

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

3

4

5 **Review question/objectives**

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

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

- 10 1. What are the center of rotation locations during physiological movements of the human lumbar  
11 spine **in any condition?**
- 12 2. What are the migration paths of the center of rotation in the human lumbar spine **in any condition**  
13 **throughout physiological movements?**

14

15 **ABSTRACT** (250 / 250 words)

16 **Objective:**

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

19

20 **Introduction:**

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

27

28 **Inclusion criteria:**

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

34

35 **Methods:**

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

42

## 43 Introduction

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

54  
55 Despite LBP's high prevalence and impact on the individual and society, the etiology of LBP remains  
56 unclear. About 85% of LBP cases are still considered non-specific, as they are not resultant of any  
57 specific known pathology, such as vertebral fracture, spinal deformity and tumor.<sup>10-12</sup> Within the non-  
58 specific LBP cases, some studies have suggested that mechanical factors (such as prolonged sitting<sup>13,14</sup>  
59 and whole body vibration<sup>15,16</sup>) or genetic makeup<sup>17</sup> may affect the development or maintenance of LBP.  
60 On a more basic level, abnormal intersegmental movements of lumbar vertebrae in terms of magnitude  
61 (e.g., abnormal increases or decreases in movement) and quality (e.g., abnormal coupling patterns)  
62 during lumbar movements (e.g., lumbar flexion and extension) have been suggested to increase the risk  
63 of injury or pain.<sup>18-21</sup> Theoretically, repeated abnormal segmental movements may damage spinal  
64 stabilizing structures by exceeding tissues' mechanical thresholds, which may impose abnormal demands  
65 on secondary restraints, creating spinal instability, injury and pain.<sup>22</sup> Since the stability of the spine is  
66 affected by the relative stability of the active (muscles), passive (ligaments, vertebrae, and intervertebral  
67 discs), and neural (neuromuscular control) subsystems, it has been hypothesized that the dysfunctions in  
68 any of the three subsystems will lead to abnormal intervertebral movements.<sup>23,24</sup>

69  
70 Altered lumbar segmental motions in patients with LBP compared to asymptomatic subjects have been  
71 previously reported in the literature.<sup>25-27</sup> However, the specific patterns of altered lumbar segmental  
72 kinematics that relate to LBP remain unclear. Specifically, while some studies have observed that LBP  
73 patients display reduced lumbar range of motion and angular velocity,<sup>25,28,29</sup> others have reported  
74 increased range of motion of the upper lumbar region as well as increased lumbar segmental mobility in  
75 people with LBP compared to asymptomatic controls.<sup>26,30</sup> These discrepancies can be partly attributed to  
76 the lack of a standardized and systematic approach in conducting lumbar spine kinematics investigations  
77 and the use of varied instruments and equipment. For example, electromagnetic tracking, inertial sensing-  
78 based system, dynamic imaging, static radiographs and 3-dimensional motion capture systems have been  
79 used in previous studies investigating lumbar spine kinematics.<sup>26,28,31-33</sup> Although objective measures are

80 needed to determine abnormal lumbar intersegmental movements during physiological and dynamic  
81 movements, there is still a measurement difference between instruments tracking the actual lumbar  
82 vertebral motions and the ones attached to the skin overlying the lumbar vertebrae.<sup>34</sup> These  
83 methodological differences could influence measurement accuracy, producing conflicting results and  
84 precluding the establishment of the lumbar kinematics alterations inherent in patients with LBP.

85  
86 Centre of rotation (COR) is defined by the point about which motion segments of the spine appear to  
87 move. It is therefore intrinsically linked to the two primary measures of joint kinematics, rotation and  
88 translation. Moreover, it has been long held that the centre of reaction force can be extrapolated from the  
89 COR, allowing the estimation of inter-joint shear and compression forces.<sup>35</sup> The ability of the COR to be  
90 resolvable into these parameters can be used to characterize/quantify the kinematic features of the  
91 lumbar spine and specific motion segments.<sup>36,37</sup> The use of COR location and migration paths therefore  
92 lends itself to a greater utility than its constituent parameters when evaluating lumbar spine and motion  
93 segment kinematics as well as intersegmental conditions. Many studies have investigated the CORs of  
94 the human lumbar spine under various conditions (e.g. dynamic movements, post-surgical, structural  
95 failure, low back pain, etc.)<sup>38-41</sup> and it is commonly noted that the locations of the CORs during  
96 physiological movements change position creating migration paths.<sup>35,37,42,43</sup> Moreover, not only is there  
97 variation of CORs position *during* a forward bend but while the average COR is usually located between  
98 the posterior, upper quarter of the lower vertebra and lower quarter of the intervertebral disc, there is a  
99 large variance of CORs between studies<sup>44</sup>. Given that different COR locations have been described to  
100 impact the lumbar kinetics, kinematics and trunk muscle activation, it is important to outline all evidence  
101 and understand the results currently available. To date, no review has been conducted to summarize and  
102 organize the state of the science related to COR locations and migration paths of the lumbar spine during  
103 lumbar spine physiological movements of any status (i.e., healthy, pathological, post-surgical, etc.).

