REVISTA NEUROCIÊNCIAS

Brain activity corresponding to swallowing and hands activity: narrative review

Atividade cerebral correspondente à deglutição e atividade das mãos: revisão de literatura

Actividad cerebral correspondiente a la deglutición y actividad de las manos: revisión de literatura

Rômulo Evandro Brito de Leão[1], Arnaldo Lobo Neto[2], Regiane Lima Gonçalves[3], Carla Cristina Paiva Paracampo[4], Fernando Allan de Farias Rocha[5]

1.Fonoaudiólogo, mestrando em Neurociências e Comportamento, Laboratório de Neurofisiologia Eduardo Osvaldo Cruz (LNEOC), Universidade Federal do Pará (UFPA). Belém-PA, Brazil. Orcid: https://orcid.org/0000-0001-7509-6834
2.Médico, pós-graduação em Radiologia e Medicina Nuclear, Clínica Lobo. Belém-PA, Brazil. Orcid: https://orcid.org/0000-0002-6761-7174
3.Tecnóloga em Radiologia e Medicina Nuclear, Clínica Lobo. Belém-PA, Brazil. Orcid: https://orcid.org/0000-0003-0066-4432
4.Livre docente, doutora em Psicologia Experimental, Núcleo de Teoria e Pesquisa do Comportamento (NTPC), Universidade Federal do Pará (UFPA). Belém-PA, Brazil. Orcid: https://orcid.org/0000-0001-6638-5597
5.Livre docente, doutor em Neurociências e Biologia Celular, Laboratório de Neurofisiologia Eduardo Osvaldo Cruz (LNEOC), Universidade Federal do Pará (UFPA). Belém-PA, Brazil. Orcid: https://orcid.org/0000-0003-0354-9544

Resumo
Objetivo. Analisar a relação entre nível de atividade cerebral durante o ato motor de mãos e a deglutição em estudos que utilizaram a Ressonância Magnética Funcional (RMF). **Método**. Foi realizada uma revisão de literatura narrativa, e as fontes de dados foram obtidas nas plataformas Pubmed, Biblioteva Virtual em Saúde e Google Acadêmico. **Resultados**. Foram encontrados poucos estudos que investigaram a ativação neurológica correlacionada ao movimento das mãos e da deglutição por meio da RMF, porém todos os estudos evidenciam relação topográfica das áreas principais para a atividade de mãos e deglutição, assim como alguns estudos mostraram alguma relação neurofuncional de ambas as atividades simultâneas. **Conclusão**. Sabe-se que o giro pré-central, possui áreas expressivas inervando as mãos e a cavidade oral, e que se encontram localizadas em áreas próximas, sendo passível de indagações sobre interações de funções. Os achados já descritos podem vir a fomentar estudos e discussões, porém são necessárias mais pesquisas para descrever e medir a relação entre as áreas motoras das mãos e da deglutição.
Unitermos. Homúnculo motor; Deglutição; Movimento de mãos; Ressonância magnética funcional

Abstract
Objective. To analyse the relationship between the level of brain activity during the hand motor act and swallowing in studies that used Functional Magnetic Resonance Imaging (FMRI). **Method**. A narrative literature review was carried out, and the data sources were obtained from Pubmed, BVS, and Google Scholar platforms. **Results**. Few studies were found that investigated the neurological activation correlated to the movement of hands and swallowing through FMRI, but all studies show a topographic relationship between the main areas for activity of hands and swallowing, as well as some studies showing some neurofunctional relationship between both concurrent activities. **Conclusion**. It is known that the precentral gyrus has significant areas innervating the hands and oral cavity, which are in nearby areas,

being subject to questions about function interactions. The findings already described may encourage studies and discussions, but more research is needed to describe and measure the relationship between the motor areas of the hands and swallowing.
Keywords. Motor homunculus; Swallowing; Hand movement; Functional Magnetic Resonance Imaging

