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Reported biological effects following Osteopathic Manipulative Treatment: A comprehensive mapping review

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ABSTRACT

Background and purpose: Osteopathic Manipulative Treatment (OMT) is a therapeutic whole-body approach mainly focused on correcting somatic dysfunctions. The aim of this scoping review is to systematically map the literature regarding the documented biological effects observed following OMT.

Methods: The 2020 JBIRM version and the PRISMA-ScR were followed for the conceptualization and reporting of this review. The protocol was registered on the "Open Science Framework Registry" (https://doi.org/10.17605/OSF.IO/MFAUP). We searched for original articles published on Medline, Embase, and Scopus, from inception to the present.

Results: Overall, 10,419 records were identified. After duplicate removal, screening for title and abstract, and specific exclusions with reasons, a total of 146 studies were included. Wide differences were detected among studies in their geographical localization, study design, temporal distribution, participants' condition, OMT protocols, and documented biological effects. Such variety in frequency distribution was properly described through descriptive statistics.

Conclusions: Biological modifications that appear to be induced by OMT have been detected in several body systems, but mostly in neurophysiological correlates and musculoskeletal changes. Results suggest a growing interest over the years on this topic, especially in the last two decades. More efforts in research are recommended to highlight whether such changes specifically depend on OMT, and to demonstrate its specific contribution to clinical practice.

1. Introduction

Osteopathic Manipulative Treatment (OMT) is a therapeutic whole-body approach mainly focused on correcting somatic dysfunctions (SD) that impair the function of related components of the somatic system: skeletal, arthrodial, myofascial structures, but also vascular, lymphatic, and neural elements.[1] Its emphasis is on both the structural and the functional integrity of the body, with its intrinsic tendency for self-healing.[2] Osteopathic practitioners use a wide range of treatment models to influence complex interaction between the somatic body and physiological functions (i.e., biomechanical, neurological, respiratory-circulatory, metabolic-energetic, and behavioral) involved in the individual health processes.[1,3]

OMT typically finds application in different fields of medicine.[4] A variety of systematic reviews pointed out its applications for different conditions, above all: acute and chronic pain,[5–7] gynaecological and obstetric disorders,[8] paediatrics[9] and neurological conditions.[10]

Nevertheless, the body's physiological processes following OMT have not yet been understood. Over the years, the research tried to provide different explanations, mostly considering different frameworks.[11,12] For instance, several authors focused on the effect OMT could have on fascia and its properties,[13,14] highlighting structural and

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viscosity changes in the tissue texture[15] and interference with some pro-inflammatory and anti-inflammatory cellular processes.[16,17] From another point of view, osteopathic manipulations are deemed effective in reducing pain because of their potential role in stimulating the production of neuropeptides (e.g beta-endorphins).[18,19]. Further, the osteopathic community has also identified the autonomic nervous system (ANS) as one of the supposed substrates through which OMT can improve body functions.[20] In this regard, several authors observed beneficial effects on physiological parameters, such as heart rate variability (HRV), both in healthy adults and in newborns.[20–22] Recently fMRI-based studies showed the neurophysiological effects of OMT, acting on the interoceptive ways or modifying the cerebral blood flow and functional connectivity.[23,24]

OMT interventions can be focused on SD, which can be defined as an altered regulatory function associated with palpable signs in the body framework across various body regions that can be distant from the symptomatic area.[1,12,15] In such a variety of contexts, it seems clear that OMT biological plausibility is still poorly understood. The definition of a biologically plausible mechanism of action could widely aid researchers in supporting the rationale for treatment efficacy, and clinicians in suggesting (or less) osteopathic manipulation, choosing the proper technical approach, selecting an adequate dosage for each patient, or even encouraging persistence in case of disappointing results.[25] According to Howell, the survival of osteopathic medicine will depend on demonstrating the results of its treatment.[26]

Considering such a context, our hypothesis is that research in osteopathy is widely characterized by a large amount of heterogeneity in methods, and that it is still not clear what are the exact OMT mechanisms of action (e.g. osteo-articular, neurological, immunological). Therefore, the aim of the current scoping review (also named systematic mapping review) is threefold: to summarize all the biological effects reported in literature following OMT, by providing insights for the therapeutic possibilities of osteopathy; to comprehensively map the literature regarding the development of the osteopathic research in this field (when, where, how); to highlight any possible variability and heterogeneity detected across studies (i.e methods, protocols, terminology). Our findings could be of strategic importance to address future research and consequently, to inform clinical practice and healthcare policies.

2. Methods

2.1. Protocol registration and reporting

This scoping review was conceived and designed following the "2020 version of the Joanna Briggs Institute Reviewers' Manual"[27] and it was here reported referring to the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews" (PRISMA-ScR)[28] (see the checklist in Appendix A). The protocol was registered on the "Open Science Framework Registry" with the following registration number: https://doi.org/10.17605/OSF.IO/MFAUP.

