2 ♀: 2	–	–	–
Sudha et al. 2013 ⁂	–	–	–	–	–	–	–	–	–	13 (8.6%)	10 (6.6%) Σ: 23 (7.6%)	21 (14%)	13 (8%) Σ: 34 (11.3%)	–

Eboh and Obaroefe 2014 ■	–	6 (6%)	–	–	–	–	–	–	–	–	–	4 (8%) 2 (4%) Σ: 6 (6%)		–
Ghosh et al. 2017	54 (45%)	165	2.4%	5.4%	10.9%		53.3%	0.6%	21.2%	–		–		–
Tallapaneni and Niveditha 2016 ⁂	59 (53.1%)	–	0	1 (0.9%)	3 2 Σ: 5 (4.5%)		R: L: 25 34 Σ: 59 (53.1%)	1 (0.9%)	9 (8.1%)	1 2 Σ: 3 (2.7%)		2 0 Σ: 2 (1.8%)		–
Uday and Ratna Prabha 2016 ⁑	113 (56.5%)	–	0	0	0	5 (4.4%)	R: L: 21 43 Σ: 64 (56.6%)	0	52 (46%)	18 28 Σ: 46 (40.7%)		1 5 Σ: 6 (5.3%)		–
Ukoha et al. 2013 ⁂	–	–	–	–	–	–	–	–	–	–	–	3.6%	3.6%	–
Kalthur et al. 2017 *	–	–	–	–	–	–	–	–	–	–	–	R: 24% L: 10% ♂: 18.9% ♀: 11.6%		–
Lekshmy et al. 2017 ⁂	123 (61.5%)	–	R: L: 36 30 Σ: 66 (53.6%)	34 (27.6%)	26 30 Σ: 56 (45.5%)		R: R: 58 54 Σ: 112 (91%)	3 (2.4%)	29 (23.6%)	50 48 Σ: 98 (79.7%)		9 11 Σ: 20 (16.3%)		–
Nagarajan and Ganesh 2017 ⁂	–	–	–	–	–	–	–	–	–	–	–	–	–	single: 7 (87.5%) double:1 (12.5%) Σ: 8 (13.3%)

Article	Presence	Total no.	WB in main sutures					WB in specific sites of the skull						
			C	S	Sq-R	Sq-L	L	B	LL	A-R	A-L	P-R	P-L	I
Narayan et al. 2019 ⁑, ⁂	13 (43%)	82	R: 3 L: 2 + 4 bilateral = Σ: 9 (10.6%)	0	2	0	R: 23 L: 19 + 10 bilateral =Σ: 52 (61.2%)	0	7 (8.2%)	0	0	2	4 + 2 bilateral = Σ: 2 (2.3%)	–
					Σ: 2 (2.3%)							Σ: 6 (7%)		–
Nayak and Shetty 2019 ⁂	24 (88.8%)	–	2 (7.4%)	–	–	–	6 (22.2%)	–	4 (14.8%)	18 (66.6%)		2 (7.4%)		–
Yadav and Salam 2020 ⁂	♂: 11 (30.6%) ♀: 8 (28.6%) Σ: 19 (29.7%)	–	1 (5.3%)	1 (5.3%)	1 (5.3%)		15 (78.9%)	–	4 (21%)	8 (42.1%)		–	–	–
SCORING = 3														
Pal and Routal 1986 ⁂	–	–	*D:*0 *M:* 0 *B:*0	*D:* 4 (5.8%) *M:* 0 *B:0*	*D:* 11 (8%) *M:* 1 (1.3%) *B:* 1 (5%)		*D:* 51 37%) *M:* 23 (30.3%) *B:* 9 (45%)	*D:* 0 *M:* 0 *B:* 0	*D:* 13 (18.8%) *M:* 4 (10.5%) *B:* 0	*D:* 8 (5.8%) *M:* 2 (2.6%) *B:* 2 (10%)		*D:* 8 (5.8%) *M:* 3 (3.9%) *B:* 2 (10%)		–
Gümüsburun et al. 1997 *	–	–	♂: 4 (2.1%) ♀: 5 4,5%) Σ: 9 (3%)	♂: 1 (0.5%) ♀: 4 (3.6%) Σ: 5 (1.6%)	♂: 14 (7.3%) ♀: 10 (9.1%) Σ: 24 (7.9%)		♂: 117 (60.9%) ♀: 70 (63.6) Σ: 187 (61.9%)	♂: 2 (1%) ♀: 0 Σ: 2 (0.7%)	♂: 26 (13.5%) ♀: 7 (3.6%) Σ: 33 (10.9%)	♂: 32 (16.7%) ♀: 14 (12.7%) Σ: 46 (15.2%)		♂: 22 (11.5%) ♀: 8 (7.3%) Σ: 30 (9.9%)		–
Govsa et al. 2014 ⁂	27	–	–	–	–	–	12 (4%)	–	–	–	–	–	–	*PI:* single:6 multiple: 3 Σ: 9 (3%) *II:* single: 2 multiple:4 Σ: 6 (2%)

Oguz et al. 2004 ⁂	–	–	–	–	–	–	–	–	–	–	–	♂: 0	♂: 4%	–
Cirpan et al. 2014 ⁂	–	–	–	–	–	–	–	–	–	–	–	–	–	3 (2%)
Cirpan et al. 2016 ⁑	89 (59.3%)	207	R:5 (3.3%) L:5 (3.3%)	7 (4.7%)	3 (2%)	10 (6.7%)	R: 56 (37.3%) L: 61 (40.7%)	3 (2%)	10 (6.7%)	10 (6.7%)	11 (7.3%)	8 (5.3%)	12 (8%)	–
Durge 2016	♂: 30 (41.7%) ♀: 42 (47.7%) Σ: 72 (45%)	–	♂: 4 ♀: 0	–	–	–	♂: 22 ♀: 34	♂: 2 ♀: 0	–	♂: 2 ♀: 0		♂: 0 ♀: 4		–
Basnet et al. 2019 ⁂	62 (88.6%)	–	3 (4.3%)	5 (7.1%)	29 (41.4%)		43 (61.4%)	0	8 (11.4%)	17 (24.3%)		18 (25.7%)		–
de Lucena et al. 2019 ⁂	–	–	–	–	–	–	–	–	–	♂: 6.7% ♀: 8.3% ♂: 11.7% ♀:5% Σ: 19 (31.7%)		–	–	–
Li et al. 2022 ⁂	182 (63.9%)	–	–	9 (4.9%)	–	–	143 (78.6%)	–	15 (8.3%)	22 (12.1%)		63 (34.6%)		7 (3.8%)
Murrieta-Angulo et al. 2019 ⁂■	–	–	–	–	–	–	–	–	–	–	–	0	0	–
Shiv et al. 2020 ⁂	♂: 19 (22.1%) ♀: 8 (18.2%) Σ: 27 (20.1%)	–	1 (0.8%)	7 (5.4%)	–	–	19 (14.6%)	–	–	–	–	–	–	–
SCORING = 4														
Finkel 1975 ⁂	♂: 114 ♀: 81	–	–	–	–	–	–	–	–	–	–	–	–	–
Goyal et al. 2019 ⁂	♂: 35 (36.1%) ♀: 17 (34%) Σ: 52 (35.3%)	–	9 (6.1%)	7 (4.8%)	–	–	41 (27.9%)	0	28 (19%)	3 (2%)		1 (0.7%)		–

Article	Presence	Total no.	WB in main sutures					WB in specific sites of the skull						
			C	S	Sq-R	Sq-L	L	B	LL	A-R	A-L	P-R	P-L	I
Marathe et al. 2010 ⁂	–	–	–	–	–	–	–	–	–	–	–	–	–	♂: 3 (1.4%) ♀: 2 (1.2%) Σ: 5 (1.3%)
Natsis et al. 2019 ⁂, ⁑	♂: 67 (72.8%) ♀: 57 (77%) Σ: 124 (74.7%)	–	♂: 39 (42.4%) ♀: 27 (36.5%) Σ: 66 (39.8%)	♂: 9 (9.8%) ♀: 9 (12.2%) Σ: 18 (10.8%)	♂: 7 ♀: 5 Σ: 12	♂: 4 ♀: 5 Σ: 9	♂: 40 (43.5%) ♀: 34 (45.9%) Σ: 74 (44.6%)	♂: 2 (2.2%) ♀: – Σ: 2 (1.6%)	♂: 1 (1.1%) ♀: 2 (2.8%) Σ: 3 (2.4%)	♂: 15 ♀: 4 Σ: 19	♂: 17 ♀: 9 Σ: 26	♂: 2 ♀: 4 Σ: 6	♂: 2 ♀: 2 Σ: 4	–
Purohit and Yadav 2019 ⁑⁑	♂: 90 (72.6%) ♀: 41 (73.2%) Σ: 131 (72.3%)	–	♂: 10 (8.9%) ♀: 6 (14.6%) Σ: 14 (10.7%)	♂: 3 (3.3%) ♀: 5 (12.2%) Σ: 8 (6.1%)	Parieto-temporal: ♂: 12 (13.2%) ♀: 11 (26.8 %) Σ: 23 (17.6%) Parieto-mastoid: ♂: 7 (7.8%) ♀: 2 (4.9%) Σ: 9 (6.9%)		♂: 55 (61.1%) ♀: 32 (78%) Σ: 87 (66.4%)	0	♂: 24 (26.7%) ♀: 8 (19.5%) Σ: 32 (24.4%)	♂: 34 (37.8%) ♀: 15 (36.6%) Σ: (49) 37.4%		♂: 24 (26.7%) ♀: 13 (31.7%) Σ: 37 (28.2%)		–

* Percentage of WB (total number of bones) in specific sites calculated in relation to whole research sample (divided into sex groups, if distinguished)

⁑ Percentage of WB (total number of bones) in specific sites calculated in relation to group of individuals with present WB only (divided into sex groups, if distinguished)

⁂ Percentage of number of skulls that have WB in specific sites, in relation to whole research sample (divided into sex groups, if distinguished)

⁑⁑ Percentage of number of skulls that have WB in specific sites, in relation to group of individuals with present WB only (divided into sex groups, if distinguished)

■ Both sides of skull treated as an independent record (total number doubled)

Abbreviations: Presence – number and/or percentage of individuals with Wormian bones in sample. Total no. – total sum of Wormian bones in the whole sample. C – coronal suture, S – sagittal suture, Sq-R – right squamous suture, Sq-L – left squamous suture, L – lambdoid suture, B – bregma – LL – lambda, A-R – right asterion, A-L – left asterion, P-R – right pterion, P-L – left pterion, I – Inca bone [*II* – interparietal, *PI* – preinterparietal]. Variants of skull morphology: *D* – dolichocephalic, *M* – mesocephalic, *B* – brachycephalic. Parietal notch bones and ossicles in parieto-temporal or parieto-mastoid suture were considered as squamous sutural bones.