Resumen

Objetivo. Analizar la relación entre el nivel de actividad cerebral durante el acto motor de la mano y la deglutición en estudios que utilizaron imágenes por Resonancia Magnética Funcional (RMF). **Método**. Se realizó una revisión narrativa de la literatura y las fuentes de datos que se obtuvieron de las plataformas Pubmed, Biblioteca Virtual en Salud y Google Scholar. **Resultados**. Se encontraron pocos estudios que investigaran la activación neurológica correlacionada con el movimiento de las manos y la deglutición através de RMF, pero todos los estudios muestran una relación topográfica entre las principales áreas de actividad de las manos y la deglutición, así como algunos estudios que muestran alguna relación neurofuncional entre ambas áreas simultâneas. **Conclusión**. Se sabe que la circunvolución precentral tiene áreas importantes que inervan las manos y la cavidad bucal, las cuales se ubican en áreas cercanas, siendo objeto de interrogantes sobre las interacciones funcionales. Los hallazgos ya descritos pueden alentar estudios y discusiones, pero se necesita más investigación para describir y medir la relación entre las áreas motoras de las manos y la deglutición.
Palabras clave. Homúnculo Motor; Deglutición; Movimiento de las manos; Resonancia Magnética Funcional

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Corresponding author: Rômulo EB Leão. Universidade Federal do Pará (UFPA). Núcleo de Teoria e Pesquisa do Comportamento (NTPC/UFPA). R. Augusto Corrêa 01. Guamá. Belém-PA, Brazil. CEP 66075-110. Phone (91) 98150-8641. Email: romuloevandro@hotmail.com

INTRODUCTION

From early childhood, the individual makes use of the hands and mouth to interact with the environment, and forms important developmental skills. There are specific areas in the brain associated with the hands and mouth and the more they are used, the more development in these brain areas is possible. Areas located in the sensory cortex that are innervated by fibers from skin stimulation on body parts make up the structure called Penfield's Homunculus or Motor Homunculus; from each area the innervation proceeds to the motor cortex and participates in the motor activation of the corresponding parts of the body[1].

The Motor Homunculus plays an important role in swallowing, which is the process of moving food from the mouth to the stomach, whose neurofunctional organization needs to be intact for its performance[2-4]. Swallowing is an important life-sustaining action and is also a complex activity from the point of view of neurological action. However, little is sought to investigate the neurological activations during the act of swallowing.

Swallowing food, although it is natural and often feels automatic, requires cortical activation[5]. The "automatic" character, however, does not happen in individuals with dysphagia, that is, who have swallowing difficulties[6]. Swallowing, in its normal pattern, involves several motor skills that are directly related to the neuronal organization of swallowing. In cases of neurological pathologies[7-9], swallowing is the target of rehabilitation indirectly, where the motor and sensory rehabilitation of body parts imply changes in the neurofunctional pattern.

In order to record neural activity during the act of swallowing or during motor activity of the hands, it is necessary to use sophisticated technological resources, such as Functional Magnetic Resonance Imaging (fMRI), which is a high-definition anatomical recording method of brain imaging during its full functioning[10,11].

Considering the movement of hands and the act of swallowing as motor actions that require cortical action[12,13], it is understood that through fRMI it is possible to study the anatomical and functional correlates of these two activities.

Understanding the anatomical and functional conditions during the act of swallowing and the act of moving the hands can allow a better understanding of this process and support future empirical studies.

Having this panorama as a background figure, the following questions are put on the agenda: are there scientific studies that correlate hand motor activity during the act of swallowing? Are there publications in the scientific literature that correlate Functional Magnetic Resonance and swallowing?

In order to clarify the relationship or correlation between swallowing, hand movement and the evaluation through neuroimaging exams, this study aimed to carry out a review of the specialized literature on the relationship between the level of brain activity during the motor act of hands and swallowing.

METHOD

A search was carried out on the topic in the VHL (Virtual Health Library), Pubmed, and Google Scholar databases as they are considered platforms of great relevance in research, which resulted in access to several works, used to build a contextualization and possibilities present in the literature that could support an answer to the guiding question: what is the relationship between the motor activity of the hands and the cortical representation of swallowing?

The consulted materials were searched with undetermined date of publication, in Portuguese, English or

Spanish. The selection of content was based on the compliance of the subjects with the objective of the work and publications that did not address the subject in question and/or that did not have the material available in full were disregarded.

The following descriptors with Boolean beacons were used for the search: "Functional Magnetic Resonance Imaging AND swallowing", "Functional Magnetic Resonance Imaging AND hands", "Functional Magnetic Resonance Imaging AND hand movement", "swallowing and hand movement", "Functional Magnetic Resonance Imaging AND food".

