

# Morphometric Characteristics of the Stapedius Muscle: A Systematic Review of Human Cadaveric Studies

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## ABSTRACT

The stapedius muscle and its tendon play a critical role in middle ear function and maintain a close anatomical relationship with the facial nerve. Precise morphometric knowledge of the stapedius is essential for safe and effective otologic procedures. To date, no systematic review has comprehensively synthesized cadaveric data on the stapedius muscle and tendon in a standardized format. This study aimed to systematically review cadaveric studies evaluating the morphometry of the stapedius muscle and tendon, including muscle belly length and width, tendon length and width, total stapedius length, and anatomical relationships with the facial nerve. A systematic search of PubMed, Scopus, and Google Scholar was performed using the keywords: “stapedius muscle,” “stapedius tendon,” and “morphometric,” combined with size-related terms. Inclusion and exclusion criteria were applied to select relevant cadaveric studies. Data extraction included study location, sample size, stapedius dimensions, sex, laterality, and tendon-to-facial nerve distance. Statistical analysis was conducted using SPSS v23.0, calculating mean  $\pm$  SD values and pooled

averages across studies. Four studies encompassing 79 stapedius specimens from Turkey, the USA, and Colombia were included. Adult muscle belly length ranged from 3.15 to 4.58 mm, while fetal specimens measured 4.52 mm. Tendon length varied between 0.99- and 1.40-mm. Muscle belly width ranged from 1.19 to 1.44 mm, tendon width from 0.36 to 0.46 mm, and total stapedius length from 4.47 to 5.91 mm. The tendon-to-facial nerve distance ranged from 1.14 to 1.22 mm. Morphometric parameters were largely consistent across age groups and populations, with minor variations. The dimensions of the stapedius muscle and tendon remain relatively stable from fetal development to adulthood. Detailed knowledge of its anatomy, particularly in relation to the facial nerve, is essential for minimizing complications during retro-tympanic and facial nerve surgical interventions.

**Keywords:** Stapedius muscle, Stapedius tendon, Morphometry, Cadaveric study, Facial nerve, Middle ear anatomy

## INTRODUCTION

The stapedius is located deep within the tympanic cavity of the middle ear. It consists of a small muscle belly that arises from the pyramidal eminence and a slender tendon that attaches to the neck of the stapes. Despite its tiny size, the stapedius serves an important functional role [1]. Through reflexive contraction, it stabilizes the stapes and limits its excessive movement during exposure to loud sounds. In this way, the stapedius acts as a regulator of vibration and helps protect the inner ear from potential acoustic damage [2,3]. Developmentally, the stapedius originates from the second pharyngeal arch, and slight variations during its formation may result in structural or morphological differences. These may include duplication of the muscle, absence of the basal tendon, or abnormal displacement of its fibers [4-7].

In clinical otology, the stapedius is most commonly encountered during surgical procedures involving the stapes, such as stapedotomy and stapedectomy. In many cases, preservation of the stapedius tendon is desirable, as its functional integrity contributes to the regulation of sound transmission and may significantly influence postoperative hearing outcomes [8]. Therefore, detailed knowledge of the stapedius muscle's dimensions, attachment sites, and possible anatomical variations is essential for preventing iatrogenic injuries during middle ear surgery [1,9].

Numerous anatomical studies have reported the morphometric characteristics of the stapedius muscle using human cadaveric material. However, the measured parameters of the muscle belly and tendon have shown considerable variation among studies [6-10]. These inconsistencies can be partly attributed to differences in dissection techniques, sample sizes, and demographic characteristics of the examined populations. Consequently, the true average dimensions of the stapedius muscle, as well as their potential relationships with factors such as side, sex, and ethnicity, remain uncertain. Considering the crucial role of accurate

anatomical information, both in research and practical surgery, it is pertinent to develop dependable reference values for the stapedius muscle [11]. This study aims to systematically review and quantitatively analyze cadaveric data on the morphometric characteristics of the human stapedius muscle.