Table 3. Wormian Bones Prevalence in Male and Female Skulls (the articles using 3rd computational strategy selected only)

Article	WB examined in	Males	Females	Statistical significance
Finkel 1975	whole skull	114 (32.2%)	81 (29.6%)	not described
Marathe et al. 2010	Inca	3 (1.428%)	2 (1.176%)	not described
Walulkar et al. 2012	whole skull	63 (9.13%)	14 (21.87%)	not described
Singh 2012	asterion	– (82.14%)	– (85.19%)	not described
Masih et al. 2013	whole skull	– (4.1%)	– (3.6%)	not described
Natsis et al. 2019	whole skull	67 (72.8%)	57 (77%)	no significant difference
Yadav and Salam 2020	whole skull	11 (30.56%)	8 (28.57%)	not described
De Lucena et al. 2019	asterion	– (18.34%)	– (13.34%)	not described
Goyal et al. 2019	whole skull	35 (36.08%)	17 (34%)	no significant difference
Shiv et al. 2020	whole skull	19 (22.09%)	8 (18.18%)	not described
Yadav and Salam 2020	whole skull	11 (30.56%)	8 (28.57%)	not described

Anthropological Review • Vol. 85(4), 123–134 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.4.08

Differences in lifestyle between students of medical and biological fields of study in Poland

Joanna Nieczuja-Dwojacka[1], Beata Borowska[2], Justyna Marchewka-Długońska[1], Alicja Budnik[1], Paweł Dąbrowski[3], Bożena Kurc-Darak[3], Joanna Grzelak[3]

[1]Institute of Biological Sciences, Faculty of Biology and Environmental Sciences, Cardinal Stefan Wyszynski University in Warsaw, Warsaw, Poland
[2]Department of Anthropology, Faculty of Biology and Environmental Protection, University of Lodz, Lodz, Poland
[3]Department of Human Morphology and Embryology, Department of Anatomy, Wroclaw Medical University, Wroclaw, Poland

Abstract: Students are a specific social group characterized by different lifestyle behaviours.

The aim of the study was to determine whether there are lifestyle differences between students of medical and biological fields from three different universities in Poland.

The research material consisted of answers from 1163 students (781 women and 382 men), aged 17.5–26.0 from the medical faculty of the Wroclaw Medical University, biological faculties of the Cardinal Stefan Wyszynski University in Warsaw and the University of Lodz. The survey included questions regarding gender, socio-demographic situation, lifestyle and eating habits. Students also provided height and weight data, which was used for BMI calculation. Chi-square test and one-way ANOVA were used to indicate differences in BMI between students and to estimate differences in lifestyle between students from three different university centres.

Medical students exhibited significantly lower BMI values compared to students from other academic centres. They also more often reported doing additional sports and assessed their overall level of physical activity significantly higher compared to students from other academic centres. Biology students reported to sleep longer and being more exhausted compared to medical students. Biology students tended to drink sugar-sweetened beverages and eat fast-food significantly more often than medical students. Students from the medical faculty in Wroclaw reported to smoke cigarettes less often compared to students from non-medical study. There were no significant differences in other studied factors, such as the use of alcohol, snacking between the meals and consumption of energy drinks.

Overall, students of medical fields reported a healthier lifestyle compared to their peers from biological faculties, although this was not consistent for all examined factors.

Key words: university students, alcohol, lifestyle, habits.

Original article

Received: 26.10.2022; Revised: 9.12.2022; Accepted: 9.12.2022

Introduction

Students are a specific group of young adults. Depending on the country and the chosen field of study, the age of students typically ranges from 18 to 28 years old. In Poland, most of students are aged 19–24. During the time of study, some young people, especially those who live in smaller towns or villages, leave their native home place and move to a different city (Little and Tang 2008).

Upon moving to a new city, students often face changes in their lifestyles and often exhibit a greater self-support, more independence in terms of making important decisions, adaptation to a new social environment often expressed by a willingness to be accepted (Wamamili et al. 2019). The changes in lifestyle include, for instance, the consumption of cheap and caloric food, lack of sleep, alcohol and cigarette abuse, and mediocre physical activity. Students are often exposed to a relatively high level of stress, resulting from changes of the environment and attempts to adapt to new social circles, as well as the need to take up a paid work in order to stay at the university (Caso et al. 2020). Many studies have shown that students tend to spend less time sleeping compared to the rest of the adult population, and has a fairly larger consumption of energy drinks (Sogari et al. 2018).

It has also been reported that students, compared to the rest of population, tend to consume a relatively large amount of alcohol. For instance, some studies show that 90% of young men and 80% of young women attending college have been drunk, and approximately 90% of college students drink alcohol intermittently. It has been argued that a high consumption of alcohol by students might indicate a desire to establish social relations in the academic community (Griffin et al. 2018). Around 30% of students have been reported smoking cigarettes, of which around 3% admitted to smoke every day (Nasser and Zhang 2019; Wamamili et al. 2019).

Although people studying at the university form a community with specific socio-demographic characteristics, it could be argued that pro-health behaviour should be more often represented by medical students.

On one hand, future doctors are expected to present a health-promoting behaviour, such as an increased physical activity, a healthy lifestyle and diet. On the other hand, many researchers have shown that medical students tend to deal with stress by abusing alcohol, smoking frequently, consuming energy drinks and eating unhealthy, high-calorie or sugar-rich meals (Cecil et al. 2014; Nasui et al. 2021). Due to the specificity of medical studies, future doctors are have been argued to be exposed to a much greater stress related to an intense, high-pressure study programme which is characteristic to this field of study (Almesned et al. 2018).

The current study aimed to determine differences in lifestyle between students studying at Wroclaw Medical University and other universities (University of Lodz and Cardinal Stefan Wyszynski University in Warsaw with biological faculties). We hypothesize that that medical students from Wroclaw should exhibit both a higher level of nutritional awareness and healthier lifestyle compared to biology students from the universities in Lodz and Warsaw.

Material and method

The study participants consisted of: medical students from the Wroclaw Medical University (WMU, Faculty of

Medicine), biology students from the Cardinal Stefan Wyszynski University in Warsaw (CSWU, Faculty of Biology and Environmental Science) and biology students from the University of Lodz (UL, Faculty of Biology and Environmental Protection). In the following text we use only the abbreviations of the universities' names.

According to the latest rankings, the medical faculty of WMU is rated at the top five of medical schools in Poland, the biology faculty of UL takes a similar place, while the faculty of biology at CSWU was classified in the 15th place (Ranking Perspektywy 2021a, b) within their respective categories. All three cities, whose students took part in the study, are recognised as traditional academic centres in Poland and have gained a significant recognition as such. Lodz, Wroclaw and Warsaw are the cities with population of over 500000, which places them in the group of largest cities in Poland (GUS 2021).

Approval to conduct the study was obtained from the Ethics and Bioethics Committee of CSWU. The questionnaires were made available online in 2016–2020 and 1,163 students took part in the study, including 781 (67%) women and 382 (33%) men. Healthy men and women, without chronic diseases, aged 17.5–26.0 were included in the study. The youngest participant in the study was 17.9-year-old and the oldest was 25.64-year-old.

The survey included questions about gender, demographic situation (living with or without parents), mother and father education level (elementary and trade school/ college/ university), additional sports (yes / no), self-assessment of physical activity (bad/ sufficient/ good/ very good), duration of sleep (less than 6 hours/ 7–8 hours/ 9 hours and more), exhaustion (yes / no), smoking (yes / no), drinking alcohol (yes / no), use of energy drinks (yes / no), snacking between meals (yes / no), eating fast-food (yes / no), and drinking sugar-sweetened beverages (yes / no).

Students were also asked to report their height and weight, on the basis of which the BMI was calculated: weigh (kg) / height (m^2).

In order to determine whether the studied variables differed among the students from three universities, the Chi-squared test was used. The one-way Anova test with Tukey post-hoc were used to determine whether there were significant differences in BMI between students from different academic centres. P values <0.05 were considered statistically significant.

As men and women answers did not differ, they were merged. Answers of biology students from CSWU and UL differed significantly, so these groups were not combined for statistical analyses.

Results

There were statistically significant differences in the lifestyle between medical and biology students (Table 1). Differences were also noted regarding additional sports activities: 56.40% of biology students of UL, 60.32% of biology students of CSWU and 75.72% of those studying medicine attended additional sports classes. Differences were also noted in self-assessment of physical activity. Medical students reported their physical fitness, as average – 26.17%, good – 51.64% and very good - 17.45%, while biology students rated their activity lower.

Medical students slept significantly shorter than their peers in biological fields

of study (Table 1). Biology students from UL reported that 77.55% of them felt tired while the corresponding figures for the CSWU biology and medical students was 66.67%, and 40.07% respectively.

Although relatively many students eat fast-food, statistically significant differences were noted (Table 1). On average, about 80% of biology students and over 73% of medical students admitted to eating fast-food. In addition, over 41% of biology students from CSWU and over 29% of biology student from UL reported drinking sugar-sweetened beverages. Among medical students, about 29% of respondents declared that they consumed this type of product. Biology students significantly more often smoke cigarettes than their peers from the medical field (Table 1).

The consumption of energy drinks, snacking and drinking alcohol did not differ among the three groups of students (Table 1).