Since this study proposes to discuss the current literature in a qualitative approach on the target topic, the main substratums found in the research found will be presented below.

RESULTS and DISCUSSION

In the scientific literature it is possible to find materials that commonly present the Motor Homunculus as a foundation for scientific investigations of monitoring or brain mapping of the body's motor activities. As, for example, in the theoretical study[14], where the authors, when seeking to define the ordered representation of the body along the length of the sensorimotor cortex, conceptualize somatotopia to this division of areas, making reference to the 1950 study by the American neurosurgeon Wilder Graves Penfield (1891-1976), a specialist in neurocytology and neurophysiology, who managed to define, by means of electrical stimulation on the surface of the primary motor cortex, the equivalence of the level of stimulation with the disproportion of hand movements and the face, thus managing to define the somatotopic map of this region that became known as "Penfield's Homunculus", in addition to other regions of the central nervous system, establishing functional patterns, including language functions[15,16]. The functional architecture of the brain described by Penfield[17] is still considered an invaluable contribution to the knowledge of functional neuroanatomy and neurophysiology[18].

The understanding of Penfield's Homunculus is of paramount importance in the neurosciences, and as can be seen in the aforementioned historical reports, the definition of somatotopia began by considering hand and face movements, actions directly related to swallowing.

Other studies also delved into cortical localization research on the motor aspect. In 1954, Penfield and Jasper carried out research with people with epilepsy through invasive electrical stimulation, and based on the results, hypothesized an area of sensory representation of the body, calling this location a "supplementary sensory" area whose accuracy of form could not be specified with his results at the time[19].

The somatotopic organization can be better understood through neuroimaging tests such as fMRI, which would greatly contribute to Penfield's pioneering findings, including the visualization of the Motor Homunculus. fMRI is one of the most sophisticated neuroimaging tests for anatomical and functional analysis of brain areas. Through this exam, it is possible to identify the functioning of the brain dynamically[20,21], in response to sensory stimuli or during a predefined task in the functional experiment paradigm[22].

But much still needs to be studied about the structure of the Motor Homunculus, even decades after the Motor Homunculus were first proposed, it is still unknown how different body parts are interrelated in human motor cortical areas in the resolution of a single neuron[23]. Another example of this deficiency it is unclear whether the ipsilateral or contralateral primary motor cortex is involved in head rotation to the right or to the left[24]. It is still worth make it clear that the thickness of the motor homunculus is heterogeneous among humans, thus suggesting a capacity for individual improvement[25].

To study the cerebral cortical processing of swallowing in the elderly, with a sample of 9 healthy elderly women, 1 left-handed and 8 right-handed, submitted to fMRI while the laryngeal movements related to swallowing were analysed by the captured images[26]. In the first stage, the elderly were asked to voluntarily swallow saliva every 40 seconds without producing exaggerated oral movements or making an effort to increase the volume of saliva. In the second stage, 3ml of water at room temperature was also offered every 40 seconds. For both tests, the subjects received a visual stimulus from a plate placed at eye level of a man drinking a glass of liquid. The findings showed that the total volume of brain activation by swallowing water (20,350mm^3) was substantially greater than that activated by swallowing saliva (5,697mm^3), indicating approximately four times more activity. The authors found a greater focus of activation in the left pericentral cortex, extending ventrolaterally to the perisylvian region and corresponding to the primary motor and primary somatosensory cortex, reinforcing that the activation areas do not differ so much from young adults. Such results may be compatible with who postulate that the face and tongue are represented in the precentral gyrus[27], and with the explain the functional topography of the somatosensory cortex of the hands, which can be identified by means of fMRI[28]. With this, it is understood that the hands have a greater representation in the cortex corresponding to their greater complexity of movement compared to other parts of the body, such as the elbow, for example[29].

In an in-depth experimental study of the Motor Homunculus, it was applied fMRI to 16 right-handed individuals who trained, approximately one hour before entering the examination machine, the movements to be performed with the body[30]. The results elucidated that the architecture of correspondences between muscular and cortical activity does not correspond to sequences of demarcated zones, but rather to the gradual progression in more medial or lateral regions, being even more evident in the correspondences between muscular activity of the face, tongue, and larynx and cortical activity. The author also added that flexion movements have greater neurological signal potential than extension.

