MUSCLE FUNCTIONAL MRI — CAN IT BE USEFUL FOR PHYSIOTHERAPY? THE EXAMPLE OF CRANIOCERVICAL REGION*

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Review of papers dealing with muscle functional magnetic resonance imaging (mfMRI) is reported. Advantages of mfMRI and its application in physiotherapy are introduced on the example of the craniocervical region. This noninvasive, relatively new technique allows to study muscle activity on the basis of the MRI signal intensity changes due to increases in the relaxation time (T2) of tissue water (T2 is determined at rest and then in a short time after chosen exercises).

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1. Introduction

Magnetic resonance imaging (MRI) is one of the techniques by which temporary physics supports medical diagnosis (MRI = NMR). Nowadays MRI has developed into a powerful tool that can visualize not only anatomically but also physiologically interesting details of soft tissues of the human body, while muscle functional magnetic resonance imaging (mfMRI) is still an innovative and relatively new technique for studying muscle activity. The other popular and widely used method of evaluation muscle activity is electromyography (EMG), a technique which records electrical signals emitted by muscles during activation. The essential differences between the two methods come from the fact that EMG bases on neural effects, while mfMRI on metabolic changes induced by muscle activity.

Muscle activity can be measured by mfMRI on the basis of signal intensity changes due to increases in the relaxation time T2 of tissue water. The MRI scans are taken at rest and then in a short time after specific exercises to provide information about muscle activity. The mechanism underlying these changes is not fully understood [1–3]. Muscle functional MRI was

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validated with EMG and the results from mfMRI analysis correspond well with the results obtained from EMG [4]. Some important advantages of mfMRI in comparison with EMG could be listed, *e.g.* it offers a noninvasive access to deeper muscles, no crosstalk and no signal disturbances connected to EMG (subcutaneous tissue, electrode type, placement), multiple locations and muscles evaluated during one scan. It allows also to assess an isolated activity of a specific muscle and study activity in the entire muscle. On the other hand, mfMRI has some drawbacks, despite absolute contraindications such as metal implants. Mainly, it bases on post-exercise evaluation, that is why no real time evaluation is possible and only spatial, not temporal, aspects can be assessed. Nevertheless, it seems that mfMRI starts to be recognized as a valuable complementary technique to EMG in evaluating muscle activity. Each method investigates different aspects of muscle characteristics so the purpose of the research should determine the choice of methodology [3].

2. Literature search strategy and inclusion criteria

The databases PubMed/Medline, Scopus, Springer and Wiley were searched for publications related to the topic with the exception of books, reference books and chapters. No limitations of time period were applied. The key word was: *muscle functional magnetic resonance imaging*.

The literature search was conducted in June 2017 leading to 120 entries. The total of 77 articles was included in the analysis after eliminating an overlap between different databases. Finally, after exclusion of non-English-language publications and articles not covering the topic, the review of 44 articles concerning human muscle studies by mfMRI is reported (Fig. 1).

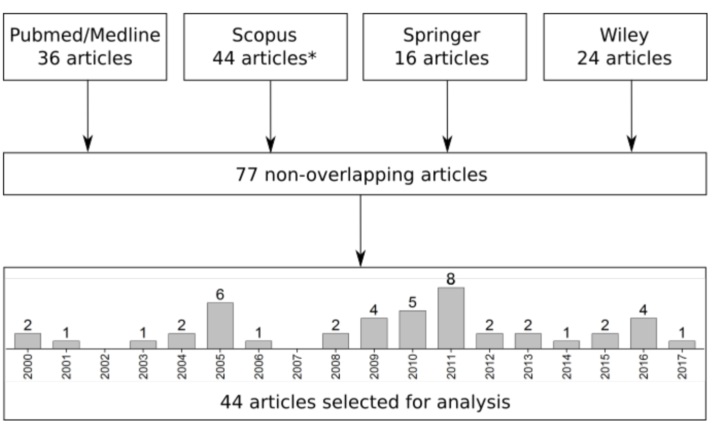

Fig. 1. Selection process for articles included in the review (*including 2 articles in Japanese).