Table 1. Differences in the lifestyle of medical and biology students

Factors		Fields of study N [%]			p level
		Biology students from CSWU	Biology student from UL	Medical students	
Additional sport activities	yes	380 [60.32]	141 [56.40]	209 [75.72]	<0.001
	no	250 [39.68]	109 [43.60]	67 [24.28]	
Self-assessment of physical fitness	low	34 [5.40]	32 [12.80]	13 [4.73]	<0.001
	average	228 [36.19]	110 [44.00]	72 [26.18]	
	good	266 [42.22]	96 [38.40]	142 [51.64]	
	very good	102 [16.19]	12 [4.80]	48 [17.45]	
Sleep duration	6h or less	202 [32.17]	58 [23.11]	123 [47.48]	<0.001
	7–9 h	395 [62.90]	179 [71.31]	142 [51.08]	
	9 h or more	31 [4.94]	14 [5.58]	4 [1.44]	
Self-assessment exhaustion	yes	414 [66.67]	190 [77.55]	111 [40.07]	<0.001
	no	207 [33.33]	55 [22.45]	166 [59.93]	
Consumption of fast- food	yes	521 [83.23]	199 [79.28]	205 [73.21]	<0.01
	no	105 [16.77]	52 [20.72]	75 [26.79]	
Consumptions of sugar-sweetened beverages	yes	263 [41.95]	75 [29.88]	81 [29.03]	<0.001
	no	364 [58.05]	176 [70.12]	198 [70.97]	
Consumption of energy drinks	yes	229 [38.23]	118 [47.01]	110 [39.29]	0.053
	no	370 [61.77]	133 [52.99]	170 [60.71]	
Snacking	yes	513 [81.82]	188 [76.11]	224 [80.29]	0.162
	no	114 [18.18]	59 [23.89]	55 [19.71]	
Consumption of alcohol	yes	531 [84.55]	202 [80.80]	240 [86.33]	0.204
	no	97 [15.45]	48 [19.20]	38 [13.67]	
Smoking	yes	129 [20.48]	43 [17.13]	35 [12.46]	<0.05
	no	501 [79.52]	208 [82.87]	246 [87.54]	

Table 2. Differences in socio-demographic factors of medical and biology students

Socio-demographic factors		Fields of study N[%]			p level
		Biology students from CSWU	Biology student from UL	Medical students	
Mother's level of education	elementary / trade school	111 [17.70]	49 [19.60]	16 [5.67]	<0.001
	college	194 [30.94]	73 [29.20]	43 [15.25]	
	university	322 [51.36]	128 [51.20]	223 [79.08]	
Father's level of education	elementary / trade school	210 [33.98]	96 [38.55]	47 [16.73]	<0.001
	college	187 [30.26]	78 [31.33]	42 [14.95]	
	university	221 [35.76]	75 [30.12]	192 [68.33]	
Living with parents	yes	326 [51.83]	164 [65.60]	74 [26.33]	<0.001
	no	303 [48.17]	86 [34.40]	207 [73.67]	

The BMI of the analysed students ranged from 14.52 to 37.64. Over 12% of them were underweight. The correct body massiveness was noted in 72%, whereas overweight and obesity in 15% and 3% respectively. The one-way ANOVA test showed that there were significant differences in the body massiveness defined as BMI between students from different fields of study ($p=0.003$). A post-hoc test showed that there were differences between BMI of biology students from CSWU (average BMI 22.27) and medical student (average BMI 21.43).

Table 2 presents differences in socio-demographic data, including parental education level and living with parents. These data significantly differ among medical and non-medical students. Mothers of medical students were reported to have the highest level of education (79.08% of mothers). In contrast, ~ 51% of mothers of biology students were reported to have higher education level. Moreover, fathers of medical students were reported to have higher education compared to fathers of students from biological fields of study.

Approximately 26.33% students from the medical faculty, and average over 58% of students from the biological faculty declared living with their parents. These socio-economic differences were statistically significant (Table 2).

Discussion

This study showed significant differences between students from medical and biological fields regarding lifestyle, BMI and socio-demographic data. Medical students exhibited significantly lower BMI values, practiced additional sports more often and assessed their level of physical activity higher compared to biology students. Moreover, medical students slept significantly shorter than their peers from other fields of study. Compared to medical students, students of biology faculties reported to feel more tired, consumed more fast-food and drink more sugar-sweetened beverages and smoke more.

There were no significant differences in other studied factors, such as consumption of energy drinks or alcohol and snacking between meals.

Medical students showed a significantly lower BMI indices, although the results were not consistent. Research from Greece showed that students living away from home developed more unfavourable eating habits than their peers staying in family homes, which was, however, not reflected in this study (Papadaki et al. 2007). One study showed that among Indian medical students, 18% were overweight, and another 8% were obese, which clearly differs from the results obtained in our research (Vibhute et al. 2018). Our findings may result from parents' higher level of education, eating habits passed on at home, or the choice of healthier food by young adults from medical fields of study (Ganasegeran et al. 2012). On the other hand, there were no significant differences in snacking between main meals (Mattson et al. 2014). Eating between meals was characteristic of about 76-81% of students from all three studied groups. Eating extra, often caloric snacks can lead to excessive caloric intake, leading to metabolic syndrome and cardiovascular risk factors (Vergetaki et al. 2011). Both medical and biology students reported to eat fast-food products often, although the latter were significantly more likely to do so. Warsaw citizens tend to be wealthier, so perhaps, that is why students from the capital city can afford this type of product (fast-food products are relatively expensive in Poland). It has been also shown that in Poland children eat fast food more often when their parents have a lower level of education but high incomes (Łoś-Rycharska and Niecławska 2010). An alternative to fast-food can be eateries, which are very common on university campuses. However, they do not always play a fundamental role in the nutrition of students, which may be caused by dissatisfaction with the proposed menu and affordability (Murray et al. 2021).

A higher consumption of sugar-sweetened beverages was observed among students of biological sciences in comparison to their counterparts from medical students. Carbonated drinks contain significant amounts of sugar, high fructose corn syrup or sweeteners. These substances are considered unhealthy. Sweeteners are added to many drinks, including fruit and vegetable drinks, sports drinks, energy drinks, sweetened water. It has been found that high consumption of sugar-containing beverages is correlated with less frequent sports activities. In the present study, medical students who reported to consumed significantly less sugary drinks also reported better physical activity. Excessive consumption of sweetened drinks significantly contributes to the development of overweight and obesity. It is worth noting that students of biology from CSWU had a significantly higher BMI than medical students (Harrington 2008; Mandal et al. 2021).

There has not been a great deal of research studies focusing on consequences of consuming large amounts of energy drinks by the university students. In one study conducted among Turkey medical students, almost 30% indicated that these are drinks similar to sports drinks (Hidiroglu et al. 2013). Students that have been reported to consume a high number of energy drinks in order to increase their concentration during exams, although it has been also reported that they tend to mix them with alcohol (Woolsey et al. 2015). Energy drinks contain ingredients that might have both positive and negative health effects. A good example is caffeine, which if consumed in mod-

eration, may contribute to the treatment of obesity diabetes, while applied in excess may lead to dehydration. It has been noted that excessive use of energy drinks may lead to palpitations, agitation and gastrointestinal upset (Kaur et al. 2019). In our study, consumption of energy drinks was observed to be at a similar level among students from different faculties. Currently, the consumption of energy drinks is very popular among children and adolescents, and this habit may extend to the later stages of life (Seifert et al. 2011).

Interestingly, students from all studied groups reported similar behaviours related to alcohol consumption. It appears that the awareness regarding the harmful influence of alcohol on the human organism is common, moreover, people from medical faculties, coming from homes with higher SES, are expected to drink alcoholic beverages less frequently. According to numerous studies, students are a specific group so that entering adulthood is often associated with gaining independence from parental care and the ability to make uninfluenced decisions. In addition, studying time is often regarded as an important period in the life of young adults during which new friendships are made with a strong need for social acceptance coupled with the avoidance of social rejection (Williams and Clark 1998). Therefore, students' social meetings are frequently accompanied by drinking alcohol. There has even been a report of relatively high alcohol consumption among students from Baghdad, where alcohol consumption is considered to be illegal (Al-Ameri et al. 2016). It is also worth mentioning that the percentage of abstainers among young adults in Poland has been reported to steadily fall (Woźniakowski et al. 2017).

There are two critical variables in maintaining a healthy body weight: the right amount of calories consumed and the right dose of physical activity (Castro et al. 2020). In our study, a higher physical activity as well as a higher self-esteem of physical activity was reported among medical students. This is also reflected by lower BMI values of the medical students compared to those exhibited by biology students. These differences can be explained by different habits experienced in family homes as well as differences in family income. It is assumed that parents of medical students, as well-educated people, could promote pro-healthy lifestyle in their children while greater affluence increases the possibility of participating in additional sports activities (Więch et al. 2017; Danaei et al. 2018). However, in terms of instilling proper eating habits and physical activity, parents' awareness may be more important than their wealth, possibly explaining differences in behaviors between medical and biology students from CSWU.

Apart from a higher alcohol consumption, the age between 19–24 can by also associated with other risky health behaviours, such as smoking. In our study, the percentage of smokers from biology faculties was significantly higher compared to medical students. Perhaps, future doctors are more aware of the adverse effects of cigarette smoking, although not all studies support this claim (Khan and Mahmood 2012).

The results of our study show that medical students, although do not avoid stimulants, more often than biology students reported good health in self-assessment questionnaires. However, they also reported to sleep significantly less compared to their peers from biology faculties. Biology students, on the other hand,

indicated a greater fatigue than medical students. Research indicates that worse well-being, including mental and physical condition, may worsen with more frequent consumption of fast-food (Zahedi et al. 2014). This may be due to the lack of essential nutrients, such as iron, vitamin B12 or poly unsaturated fatty acids in this type of diet, which can lead to neurotransmitter disorders. It could be argued that because biology students consumed, on average, more fast-food and had a lower level of physical activity, they also exhibited lower indices of well-being (Zahedi et al. 2014). Some researchers have reported a worse sleep quality and its shorter duration among medical college students (Lemma et al. 2014), due to either stress (demanding study programme), or a more frequent use of alcohol and cigarettes (De Castro Corrêa et al. 2017). Insufficient sleep reduces resistance to stressful situations, which may result in an increase of the amount of food and alcohol consumed (Perrotte et al. 2018). However, it has been also reported that improving the sleep quality is associated with a higher level of involvement in sport and extracurricular activities. Indeed, medical students reported to practice additional sports more often than their peers, and smoked statistically less frequently, hence their better well-being, despite the reported deficiencies in sleep duration.