The authors cited so far, who describe the Motor Homunculus, promote the theory that there is a relationship between hand movements and swallowing. So, the more an individual moves his hands to bring food to his mouth and swallow, the more the cortical areas are activated and developed, making it possible for there to be a change in the neurological pattern with hand training associated with swallowing. That is, the more the individual eats, the more neurological programming develops through activation of the Motor Homunculus.

A study carried out a study using fMRI with 36 participants, 18 musicians and 18 non-musicians, with the objective of determining the differences in brain network activation during listening to musical stimuli[31]. The authors identified that the motor and sensory Homunculus area of music is more developed in regions of upper limbs and trunk representation, probably due to constant training throughout life, making these areas improved. Nevertheless, exposure to music for musicians increases the connectivity of these areas even when they are not moving, suggesting a subtlety in the reorganizations of brain networks. The authors argue that when thought is oriented towards an action, an internal motor simulation is generated with activation of cortical motor areas, thus presenting theoretical substrates that allow us to believe that the brain area of the hands, located in the Motor Homunculus, can be improved with the use/training, this area close to the swallowing structures area (lips, tongue, cheeks...).

Studies discuss the issues that were already discussed in 1996[31-33]. In a study carried out with fMRI in monkeys, the author identified that during hand and mouth movement, the level of cortical activation was higher, awakening about 532 neurons in the rostral part of inferior area 6 (area F5), where mirror neurons are located[34]. The authors postulate a correspondence system related to human neurons.

A study with four women using fMRI during food swallowing, aimed to map the brain activation regions, suggesting in her results that the primary motor cortex is one of the main components of the swallowing action[35]. It was also possible to observe that both hemispheres are activated in all phases of swallowing, with emphasis on the cerebellum, which was active during olfactory stimulation and concomitantly with the activation of the primary motor cortex, thus evidencing a direct and close relationship between the adjustment deglutition, involving the pre-cuneiform area, where the somatotopic location of the mouth (jaw, lips and tongue) is close to that of the arms and hands, reinforcing the idea that the integration of these areas may be interesting for neurological reorganization[36].

In a study carried out with six rabbits aimed to explore the feasibility of using FMR to assess muscle dysfunction in non-human animals after tooth extraction[37]. The authors identified that the values of neuronal activity ipsilateral to the extraction were greater than those contralateral to the extraction, concluding that the fMRI can characterize a functional abnormality in the masticatory muscles.

Through the use of fMRI, it was investigated the brain activity corresponding to head movements in 18 participants who were asked at the evaluator's command to perform isometric head movements and hand movements[24]. The results indicated that such movements are associated with modification of bilateral responses in the precentral gyrus medial and lateral to the hand area, as well as the supplementary motor area, insula, putamen, and cerebellum. A study with isometric contractions, but this time with upper limbs, showed findings that suggest a possible relationship between isometric movements and the level of cortical activation[38].

Those results indicate the occurrence of movements concomitant to the activation of brain areas, and allow inferring that the greater the amplitude of movement, the greater the potential of a neurological activation signal[24,38]. However, it is interesting to draw attention to the interpretation that not only would the Motor Homunculus be responsible for activating the hands, but that the supplementary motor area (another area of the brain) would also possibly be responsible for swallowing[24]. Such an interpretation confuses the participation of certain areas with the origin, in these areas, of movement activation.

The supplementary motor area was identified in 2012, using fMRI in a case study, which aimed to identify the cortical activation correlated with the movement of 20 body parts[36]. In 2019, another study with 16 participants and recognized a complementary cortical activation area located in the medial parietal area of the parietal lobe[19]. This area is called precuneiform and it is a supplementary motor area that is mirrored to the primary motor area, having involvement in motor, cognitive and visual processes. Each participant performed 20 body movements (legs, arms, and face), being monitored in the topography by fMRI. The results showed whole-body activation gradient connected to various areas of the brain with different connectivity to different parts of the body. The authors suggest that the sensory and motor representations found in the parietal lobe indicate that swallowing and hand movement require more neurological activations than imagined when considering only the motor homunculus.

