PHYSIOLOGY OF TONGUE MOVEMENT AND ITS NEUROPHYSIOLOGICAL BASIS IN SPEECH

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Abstract: The tongue plays a pivotal role in articulation and speech production, enabling complex movements necessary for phoneme formation and intelligible communication. This article reviews the physiological mechanisms governing tongue movements and their neurophysiological control during speech. Emphasis is placed on the muscular anatomy of the tongue, neural pathways involved in motor coordination, and integration within central nervous system structures. Understanding these processes is essential for diagnosing and treating speech disorders arising from neurological impairments.

Keywords: tongue movement, speech production, neurophysiology, motor control, articulation, cranial nerves

Speech production is a highly coordinated motor activity involving multiple articulators, among which the tongue is arguably the most versatile and essential. The tongue's capacity for rapid, precise, and diverse movements enables the production of a wide range of speech sounds. These movements are controlled by intrinsic and extrinsic muscles innervated by several cranial nerves.

The tongue's unique muscular structure allows for complex and rapid movements that are essential for articulation. These movements are intricately coordinated by the central nervous system (CNS), involving multiple brain regions and neural pathways. Understanding the physiology behind tongue movement provides insight into how speech sounds are produced and how disorders affecting tongue mobility can impair communication.

Despite its importance, the tongue's motor control mechanisms are not fully understood, particularly how sensory feedback and cortical inputs integrate to produce smooth and precise speech. This study aims to review current knowledge of the tongue's muscular anatomy and neurophysiological control during speech production.

The neurophysiological control of tongue movement involves integration across cortical, subcortical, and brainstem structures. This intricate control system ensures the smooth execution of articulatory gestures necessary for fluent speech. This paper aims to elucidate the physiology of tongue movements and their neurophysiological basis within the context of speech production.

This study employs a comprehensive literature review approach. Peer-reviewed journal articles, neurophysiological textbooks, and clinical studies related to tongue anatomy, motor control, and speech production were systematically searched using academic databases such as PubMed, Scopus, and Google Scholar.

Key search terms included “tongue movement,” “speech neurophysiology,” “cranial nerves and speech,” and “motor control of articulation.” Selection criteria focused on studies involving healthy adults, neuroimaging studies highlighting motor cortex activation during speech, and clinical reports on dysarthria and other motor speech disorders.

Additionally, relevant neuroanatomical data were extracted from standard anatomy texts to elucidate the muscular structure and neural innervation of the tongue.

The tongue consists of **intrinsic muscles** (superior longitudinal, inferior longitudinal, transverse, and vertical muscles) that shape the tongue, and **extrinsic muscles** (genioglossus, hyoglossus, styloglossus, and palatoglossus) that position it within the oral cavity.

- **Intrinsic muscles** modify the tongue’s shape for articulation (e.g., curling, flattening).
- **Extrinsic muscles** move the tongue forward, backward, upward, and downward.

These muscles receive motor innervation primarily from the **hypoglossal nerve (cranial nerve XII)**, except for the palatoglossus, which is innervated by the **vagus nerve (cranial nerve X)**.

Neurophysiological Control of Tongue Movement

Tongue movement during speech is governed by a complex network involving:

- **Primary motor cortex (precentral gyrus):** initiates voluntary tongue movements.
- **Premotor and supplementary motor areas:** plan and sequence motor actions.
- **Basal ganglia and cerebellum:** coordinate movement timing and smoothness.
- **Brainstem nuclei (hypoglossal nucleus):** relay motor commands to tongue muscles.
- **Sensory feedback loops:** via the trigeminal (CN V), facial (CN VII), glossopharyngeal (CN IX), and vagus (CN X) nerves provide proprioceptive and tactile information necessary for fine control.

Neurophysiological studies indicate that tongue motor control involves feedforward and feedback mechanisms enabling real-time adjustments during speech.

Role of Tongue Movement in Speech Production

Precise tongue positioning and shaping are critical for articulating consonants and vowels. For example:

- **Alveolar sounds** like /t/, /d/, and /n/ require the tongue tip to contact the alveolar ridge.

- **Velar sounds** like /k/ and /g/ involve the dorsum of the tongue contacting the soft palate.
- Vowels depend on tongue height and advancement controlled by intrinsic and extrinsic muscles.

Impairments in tongue motor control due to neurological disorders (e.g., stroke, Parkinson's disease, amyotrophic lateral sclerosis) often result in dysarthria, characterized by slurred or imprecise speech.

The physiology and neurophysiology of tongue movement form the foundation of articulatory speech production. A detailed understanding of the muscular anatomy and neural control pathways is crucial for clinicians and researchers working in speech-language pathology and neurology. Advances in neuroimaging and neurophysiological techniques continue to enhance our knowledge, aiding in the diagnosis and rehabilitation of speech disorders.

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