Centre of rotation locations during lumbar spine movements: a scoping review protocol

Review question/objectives

The objective of this scoping review is to identify and map the evidence related to the locations and migration path for the center of rotation during physiological movements of the human lumbar spine in any condition (i.e., healthy, pathological injured, instrumented, etc.).

Specifically, the two research questions addressed in this scoping review are:

1. What are the center of rotation locations during physiological movements of the human lumbar spine in any condition?
2. What are the migration paths of the center of rotation in the human lumbar spine in any condition throughout physiological movements?

ABSTRACT (250 / 250 words)

Objective:

The objective of this review is to identify and map the scientific literature describing the center of rotation (COR) locations and migration paths during lumbar spine movements of lumbar spines of any status.

Introduction:

The importance of lumbar spine kinematics has been described and altered kinematics has been associated with pain and injury. Intervertebral segments' CORs, the point about which spinal segments rotate about, are important for determining the lumbar spine kinematic features and the potential for increased injury risk during movements. Although many studies have investigated the CORs of human lumbar spine, no review has summarized and organized the state of the science related to COR locations and migration paths of the lumbar spine during lumbar spine movements.

Inclusion criteria:

This review will consider studies that include human lumbar spines of any ages in any status condition (e.g., heathy, pathological) during lumbar spine movements. Quantitative study designs, including clinical, observational, laboratory biomechanical experimental studies, mathematical and computer modelling studies will be considered. Only studies published in English will be included, and there will be no limit on dates of publication.

Methods:

PubMed, Medline, EMBASE, the Cochrane Library Controlled Register of Trials, CINAHL, ACM Digital Library, Compendex, Inspec, Web of Science, Scopus, Google Scholar, dissertation and thesis repositories will be searched. After titles and abstracts screening of identified references, two independent reviewers will screen the full-text of identified studies and extract data. Data will be summarized, categorized and a comprehensive narrative summary will be presented with their respective results.

Introduction

Low back pain (LBP) is a major healthcare challenge worldwide. The condition is incredibly common throughout all ages of the population, affecting 80% of the people at some point in their life and approximately 7.3% of the population at any one time.[1–4] Even though the majority of LBP have no evidence of serious pathologies, this does not translate into a trivial situation for the patient or society. Low back pain is a highly burdensome condition that is the leading cause of years lived with disability worldwide.[1] It is the most common reason for lost worked days in the USA,[5] has a similar economic impact as cardiovascular diseases and cancer[6] and has a substantial impact on the quality of life of individuals, especially in terms of financial wellbeing[7] and social identity[8]. Emerging research suggests that LBP is best viewed as a variable condition of long duration, with the majority of cases resulting in either constant or fluctuating trajectories of symptoms[9].

Despite LBP's high prevalence and impact on the individual and society, the etiology of LBP remains unclear. About 85% of LBP cases are still considered non-specific, as they are not resultant of any specific known pathology, such as vertebral fracture, spinal deformity and tumor.[10–12] Within the non-specific LBP cases, some studies have suggested that mechanical factors (such as prolonged sitting[13,14] and whole body vibration[15,16]) or genetic makeup[17] may affect the development or maintenance of LBP. On a more basic level, abnormal intersegmental movements of lumbar vertebrae in terms of magnitude (e.g., abnormal increases or decreases in movement) and quality (e.g., abnormal coupling patterns) during lumbar movements (e.g., lumbar flexion and extension) have been suggested to increase the risk of injury or pain.[18–21] Theoretically, repeated abnormal segmental movements may damage spinal stabilizing structures by exceeding tissues' mechanical thresholds, which may impose abnormal demands on secondary restraints, creating spinal instability, injury and pain.[22] Since the stability of the spine is affected by the relative stability of the active (muscles), passive (ligaments, vertebrae, and intervertebral discs), and neural (neuromuscular control) subsystems, it has been hypothesized that the dysfunctions in any of the three subsystems will lead to abnormal intervertebral movements.[23,24]