What is understood about the somatotopic condition of the brain then, is that the precentral cortex is not the only one to have activity during the performance of body functions, but that there are other areas that contribute to movement or sensory performance, as is defended by scholars[32,33]. Therefore, the brain works in an integrated way with several areas when performing a motor or sensory activity[34]. Feeding involves these activities, as the act of eating implies sensitivity to the perception of the texture, temperature, consistency, and weight of the food, in addition to sensitivity to the perception of food in the oral cavity, hand movements to pick up food, movement of lips, tongue, cheeks. Eating, then, involves hands and mouth in terms of motor and sensory aspects, and different areas of the brain that are integrated during the performance of the activity.

Before performing the movement, the act of thinking about the movement is important since the motor imagination is capable of producing extensive brain activation in primary and secondary motor areas, in addition to integration with the limbic system[39]. It is worth remembering that swallowing is classified by phases, and the first phase occurs before inserting food into the mouth, when there is a neural activity that can be considered as a neurological preparation or neurological organization for the act of swallowing; this phase is called the anticipatory phase of swallowing[40,41].

"Neural networks grow or degenerate depending on the exposure or use of the activity ("use it or lose it"), so plasticity is dependent on experience"[42]. Thus, it is understood that when an individual is exposed to the food context during swallowing, sensory, tactile, visual, olfactory, auditory, proprioceptive and kinesthetic stimuli start to participate in the neural network that ends in swallowing.

Neurological integration to perform motor skills is important for the perfect performance of functions[43], including movements of phonoarticulatory organs.

As early as 1998, the repetition of hand movements can lead to motor system remodeling, in addition to the subject-environment interactions affecting the organizational characteristics of the somatosensory cortex[44]. Based on this thought, passive and active stimulation of upper and lower limbs generate cortical activation potentials[45]. Therefore, hand movements can be monitored at a cortical level during their actual action and are even associated with swallowing.

In a cohort study with 33 patients with Amyotrophic Lateral Sclerosis (ALS) and 44 healthy patients using fMRI, it was pointed out volumetric differences and signs of focal grey matter atrophy in the motor homunculus in the presence of pathology, with relevant impact considering the degree of advancement of the disease itself[46]. Thus, the lower the performance of the body's motor function, the smaller the volume of the motor homunculus, with these variables being correlated.

On the sensory aspect, a study with 18 individuals who had an upper limb amputated and underwent fMRI, with the aim of characterizing intra-network plasticity (within the sensorimotor network) and inter-network plasticity (between the sensorimotor network and standard mode network?) in the face of the phenomenon of phantom limb sensation[47]. The findings show that in the primary sensorimotor cortex amputation of an upper limb results in altered cortical activation in the area that was normally activated by the absent hands. These authors argue that sensorimotor deprivation does not only produce local remapping in the pre- and post-central gyrus area, but in a cascade of cortical reorganization on a network scale, reinforcing that the brain does not work through the performance of isolated areas, but through their functional integration.

CONCLUSIONS

As it was possible to identify in the literature presented in this article, neuroanatomical evidences show an intimate proximity of the areas of activation of the movements of hands and oral cavity in the passage through the neurological structure known as "Motor Homunculus".

It was possible to find studies using fMRI to investigate the neurological activity underlying hand movements and swallowing, but only one study sought to investigate swallowing itself[35] and only one study investigated the correlation between activities of hands and swallowing[34], highlighting the need for further research on the subject. An important fact that draws attention in the studies is that, possibly due to the difficulty in performing the fMRI examination, the studies have small samples, limiting the use of parametric tests of functional correlations between movements and activation of cortical areas.

Evidently, this review does not exhaust the subject that involves the cortical areas of swallowing. On the contrary, it seeks to expand the view to the possibility of developing lines of study that can contribute to a better neuroanatomical-functional understanding of swallowing.

Thus, for the areas of knowledge that are willing to study normal swallowing patterns and their deviations, the findings and interpretations described here may encourage studies and discussions, but they require a large investment through clinics and research centers.

The perspective is that in the future, fMRI will be associated with other exams or neuroimaging techniques, making it possible to record functional films and more intense exams. We believe that through fMRI it will be possible to advance in understanding the cortical participation in sensory and motor integration and, through this knowledge, acquire important subsidies for rehabilitation principles for patients affected by neurological disorders. The contributions of fMRI in rehabilitation are still little explored in studies, but it may prove to be of great value when this type of resource starts to be used, which will allow the validation or questioning of adopted therapeutic strategies.

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