## MATERIALS & METHODS

### Search Strategy

An extensive review of literature was performed through search in electronic databases, such as Google Scholar, PubMed and Scopus. "Keyword used for search were "stapedius muscle", stapedius tendon" and morphometric other color with "size", "length", width or diameter". Only cadaver studies were included and case reports, case series, letters to editors and brief communications were excluded. No restrictions were placed on publication date, language or age of participants." Other relevant studies were identified through the reference list of included articles and duplicates were excluded.

### Study and Participant Selection

Titles and abstracts were screened to select studies for full text review. Selection criteria were based on the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines" [12].

### Data Extraction

Details from eligible studies were recorded as: "Country of study, Sample size, and Morphometric parameters measured for the stapedius tendon (ST) and muscle belly like ST belly length, ST tendon length, ST belly width, ST tendon width total length of stapedius side- and sex-based values." Distance between Stapedius Tendon and FN during dissection was also considered.

### Statistical Analysis

The data were "interpreted by using SPSS Version 23.0". For all results, means  $\pm$  standard deviations (SD) were computed. Then, the mean data of these parameters

were compared according to geographical or population groupings if possible, differences existed in the morphometric characteristics of endocasts. Means (pooled across studies) of muscle and tendon dimensions were calculated to present a general review.

## RESULT

### Study inclusion

Following the completion of the literature search, the systematic review underwent a

rigorous multi-stage screening process. Initially, 189 articles were identified. The first exclusion criterion was publication date, which led to the removal of 36 articles published before 2007, reducing the pool to 153 records. Subsequently, language restrictions were applied, resulting in the exclusion of 69 non-English articles, leaving 84 records for further evaluation.

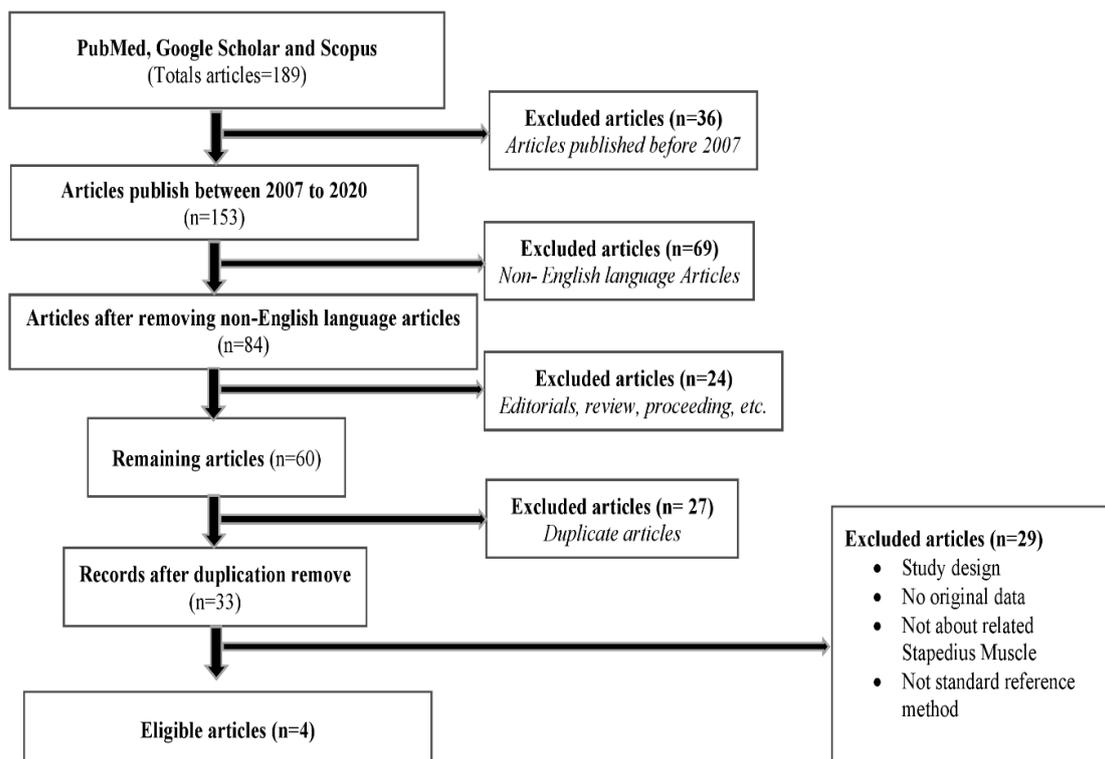


Figure 1. Flowchart depicts search of the literature and screening strategy for systematic review