2.2. Research question and search strategy

This study aimed to map and summarize the literature regarding the reported biological effects following OMT and not to provide a synthesis of evidence on a certain topic (e.g. effectiveness of interventions, quantification of a risk factor). The term "biological effect" encompasses any documented physiological response that can be detected through various types of medical examinations and may be linked to the application of OMT. This includes a wide range of observable changes in the body's functioning, such as neurophysiological responses, musculoskeletal adaptations, cardiovascular, respiratory and lymphatic functions modification, as well as other measurable outcomes resulting from OMT interventions.

For such a purpose, the research question is definable in terms of "population, concept and context" (PCC), and not through the PICO framework, which is recommended for systematic reviews.[29]

Thus, our research question was the following: to date, what is reported in the current literature regarding the potential biological effects resulting from OMT applications (*concept*) on people presenting any possible condition (*population*), provided in any possible setting (*context*).

As for the inclusion criteria, any original research that reported biological effects following the application of OMT, without any restrictions in terms of age, sex, clinical condition of the participants and frequency and length of treatments. Studies dealing with healthy people were also included since the focus of the current review is on the biological response, rather than on a specific condition. Furthermore, it is important to remark that systematic reviews with or without meta-analyses are eligible in a scoping review, since those studies bring new evidence and contribute providing original contents to the literature panorama, so that mapping them becomes potentially relevant.[28,29] Conversely, narrative reviews, letters, conference proceedings, editorials and commentaries were excluded.

Due to the intrinsic variability of OMT applications, all the following combinations were considered: soft-tissue techniques, high-velocity low amplitude techniques (HVLA), craniosacral treatment, myofascial release (MFR), and visceral manipulations. Furthermore, we considered studies that dealt with OMT interventions performed in a standardized, semi-standardized or non-standardized modality (i.e. black box). Studies that solely investigated a single osteopathic technique, or in which the practitioners were not in the context of osteopathic medicine were excluded. The term "biological effects" refers to observable and measurable changes in the body's physiological processes that occur as a result of OMT. Biological effects can include alterations in musculoskeletal dynamics, variations in neurophysiological function, changes in circulatory or lymphatic flow, and other systemic responses. Changes in motor activities' performance (e.g. walking) and, more in general, in general functional status (e.g. disability levels) were excluded because of their dependency on the external environment.[30]

2.3. Study selection and data extraction

The main systematic database search was conducted in January 2023 and then, periodic updates were performed in the following months, up to October 2023. We searched for original articles published on Medline (via Pubmed), Embase and Scopus, from inception to the present. Gray literature was sought through "Osteopathic Web Research" and via the Google search toolbar. Specific details regarding the search strategy and the choice of terms are reported in the Supplementary files.

The obtained records were uploaded, organized and managed through the software "Rayyan" (https://www.rayyan.ai/).[31] Study selection was conducted by starting with a pre-screening team meeting to discuss the study aims, and inclusion and exclusion criteria until a consensus was definitely reached. The selection process consisted of two distinct phases: screening for title/abstract and full-text reading. Two independent blinded reviewers (IB, MG) screened the articles and disagreements were resolved through discussion and consensus with a third reviewer (FDF). To test the consistency of extracting and reporting methods, six hours of training were carried out by the reviewers in three online meetings and subsequently, a trial was performed with ten studies randomly chosen among the included records. According to this modality, the study selection, data extraction, and synthesis of the results were performed by two independent reviewers (IB, MG). All the discrepancies were resolved through a discussion with a third expert reviewer (FDF).

The selection process is detailed in Fig. 1.

The data extraction form had been developed, discussed, implemented, and accepted by all authors of the study. The following information was included:

