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Mini Review

Functional and Structural Cortical Differences in Persons with Stuttering: A review on Underlying Mechanisms in the Literature in Last Decade

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Introduction

Stuttering is known as the disorder of speech fluency. It is characterized by the oral and laryngeal blocks, repetition of words, syllables or sounds or prolongation of sounds [1]. According to the definition by Legislative Council of the American Speech-Language-Hearing Association [2], stuttering is a speech disorder that includes repetition of word or syllables partially or wholly, prolongation of sounds and silent blocks. Avoidance and/or escaping behaviors may also be observed in persons with stuttering (PWS), [3]. Theorical studies in the past about stuttering mainly focused on physcological side/symptoms of the disorder. According to former vision, stuttering was a speech disorder caused or triggered by the anxiety of an individual.

Brain Imaging Studies on Stuttering

Invention and use of brain imaging technologies led researchers to work more profoundly on the underlying mechanism of stuttering . In the current studies with the use of brain imaging technologies like MRI, MEG or FMRI, researchers found out some structural and functional differences in the cortical network of PWS compared to non-stutters. The current theoretical approach on stuttering has focused on motor control anatomy of speech and dysfunctions of definite areas (will be mentioned down) in PWS. General neuropsychological view on the disorder may be summed up in two categories:

a) Studies that focus on structural changes/ differences in the brain of PWS

b) Studies that focus on functional changes/ differences in the brain of PWS, [4].

Initially, potential regions / units that are responsible for stuttering are reported as cortico - basal ganglia - thalamocortical circuits, inferior frontal gyrus (Broca's area), and superior temporal gyrus [5]. These regions are thought to be responsible for selection of articulatory motor movements [6]. As the speech is considered as a flawless and effortless production of head, laryngeal and thorasic muscles in coordination, most of the studies focused on the motor execution problems in stuttering [7]. The most important cortical structure for motor preparation is the premotor cortex (PMC) with a distinct role of its ventral part (vPMC) for speech [8]. Adjacent to and partly overlapping with vPMC is the inferior frontal gyrus (IFG) which includes in the left hemisphere, the well-known Broca's area (Brodmann area 44, 45). Several studies on stuttering reported both anatomical and functional disturbances in this region. Activation differences – both hyper and hypo- were observed unilaterally and bilaterally in silent reading and speech production tasks [9]. The most recurrent finding is an anomalous right laterality in activity of the frontal operculum, the homologue of Broca's area [10]. Three magneto- encephalography (MEG) studies revealed some interesting findings as well. Walla et al. [11] observed in adults who stutter (AWS) a decreased preparatory activity in or close to bilateral motor cortex preceding overt word reading. Sowman et al. [12] showed large differences in inferior frontal areas between fluent and stuttered speech. In this case report, blocks, as compared to fluent utterances, were associated with decreased activation in left and increased activation in right IFG extending into orbitofrontal areas. Finally, Salmelin et al. [13] found an advanced activation of the left motor cortex and a delayed activation of left IFG during overt reading. AWS suggested initiating motor programmes before preparing the articulatory code. This timing deficit has been linked with decreased white matter density in tracts connecting Broca's area and left motor cortex [14,15]. Another view is also focused on the white and grey matter integrity in PWS. The most observed finding in the studies is the decrease of white matter volume in the regions of left arcuate/superior longitudunal fasciculus [14-17]. The goal of this mini review is to investigate the original studies on neural etiology of stuttering in tha last ten years.

Method

Research was carried on PubMed/MEDLINE and Google Scholar in English and Turkish. Medical Subject Headings (MeSH) keywords were chosen as "stuttering", "basal ganglia", "inferior frontal gyrus", "fluency disorders" and for a general search "neural mechanism of stuttering", "structural differences in stuttering", "functional cortical differences in stuttering "were chosen to search the databases. This review included the free full text papers, abstracts and conference presentation texts published in the last decade (between 2013 – 2022). Gender differences and genetic factors were not taken into consideration. Research that included children was excluded from the study as the maturation process of child brain might not finish yet.

Results

Table 1 sums up the literature of original research including free texts on neural mechanism of stuttering between 2013 and 2022. 39 papers were included in the first search, but 22 of them were excluded as participants were younger than 18. As "19 – 44 adult" and "Adult: 19+" filters were applied. Then existing 17 papers were scanned and books and documents, reviews, systematic reviews and meta-analysis papers were excluded. To sum up original studies, researchers found significant differences especially in the right hemisphere activation between PWS and non-stutter adult group. The primary finding of all studies was a deficit in the motor control and coordination in PWS group. Ventral precentral gyrus extends to the motor movement of tongue; and a difference in this region was observed in two different studies. One study focuses on the iron concentration as the highest concentration of iron is in the basal ganglia.

Discussion and Conclusion

Since the very beginning of the stuttering and brain imaging/ maping studies, theoritical view has maşnly focused on motor control anatomy of speech and dysfunctions of mentioned areas in PWS. Potential regions / units that are responsible of stuttering are cortico - basal ganglia - thalamocortical circuits, inferior frontal gyrus (Broca's area), and superior temporal gyrus [5]. Especially IFG is very important as it plays an essential role for speech planning. Decreased volumes and integration of grey and white matter integrity in these regions were commonly observed in PWS [18,19]. These regions are also thought to be responsible for selection of articulatory motor movements [6].

Based on results of the published papers in the last decade, it was seen that significant activation differences were observed especially in the right hemisphere. Earlier studies in the field also focused on the lateralization problems and blaimed the hemispheric inconsistency for the disorders on the speech flow [20-22]. Overactivation in the motor areas of the right hemisphere was observed in PWS during speech production tasks [23-25]. EEG studies also showed that connections between cortical waves were significantly different in PWS. However as EEG is the measurement of the post synaptic potentials of the activation in the brain, results should be confirmed by the use of other topographic measurements [26].

The nature of the stuttering is both sensorial and motor. Although for many years it had been interpreted as a lack of motor control, studies revealed the fact that auditory integration of speech was also impacted in the PWS. Modern speech production theories explained two pathways about language processing: The Dorsal and the ventral streams. The dorsal stream is thought to be playing a major role in connecting the auditory – motor areas for the speech production and this area is also claimed to dysfunction in PWS, [7]. Furthermore, more studies are needed to comprehend the neural structure of stuttering. Relationship of the significant differences in the cortical regions and stuttering may be a reason or the result of the progression [27-29]. Longitudinal studies and outcomes of the therapies should also be taken into care to reveal the stuttering mechanism.

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