The article type was considered using Google scholar, PubMed and Scopus filters, and 24 records representing inappropriate publication types were removed, yielding 60 records. A duplicate screening was then performed, eliminating 27 duplicate entries, and leaving 33 studies for full-text assessment based on predefined scientific inclusion criteria. During this stage, 29 studies were excluded due to insufficient study design, lack of original data, irrelevant topics, or use of non-standard reference systems. Ultimately, four studies met all inclusion criteria and were retained for the review (Figure 1). The quality and

robustness of the systematic review are therefore dependent on these studies. These selected articles form the foundation for the qualitative synthesis, and, where data allow, a single-factor meta-analysis. This structured and meticulous process underscores the specificity and rigor of the research question addressed in this review.

### Study characteristics

A total of encompassing 79 cadaveric stapedius muscles (ST) from Turkey, the USA, and Colombia, covering both adult and fetal populations. Study designs primarily involved cadaveric dissections,

with measurements performed using digital or manual techniques, reflecting methodological variability across studies. Beger et al. (2019, Turkey) [13] analyzed 24 fetal specimens (gestational age  $24.27 \pm 3.24$  weeks) with digital measurements, equally representing both sexes (6 males, 6 females); laterality was not reported. Beger et al. (2020, Turkey) [14] investigated 20 adult cadavers (mean age  $75.7 \pm 13.75$  years), equally divided by sex (5 males, 5 females) and laterality (10 left, 10 right). Cheng and Gan (2007, USA) [15] examined 12 adult specimens aged 51–92 years (median 71 years) via traditional dissection, including 6 males and 6 females, though