first author's name, year of publication, country, type of journal,

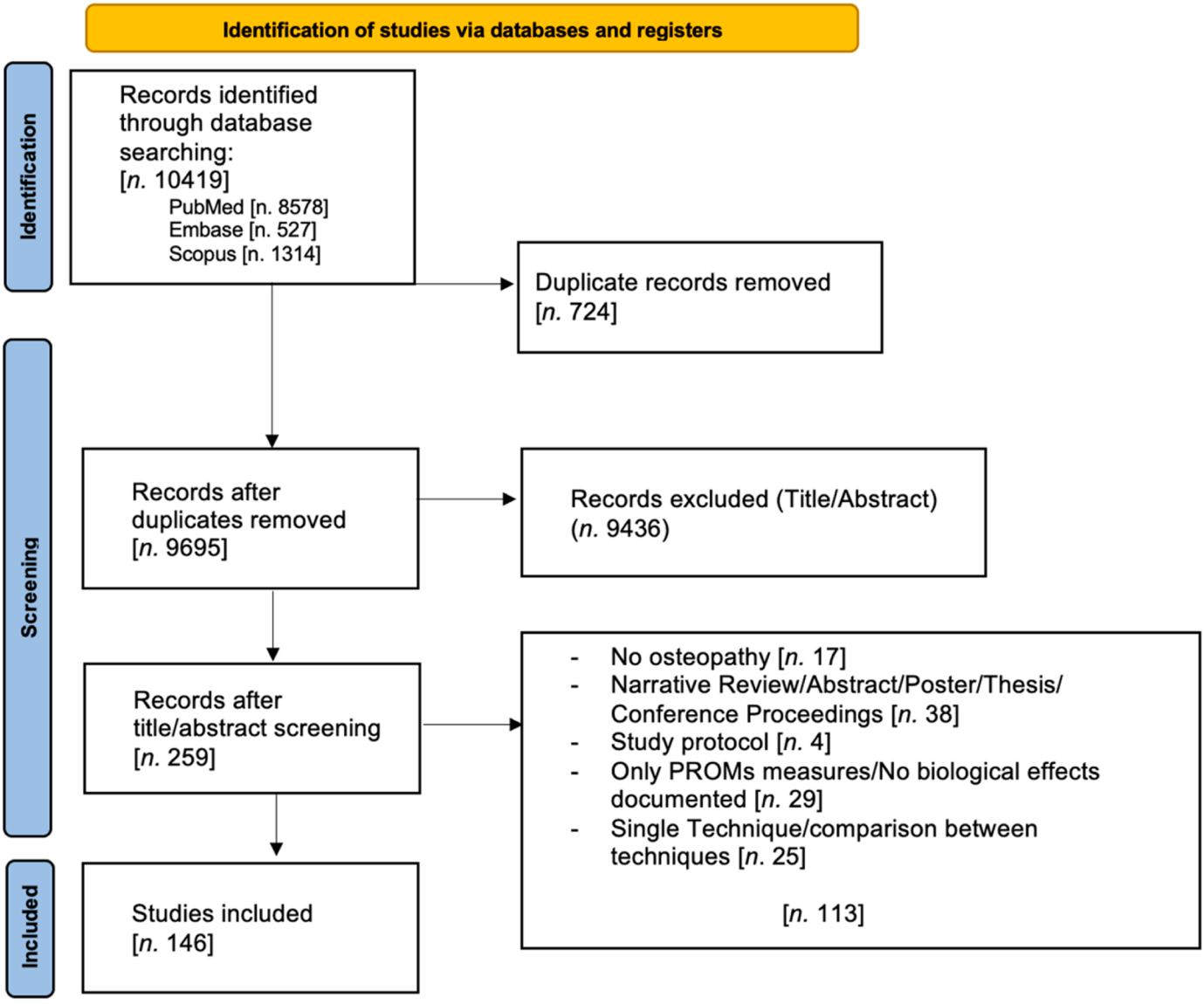

Fig. 1. PRISMA flow diagram reporting the studies selection process.

study design and aim, population characteristics, SD assessment (yes/no), type of osteopathic approach, documented biological effects, and employed instruments for clinical evaluation.

2.4. Synthesis of the results

Data and results were reported numerically and thematically. Descriptive statistics were used by using mean, medians, percentages, standard deviations and interquartile ranges for all the considered variables. Following the statistical analysis, results have been examined and specific thematic areas were detected and reported in the discussion section of this paper.

Within the mapping process, we reported data regarding studies that found biological changes following OMT: it is important to remark that, as a scoping review, no critical appraisal on the methodological quality of the included studies was done. Pie charts, histograms or bar graphs and a worldwide map were also used to improve the readability of the results. All the included studies are reported in Appendix B.

3. Results

Overall, 10,419 records were identified as a result of the database search. After duplicate removal, 9695 articles were screened for title and abstract. Subsequently, 9436 records were deleted as not pertinent and then, other 113 were removed with reasons following the full-text reading. Finally, a total of 146 studies were included in the current review. For further details, see the flowchart reported in Fig. 1.

3.1. Characteristics of the included studies

The included articles presented different study designs, as graphically reported in Fig. 2.

In detail, 72.1 % of the present research was made of clinical trials (approximately 62 % of which were RCTs), 10 % were represented by analytic observational studies, 9.6 % were case reports and the remaining 8.1 % consisted of systematic reviews and meta-analyses. Further, only 33.1 % of the studies were published in osteopathic journals.

The geographical distribution of the study was quite heterogeneous, with 38.3 % of publications in the United States, 22.6 % in Italy, 8.3 %

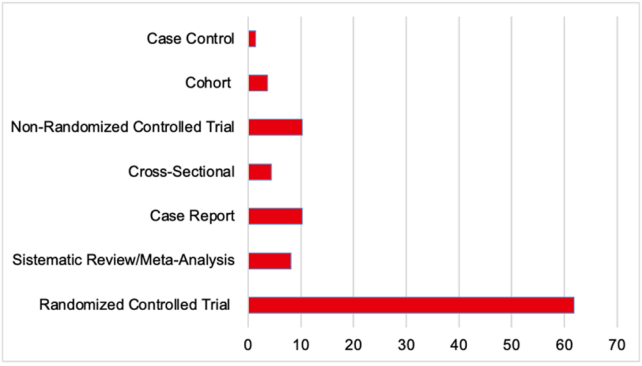

Fig. 2. Study designs percentage distribution of the included studies.

in Brazil and 6.8 % in Spain. Additionally, 8 studies were conducted in Poland (6 %) and 4 in the UK (3 %). All the contributions from other countries resulted sporadically and were reported in Fig. 3.