Altered lumbar segmental motions in patients with LBP compared to asymptomatic subjects have been previously reported in the literature.[25–27] However, the specific patterns of altered lumbar segmental kinematics that relate to LBP remain unclear. Specifically, while some studies have observed that LBP patients display reduced lumbar range of motion and angular velocity,[25,28,29] others have reported increased range of motion of the upper lumbar region as well as increased lumbar segmental mobility in people with LBP compared to asymptomatic controls.[26,30] These discrepancies can be partly attributed to the lack of a standardized and systematic approach in conducting lumbar spine kinematics investigations and the use of varied instruments and equipment. For example, electromagnetic tracking, inertial sensing-based system, dynamic imaging, static radiographs and 3-dimentional motion capture systems have been used in previous studies investigating lumbar spine kinematics.[26,28,31–33] Although objective measures are needed to determine abnormal lumbar intersegmental movements during physiological and dynamic movements, there is still a measurement difference between instruments tracking the actual lumbar vertebral motions and the ones attached to the skin overlying the lumbar vertebrae.[34] These methodological differences could influence measurement accuracy, producing conflicting results and precluding the establishment of the lumbar kinematics alterations inherent in patients with LBP.

Centre of rotation (COR) is defined by the point about which motion segments of the spine appear to move. It is therefore intrinsically linked to the two primary measures of joint kinematics, rotation and translation. Moreover, it has been long held that the centre of reaction force can be extrapolated from the COR, allowing the estimation of inter-joint shear and compression forces.[35] The ability of the COR to be resolvable into these parameters can be used to characterize/quantify the kinematic features of the lumbar spine and specific motion segments.[36,37] The use of COR location and migration paths therefore lends itself to a greater utility than its constituent parameters when evaluating lumbar spine and motion segment kinematics as well as intersegmental conditions. Many studies have investigated the CORs of the human lumbar spine under various conditions (e.g. dynamic movements, post-surgical, structural failure, low back pain, etc.)[38–41] and it is commonly noted that the locations of the CORs during physiological movements change position creating migration paths.[35,37,42,43] Moreover, not only is there variation of CORs position *during* a forward bend but while the average COR is usually located between the posterior, upper quarter of the lower vertebra and lower quarter of the intervertebral disc, there is a large variance of CORs between studies[44]. Given that different COR locations have been described to impact the lumbar kinetics, kinematics and trunk muscle activation, it is important to outline all evidence and understand the results currently available. To date, no review has been conducted to summarize and organize the state of the science related to COR locations and migration paths of the lumbar spine during lumbar spine physiological movements of any status (i.e., healthy, pathological, post-surgical, etc.).

This work is of great importance so clinicians and researchers can have a better understanding of the current evidence related to lumbar intersegmental movement, how it may relate to LBP and other lumbar spine conditions, and to provide recommendations on standardized approaches for future investigations. Specifically, the recommendations expected at the end of this work will constitute strong foundations for the design of research protocols evaluating lumbar kinetics, kinematics, muscle activity and biomechanical experiments through COR measurement. On a clinical perspective, this work may help the development of new standardized measurement tools that could be integrated in clinical practice to evaluate and manage patients with lumbar spine conditions.

Therefore, the objective of the current scoping review is to map the scientific literature describing the COR locations and migration paths during lumbar spine physiological movements of lumbar spines of any status. A preliminary search for existing reviews on COR locations and migration during lumbar spine movements was carried on February 22nd, 2019 using the following databases: JBI Database of Systematic Reviews and Implementation Reports, PROSPERO, Cochrane Library, PubMed, EBSCO and CINAHL; no similar reviews to the current proposed scoping review were found.

Inclusion Criteria

Participants

This review will examine studies that include humans of any ages (pediatric, youth, adult and elderly) in any condition (healthy, athlete, injured, pathological, post-surgery/instrumented, cadaveric) during basic physiological movements of the lumbar spine (flexion, extension, lateral bending, axial rotation, or a combination of movements with and without axial loading).

Concept

The concept addressed in this scoping review is the locations and migration paths of CORs during lumbar spine movements measured by, but is not limited to, static and dynamic imaging, motion capture, sensor tracking and mathematical models.