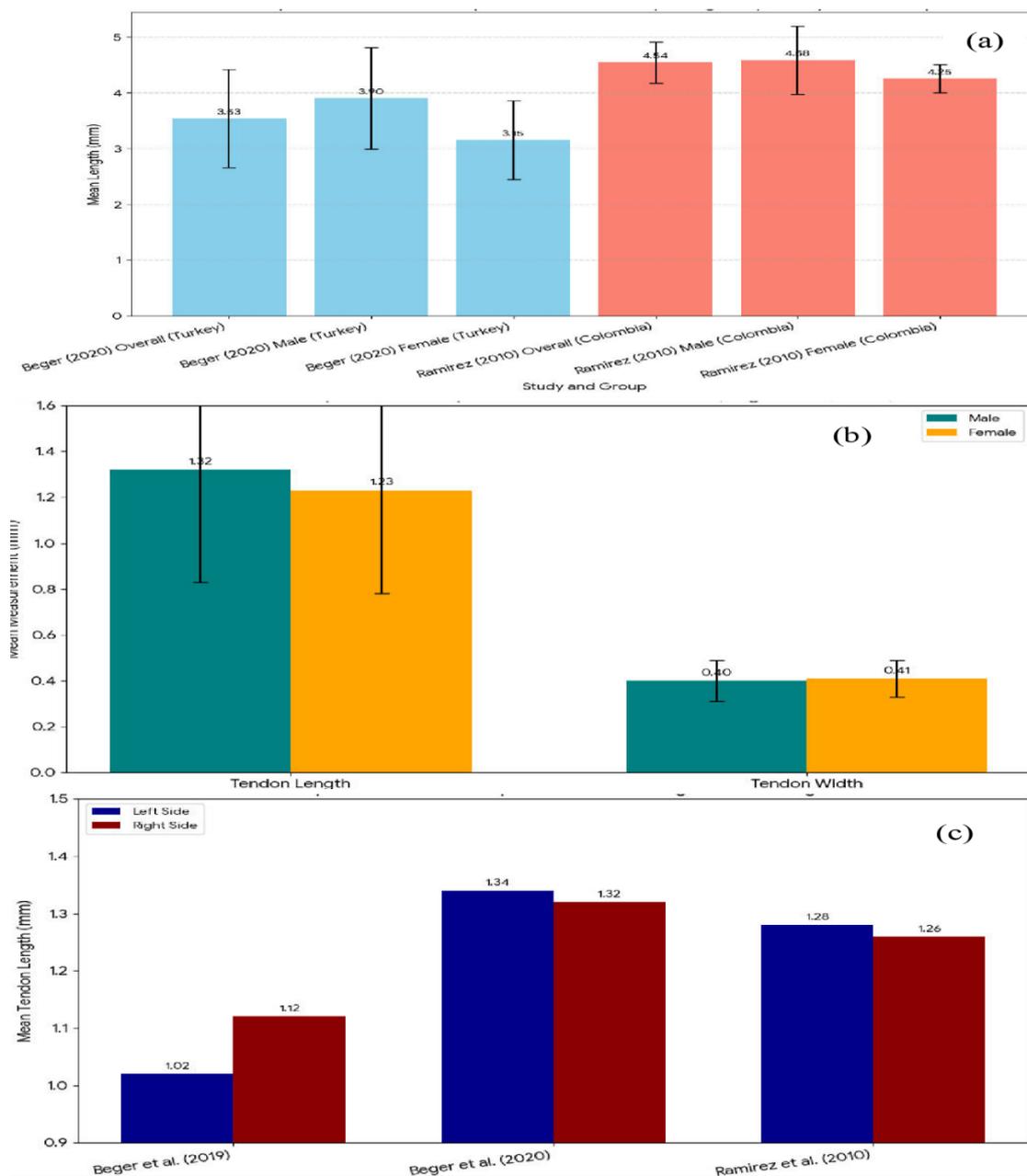
laterality was unspecified. Ramirez Aristeguieta et al. (2010, Colombia, Mestizo population) [16] assessed 23 adult cadavers using manual measurements, predominantly male (21 males, 2 females) with 12 left- and 11 right-sided specimens. Across all studies, the overall sample comprised 38 males and 19 females, with 22 left- and 21 right-sided specimens; the remaining data were either not reported or unspecified. These studies collectively provide a comprehensive representation of population- and age-specific variations in ST morphology, while highlighting methodological differences that may contribute to heterogeneity in pooled measurements (Table 1).

**Table 1. Demographic and methodological characteristics of the cadaveric studies**

Country	Study	Year	Type of Study & Mode of Measurement	Sample Size of ST	Male (n)	Female (n)	Age (Years / Weeks)	Left (n)	Right (n)
Turkey	Beger et al. [13]	2019	Dissection of fetal specimens; Digital morphometric analysis	24	6	6	$24.27 \pm 3.24$ weeks	NR	NR
Turkey	Beger et al. [14]	2020	Dissection of adult specimens; Digital morphometric analysis	20	5	5	$75.70 \pm 13.75$ years	10	10
USA	Cheng and Gan [15]	2007	Dissection of adult cadaveric specimens	12	6	6	71 (51–92 years)	NR	NR
Mestizo race, Colombia	Ramirez Aristeguieta et al. [16]	2010	Dissection of adult specimens; Manual morphometric analysis	23	21	2	NR	12	11

Morphometric analysis revealed that muscle belly length ranged from  $3.15 \pm 0.71$  mm to  $4.58 \pm 0.34$  mm in adults and  $4.52 \pm 0.41$  mm in fetal specimens. Tendon length varied between  $0.99 \pm 0.09$  mm (Cheng and Gan, 2007) [15], and  $1.40 \pm 0.10$  mm (Ramirez Aristeguieta et al., 2010), [16] reflecting sex- and population-specific differences. Muscle belly widths, reported in select studies, ranged from  $1.19 \pm 0.31$  mm to  $1.44 \pm 0.32$  mm, whereas tendon

widths varied from  $0.36 \pm 0.07$  mm to  $0.46$  mm. Total stapedius length ranged from  $4.47 \pm 1.04$  mm to  $5.91 \pm 0.37$  mm, indicating notable inter-study variation. Beger et al. (2020) [14], reported distance of the stapedius tendon and facial nerve ranged from  $1.14 \pm 0.13$  mm to  $1.22 \pm 0.23$  mm (Figure 2). These findings provide a robust quantitative foundation for understanding ST morphology, which is critical for surgical planning and anatomical research.