Research on the OMT biological effects appears to have increased over years, particularly in the period 2002–2022, reaching a higher number of annual publications in 2019 and in 2021 (19 studies per year, 14.3 % each). The trend for the number of publications over time is better shown in the graph (Fig. 4).

3.2. Characteristics of the participants

The total sample size consisted of 4295 subjects (range: 1–140; mean: 34.3, SD: 26.9; median: 29.5; mode: 1). The mean age of the participants was 34.1 years (SD: 19.8; median: 33; mode: 24; range: 0–87). The clinical conditions presented by the recruited populations were different across the studies and those can be grouped into 11 macro-categories (see Fig. 5). The most relevant were musculoskeletal pain (21.1 %), cardiovascular diseases (10.5 %), gynecological (6.8 %) and neurological disorders (6.8 %). Other clinical conditions were less frequently observed, whereas in almost 31 % of the studies the participants were healthy people. More in detail, these studies dealt with modifications related to respiratory, circulatory and neurologic functions.

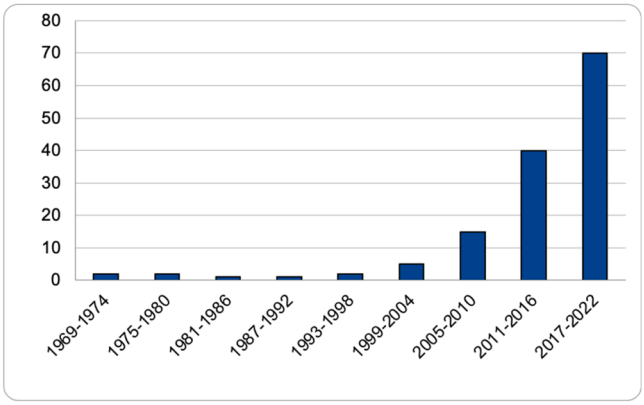

Fig. 4. Publications (%) distributed over years from 1969.

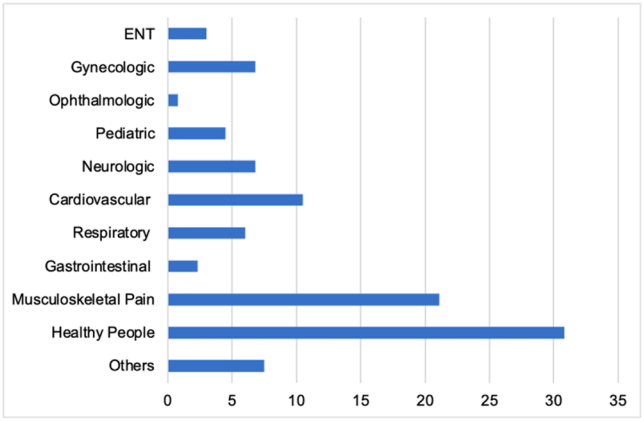

Fig. 5. Distribution (%) of the clinical conditions observed in the study participants.

3.3. Characteristics of the interventions

The interventions were characterized by different types of approaches. The protocols were mostly standardized (59 %), followed by non-standardized (28.2 %) and semi-standardized (12.8 %). OMT was

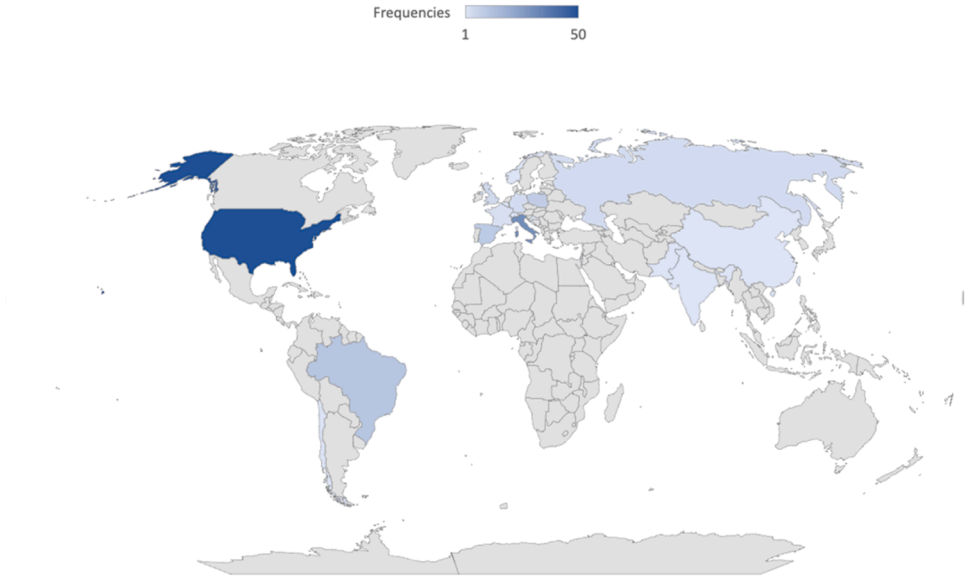

Fig. 3. Publications' geographical distribution worldwide.

oriented to different body regions, even if 45.3 % of the studies reported techniques applied very close to the anatomical area affected by the clinical condition of interest (i.e. pelvic region for the gynecological studies).

