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Review Paper

Determination of Sex Using Hyoid Bones in Forensic Identification: a Systematic Review

Qurotul Ainayah

Magister Ilmu Forensik, Sekolah Pascasarjana, Universitas Airlangga.
*E-mail: qurotul.ainayah-2023@pasca.unair.ac.id

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Abstrak

Tulang hyoid, sebuah struktur tulang tunggal di leher manusia, memiliki potensi signifikan dalam identifikasi forensik, khususnya untuk penentuan jenis kelamin individu. Penelitian ini bertujuan untuk mengevaluasi efektivitas pengukuran antropometri dan analisis morfologis tulang hyoid dalam berbagai populasi. Dengan menggunakan protokol PRISMA dan basis data seperti Publish or Perish, Science Direct, serta Google Scholar, sebanyak 130 literatur awal berhasil diidentifikasi, kemudian diseleksi menjadi 10 artikel yang relevan untuk dianalisis lebih lanjut. Hasil penelitian menunjukkan bahwa dimensi tulang hyoid, seperti panjang dan lebar, secara signifikan berbeda antara laki-laki dan perempuan di berbagai populasi. Misalnya, analisis morfometri menunjukkan tingkat akurasi 73% untuk identifikasi jenis kelamin berdasarkan karakteristik tertentu. Studi lain menggunakan CT-scan mengungkapkan keakuratan tinggi dalam membedakan jenis kelamin dengan area di bawah kurva ROC mencapai 81,8%. Penelitian ini juga menemukan variasi ukuran tulang hyoid yang dipengaruhi oleh populasi, metode analisis, dan teknik pengukuran. Misalnya, ukuran rata-rata tulang hyoid pada laki-laki cenderung lebih besar dibandingkan perempuan, dengan nilai panjang rata-rata yang signifikan di berbagai studi. Hasil ini menegaskan pentingnya mempertimbangkan faktor populasi dalam interpretasi data forensik. Kesimpulan penelitian menekankan bahwa tulang hyoid adalah alat yang andal dalam identifikasi jenis kelamin, khususnya ketika metode yang digunakan melibatkan pengukuran morfometrik dan teknik CT-scan. Studi ini merekomendasikan kolaborasi lintas disiplin antara ahli forensik, radiolog, dan antropolog untuk meningkatkan akurasi serta validitas hasil identifikasi. Dengan pendekatan yang sistematis, penggunaan tulang hyoid berpotensi memperkuat praktik forensik modern melalui landasan ilmiah yang kuat.

Kata Kunci: Tulang hyoid; identifikasi forensik; penentuan jenis kelamin; pengukuran antropometri; analisis morfometrik; CT-scan; dimorfisme seksual.

Abstract

The hyoid bone, a single bone structure in the human neck, has significant potential in forensic identification, particularly for sex determination. This study aims to evaluate the effectiveness of anthropometric measurements and morphological analysis of the hyoid bone across different populations. Using the PRISMA protocol and databases such as Publish or Perish, Science Direct, and Google Scholar, 130 initial studies were identified, with 10 relevant articles selected for detailed analysis. The results reveal significant differences in the dimensions of the hyoid bone, such as length and width, between males and females in various populations. Morphometric analysis demonstrated a 73% accuracy rate in sex identification based on specific characteristics. Other studies utilizing CT-scan techniques reported high accuracy in sex differentiation, with an area under the ROC curve reaching 81.8%. This research also highlights variations in hyoid bone dimensions influenced by population characteristics, analytical methods, and measurement techniques. For instance, the average size of the hyoid bone in males tends to be larger than in females, with statistically significant differences across studies. These findings emphasize the importance of considering population-specific factors in forensic data interpretation. The study concludes that the hyoid bone is a reliable tool for sex determination, especially when methods involve morphometric measurements and CT-scan techniques. Collaboration among forensic experts, radiologists, and anthropologists is recommended to enhance the accuracy and validity of identification outcomes. A

systematic approach to using the hyoid bone has the potential to strengthen modern forensic practices with robust scientific foundations.
Keywords: Hyoid bone; forensic identification; sex determination; anthropometric measurements; CT-scan; sexual dimorphism

1. Introduction

The hyoid bone, a single bone structure located in the human neck, has become a fascinating subject of research in the context of forensic identification. Its ability to provide crucial clues during the process of individual identification has garnered the interest of researchers to explore its morphological characteristics as a tool for determining sex in forensic investigations.