It should be noted that the differences in socio-economic factors characterizing the studied groups. Academic centres in Poland are most often located in large cities. In the 2019/2020 academic year, there were over 1,204 million students, including the CSWU – 9332, the WMU – 6324 and the UL – 24829 (GUS 2019). Students in Poland often choose a university in their hometown, while in other countries, such as the United Kingdom, students most often leave the parental home and move to a university residence (Lewis et al. 2014). In this study, the highest percentage of students living with their parents was recorded in UL. This may be related to the economic characteristics of the city – Lodz is one of the cities in Poland with the lowest income per capita, and great number of young people cannot afford to study outside of their home city. On the other hand, the field of biology at UL is highly placed in the university rankings and popular among young people (GUS 2019, Ranking Perspektywy 2021a). In Warsaw, on the other hand, the educational offer is wider, which may convince young people to stay in the hometown. With regards to WMU, the relatively small number of people staying at home may be related to the lack of this type of university in the Lower Silesian Voivodeship. It is also worth noting that the medical faculty in Wroclaw has one of the best ratings in Poland (Ranking Perspektywy 2021b).

Our study shows that students from medical university exhibit a healthier lifestyle than their peers from biological faculties, especially in terms of eating habits or physical activity. A healthier lifestyle reported by students of medical faculty might be related to the study program, during which healthy lifestyle habits are widely discussed. Moreover, healthy habits taken from home accompanied by a high socio-economic status (SES) may also contribute to making pro-healthy choices. Such factors may encourage medicals tudents to keep themselves in a good physical shape and mental condition (Brehm et al. 2016).

The results of our study show that the consumption of alcohol and energy drinks does not differ between the sur-

veyed groups of students. Therefore, there is an ongoing need for health promotion, such as changes in behaviour, specifically related to eating habits, physical activity, sleep hygiene, health effects of alcohol and cigarettes among the population of higher education students.

One of the limitations of this study is that it was conducted in three different cities at universities with different quality rankings and a small number of students. Moreover, a subjective assessment of the family's economic situation was used instead of an objective data such as income. It can be a particularly sensitive question, causing a discontent, which may result in failure to complete the survey (Czarnocińska et al. 2020).

Acknowledgements

This study did not receive any financial support.

Conflict of interests

Authors declare that there is no conflict of interest regarding publication of this paper.

Authors' contributions

JN-D was responsible for the statistical analysis, interpretation of the results, and for the accuracy of the presentation of the results and the editing of the text; BB was responsible for proofreading the text; AB approved the final version; JM-D was responsible for statistical analysis and interpretation of the results; PD, B-KD were responsible for the design of the survey, JG were for the statistical analysis, interpretation of the results, and for the accuracy of the presentation of the results and the editing of the text.

Corresponding author

Joanna Nieczuja-Dwojacka, Institute of Biological Sciences, Faculty of Biology and Environmental Sciences, Cardinal Stefan Wyszynski University in Warsaw; Warsaw, Poland; Wóycickiego St. 1/3, 01-938 Warsaw; e-mail: j.nieczuja@uksw.edu.pl

References

Al-Ameri RJK, Al-Badri H, Lafta RK. 2016. Prevalence of alcohol consumption among university students in Baghdad: A crosssection survey from Iraq. Epidemiol Biostat Public Health 13(4):e11942–1.

Almesned IS, Alqahtani NG, Alarifi JA, Alsaawy TN, Agha S, Alhumaid MA. 2018. Prevalence of primary headache among medical students at King Saud bin Abdulaziz University for Health Sciences, Riyadh, Saudi Arabia. Fam Med Prim Care Rev 7(6):1193–6, https://doi.org/10.4103/jfmpc.jfmpc_240_18

Brehm BJ, Summer SS, Khoury JC, Filak AT, Lieberman MA, Heubi JE. 2016. Health status and lifestyle habits of us medical students: a longitudinal study. Ann Med Health Sci Res 6(6):341–7.

Caso D, Capasso M, Fabbricatore R, Conner M. 2020. Unhealthy eating and academic stress: The moderating effect of eating style and BMI. Health Psychol Open 7(2):2055102920975274, https://doi.org/10.1177/2055102920975274

Castro EA, Carraça EV, Cupeiro R, López-Plaza B, Teixeira PJ. González-Lamuño D, Peinado AB. 2020. The effects of the type of exercise and physical activity on eating behavior and body composition in overweight and obese subjects. Nutrients 12(557), https://doi.org/10.3390/nu12020557

Cecil J, MsHale C, Hart J, and Laidlaw A. 2014. Behaviour and burnout in medical students. Med Educ Online 9, https://doi.org/10.3402/meo.v19.25209

Czarnocinska J, Wadolowska L, Lonnie M, Kowalkowska J, Jezewska-Zychowicz M, Babicz-Zielinska E. 2020. Regional and socioeconomic variations in dietary patterns in a representative sample of young polish females: a cross-sectional study (GEBaHealth project). Nutr J 19(1):26, https://doi.org/10.1186/s12937-020-00546-8

Danaei M, Momeni M, Sheikhshoaei M, Khalooei A. 2018. Physical activity and its determinant factors among medical students of Kerman University of Medical Sciences Soc Determ Health 4(1):36–43.

De Castro Corrêa C, De Oliveira FK, Pizzamiglio DS, Ortolan EVP, Weber SAT. 2017. Sleep quality in medical students: a comparison across the various phases of the medical course. J Bras Pneumol 43(4):285–9, https://doi.org/10.1590/S1806-37562016000000178

Ganasegeran K, Al-Dubai SA, Qureshi AM, Al-abed AA, AM R, Aljunid AM. 2012. Social and psychological factors affecting eating habits among university students in a Malaysian medical school: a cross-sectional study. Nutr J 11(48), https://doi.org/10.1186/1475-2891-11-48

Griffin C, Freeman M, Adams S, Smith P. 2018. 'All suffering together': student drinkers' experiences of alcohol hangover. Addict Res Theory 26:533–40.

GUS, Statistics Poland. 2019. Higher education and its finances in 2019. Available at: http://stat.gov.pl/obszary-tematyczne/edukacja/ [Accessed 5 October 2021].

GUS, Statistics Poland. 2021. Statistical Yearbook of the Republic of Poland. Available at: https://stat.gov.pl/obszary-tematyczne/roczniki-statystyczne/roczniki-statystyczne/rocznik-statystyczny-rzeczypospolitej-polskiej-2021,2,21.html [Accessed 5 December 2022].

Harrington S. 2008. The role of sugar-sweetened beverage consumption in adolescent obesity: A review of the literature. J Sch Nurs 24(1):3–12.

Hidiroglu S, Tanriover O, Unaldi S, Sulun S. 2013. A survey of energy-drink consumption among medical students. J Pak Med Assoc 63(7):842–5.

Kaur J, Kumar V, Goyal A, Tanwar B, Gat Y, Prasad R, Suri S. 2019. Energy drinks health effects and consumer safety. Food Sci Nutr 49(6):1075–87, https://doi.org/10.1108/NFS-11-2018-0331

Khan S, Mahmood SE. 2012. Tobacco use among medical students: Are they the role models of the society?. J Clin Diagn Res 6(4):605–607.

Lemma S, Berhane Y, Worku A, Gelaye B, Williams MA. 2014. Good quality sleep is associated with better academic performance among university students in Ethiopia. Sleep Breath 18(2):257–63, https://doi.org/10.1007/s11325-013-0874-8

Lewis J, West A, Roberts J, Noden P. 2014. Parents' involvement and university students' independence. Fam Relatsh Soc 4(3):417–32.

Little B, Tang W-Y. 2008. Age differences in graduate employment across Europe. Bristol: Higher Education Funding Coucil for England.

Łoś-Rycharska E, Niecławska A. 2010. Spożycie pokarmów typu fast-food przez dzieci w wieku poniemowlęcym i przedszkolnym, Fast-food consumption by 2–3 years old and preschool children. Pediatr Pol 85(4):345–352.

Mandal SK, Revadi G, Parida D, Majumdar A. 2021. Prevalence, patterns, clinico-social and behavioural factors associated with the consumption of sugar sweetened beverages among undergraduate medical students of Central India. medRxic

2021.08.29.21262509, https://doi.org/10.1101/2021.08.29.21262509

Mattson MP, Allison DA, Fontana L. 2014. Meal frequency and timing in health and disease. PNAS 111(47):16647–53, https://doi.org/10.1073/pnas.1413965111

Murray S, Peterson C, Primo C, Elliot C, Otlowski M, Auckland S, Kent K. 2021. Prevalence of food insecurity and satisfaction with on-campus food choices among Australian university students. Int J Sust Higher Ed 22(4):731–46, https://doi.org/10.1108/IJSHE-09-2020-0348

Nasser A, Zhang X. 2019. Knowledge and factors related to smoking among university students at Hodeidah University, Yemen. Tob Induc Dis 17:42, https://doi.org/10.18332/tid/109227

Nasui BA, Popa M, Buzoianu AD, Pop AL, Varlas VN, Armean SM, Popescu C A. 2021. Consumption and behavioral consequences in Romanian Medical University Students. J Environ Public Health 18:7531, https://doi.org/10.3390/ijerph18147531

Papadaki A, Hondros G, Scott JA, Kapokefalou M. 2007. Eating habits of University students living at, or away from home in Greece. Appetite 49(1):169–76.

Perrotte JK, Baumann MR, Knight CF. 2018. Traditional gender roles and the stress–alcohol relationship among latina/o college students. Substance Use & Misuse 53(10):1700–05, https://doi.org/10.1080/10826084.2018.1429472

Ranking Perspektywy. 2021a. Biologia 2021. Available at: https://2021.ranking.perspektywy.pl/ranking/ranking-kierunkow-studiow/kierunki-przyrodnicze/biologia [Accessed 5 December 2022].