A control group was considered in 87 studies and it consisted of a sham application or a manual-placebo in the majority of cases (34.5 %); other possibilities were "no intervention" (16.1 %), usual care (12.6 %), exercises (5.7 %) and drugs administration (2.3 %); further, in 24.1 % of cases there was a combination of those interventions and in 4.6 % occasional typologies of control therapy were detected.

The mean number of OMT sessions was 3.27 (SD: 4.84; median: 1; mode: 1; range: 1–40) and the mean duration of OMT sessions was 26.2 min (SD: 16.67; median: 30; mode: 30; range: 2–90). In most of the cases (66.4 %), a combination of different manipulative techniques was investigated; the MFR was the most frequently studied approach (63.6.2 %), then followed cranio-sacral treatment (42.6 %), joint mobilization (31 %), balanced ligamentous tension (22.1 %), and muscle-energy techniques (18.8 %), HVLA (17.1 %), lymphatic approach (13.3 %), strain-counterstrain and visceral manipulation (8.5 % each), indirect techniques (6.2 %), and biodynamic approach (0.8 %).

The studies were conducted in different settings, mostly in university research centers or in osteopathic educational institutes (46 %), but also in outpatient centers (20 %), hospitals (18 %), private practice and laboratories (less than 1 % each); the 13 % of the studies did not specify any setting.

Finally, OMT was focused on SD in 31.2 % of the studies; conversely, it was not considered in 60.8 % of the works. In all the other cases (8 %), the study did not clarify this aspect. All the details regarding the interventions' features are reported in Fig. 6.

3.4. Documented biological effects

In the included studies which reported changes following OMT, different types of biological effects were observed (Fig. 7). In particular, most of them investigated how OMT could affect neurophysiology (41.3 %), musculoskeletal system (20.3 %), cardiovascular and lymphatic function (13.5 %), respiratory system (11.3 %), immunological (5.3 %) and gastrointestinal function (3.8 %); other occasional assessed biological modification consisted of 4.5 %.

The biological modifications were detected through different instruments (Fig. 8). The most widely used was electrophysiology (18 %), followed by spirometry (10.5 %), ultrasounds (6.8 %), laboratory tests and blood pressure (6 % each), MRI and symptoms or disease resolution (4.5 % each). The majority of the studies (21.1 %) employed a mix of the above-mentioned procedures. Biological changes were detected in 82.7 % of the studies. The distribution of such modifications for each

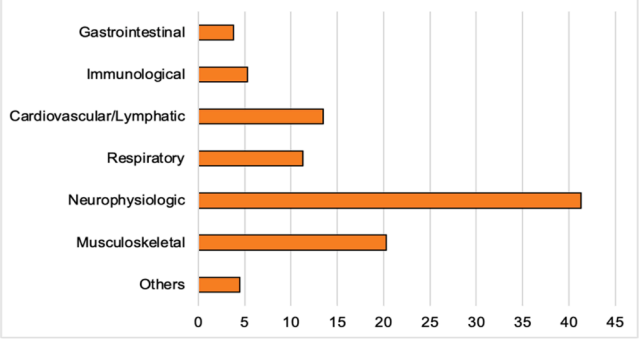

Fig. 7. Biological modifications investigated in the included studies.