The determination of sex using the hyoid bone is a useful but secondary method in forensic anthropology. While not as accurate or commonly used as the pelvis or skull, it becomes highly relevant in cases of neck trauma or when skeletal remains are incomplete. With improved imaging and analytical techniques, the prevalence of hyoid-based sex estimation in forensic casework is gradually increasing, especially in multidisciplinary approaches.

This systematic review aims to examine the effectiveness of sex determination using single bones, particularly the hyoid bone, across various population groups. By analyzing scientific literature from different populations using morphological and metric analysis methods, we can understand the variations in hyoid bone characteristics between male and female populations and evaluate the accuracy of anthropometric measurements of the hyoid bone in identifying the sex of individuals in a forensic context.

2. Method

2.1. Study Design and Ethical Considerations

The systematic review protocol adheres to the Preferred Reporting System for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and has been registered in the Prospective Register of Systematic Reviews (PROSPERO).

The methodology employed in this study adheres to the guidelines of the Preferred Reporting System for Systematic Reviews and Meta-Analyses (PRISMA) and has been registered in the Prospective Register of Systematic Reviews (PROSPERO). Research questions were formulated based on Population (P), Intervention (I), and Outcome (O), focusing on the characteristics of the hyoid bone, anthropometric measurements, and the accuracy of sex determination.

Information sources include databases such as Publish or Perish, Science Direct, and Google Scholar. Keywords were used to search for scientific articles published between 2010 and 2022, resulting in 130 relevant pieces of literature. The selection process included stages of identification, screening, and inclusion, yielding 10 articles that met eligibility criteria for further analysis. Data analysis was conducted by comparing study results regarding measurements and populations used for sex estimation methods involving the hyoid bone. Data extraction highlighted variations in size and dimensions of the hyoid bone among different populations, as well as the accuracy of Computed Tomography Scan (CT-scan) methods and morphometric measurements in sex determination. The discussion explores these findings further, considering the reliability and validity of the methods used, as well as their practical implications in forensic identification practices.

2.2. Research Questions and Eligibility Criteria

The research questions were formulated based on Population (P), Intervention (I), and Outcome (O) as follows:

1. **Population (P):** How do the characteristics of the hyoid bone vary between male and female populations in forensic identification?
2. **Intervention (I):** How can anthropometric measurements of the hyoid bone be used to distinguish sex in forensic investigations?
3. **Outcome (O):** How accurate is the use of anthropometric measurements of the hyoid bone in identifying the sex of individuals in a forensic context?

The primary research question is: "Are there significant differences in the characteristics of the hyoid bone between males and females, and how accurate are anthropometric measurements of the hyoid bone for determining sex in forensic identification?"

2.3. Information Sources and Search Strategy

Primary data were obtained from databases such as Publish or Perish, Science Direct, and Google Scholar. Keywords were constructed using Boolean operators "AND" and "OR" as shown in Table 1. Articles were limited to those published between 2010 and 2022.

Table 1. Information Sources and Search Strategy

Database	Keywords	Result
Publish or Perish	"hyoid bones" or "sex determination" and "gender"	22
Science Direct		31
Google Scholar		77

2.4. Study Selection

The literature selection was conducted in three stages:

1. **Identification:** Studies identified through database searches were stored in the Mendeley Desktop reference manager. Duplicates detected by the system were removed, as well as books as a type of literature.
2. **Screening:** Titles of studies that did not utilize single bones were excluded. Additionally, literature that did not focus on single bones in specific populations was excluded.
3. **Inclusion:** The selected studies pertained to sex determination in populations and results concerning single bones, with literature ranked at least Q3, written in English, and fully accessible for further review.

3. Result

3.1. Study Selection Results

The literature selection process resulted in 130 scientific articles from three databases. Duplicate articles (19) were removed, leaving 111 articles. Subsequently, 7 articles in book format were excluded, leaving 104 articles for screening. After removing articles that did not discuss single bones, 28 articles remained. Of these, 8 articles that did not analyze populations and 10 articles ranked below S4 were excluded, resulting in 10 articles for final analysis.