Context

The proposed scoping review will consider studies investigating the COR locations and migration paths during movements of the human lumbar spine conducted in any environment including, but not limited to, clinical or laboratory setting, computer modelling from any geographical region.

Types of Studies

This review will consider all types of quantitative study designs, including clinical and laboratory biomechanical experimental studies and observational designs (cohort studies, case-control studies, cross-sectional studies, case studies and descriptive studies). Additionally, mathematical and computer modelling studies will also be considered for inclusion. Studies published in English from database inception up to the date in which the search will be conducted will be considered for inclusion.

Exclusion Criteria

Studies will be excluded if they: 1) involve animal models, 2) investigate spine regions other than the lumbar region (e.g., thoracic, thoracolumbar, lumbosacral), or 3) explore other outcomes as a function of the center of rotation location (e.g., facet joint forces, intradiscal pressure, muscle activity, range of motion, kinematics with different COR locations).

Methods

This protocol has been registered with the Open Science Framework on 12 December 2018 (https://osf.io/znbca/). The protocol has been developed based on the methodological framework for scoping reviews proposed by Arksey and O'Malley[45] and further refined based on the Joanna Briggs Institute methodology for scoping reviews.[46] The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR)[47] was also followed.

Search Strategy

It is anticipated that relevant studies will be found in health sciences as well as engineering databases. To ensure that all studies will be identified, comprehensive search strategies will be developed by two librarians with experience in developing systematic search strategies: one specialized in health sciences and one in engineering. They will work together to develop a basic multiple structured search strategy, and then refine the strategy individually to tailor the search strategy to their respective area of expertise.

The search strategies will be based on the framework recommended by the Joanna Briggs Institute methodology for scoping reviews:[46] Population – Concept – Context (PCC). This framework was adapted from the PICO strategy (Population – Intervention – Comparison – Outcome), which is commonly used to provide readers with specific information on the focus and applicability of clinical investigations and systematic reviews. Search strategies developed by both librarians (health sciences and engineering) will be peer-reviewed by other librarians from the same institution using the Peer Review of Electronic Search Strategies (PRESS) checklist.

The following descriptors, indexed terms, keywords and their combinations will be used to construct the strategies: "lumbar vertebra*", "lumbar spine*", "lumbar segment*", "lower spine*", "center* of rotation", "centre* of rotation", "centrode", "axis of rotation", "axes of rotation" and "helical axis". The search strategy developed for Medline is detailed in Appendix I. The reference lists of relevant articles will also be screened to locate potential additional relevant articles.

Information Sources

The identification of studies relevant to this review will be achieved by searching published literature on health sciences and engineering electronic databases as well as grey literature including PubMed, Medline, EMBASE, the Cochrane Library Controlled Register of Trials, CINAHL, ACM Digital Library, Compendex, Inspec, Web of Science, Scopus, Google Scholar web search, dissertation and thesis repositories. Despite of the potential overlap between PubMed and Medline databases, preliminary search resulted in unique references emerging from both databases. Therefore, the developed search strategy will be conducted on both databases with specific efforts to remove duplicate publications.

Study Selection

After de-duplication of publications retrieved from searches in the abovementioned databases, a two-level screening will be conducted to select relevant studies. The first level will include screening of titles and abstracts by two independent reviewers (MF and DDC) in order to identify publications that are eligible for full-text screening. The second level will involve the two reviewers (MF and DDC) independently assessing the full-text articles' eligibility based on the inclusion/exclusion criteria. Any disagreements between reviewers regarding study eligibility will be resolved through a discussion with a third reviewer (AB) until full consensus is achieved. Reasons for exclusion of full-text articles will also be recorded. Given that this is a scoping review, methodological quality assessment will not be conducted. Therefore, studies will not be excluded based on their methodological quality. A PRISMA flow diagram will be used to summarize the results of this search process.[48]

Data Extraction

Data of included studies will be extracted by two independent reviewers (MF and AB). A data extraction form will be developed to extract study characteristics (authors, year of publication, country, and the study design) and detailed information regarding: 1) sample or population (i.e., sample size, type of sample, sample status [e.g., healthy, injured, pathological, instrumented]) and 2) COR measurement (i.e., COR measure/calculation method, COR location or migration path), and 3) lumbar spine (e.g., lumbar movement in which COR was measured, lumbar levels) of each included study in the scoping review. A provisional data extraction form is detailed in Appendix II. Information to be extracted from included studies may be refined and additional categories may be added during the data extraction process.