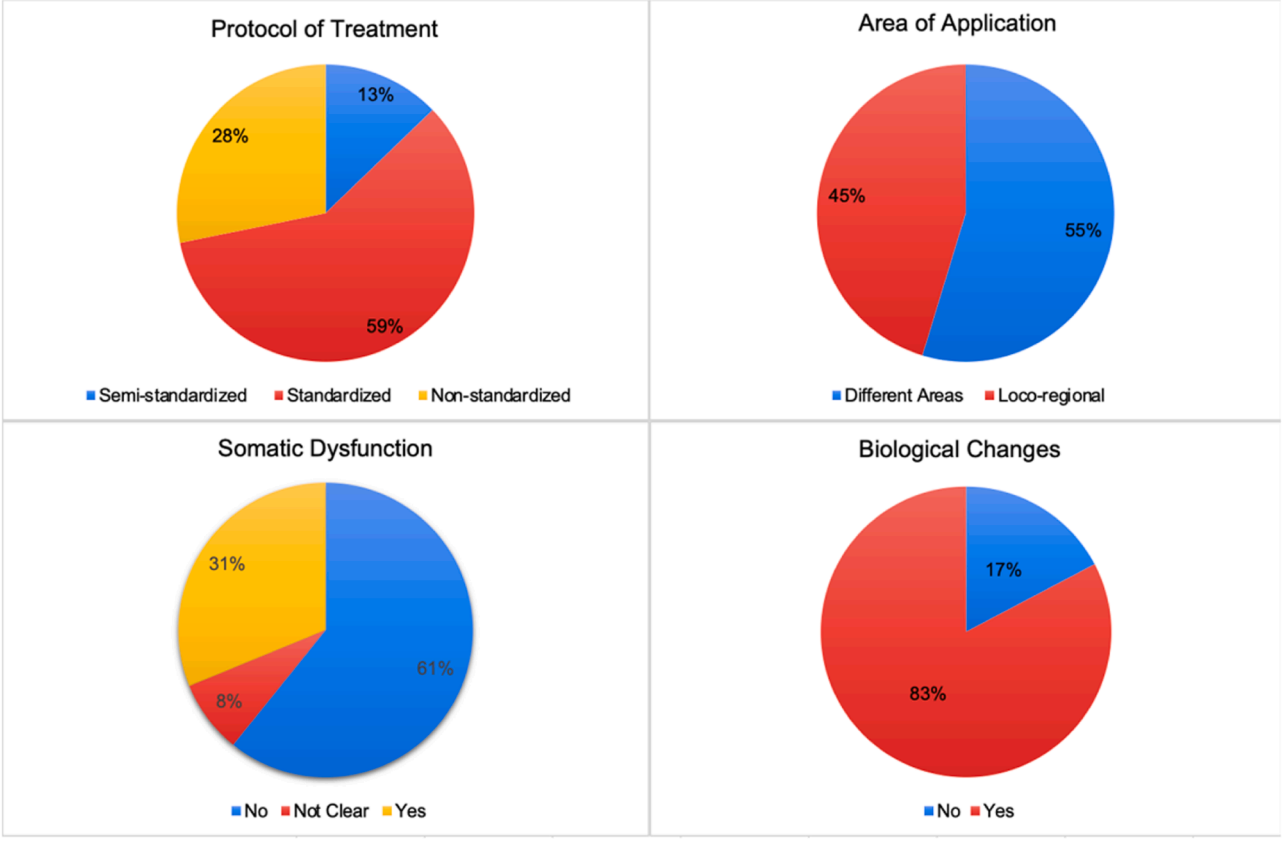

Fig. 6. Percentages of the protocol of treatment, area of application, SD-oriented treatment and biological changes resulted in the included studies.

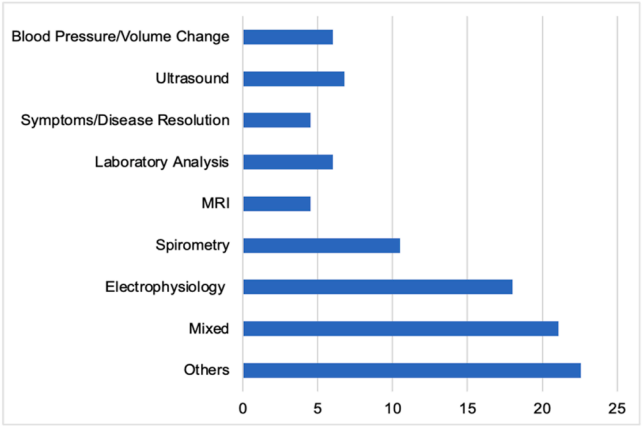

Fig. 8. Instrumental assessment tools for biological modifications following OMT.

biological effect was specifically detailed in Table 1.

4. Discussion

To the best of our knowledge, this is the first comprehensive review aimed to map the current literature regarding the documented biological effects following OMT. This topic is deemed to be of crucial importance since it would allow us to better understand the suitability of OMT clinical applications, and also to strategically address future research and healthcare policies. Given that current literature is stressing the importance of such aspects,[26,32] we found a favorable context to undertake this research.

As the scoping review methodology requires,[29,33] we grouped all the obtained results in different thematic areas. Four major topics have been detected and are worthy of discussion: 1) a growing interest, not worldwide; 2) OMT responses potentially extend to different biological systems; 3) OMT applications are extremely heterogeneous in research; 4) major interest in neurophysiology and in musculoskeletal modifications.

4.1. A growing interest, not worldwide

Our results suggest that the number of publications regarding OMT biological responses is increasing over the years, especially in the last two decades. However, such growing interest does not appear uniformly distributed all over the world. In detail, the United States and Italy proved to be the most active countries in osteopathic research concerning the study of its biological effects. Brazil, Spain, Poland and the UK also played a relevant role. Unfortunately, most of the other countries produced less, sporadic, or even no publications on this topic.