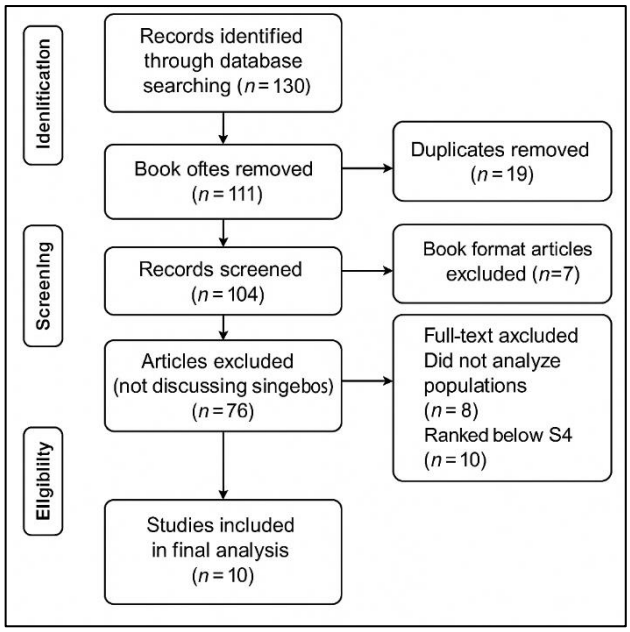

Figure 1. Prisma Identification of Selected Studies

3.2. Data Extraction

This study compared analyses of the hyoid bone across different populations. Table 2 lists the selected journal references, publication years, populations, methods, and results. Using population-specific data, the study analyzed sex determination from single bones across diverse populations.

The extracted data highlight significant findings, such as variations in the size and dimensions of the hyoid bone between males and females, the application of CT-scan methods, and the accuracy of morphometric measurements in sex determination. These findings underscore the relevance of population-specific factors and the effectiveness of forensic tools like CT-scans and anthropometric techniques in forensic investigations.

Table 2. Measurements and Populations Used for Sex Estimation Methods

Citation	Population	Method	Results	Outcomes
[1]	Turki	Metrik	Results show that age and sex estimation can be conducted using metric measurements and hyoid bone fusion in the Turkish population.	Age and sex estimation using metric measurements and hyoid bone fusion in the Turkish population.

[2]	Population-specific	Morphometric analysis	Found that the male hyoid is longer and wider than the female hyoid. Strong statistical significance was observed for some measurements, with 73% accuracy achieved using certain combinations of measurements. However, the results were inconsistent with previous studies, which concluded that the distal part of the hyoid bone is more sexually dimorphic than other parts.	Morphometric features and sexual dimorphism of the adult hyoid bone: A population-specific study with forensic implications.
[3]	Japan	Multidetector computed tomography (CT-scan)	Analysis shows significant differences in hyoid bone morphological features between males and females. For example, the length and width of the hyoid cavity tend to be larger in males than in females. Based on these findings, the researchers concluded that sex determination using morphological features of the hyoid bone with CT can provide fairly accurate results.	This study demonstrates that CT can accurately evaluate hyoid bone morphological features for sex determination.
[4]	Tunisian	CT-scan	CT-scan analysis can be used to estimate age and sex in the Tunisian population. The correlation between actual and estimated ages was good, with an area under the ROC curve of 81.8% for sex determination.	Effective CT-scan analysis for estimating age and sex in Tunisia with a good correlation, area under the ROC curve at 81.8%.
[5]	Non-specific	Radiological anatomy study	The results of this study show varying hyoid bone sizes across different populations, based on both sex and measurement methods used.	Results show variations in hyoid bone size across different populations by sex and measurement methods.
[6]	Cadaver	Specific measurement methods	This study shows significant differences in hyoid bone size between males and females, with average hyoid bone length in females of 31.92±2.11 mm and in males of 25.92±1.50 mm.	Significant differences in hyoid bone size between sexes.
[7]	-	-	The results show varying hyoid bone sizes between males and females, with an average hyoid bone length in females of 42.29±7.56 mm and in males of 38.78±13.93 mm.	Differences in hyoid bone size between sexes: females (42.29±7.56 mm) and males (38.78±13.93 mm).
[8]	-	-	The study shows varying hyoid bone sizes between males and females, with an average hyoid bone length in females of 20.71±3.96 mm and in males of 38.47±10.17 mm.	Significant differences in hyoid bone size between sexes.
[9]	217 male cadavers and 155 female cadavers	Morphometric study	Specific hyoid bone measurements, such as body length and the angle between the horns and body, are associated with sex determination. Discriminant formulas were determined for sex identification, concluding that morphometric analysis of the hyoid bone can accurately determine individual sex.	Morphometric analysis of the hyoid bone is accurate for sex identification.