**Figure 2: Morphometric measurements of the stapedius muscle and tendon reported in included cadaveric studies. (a) Comparison of mean Stapedius muscle Belly Length by study and group. (b) Gender comparison of Stapedius tendon dimension. (c) Comparison of Mean Stapedius tendon lengths: left Vs right**

## DISCUSSION

The stapedius (ST) muscle represents a critical structure in otologic surgery due to its diminutive size, deep anatomical location, and close proximity to the facial nerve and other vital structures within the middle ear. Its belly and tendon can obscure the retrotympenic space, occasionally requiring partial or complete removal to achieve optimal surgical exposure [17]. This limited surgical corridor increases the risk

of iatrogenic facial nerve injury, making detailed morphometric knowledge essential for safe and effective procedures. Despite its surgical significance, standardized measurements of the ST muscle and tendon are largely absent from classical anatomical references, highlighting the need for systematic anatomical investigation [18]. In this analysis, a total of 79 ST muscles from fetal and adult cadaveric specimens across different populations were examined,

providing a comprehensive perspective on developmental and population-based variations. Measurements were obtained using both digital and manual dissection techniques, allowing for precise evaluation of fetal specimens as well as adult temporal bones [19, 20]. The sample included 38 males and 19 females with nearly equal representation of left and right sides. No significant differences were observed based on sex or laterality, suggesting bilateral anatomical symmetry and reinforcing the predictability of ST morphology for surgical planning [21]. Minor variations in measurements likely reflect methodological differences, population-specific anatomical diversity, and tissue preservation, rather than true structural disparity [22, 23]. Digital techniques offered superior accuracy, especially in small fetal specimens, whereas manual methods produced consistent results with minimal variation [24].

Morphometric analysis revealed that the ST muscle belly ranged from approximately 3 to 4.5 mm in length, while the tendon measured 1.0 to 1.4 mm. Total muscle length ranged from 4.5 to 5.9 mm [25]. Interestingly, fetal specimens demonstrated tendon dimensions comparable to adults, indicating that the ST muscle reaches near-adult proportions during the fetal period, and suggesting minimal postnatal growth in both belly and tendon [26]. Population-specific differences were more pronounced in muscle belly length than in tendon length, reflecting potential genetic or environmental influences on muscle development. The widths of both the muscle belly and tendon remained largely consistent across populations, and total muscle length varied only slightly [27-29].

The mean “distance between the ST tendon and the facial nerve” was approximately 1.1–1.3 mm, confirming a narrow surgical margin that underscores the importance of careful manipulation during middle ear procedures. This narrow anatomical relationship emphasizes the potential risk of facial nerve injury during surgical

interventions involving the ST muscle, such as stapedotomy, tympanoplasty, or exposure of the retrotympanic space. Knowledge of these dimensions is therefore critical for preoperative planning, intraoperative orientation, and minimizing iatrogenic complications [30, 31].

Overall, this study confirms the consistent morphology of the ST muscle across age groups and populations while highlighting subtle variations in muscle belly length. The findings demonstrate that the ST tendon achieves near-adult dimensions prenatally, and its close spatial relationship with the facial nerve remains constant. By providing precise morphometric data, these results enhance anatomical understanding and provide valuable guidance for otologic and neurotologic surgeons, ultimately improving surgical precision and patient safety.

## CONCLUSION

It is essential for surgeons to be well-acquainted with the standard morphometric characteristics of the stapedius muscle and tendon. This systematic review confirms that the dimensions of both the muscle belly and tendon remain relatively constant from the fetal period to adulthood. Direct anatomical measurements are consistent with radiographic assessments of the stapedius muscle. Understanding the microanatomy of the stapedius and its close relationship with the facial nerve is crucial during retro tympanic procedures or facial nerve surgeries, including decompression or nerve grafting, to minimize complications and optimize outcomes.

### *Declaration by Authors*

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