This data seems to be totally in line with previous studies. For instance, Morin et al.[34] in their 2021 bibliometric analysis, found the same countries as the most active in osteopathic research. In the same way, a 2022 international overview of SD showed a similar trend.[32] A possible explanation for such variations could be found both in the different professional regulations of the osteopathic profession and in the cultural diversity worldwide.[35]

As all those authors properly stated in their works, such increasing interest appears strongly in sync with practice development and innovations. However, it's our opinion that a wider diffusion of research on the osteopathic matter is needed, especially considering all the therapeutic implications that OMT seems to have in chronic and disabling diseases.[5,6,36,37,38]

Another relevant claim coming from our results is that a large number of papers (almost 77 %) were published in non-osteopathic journals. This fact is considered positive, since it implies that an interdisciplinary culture on the osteopathic approach has been developed and promoted.

Table 1
Distributions of biological effects' modifications in the included studies.

Biological system studied	Number of studies reporting biological modifications	Percentage of studies reporting biological modifications
Musculoskeletal	24	79
Neurophysiologic	50	88
Respiratory	8	53
Cardiovascular-Lymphatic	19	96
Immunological-Metabolic	10	100
Gastrointestinal	6	81
Others	5	83

4.2. OMT responses potentially extend to different biological systems

In this section, we qualitatively resumed and discussed the findings of our literature mapping process, without any intention to provide judgements about the robustness of the findings obtained by the included studies.

Our review showed how researchers investigated several biological effects following OMT. The most assessed were neurologic and neurophysiological parameters such as brain area activations (observed through fMRI or transcranial magnetic stimulation), or cardiovascular modifications as an expression of ANS activity.[23,24,39,40,41] Secondly, musculoskeletal modifications were often studied through imaging, electrophysiological parameters (e.g. EMG) and ultrasounds.[42–46] Besides, many studies dealt with respiratory function and cardiovascular activity, generally investigated through spirometry, imaging, electrophysiology and hemodynamics.[47–51] Finally, a minor part of the included studies focused on immunological and gastrointestinal modifications.[52–56] Other biological systems investigations were occasional.

Such a large variety of observed biological responses should surprise only partially, since osteopathic medicine differs from all the other conventional approaches precisely for its global and person-centered vision.[57] The peculiar aspect of osteopathy lies in the conceptualization of human health as a derivation of the correct functioning of different systems, perfectly integrated into each other.[58] Osteopaths use to identify body dysfunctions by assessing alterations in movement patterns, tissue textures and in tenderness. Thus, the so-called SD is considered an altered regulative function associated with local inflammatory signs palpable in the body framework.[59] For such reasons, investigating the biological plausibility of OMT should necessarily imply studying a variety of biological modifications following osteopathic approaches.

However, in such a variable context, we should not forget how the large majority of the mentioned responses are mainly referable to neurological effects. For instance, changes observed in HRV, blood pressure, and arteries' dilatation, but also in cerebral perfusion and muscular activity could be traced back to changes in neurological function, particularly regarding the ANS.[60,61] Therefore, even if OMT is addressable to several anatomical areas in different clinical conditions, the nervous system could represent the main target on which osteopathy acts.[62] Thus, the osteopathic manual inspection could represent the proper instrument useful to assess the nervous system function.[61] Further research is necessary to confirm this hypothesis.

4.3. OMT protocol heterogeneity in research

Systematic reviews on OMT effectiveness have been increasing in the last few years, and one of the most important limitations that prevents the generalization of results is given by the extreme diversity of OMT protocols detected among trials.[4]

Research in manual therapies appears methodologically heterogeneous in terms of technicalities and dosage, and osteopathy is not an exception.[62,63] Furthermore, reporting is overall inadequate.[6] As a consequence, the studies are scarcely reproducible and results become poorly generalizable. As a matter of fact, research on OMT biological effects suffers from the same problems. Specifically, we counted eleven different manipulative approaches, eventually combined in different modalities and administered with different dosages. Treatments were frequently standardized, and this operativity does not reflect the real osteopathic clinical practice.[6,63] Moreover, only in a minority of cases, OMT was oriented to SD. It becomes clear that biological responses could be definitely inconstant and poorly reproducible in such a context. For this reason, all the positive results that emerged in the included studies can represent only cues, certainly not definitive proofs, regarding the biological modifications induced by OMT. However, it is likely that in the near future research will gradually show how some of the traditional osteopathic principles, might be definitely revised in the light of a more up-to-date evidence-based framework. Simultaneously, it should not be forgotten that all non-pharmacological research inevitably suffers from relevant bias sources (e.g unblinding of personnel and patients, low reliability in palpatory assessments, operator-dependent efficacy). However, all those issues should not prevent clinicians and researchers from investigating the OMT effectiveness and its related biological responses.