Ranking Perspektywy. 2021b. Kierunek lekarski. Available at: https://2021.ranking.perspektywy.pl/ranking/ranking-kierunkow-studiow/kierunki-medyczne-i-o-zdrowiu/kierunek-lekarski [Accessed 30 August 2022].

Seifert S, Schaechter JL, Hershorin ER, Lipshultz SE. 2011. Health effects of energy drinks on children, adolescents, and young adults. Pediatrics 127(3):511–27, https://doi.org/10.1542/peds.2009-3592

Sogari G, Velez-Argumedo C, Gómez MI, Mora C. 2018. College students and eating habits: a study using an ecological model for healthy behavior. Nutrients 10(12):1823, https://doi.org/10.3390/nu10121823

Vergetaki A, Linardakis M, Papadaki A, Kafatos A. 2011. Presence of metabolic syndrome and cardiovascular risk factors in adolescents and University students in Crete (Greece), according to different levels of snack consumption. Appetite 25:278–85.

Vibhute NA, Baad R, Belgaumi U, Kadashetti V, Bommanavar S, Kamate W. 2018. Dietary habits amongst medical students: An institution-based study. Fam Med Prim Care Rev 7(6):1464–6, https://doi.org/10.4103/jfmpc.jfmpc_154_18

Wamamili B, Wallace-Bell M, Richardson A, Grace RC, Coope P. 2019. Cigarette smoking among university students aged 18–24 years in New Zealand: results of the first (baseline) of two national surveys. BMJ Open 9:e032590, https://doi.org/10.1136/bmjopen-2019-032590

Więch P, Bazaliński D, Chmiel Z, Ratajczyk J, Januszewicz P, Binkowska-Bury M. 2017. Socio-demographic factors and health-oriented behaviors of University Students in the Podkarpacie Region. Long-term prospective research. Barometr Regionalny 15(3):93–102.

Wiliams A, Clark D. 1998. Alcohol consumption in university students: the role of reasons for drinking, coping strategies, expectancies, and personality traits. Addict Behav 23(3):371–8.

Woolsey CL, Jacobson BH, Wiliams RD, Barry AE, Davidson RT, Evans MW, Beck NC. 2015. A comparison of the combined-use alcohol and energy drinks to

alcohol-only on high-risk drinking and driving behaviours. Subst Use Misuse 50(1):1–7.

Woźniakowski M, Zarobkiewic M, Sławiński M, Świerszcz Ł, Roszkowska A, Piecewicz-Szczęsna H. 2017. The prevalence of alcohol use among medical students in Poland. Journal of Education, Health and Sport 7(9):184–9.

Zahedi H, Kelishadi R, Heshmat R, Motlagh ME, Ranjbar SH, Ardalan G, Payab M, Chinian M, Asayesh H, Larijani B, Qorbani M. 2014. Association between junk food consumption and mental health in a national sample of Iranian children and adolescents: The CASPIAN-IV study. Nutrition 30(11–12):1391–7, https://doi.org/10.1016/j.nut.2014.04.014

Anthropological Review • Vol. 85(4), 135–146 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.4.09

Anatomical variations of the flexor carpi ulnaris in the fetal period

Katarzyna Siwek[1], Robert Krupa[2], Andrzej Mrożek[3], Jacek Ciach[1], Jagoda Urbańska[4], Małgorzata Suchanecka[1]

[1] Division of Anatomy, Wroclaw Medical University, Wroclaw, Poland
[2] Faculty of Health Sciences, Wroclaw Medical University, Wroclaw, Poland
[3] Clinical and Dissecting Anatomy Students Scientific Club, Faculty of Medicine, Wroclaw Medical University, Wroclaw, Poland
[4] Faculty of Stomatology, Wroclaw Medical University, Wroclaw, Poland

Abstract: *Introduction*: The Flexor Carpi Ulnaris (FCU) is a part of the palmar the forearm muscle group and one of the most important muscles for upper limb functioning - is responsible for flexion and adduction of the hand at the radio-carpal joint. There are clinically significant but rare anatomical variations of FCU. The variability of the FCU has not been described up to now, and no typology of the muscle based on its more variable terminal attachment has been created.

Aim of the study: Determination of FCU muscle typology based on available fetal material.

Material and methods: A total of 114 human fetuses (53 female, 61 male) between 117 and 197 days of fetal life were eligible for the study. Preparations were carried out using classical anatomical techniques based on a previously published procedure. Thanks to that significant anthropometric landmarks were visible for the gathering of metric measurements. Metric measurements were taken and statistically analysed using R-Project software.

Results: A new typology was created based on variable muscle insertions. Additionally, the presence of an atypically located, additional, separated muscle belly was described. A comparison of measurements of the left upper limb in relation to the right upper limb showed significant differences for forearm length to the anthropometric point of the stylion radiale, limb length, total FCU length and FCU length which means that the left limb is longer than the right limb. A comparison of FCU insertion types between left and right upper limb showed there's no significant difference between counts of each type.

Conclusion: The FCU is a muscle that is easy to palpate and may therefore act as a topographical marker for healthcare professionals. Knowledge of its variability is not only of theoretical importance but also has clinical significance. The current publication demonstrates presence of variability in FCU terminal attachment. Certainly, this topic requires further research and continued work on a detailed understanding of forearm anatomy in the fetal period.

Key words: fetal anatomy, forearm muscles, dissection, cadavers, flexor carpi ulnaris.

Received: 15.11.2022; Revised: 13.12.2022; Accepted: 15.12.2022

Introduction

The Flexor Carpi Ulnaris (FCU) is one of the important muscles of the forearm (Kreulen et al. 2004). Anatomically, it is a part of the palmar forearm muscle group. It is located medially in the superficial layer of the forearm muscles (Budoff et al. 2005). The proximal attachment of the muscle is based on two heads – the humeral head, which begins on the medial epicondyle of the humerus, and the ulnar head, the origin of which is located on the posterior wall of the olecranon. It is worth noting that the initial part of the muscle is also closely connected with the surrounding fascia of the forearm. (Ziajkiewicz et al. 2010). The muscle passes downward, parallel to the flexor digitorum superficialis. Then it turns into a long tendon attached to the pisiform and proximal part of hamate bone (Fridén et al. 2004).

Physiologically, that muscle is responsible for flexion and adduction of the hand at the radio-carpal joint. In addition, the humeral head supports the flexion at the elbow joint (Esplugas et al. 2016). The evolution of hominids ultimately led to the adoption by humans of an upright position. This lead to changed characteristics of the fore limb. It lost its locomotor function and became an upper limb – a manipulative tool (Capdarest-Arest et al. 2014; Marzke 1997; Skinner et al. 2015). The change in the function of this organ required some adjustment in the musculature of the limb. This became especially evident in the distal part of the limb – data clearly indicate the different dynamics of muscle development in the proximal and distal parts of the upper limb. The muscles of the forearm develop later in the embryonic period. This may contribute to greater variability in their terminal attachments as well as increased variation in the structure of the entire muscle (Bobzin et al. 2021; Giuliani Piccari Scarpa et al. 1977; Guéro 2018).

These assumptions are somewhat confirmed by observations from a number of "case-studies" that indicate the presence of a number of rare anatomical variations of FCU. Some of these are clinically significant. For example, a 1992 study showed a case of FCU terminal tendon duplication leading to ulnar nerve dissection (al-Qattan, Duerksen 1992). In contrast, authors from the Czech Republic, for example, demonstrated the significant importance of additional detached FCU fragments as a cause of increased risk of iatrogenic complications (Kunc et al. 2019). Similar observations are also shown by authors from Australia (Ang et al. 2010).

On the other hand, on a large material of matures/senilis specimens, the authors showed a relatively high stability of the FCU course (Loth 1931). The stability of the course and of proximal and distal attachments is emphasized by many authors of papers from the late 19th and early 20th centuries (Loth 1912; Wood 1867).

The historical scientific data are somewhat at odds with the new literature reports indicating the presence of quite a lot of variability in FCU.

This noticeable difference in the frequency of FCU variation is perhaps the result of the microevolution process described in the available literature (Kralik, et al. 2017; Pelletier and Coltman 2018). The result of the accumulation of single mutations as a cause of the observed variability cannot be excluded either. Indeed, the available scientific data indicate that the neonatal genome currently contains, on average, more than 70 new mutations (Conrad et al. 2011).

Therefore, in the opinion of the authors of this paper, an analysis based on a larger number of cases is necessary. Recent literature reports are mainly on the evaluation of single case – studies (Ata et al. 2018; Bhardwaj et al. 2013; Pressney et al. 2020; Yamamoto et al. 2021).

Based on the research data that were presented, an attempt was made to assess the anatomical variability of FCU. Due to very limited access to cadavers of adult individuals, it was decided to carry out such an analysis based on fetal material. In the past, a scientific team from our Unit has already carried out a metric assessment and evaluation of the growth dynamics of FCU (Ziajkiewicz et al. 2010).

However, the variability of the FCU has not been determined up to now, and no typology of the muscle has been created based on its more variable terminal attachment.

It is worth noting that an additional but scientifically significant reason for the choice of such material is also the fact of a much later formation of the FCU in the fetal period, which may translate into the presence of greater variability in the structure of the muscle.

Aim of work

Determination of FCU muscle variations based on available fetal material.

Materials and methods

A total of 114 human fetuses (53 female, 61 male) between 117.0 and 197.0 (median 177.0) days of fetal life were eligible for the study. The material came from the fetal collection stored in the fetal laboratory of the Division of Anatomy.

Basic metrics characterizing the study sample of fetuses are included in Table 1.

Fetal material was obtained from local gynecological clinics between 1960 and 1996. The fetuses were from unplanned preterm births or miscarriages. The course of delivery as well as the decision to stop resuscitating the fetus was made by a medical team independent of the researchers.