3. Application of mfMRI in physiotherapy

3.1. Aplicability and requirements of mfMRI for use in physiotherapy

Physiotherapists need knowledge about muscles, its function and structure to better plan and evaluate therapy. Therefore, development of methods enabling to better understand functioning of musculoskeletal system is essential. Muscle functional MRI, which is nowadays used only in research, can be a valuable complementary technique for physiotherapists because of its high reproducibility and the potential to widen knowledge about muscle function in order to provide information about muscle activity during specific exercises [3].

The reported research, using mfMRI to study human muscle activity, can be divided into the following areas: muscle recruitment patterns [5–15], experimental pain studies [16–21], assessment of muscle activity during specific activities/exercises [4, 22–37], evaluation of training effects [38, 39], creatine supplementation [40], fast-mfMRI [41, 42], methods of analysis [43] and interrelations between mfMRI and other techniques [44].

Further research is needed to understand mechanisms underlying changes in post-exercise increase in T2 relaxation time, optimize technical aspects of mfMRI and conduct studies evaluating muscle activity during specific exercises and changes in muscle activation patterns in individuals with musculoskeletal dysfunctions. Detailed description of procedures should also be prepared as till now only laboratory studies by mfMRI are available and most of them were carried out on healthy subjects.

3.2. The example of craniocervical region studied by mfMRI

Because of mfMRI ability to access deep muscles, it gives opportunity to investigate muscles which are hard accessible using other techniques *e.g.* muscles of the craniocervical region. Among analyzed articles there are ten related to craniocervical region, five of them assess muscle activity during specific activities/exercises (concerning masticatory muscles [23, 27, 36], swallowing muscles [25], neck extensor muscles [28]), two evaluate muscle recruitment patterns differences between healthy subjects and patients (chronic mechanical neck pain [9], chronic whiplash-associated disorder [13]) and two were experimental pain studies of the upper trapezius (craniocervical flexion exercise [18], cervical extension exercises [19]).

General protocol for a study using mfMRI will be presented on the example of evaluation of the activity of masticatory muscles during unilateral tooth clenching (Fig. 2). The authors of the research assume that forward displacement of the occlusal contact point during unilateral tooth clenching increase activity of the ipsilateral lateral pterygoid muscle. Nine healthy subjects were asked to clench unilaterally using resin caps placed on the left

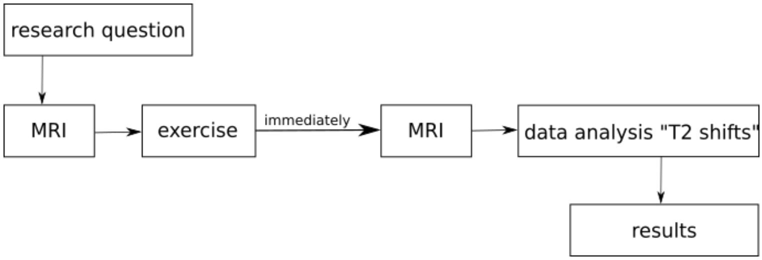

Fig. 2. Scheme of general protocol of research using mfMRI.

upper and lower first molar or first premolar. The bite force was kept constant at 40% of the maximum voluntary clenching force for 1 min. At rest and immediately after activity T2-weighted MRI scans were taken and "T2 shifts" were calculated to evaluate muscles activity. Due to the results, there is a "significantly decreased ipsilateral deep masseter activity and increased superior head of the ipsilateral lateral pterygoid muscle activity during forward displacement of the occlusal contact point from the first molar to first premolar during unilateral tooth clenching" which confirmed the hypothesis posed by the authors [23].

4. Conclusions

The searching strategy applied here gave 44 papers published in 31 journals and no entry earlier than year 2000, even if there was no time limitation. That means that literature studies with different search strategies and multiple keywords should be continued to complete the database on mfMRI as a still new but promising technique for studying human muscles. Furthermore, the term muscle functional magnetic resonance imaging or its abbreviation mfMRI should be widely used as one of the keywords to enable proper search for papers in this field.

Advantages of mfMRI seem to overcome the limitations of this noninvasive method of muscle activity studies. The mfMRI, the same as earlier MRI and functional MRI (fMRI), turns out to be a promising tool in medical sciences and physiotherapy itself.

Further investigations, including laboratory and clinical studies on healthy subjects and patients are necessary. They should be accompanied by review papers and theoretical studies leading to deeper understanding of the basics of mfMRI and improving both the quality of the collected images and the software enabling the users (skilled but not the specialists in the theory) to draw conclusions from the collected data properly.

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