4.4. Major interest in neurophysiology and in musculoskeletal modifications

Most of the included studies were mainly focused on neurophysiological modifications. Some fMRI-based research found possible functional changes in the brain after OMT: for instance, Cerritelli highlighted the modifications in the brain correlates of interoception[40], Tramontano in cerebral functional connectivity[24]and Tamburella and colleagues reported relevant cerebral perfusion changes following OMT in healthy people.[23] However, the large majority of the studies focused on changes detected in HRV[64], arterial pressure, blood perfusion, and vessel dilatation.[51,65,66] These types of responses were detected by measuring cardiovascular parameters, even if all the authors agreed in attributing to ANS the role of such modifications.[61]

In a different context, several authors investigated possible effects on the musculoskeletal system following OMT. Almost all those studies reported a decrease in myoelectric activity after different kinds of manipulation, especially myofascial techniques. However, Saavedra did not achieve the same results.[67] In any case, it is still not clear if such changes imply improvements in the clinical conditions for the patients. In general, different systematic reviews pointed out there is low- to moderate-quality evidence that OMT can improve pain and functional status in chronic painful conditions.[4–6,37] Due to methodological issues in osteopathic research, further studies are needed. Finally, only one study specifically focused on tissue texture changes following OMT, reporting non-significant modifications[45]; considering the recent increasing evidence on fascia properties and relative dysfunctions,[13,68,69] this field of research would deserve more exploration in the near future.

Our search found a fair number of studies that investigated respiratory function. The reported results appear contrasting. More in detail, Stępnik[70] did not find any significant change in lung volumes in healthy people and Jones[47] obtained the same negative results in subjects with asthma. Conversely, Lorenzo[48] and colleagues reported some partial variations in the spirometry obtained with the combination of both OMT and pulmonary rehabilitation. In the same way, Noll and colleagues[49] remarked on significant changes in expiratory volumes and in lung capacity in COPD elderly people. It seems clear that osteopathic manipulations are far from demonstrating improvements in respiratory function, thus more efforts should be addressed to definitely point out this aspect.

Other biological effects (e.g immunological, gastrointestinal, lymphatic, urinary and phoniatric) were only explored occasionally, so that no specific considerations can be made. However, some interesting cues emerged, thus insiders and stakeholders should explore these preliminary findings.

4.5. Future perspectives

The results of the present review definitely confirmed our preliminary hypothesis: a wide heterogeneity in methods and protocols greatly affects the current research on osteopathic biological plausibility, preventing any possible generalization. In light of the previously mentioned arguments, some specific recommendations could be drawn in order to address future efforts. Considering the amount of cues related to ANS responses, one of the next steps should be focusing on the implications that such modifications have in different clinical contexts. Nowadays, there is still little high-quality evidence regarding OMT effectiveness.[5,6] It's our opinion that modifications observed in the brain areas deserve particular attention, especially those related to pain elaboration and self-perception.[71] Further studies are necessary to confirm such interesting trends, in particular regarding chronic musculoskeletal conditions in which nociplastic pain is suspected to be present.[72] In this regard, osteopathic care could also be investigated as a preventive strategy for chronic diseases.

From another perspective, a relevant theme worthy of being explored is whether all observed biological effects are specifically attributable to osteopathy or, more in general, to any type of manipulative approach, To the best of our knowledge, there is currently no specific statement that precisely delineates the differences between osteopathic techniques and all other types of manual approaches commonly employed by various practitioners (e.g., physiotherapists, manual therapists, chiropractors).[73] Some potential exceptions are represented by the so-called "indirect" or "exaggeration" techniques; given their application modalities (e.g., applied forces, localization), they may differentiate osteopathic care and its effects without overlapping with other therapies.

Furthermore, new strategies in manual assessment procedures should be proposed and investigated in osteopathy, as low levels of reliability and validity have been observed so far. As is known, no specific therapeutic recommendations can be made without prior valid diagnostics.[59] We believe this is a crucial aspect for the future of the osteopathic medicine, conceptually preceding the study of OMT biological effects.

4.6. Limitations

Potential limitations of this scoping review are intrinsic to the nature of the study. Since a great number of articles were potentially of interest, some records may have been skipped. Further, despite our selection criteria did not include studies dealing with the combination of the OMT with other therapies, it might be possible that some of the included research adopted co-interventions in their protocol, without explicitly stating it. Another limitation is that the analyzed studies did not report specific effects according to the OMT technical approach; consequently, we did not discuss a breakdown of the physiological effects for each approach. Finally, the aim of a scoping review is not to define the level of evidence on a specific matter, rather to overall map the whole literature regarding a certain thematic area.

5. Conclusions

Biological modifications induced by OMT have been already investigated in different body systems. The large majority of the studies mostly focused on the neurophysiological correlates and secondly on musculoskeletal changes. However, a wide heterogeneity in methods and in the objectives of the existent research was detected, so we are far

from having consistent research on this matter.

Further, more efforts should be made to differentiate whether such biological changes specifically depend on osteopathic treatment, and to demonstrate its specific contribution to clinical practice.

CRediT authorship contribution statement

Irene Bruini: Methodology. **Matteo Galli:** Methodology. **Luca Vismara:** Writing – review & editing, Supervision. **MARCO TRAMONTANO:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Fulvio Dal farra:** Writing – original draft, Data curation, Conceptualization. **Andrea Bergna:** Writing – review & editing, Supervision. **Christian Lunghi:** Writing – review & editing, Methodology, Formal analysis.

Author Contributions

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Informed Consent Statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ctim.2024.103043.

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