The fetuses were stored in a dedicated preservative fluid containing formaldehyde, ethyl alcohol and glycerol in fixed proportions. The material was stored in a darkened room – a specialized

Table 1. Characteristics of the study sample of featuses

feature	N	min	max	SD
age.morph.day	73	117.0	197.0	177.93
age.cal.day	67	68.0	254.0	166.63
arm.leng.R	114	32.9	68.2	54.97
arm.leng.L	114	32.9	68.3	54.82
for.leng.R	114	26.2	54.2	43.87
for.leng.L	114	26.2	57.8	44.27

Abbreviations: age.morph.day – featus morphological age in days; age.cal.day – featus calendar age in days; arm.leng.R – length of right arm, arm.leng.L – length of left arm; for.leng.R – length of right forearm; for.leng.L – length of left forearm; N – total number of individuals; min – minimal value in centimeters; max – maximal value in centimeters; SD – standard deviation

laboratory with constant temperature and no exposure to light. The method of storing and preserving the material did not change throughout the period from the acquisition of the material to its use for scientific purposes (Karykowska et al. 2021; Suchanecka et al. 2022; Ziółkowski et al. 1994).

Fetuses with apparent anatomical and developmental abnormalities and those without basic clinical and morphological documentation were excluded from the study. Material with secondary damage and deformities due to improper storage was also excluded. The scientific value and reliability of the fetal collection has been confirmed in many previous scientific publications (Dudek et al. 2018; Gworys and Domagała 2003; Karykowska et al. 2022a; Karykowska et al. 2022b; Kędzia et al. 2022; Wozniak et al. 2019).

The study was conducted between October 2020 and March 2022. Preparations were carried out using classical anatomical techniques based on a previously published scheme of procedure (Suchanecka et al. 2022). It was based on removing the skin and subcutaneous tissue, then gaining full access to the fascia of the forearm to cut it and open the anterior compartment.

The next aim of the dissection was to make significant anthropometric points visible for the gathering of metric measurements.

A detailed dissection of the Flexor Carpi Ulnaris muscle was then carried out (shown on Figure 1), so that the planned metric measurements could be carried out in a reproducible and reliable manner. In the final stage of the study, the location of the initial attachment as well as the end attachment of the muscle was assessed in order to classify the individual case into the typology that had been created earlier.

The phases of the scientific work were documented with schematic figures and standard photographs. Photographs were taken with a digital system from Tagarno Prestige (Tagarno Innovision A/S, Denmark) and with a Sony Alfa 7II digital camera (Minato, Tokyo, Japan) stabilised on a Manfrotto tripod (Vitec Group, Richmond,UK). Metric measurements were taken using a Mitutoyo Absolute Digimatic digital calliper (Mitutoyo Corporation, Kanagawa, Japan). Each metric measurement was taken three times by two independent observers (KS, MS) and an average was then calculated from the results, which formed the basis for further analysis. Statistical analysis was

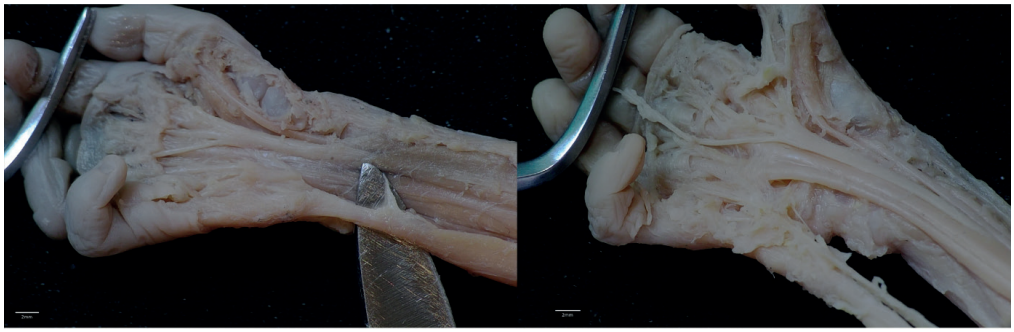

Fig. 1. Dissection stages of Flexor Carpi Ulnaris on fetal cadavers

performed using R-Project software (The R Foundation for Statistical Computing, Vienna, Austria).

Statistical methods

Data of each fetus were obtained from two sources:

- continuous variables (31): a fetus' record card: morphological age, calendar age, mass, v-pl, v-tub (vertex-plantare,vertex-tuberale) and direct measurements with a certifed and validated caliper: other 26 variables (13 for left and analogous 13 for right side of each specimen);
- categorical variables (3): a fetus' record card or a direct observation (sex) and a type of insertion of FCU on left and right upper limb.

A significance level of $\alpha = 0.05$ was assumed. All collected numerical values were summarized using: mean, median, min, max and 95% CI for mean. A Shapiro-Wilk test was performed for each variable in order to check if it is normally distributed. The same calculations were performed after dividing the data into two groups: females and males. A comparison between sexes was done with a Mann-Whitney test (because most of the variables were not distributed normally). Measurements of the left upper limb were compared against measurements of the right upper limb using Wilcoxon signed rank test. Linear regression coeffcients between respective variables of left and right side were also calculated. We did not assume a priori any correlations in each pair of 31 numeric variables: our aim was to find such. For each unique pair of collected variables a scatter plot with a linear regression line was generated. The number of created plots was large: The entire study protocol was approved by the local bioethics committee (KB167/21).

Results

Based on the conducted analysis, a new typology was created, due to muscle insertion.

Type1 – insertion to pisiform bone
Type 2 – insertion to 4th metacarpal bone
  2a – inserted medially
  2b – inserted laterally
Type 3 – insertion to 5th metacarpal bone
  3a – inserted medially
  3b – inserted laterally
Type 4 – insertion to flexor retinaculum

Exact appearance of every mentioned type is shown on Figure 2.

Additionally, in individual cases, the presence of an atypically located, additional, separated muscle belly located under the main FCU mass, running from the area of the medial epicondyle of the humerus to the pisiform bone was described.

It has been shown that in the most cases type 1 is dominant. Other types occur with a statistically lower frequency than type 1 – shown on Table 2.

Table 2. Frequency of different types of FCU due to its distal attachment

Type variation	Left		Right	
	Frequency	%	Frequency	%
Type 1	78	68.42	81	71.05
Type 2a	6	5.26	7	6.14
Type 2b	9	7.89	8	7.02
Type 3a	11	9.65	7	6.14
Type 3b	7	6.14	9	7.89
Type 4	3	2.63	2	1.75

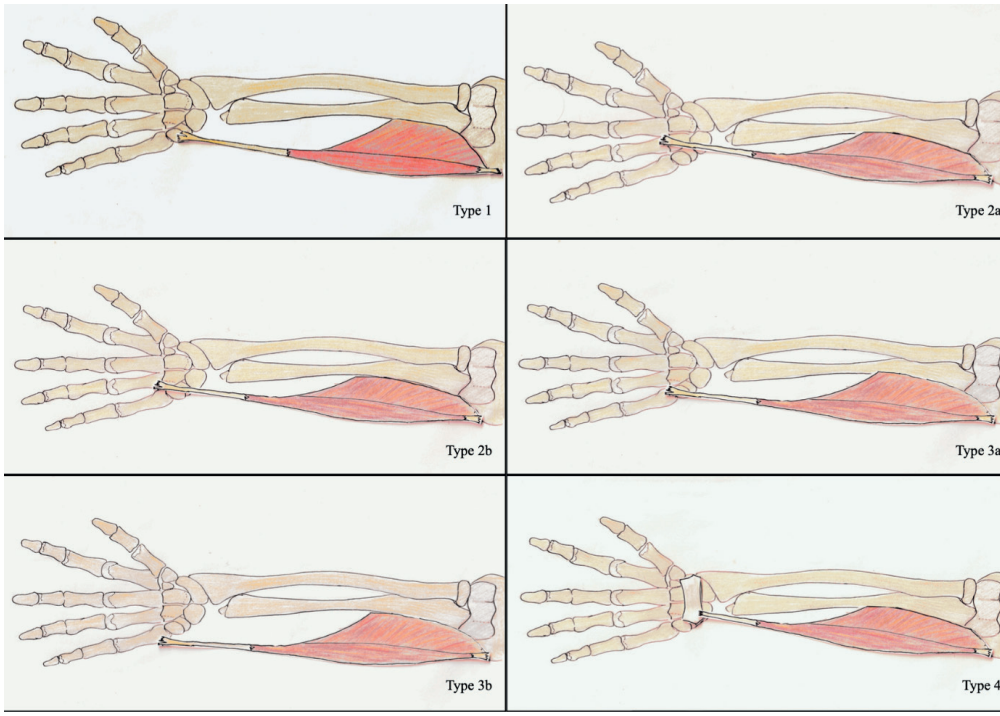

Fig. 2. Exact appearance of each mentioned Flexor Carpi Ulnaris type

Numerical variables

For the most of numerical variables Shapiro-Wilk tests rejected the null hypothesis that a variable is normally distributed. However, interestingly, this does not apply to female fetuses in which for about a half number of variables the normality test failed to reject the null hypothesis. We do not know any plausible explanation. Further statistical tests rejected the hypothesis that there is a difference between females and males for each of 31 numerical variables.

Comparisons of the left upper limb measurements versus the right upper limb showed significant differences for: forearm length to stylion radiale anthropometric point, the length of the hand the total length of FCU and length of FCU belly. For each measurement pair of the analogous quantities in left and right upper limb a scatter plot with an added linear regression line was created. Almost all plots (12 out of 13) showed a significant, strong ($r > 0.85$) positive linear relationship; in 10 out of 13 plots the coefficient r was greater or equal to 0.90. Only the relationship between FCU tendon length (left vs right) was moderate ($r = 0.50$), which can be easily explained by an overly vague definition of how this measurement should be performed. Our attempt to find meaningful relationships between other quantities was successful. From 465 analysed pairs of variables, we found 44 pairs which showed a statistically significant strong positive linear relationship. What is interesting and

unexpected for us is that among these 44 relationships, there is only one in which the fetus' mass is present and only one which considers the fetus' age. For categorical variables the chi-square tests rejected, with an ifinitesimaly low p-values, that types of FCU insertions are equally distributed, both in left and right upper limb.