104  
105 This work is of great importance so clinicians and researchers can have a better understanding of the  
106 current evidence related to lumbar intersegmental movement, how it may relate to LBP and other lumbar  
107 spine conditions, and to provide recommendations on standardized approaches for future investigations.  
108 Specifically, the recommendations expected at the end of this work will constitute strong foundations for  
109 the design of research protocols evaluating lumbar kinetics, kinematics, muscle activity and  
110 biomechanical experiments through COR measurement. On a clinical perspective, this work may help the  
111 development of new standardized measurement tools that could be integrated in clinical practice to  
112 evaluate and manage patients with lumbar spine conditions.

113  
114 Therefore, the objective of the current scoping review is to map the scientific literature describing the  
115 COR locations and migration paths during lumbar spine physiological movements of lumbar spines of any  
116 status. A preliminary search for existing reviews on COR locations and migration during lumbar spine

117 movements was carried on February 22<sup>nd</sup>, 2019 using the following databases: JBI Database of  
118 Systematic Reviews and Implementation Reports, PROSPERO, Cochrane Library, PubMed, EBSCO and  
119 CINAHL; no similar reviews to the current proposed scoping review were found.

120

## 121 **Inclusion Criteria**

### 122 *Participants*

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

127

### 128 *Concept*

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

132

### 133 *Context*

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

137

### 138 *Types of Studies*

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

144

### 145 *Exclusion Criteria*

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

150

151

## 152 **Methods**

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

158

### 159 *Search Strategy*

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

165

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

173

174 The following descriptors, [indexed terms](#), keywords and their combinations will be used to construct the  
175 strategies: “lumbar vertebra\*”, “lumbar spine\*”, “lumbar segment\*”, “lower spine\*”, “center\* of rotation”,  
176 “centre\* of rotation”, “centrode”, “axis of rotation”, “axes of rotation” and “helical axis”. The search strategy  
177 developed for Medline is detailed in [Appendix I. The reference lists of relevant articles will also be  
178 screened to locate potential additional relevant articles.](#)

179

### 180 *Information Sources*

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

188

### 189 *Study Selection*

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

200

#### 201 *Data Extraction*

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

210

#### 211 *Data Presentation*

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

226

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356

357

358 **Appendix I. Search strategy for Medline**

359

360 Search conducted in February 2019, retrieving 1134 references.

361

362 1. MH Lumbar Vertebrae

363 2. TI lumbar\* or AB lumbar\*

364 3. TI lower n2 spinal\* or AB lower n2 spinal\*

365 4. TI lower n2 spine\* or AB lower n2 spine\*

366 5. TI (L1 or L2 or L3 or L4 or L5) or AB (L1 or L2 or L3 or L4 or L5)

367 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)

368 7. TI body n2 joint or AB body n2 joint\*

369 8. TI human n2 joint\* or AB human n2 joint\*

370 **9. 1-8/OR [\*\*lumbar spine]**

371

372 10. MH Rotation

373 11. TI (axes\* AND rotation\*) or AB (axes\* AND rotation\*)

374 12. TI (axis\* AND rotation\*) or AB (axis\* AND rotation\*)

375 13. TI (axis\* AND helical\*) or AB (axis\* AND helical\*)

376 14. TI (axes\* AND helical\*) or AB (axes\* AND helical\*)

377 15. TI (center\* AND rotation\*) or AB (center\* AND rotation\*)

378 16. TI (centre\* AND rotation\*) or AB (centre\* AND rotation\*)

379 17. TI centrod\* or AB centrod\*

380 **18. TI motion n2 characteristic\* or motion n2 characteristic\***

381 **19. 10-18/OR [\*\*center of rotation]**

382

383 20. 9 AND 19

384 21. LIMIT 20 English Language

385 22. LIMIT 21 NOT (animal\* NOT human\*)

386

387 **Appendix II. Provisional data extraction form**

388

389 **Study characteristics:**

390

391 • **Human studies:**

392

▪ Author

393

▪ Year of publication

394

▪ Population characteristics

395

○ Living status (live vs. cadaveric)

396

○ Age

397

○ Sex

398

▪ Sample size (n)

399

▪ Sample status (i.e., healthy, injured, pathological, rehabilitated, instrumented)

400

▪ Lumbar level

401

▪ Motion characteristics (e.g., flexion, extension, lateral bending, axial rotation, combined movement)

402

▪ Loading characteristics (e.g., axial loading, active/passive movement)

403

▪ Method of COR location measurement (e.g., imaging, motion capture, mathematical model estimation)

404

▪ COR location / migration path

405

406

407

408

409 • **Modelling studies:**

410

▪ Author

411

▪ Year of publication

412

▪ Model characteristics

413

○ Type of model

414

○ Source of data and characteristics (e.g., age, sex, condition - healthy, injured, pathological, instrumented, etc)

415

○ Geometry (personalised/generic/idealised)

416

○ Material characteristics

417

▪ Number of models and boundary conditions

418

▪ Lumbar level

419

▪ Motion characteristics (e.g., flexion, extension, lateral bending, axial rotation, combined movement)

420

▪ Loading characteristics (e.g., axial loading, active/passive movement)

421

▪ Method of COR location measurement (e.g., imaging, motion capture, mathematical model estimation)

422

▪ COR location / migration path

423

424

425

426