Data Presentation

General and specific descriptions of the locations and migration paths of COR locations during lumbar spine movements will be combined and summarized, producing a list of locations and migration paths that have been reported in the literature. Firstly, a summary of the overall characteristics of each included study, such as population, study setting and method for measuring COR location will be presented. In order to present the data in a comprehensive and useful manner, data summaries will be divided and sub-divided into emerging categories. Some anticipated categories are: 1) type of sample (e.g., human, modelling data), 2) status of the participants (e.g. healthy, post-surgical, or pathological), and 3) physiological movements investigated (e.g., COR during flexion, extension, lateral bending, and axial rotation). However additional categories may emerge during the screening and data extraction stages. The categories to be used as primary, secondary or tertiary are planned to be as above described (i.e, the primary category being type of sample, secondary status of sample and tertiary the movement), however categories may change based on the data extracted and on what the authors judge to be more comprehensive. Results of this study will be presented descriptively with the supplementation of tables, figures and graphs. To ensure adequate reporting quality, the PRISMA-ScR checklist will be used.[47]

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Appendix I. Search strategy for Medline

Search conducted in February 2019, retrieving 1134 references.

1. MH Lumbar Vertebrae
2. TI lumbar* or AB lumbar*
3. TI lower n2 spinal* or AB lower n2 spinal*
4. TI lower n2 spine* or AB lower n2 spine*
5. TI (L1 or L2 or L3 or L4 or L5) or AB (L1 or L2 or L3 or L4 or L5)
6. TI (L-1 or L-2 or L-3 or L-4 or L-5) or AB (L-1 or L-2 or L-3 or L-4 or L-5)
7. TI body n2 joint or AB body n2 joint*
8. TI human n2 joint* or AB human n2 joint*
9. **1-8/OR [**lumbar spine]**

10. MH Rotation
11. TI (axes* AND rotation*) or AB (axes* AND rotation*)
12. TI (axis* AND rotation*) or AB (axis* AND rotation*)
13. TI (axis* AND helical*) or AB (axis* AND helical*)
14. TI (axes* AND helical*) or AB (axes* AND helical*)
15. TI (center* AND rotation*) or AB (center* AND rotation*)
16. TI (centre* AND rotation*) or AB (centre* AND rotation*)
17. TI centrod* or AB centrod*
18. TI motion n2 characteristic* or motion n2 characteristic*
19. **10-18/OR [**center of rotation]**

20. 9 AND 19
21. LIMIT 20 English Language
22. LIMIT 21 NOT (animal* NOT human*)

Appendix II. Provisional data extraction form

Study characteristics:

- **Human studies:**
  - Author
  - Year of publication
  - Population characteristics
    - Living status (live vs. cadaveric)
    - Age
    - Sex
  - Sample size (n)
  - Sample status (i.e., healthy, injured, pathological, rehabilitated, instrumented)
  - Lumbar level
  - Motion characteristics (e.g., flexion, extension, lateral bending, axial rotation, combined movement)
  - Loading characteristics (e.g., axial loading, active/passive movement)
  - Method of COR location measurement (e.g., imaging, motion capture, mathematical model estimation)
  - COR location / migration path

- **Modelling studies:**
  - Author
  - Year of publication
  - Model characteristics
    - Type of model
    - Source of data and characteristics (e.g., age, sex, condition - healthy, injured, pathological, instrumented, etc)
    - Geometry (personalised/generic/idealised)
    - Material characteristics
  - Number of models and boundary conditions
  - Lumbar level
  - Motion characteristics (e.g., flexion, extension, lateral bending, axial rotation, combined movement)
  - Loading characteristics (e.g., axial loading, active/passive movement)
  - Method of COR location measurement (e.g., imaging, motion capture, mathematical model estimation)
  - COR location / migration path