A comparison of FCU insertion types between left and right upper limb showed there is no significant difference between counts of each type. This statement holds also for males and females considered separately.

Discussion

The ulnar specific pathway formed by the FCU but also the flexor digitorum profundus as well as the flexor digitorum superficialis is 'used' by the ulnar vessels and nerves as a pathway from the humero-ulnar joint area towards the hand (Grechenig et al. 2000).

The FCU is a muscle that is easy to palpate and may therefore act as a topographical marker for healthcare professionals in the search for local neurovascular bundle. Some researchers suggest that the FCU is an important anatomical landmark for surgeons and ultrasonographers. Knowledge of the variability of the terminal segment of this muscle is therefore not only of cognitive importance but also of profound clinical significance (Mizia et al. 2021).

Due to the limited access to anatomical specimens of adults, there was a strong need to look for alternative sources of biological material (Ghosh 2017; McCumber et al. 2021). Fetal collections assembled in many anatomical laboratories in the 19th and 20th centuries could be such a source (Rohan et al. 2019).

In Poland, due to the high fertility rate and, at the same time, the underfunding of health care during the communist period between 1960 and 1990, the Department of Anatomy was enriched with a collection of genetically defect-free fetuses. This material is unique. The socio-economic progress and advances in medical science have resulted in low mortality rate of fetuses and newborns in Poland today (Krzyżak et al. 2014; Troszyński et al. 2009; Wiśniewski et al. 2019).

The fetal material, due to its much smaller size, is easier to store. Thus, it is possible to collect a large number of foetuses, which increases the chances of conducting a reliable statistical analysis of the results and conducting research on a relatively large study material. In the case of the study described here, anatomical analysis was carried out using 114 fetuses from the local anatomical collection.

It showed a stable course of FCU, which is consistent with the standard textbook description. The initial attachment in all cases is typical and the terminal tendon attaches in a standard manner in most cases.

Similar observations are shown by Loth and Wood evaluating FCU on adult material (Loth 1931; Wood 1866).

It should be noted, that the current publication demonstrates the presence of variability in FCU terminal attachment. Various types of the distal attachment and their percentages are shown on Figure 3.

An interesting novelty compared to previous studies was the demonstration of the presence of a statistically significant difference in selected bilateral measurements with a statistically significant difference in favor of the left upper

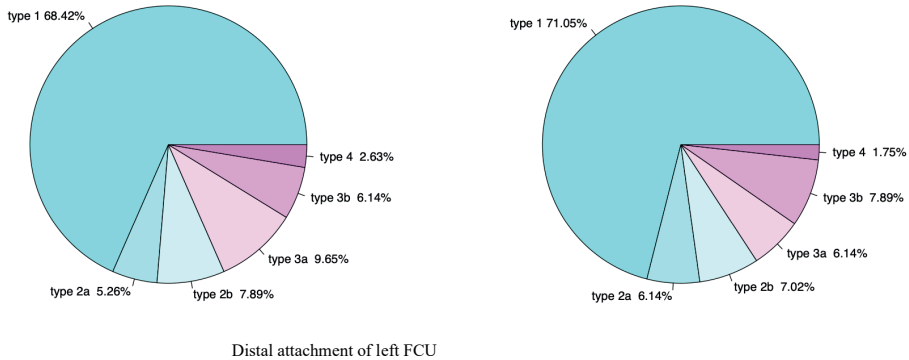

Fig. 3. Various type of the distal attachment of Flexor Carpi Ulnaris

limb. Due to the established measurement procedure – two independent researchers take the same measurements three times and the average of all these measurements is included in the analysis – the authors are of the opinion that the differences shown are not a result of measurement errors. It is worth noting that the individual researchers did not have access to data collected by the second author.

Similar differences were shown in the work concerning the flexor carpi radialis (Suchanecka et al. 2022).

A relationship between the variation shown and intrauterine limb developmental limitations or atypical response to the preservative material used or specific fetal developmental disorders cannot be excluded either. There are hypotheses in the literature that suggest that the lateralization process of the brain is initiated already in fetal life, which may indirectly explain the demonstrated differences.

However, other factors related to human evolution must be taken into account. For example, Saniotis et al. (2021) point out that the directional factors of evolution are mutations and natural selection. According to the authors of this publication, it cannot be excluded that the observed variation in selected muscles is the result of a single mutation that disrupts or alters the process of fetal development.

It has been proved in the case of muscles that a reprogramming of gene transcription is associated with remodeling of the contractile properties of the fibers (slow, fast fibers) and a remodeling of the metabolic profile of the muscle (Aleman et al. 2022; Baumert et al. 2018).

Whether single mutations can contribute to increased variability in muscle attachment - this question is difficult to answer unequivocally. Certainly, genetic disorders affect skeletal muscle function in animals in such a way that atypical-looking muscle fibers are formed (Yuan et al. 2021). Thus, it is possible to hypothesize a potential link between mutations and muscle variability (Krämer et al. 2006).

You et al. (2022) conclude that mutations are an inevitable consequence of the poor quality of the chemical bonds between the bases that make up DNA. Their number is gradually increasing in humans due to the species' increased exposure to mutagenic agents as well as better health protection.

Improving intrauterine as well as extrauterine health care reduces the opportunity for natural selection to operate. As a result of reduced evolutionary pressure, the number of mutations and developmental disorders are increasing - and this may also be translated into the observed higher variability and altered symmetry when compared to the past.

Certainly, this topic requires further research and continued work on a detailed understanding of forearm anatomy in the fetal period.

Limitations:

1. Limited access to material: due to limited access to good quality anatomical specimens at ages younger than fetal day 117, it was not possible to perform an anatomical analysis linking the proposed typology to the age classes of the fetuses.
2. Method of preservation of the material, which adversely affects selected fetal parameters.

Acknowledgements

The authors would like to thank Ms Alina Proniewicz for her assistance with the project. The study was supported by statutory grant SUBZ.A351.22.038 (The presented research results, carried out within the framework of the topic according to the register in the S system with the number SUBZ.A351.22.038, were financed from the subsidy granted by the Minister of Science and Higher Education).

In accordance with the guidelines of the editors of anatomical journals (Iwanaga et al. 2022).

The authors sincerely thank those who donated their bodies to science so that anatomical research could be performed. Results from such research can potentially increase humankind's overall knowledge that can improve patient care. Therefore, these donors and their families deserve our highest gratitude.

Conflict of interests

The authors declared no conflict of interest.

Authors' contributions

KS was project supervisor, conceived the paper and co-edited the final version of the manuscript; RK was responsible for the preparation of the foetal material and literature selection; AM was responsible for the preparation of the foetal material and writing the final version of the manuscript; JC collected the data and performed statistical computations; JU assisted with writing the manuscript and was responsible for figures creating; MS was responsible for the preparation of the fetal material and literature selection; all authors substantially contributed to revisions.

Corresponding author

Małgorzata Suchanecka, Division of Anatomy, Wroclaw Medical University, Wroclaw Poland, Phone: 717841331, fax: 717840079; e-mail: malgorzata.suchanecka@umw.edu.pl

References

al-Qattan MM, Duerksen F. 1992. A variant of flexor carpi ulnaris causing ulnar nerve compression. J Anat 180 (Pt 1):189–90.

Aleman M, Scalco R, Malvick J, Grahn RA, True A, Bellone RR. 2022. Prevalence of Genetic Mutations in Horses With Muscle Disease From a Neuromuscular Disease Laboratory. J Equine Vet Sci 118:104129.

Ang GG, Rozen WM, Vally F, Eizenberg N, Grinsell D. 2010. Anomalies of the flexor carpi ulnaris: clinical case report and cadaveric study. Clin Anat 23(4):427–30.

Ata AM, Kara M, Aydin G, Kaymak B, Gürçay E, Özçakar L. 2018. Ultrasound Imaging for Muscle Variations: Digastric Flexor Carpi Ulnaris, Gastrocnemius Tertius, and Supernumerary Fibularis Longus in an Asymptomatic Family. Am J Phys Med Rehabil 97(11):e107–09.

Baumert P, G-REX Consortium, Stewart CE, Lake MJ, Drust B, Erskine RM. Variations of collagen-encoding genes are associated with exercise-induced muscle damage. 2018. Physiol Genomics. Sep 1;50(9):691–693.

Bhardwaj P, Bhandari L, Sabapathy SR. 2013. Supernumerary flexor carpi ulnaris–case report and review. Hand Surg 18(3):393–97.

Bobzin L, Roberts RR, Chen HJ, Crump JG, Merrill AE. 2021. Development and maintenance of tendons and ligaments. Development 148(8):dev186916.

Budoff JE, Kraushaar BS, Ayala G. 2005. Flexor carpi ulnaris tendinopathy. J Hand Surg Am 30(1):125–29.

Capdarest-Arest N, Gonzalez JP, Türker T. 2014. Hypotheses for ongoing evolution of muscles of the upper extremity. Med Hypotheses 82(4):452–56.

Conrad DF, Keebler JE, DePristo MA, Lindsay SJ, Zhang Y, Casals F, et al. 2011. 1000 Genomes Project. Variation in genome-wide mutation rates within and between human families. Nat Genet Jun 12;43(7):712–4.

Dudek K, Nowakowska-Kotas M, Kędzia A. 2018. Mathematical models of human cerebellar development in the fetal period. J Anat 232(4):596–603.

Esplugas M, Garcia-Elias M, Lluch A, Llusá Pérez M. 2016. Role of muscles in the stabilization of ligament-deficient wrists. J Hand Ther 9(2):166–174.

Fridén J, Lovering RM, Lieber RL. 2004. Fiber length variability within the flexor carpi ulnaris and flexor carpi radialis muscles: implications for surgical tendon transfer. J Hand Surg Am 29(5):909–14.

Ghosh SK. 2017. Paying respect to human cadavers: We owe this to the first teacher in anatomy. Ann Anat 211:129–34.

Giuliani Piccari Scarpa G, Marchini M, Nicoletti P. 1977. Osservazioni sullo sviluppo dell'articolazione scapolo-omerale nell'uomo, con particolare riferimento ai suoi rapporti con il tendine del capo lungo del muscolo bicipite del braccio. Arch Ital Anat Embriol 82(1):85–98.