[10]	60 hyoid bones, 36 male and 24 female	Anthropometric measurements	This study used 12 key anthropometric measurements on each hyoid bone. Results show significant differences in hyoid bone size between males and females, with all measurements larger in males. These findings can be applied to forensic and archaeological studies, with a high level of accuracy. Additionally, strong correlations were found between an individual's height and the width and thickness of the hyoid bone.	Significant differences in hyoid bone size by sex, useful for forensic and archaeological identification.

4. Discussion

The hyoid bone, a single bone structure in the human neck, has become an intriguing subject of research due to its morphological characteristics, which can provide critical clues in forensic identification. Research conducted by Odabasi *et al.* in 2013 revealed that age and sex estimation could be achieved using metric measurements and hyoid bone fusion in the Turkish population. This suggests that the characteristics of the hyoid bone can vary across different populations, which is further supported by research on the Tunisian population conducted by Haj Salem et al. in 2020 using CT-scan methods. Their findings demonstrated that CT-scan analysis could effectively estimate age and sex with a high degree of accuracy in the Tunisian population.

Research by Mukhopadhyay (2010) showed that the hyoid bone in males has larger dimensions than in females, while studies by Kopuz C (2016) and Fakhry et al. (2013) also reported significant differences in hyoid bone size between sexes. However, these findings are not always consistent. For instance, research by Ahmet Dursun (2020) found variations in hyoid bone size across different populations, influenced by sex and measurement methods.

In forensic identification, achieving accurate and reliable results is crucial. A study by Torimitsu et al. in 2017, using multidetector computed tomography (CT-scan), showed significant differences in the morphological features of the hyoid bone between males and females. This indicates that sex determination using CT-scan analysis of hyoid bone morphology can provide sufficiently accurate results to aid in individual identification.

Additionally, research by Arash Okas (2018) highlighted the application of morphometric measurements of the hyoid bone in forensic medicine. The findings indicated that morphometric analysis of the hyoid bone could accurately determine an individual's sex. Research by Kapil Amgain (2020) reinforced this, demonstrating the utility of anthropometric measurements of the hyoid bone in both forensic and archaeological studies.

In the context of using the hyoid bone for forensic identification, it is essential to consider the reliability and validity of the applied methods. For example, research by Balseven-Odabaşi et al. (2022) revealed significant differences in hyoid bone size between sexes, supported by other studies showing notable sexual dimorphism in the bone's dimensions.

Several factors must be considered when interpreting these findings. First, consistent techniques and methods in the measurement and analysis of the hyoid bone significantly influence result accuracy. Second, the studied population's characteristics can affect the generalizability of research findings. For instance, using samples from individuals of varying ages, ethnicities, and geographical regions can provide a broader understanding of hyoid bone morphological variations. Furthermore, in forensic identification practices, interdisciplinary collaboration among forensic experts, radiologists, and anthropologists is necessary to ensure that all identification aspects, including hyoid bone analysis, are conducted meticulously and adhere to strict scientific standards.

5. Conclusion

Research on the use of the hyoid bone in forensic identification reveals significant findings in distinguishing sex and estimating age within specific populations. It has been found that the morphological characteristics of the hyoid bone vary among different populations, as evidenced by studies on Turkish and Tunisian populations. The application of CT-scan techniques and morphometric measurements has proven effective in determining an individual's sex with a high degree of accuracy. Despite variations in the size and dimensions of the hyoid bone between sexes, result consistency remains a consideration. Collaboration among forensic experts, radiologists,

and anthropologists is necessary to ensure accurate forensic identification practices. Utilizing the hyoid bone in forensic identification holds great potential to strengthen forensic practice by providing a robust scientific foundation.

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