Grechenig W, Clement H, Egner S, Tesch NP, Weiglein A, Peicha G. 2000. Musculo-tendinous junction of the flexor carpi ulnaris muscle. An anatomical study. Surg Radiol Anat 22(5–6):255–60.

Guéro S. Developmental biology of the upper limb. 2018. Hand Surg Rehabil 37(5):265–74.

Gworys B, Domagala Z. 2003. The typology of the human fetal lanugo on the thorax. Ann Anat 185(4):383–86.

Iwanaga J, Singh V, Takeda S, Ogeng'o J, Kim HJ, Moryś J et al. 2022. Standardized statement for the ethical use of human cadaveric tissues in anatomy research papers: Recommendations from Anatomical Journal Editors-in-Chief. Clin Anat 35(4):526–528.

Karykowska A, Domagała ZA, Gworys B. 2022. Musculus peroneus longus in foetal period. Folia Morphol (Warsz) 81(1):124–33.

Karykowska A, Domagala ZA, Gworys B. 2022. Topography of the common fibular nerve terminal division in human foetuses. Folia Morphol (Warsz) 81(1):37–43.

Karykowska A, Rohan-Fugiel A, Mączka G, Grzelak J, Gworys B, Tarkowski V, Domagała Z. 2021. Topography of muscular branches of the superficial fibular nerve based on anatomical preparation of human foetuses. Ann Anat 237:151728.

Kędzia A, Dudek K, Ziajkiewicz M, Wolanczyk M, Seredyn A, Derkowski W, Domagala ZA. 2022. The morphometrical and topographical evaluation of the superior gluteal nerve in the prenatal period. PLoS One 17(8):e0273397.

Králík M, Ingrová P, Kozieł S, Hupková A, Klíma O. 2017. Overall trends vs. individual trajectories in the second-to-fourth digit (2D:4D) and metacarpal (2M:4M) ratios during puberty and adolescence. Am J Phys Anthropol Apr;162(4):641–656.

Krämer DK, Ahlsén M, Norrbom J, Jansson E, Hjeltnes N, Gustafsson T, et al. 2006. Human skeletal muscle fibre type variations correlate with PPAR alpha, PPAR delta and PGC-1 alpha mRNA. Acta Physiol (Oxf) 188(3-4):207–16.

Kreulen M, Smeulders MJ, Hage JJ. 2004. Restored flexor carpi ulnaris function after mere tenotomy explains the recurrence of spastic wrist deformity. Clin Biomech (Bristol, Avon) 19(4):429–32.

Krzyżak M, Maślach D, Piotrowska K, Charkiweicz AE, Szpak A, Karczewski J. 2014. Perinatal mortality in urban and rural areas in Poland in 2002-2012. Przegl Epidemiol 68(4):675–79.

Kunc V, Stulpa M, Feigl G, Kachlik D. 2019. Accessory flexor carpi ulnaris muscle with associated anterior interosseous artery variation: case report with the definition of a new type and review of concomitant variants. Surg Radiol Anat 41(11):1315–18.

Loth E. 1912. Beiträge zur Anthropologie der Negerweichteile (Muskelsystem). Strecker & Schröder.

Marzke MW. 1997. Precision grips, hand morphology, and tools. Am J Phys Anthropol 102(1):91–110.

McCumber TL, Latacha KS, Lomneth CS. 2021. The state of anatomical donation programs amidst the SARS-CoV-2 (Covid-19) pandemic. Clin Anat 34(6):961–65.

Mizia E, Pekala PA, Skinningsrud B, Rutowicz B, Piekos P, Baginski A, Tomaszewski KA. 2021. The anatomical landmarks effective in the localisation of the median nerve during orthopaedic procedures. Folia Morphol (Warsz) 80(2):248–54.

Pelletier F, Coltman DW. 2018. Will human influences on evolutionary dynamics in the wild pervade the Anthropocene? BMC Biol. Jan 15;16(1):7.

Pressney I, Upadhyay B, Dewlett S, Khoo M, Fotiadou A, Saifuddin A. 2020. Accessory flexor carpi ulnaris: case report and review of the literature. BJR Case Rep 6(3):20200010.

Rohan A, Domagała Z, Abu Faraj S, Korykowska A, Klekowski J, Pospiech N, Wozniak S, Gworys B. 2019. Branching patterns of the foetal popliteal artery. Folia Morphol (Warsz) 78(1):71–78.

Saniotis A, Henneberg M, Mohammadi K. 2021. Genetic load and biological changes to extant humans. J Biosoc Sci Jul;53(4):639–642.

Skinner MM, Stephens NB, Tsegai ZJ, Foote AC, Nguyen NH, Gross T, Pahr DH, Hublin JJ, Kivell TL. 2015. Human evolution. Human-like hand use in Australopithecus africanus. Science 347(6220):395–99.

Suchanecka M, Siwek K, Ciach J, Eicke K, Tarkowski V. 2022. Typology of flexor carpi radialis muscle in human fetuses. Folia Med Cracov 62(1):5–17.

Troszyński M, Niemiec T, Wilczyńska A. 2009. Ocena funkcjonowania trójstopniowej selektywnej opieki perinatalnej na podstawie analizy umieralności okołoporodowej wczesnej i cieć cesarskich w Polsce w 2008 roku [Assessment of three-level selective perinatal care based on the analysis of early perinatal death rates and cesarean sections in Poland in 2008]. Ginekol Pol 80(9):670–677.

Wingate Todd T. 1931. Anthropologie des parties molles. E LOTH.. Pages vii + 539. Masson et Cie. The Anatomical Record 51(2):219–22.

Wiśniewski M, Baumgart M, Grzonkowska M, Szpinda M, Pawlak-Osińska K. 2019. Quantitative anatomy of the ulna's shaft primary ossification center in the human fetus. Surg Radiol Anat 41(4):431–39.

Wood J. 1866. Variations in Human Myology Observed during the Winter Session of 1865-66 at King's College, London. Proc R Soc Lond 15:229–244.

Wozniak S, Pytrus T, Kobierzycki C, Grabowski K, Paulsen F. 2019. The large intestine from fetal period to adulthood and its impact on the course of colonoscopy. Ann Anat 224:17–22.

Yamamoto R, Izumida M, Sakuraya T, Emura K, Arakawa T. 2021. The ulnar nerve is surrounded by the tendon expansion of the flexor carpi ulnaris muscle at the wrist: an anatomical study of Guyon's canal. Anat Sci Int 96(3):422–26.

You W, Henneberg R, Henneberg M. 2022. Healthcare services relaxing natural selection may contribute to increase of dementia incidence. Sci Rep 25;12(1):8873.

Yuan Z, Sunduimijid B, Xiang R, Behrendt R, Knight MI, Mason BA, Reich CM, Prowse-Wilkins C, Vander Jagt ChJ, Chamberlain AJ, MacLeod IM, Li F, Yue X, Daetwyler HD. 2021. Expression quantitative trait loci in sheep liver and muscle contribute to variations in meat traits. Genet Sel Evol 18;53(1):8.

Ziajkiewicz M, Kędzia A, Dudek K. 2010. Flexor carpi ulnaris (FCU) muscle (m. flexor carpi ulnaris) in foetal period. Arch Perinat Med 16(4):218–24.

Ziółkowski M, Trzaska M, Kurlej W, Porwolik K, Porwolik M. 1994. Relationship between the intervertebral foramina and the spinal nerves at the level of C4-T2 of the human fetal vertebral column. Folia Morphol (Warsz) 53(3):197–203.

Notes for Authors

The Anthropological Review is the official journal of the Polish Anthropological Society, founded by Adam Wrzosek in 1926. It succeeds the Przegląd Antropologiczny (1926–2000; vols. 1–63) and Przegląd Antropologiczny – Anthropological Review (2001–2006; vols. 64–69), and it is abstracted in: Index Copernicus (Medical Science Int.), IBSS: International Bibliography of the Social Sciences (LSE), SCOPUS (Elsevier), Zoological Record (Thomson Reuters).

Open access to the journal is via https://czasopisma.uni.lodz.pl/ar/index. Anthropological Review comes out four times a year in print and online. It publishes peer-reviewed papers from physical anthropology and related disciplines, including: biology, ecology, human auxology, population genetics, bio-demography and bio-archeology. The journal accepts original research reports, overview articles, literature reviews and meta-analyses, short notes and communications and book reviews.

Submission of a paper to Anthropological Review implies that the paper is not being considered for publication elsewhere. The paper (in English) should be prepared in accordance with the instruction for authors and submitted electronically by https://czasopisma.uni.lodz.pl/ar/index.

Each submission should be accompanied by a cover letter, and the istructions can be downloaded from https://czasopisma.uni.lodz.pl/ar/index.

Preliminary accepted articles are subject to evaluation by two anonymous reviewers and, where appropriate, by the Statistical Advisor. The principle of double-blinded reviewing applies with names of both the authors and reviewers concealed. The reviews received, including Editors' comments, are forwarded to the Author as PDF documents. Author's revisions must be in PDF format within the deadline set by the journal Editors. The corrected version will be re-evaluated where nessesary, and the Editors will notify the Author whether the article has been accepted for publication.

The Editors' correspondence is conducted by e-mail. Editorial corrections are permitted to authors only in substantial matters and the Editors reserve the right to make necessary corrections and shortenings without the authors' prior consent. The Editors may refuse article publication following consultation with Editorial Board members.

Material accepted for publication becomes the property of the Editors and may not be published in whole or in part in other journals without prior written consent.

Initiating Editor: Katarzyna Smyczek

Language Editor: Piotr Fedurek, Ludwik Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences

Technical Editor: Anna Jakubczyk

Typesetting: Munda – Maciej Torz

Cover design: Tomasz Kasperczyk

Adjusting the cover design: Monika Rawska

Cover photos: stock.adobe.com/klevo; stock.adobe.com/adimas

Łódź University Press
90-237 Łódź, ul. Jana Matejki 34A
www.wydawnictwo.uni.lodz.pl
e-mail: ksiegarnia@uni.lodz.pl
tel. 42 635 55 77