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## Measures of trunk muscle strength and their measurement properties: a protocol for a systematic review and narrative synthesis of clinical measures

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**Measures of trunk muscle strength and their measurement properties: a protocol for a systematic review and narrative synthesis of clinical measures**

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**Abstract**

**Introduction**

Spinal musculoskeletal conditions, including low back and neck pain are leading causes of disability globally. The trunk muscles, which comprise muscles in the thoracic and lumbar regions are essential for functional activities, necessitating mobility, motor control, and strength. To investigate the effectiveness of interventions directed at improving trunk muscle strength, it is essential to have valid, reliable and responsive performance based outcome measures (PBOM). Whilst isokinetic dynamometry is considered the gold standard PBOM, the associated costs, size/weight and operational complexity of this equipment preclude its use in a clinical setting. There is therefore a need to evaluate the measurement properties of alternative accessible measures of trunk strength. This systematic review therefore aims to investigate the measurement properties of PBOM of trunk muscle strength measures appropriate for use in a clinical setting.

**Methods and analysis**

This protocol has been designed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis-Protocols (PRISMA-P). CINAHL, Web of Science, Pedro, MEDLINE, EMBASE, SPORTDiscuss and the grey literature will be searched. Eligibility criteria include studies investigating measurement properties of PROM for trunk muscle strength for use in a clinical setting in adults with and without spinal musculoskeletal complaints. Two independent reviewers will determine the eligibility of the studies through screening process of titles, abstract and the full text. Both reviewers will assess the risk of bias using (CONsensus-based Standards for the selection of health status Measurement Instruments) COSMIN risk of bias tool and then extract the data from included studies. The overall quality of the included studies will be evaluated using the GRADE approach. A narrative synthesis will be carried out if meta-analysis is not applicable. Findings from this systematic review will aid clinicians and practitioners working in the field e.g. sport, in using the most appropriate PBOM to measure trunk muscle strength.

**Ethics and dissemination** No research ethics application is needed as there are no patient data in this study. The results of this study will be submitted to a peer reviewed journal and presented at conferences.

## Strengths and limitations of the study

- This is the first systematic review that will evaluate measurement properties of performance based outcome measures that are used to assess trunk muscle strength in a clinical setting.
- This study will use the consensus-based standards for the selection of health measurement instrument (COSMIN) checklist to inform and improve the selection of trunk strength outcome measures.
- The term trunk is an umbrella term to reflect all muscles in the thoracic and lumbar spine, which may limit applicability of findings to specific clinical complaints in a specific spinal region

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3 73 **INTRODUCTION**  
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5 74  
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7 75 Musculoskeletal (MSK) conditions are common, not only among elderly but among children, teenagers  
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9 76 and adults<sup>1</sup>. Back pain, neck pain, osteoarthritis and rheumatoid arthritis are considered among the  
10  
11 77 most disabling MSK conditions that affect both physical and psychological capacities of individuals <sup>2</sup>.  
12  
13 78 MSK disorders are considered the second highest contributor to years lived with disability <sup>3</sup>. Low back  
14  
15 79 pain (LBP) is the single leading cause of disability worldwide <sup>3</sup> and neck pain ranked as the fourth  
16  
17 80 highest cause of years lived with disability <sup>4</sup>. Therefore, spinal pain remains the main contributor of  
18  
19 81 global disability<sup>1</sup>. Recent data suggest that the lifetime prevalence of spinal pain is 20% to 70% for  
20  
21 82 neck pain <sup>4</sup>, 3.7 to 77% for thoracic spine pain <sup>5</sup> and 58- 84% for low back pain <sup>6</sup>. Which therefore place  
22  
23 83 great economic burden on health services globally, in the UK for instance the estimated cost of  
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25 84 managing chronic LBP alone is around £1.8- 2.3 billion <sup>7</sup>.

26  
27 85 Muscles of the trunk which includes those with attachments to both the thoracic and lumbar spines,  
28  
29 86 are central to providing mobility and stability of the spine during functional activities, including, gait  
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31 87 and daily life activities <sup>8</sup>. Research has identified that weak trunk muscles are associated with  
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33 88 exaggerated spinal curves <sup>9 10</sup>, and are a risk factor for spinal disorders <sup>11 12</sup> and risk of falling <sup>13</sup>. Several  
34  
35 89 studies have suggested that patients with spinal MSK conditions may benefit from trunk strength  
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37 90 training as essential part of the rehabilitation programs <sup>14</sup>. As a result, performance based outcome  
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39 91 measures (PBOM) of trunk muscle strength are important to evaluate patient clinical progression <sup>15</sup>  
40  
41 92 and to determine the effectiveness of therapeutic rehabilitation programs <sup>16</sup>.

42  
43 93 To evaluate trunk muscle strength, manual muscle testing <sup>17</sup>, hand-held dynamometer <sup>18</sup>, strain gauge  
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45 94 tests <sup>19</sup>, Isostation <sup>20</sup> and isokinetic test <sup>21</sup> have been described as available methods. However, the  
46  
47 95 PROM need to obtain good level of measurement properties to be clinically and scientifically useful to  
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49 96 help guide clinical decision making and treatment monitoring <sup>22 23</sup>. A measurement property is the  
50  
51 97 quality aspect of an instrument and due to variations in the terminology and definitions of these  
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53 98 measurement properties, the Consensus-based Standards for the Selection of Health Measurement  
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55 99 Instruments (COSMIN) initiative developed a consensus-based taxonomy of measurement properties  
56  
57 100 <sup>24</sup>. The aforementioned taxonomy covers the three main domain (reliability, validity and  
58  
59 101 responsiveness)<sup>25</sup>.

60  
61 102 Several literature reviews have been published summarising and critically appraising the trunk muscle  
62  
63 103 strength PBOM <sup>26-29 30 31</sup>. However, few have assessed their measurement properties. Two reviews  
64  
65 104 have evaluated the measurement properties of trunk muscle strength using Iso-machines (Isokinetic  
66  
67 105 and Isostation) <sup>28 29</sup>. Acceptable levels of reliability were reported for flexion and extension up to 120°/

sec, with limited and conflicting evidence regarding the reliability of trunk lateral bending strength<sup>29</sup>. However, conflicting evidence also exists regarding the validity of Iso-machines across both reviews<sup>28</sup><sup>29</sup>.

Other reviews have reported some measurement properties of trunk muscle strength measures in neurological conditions<sup>30,31</sup>. However, the reliability of the PBOM with one group does not necessarily generalise to another<sup>32</sup> and the value of these measures for use in a spinal MSK population is questionable<sup>33</sup>. Establishing measurement properties of any PBOM within a defined population is important to eliminate any potential bias and to have confidence in findings<sup>25</sup>. To the best of the author's knowledge, no systematic review has been published targeting the psychometric properties of the trunk muscle strength PBOM for use in a clinical setting. Therefore, a systematic review is needed to comprehensively evaluate the psychometric properties of the different clinical trunk strength outcome measures in healthy participants and patients with spinal musculoskeletal complaints. This systematic review aims to assess the measurement properties (validity, reliability and responsiveness) of trunk muscle strength PBOM for use in a clinical setting.

## **Aim**

To evaluate the measurement properties (validity, reliability and responsiveness) of the trunk muscle strength outcome measures appropriate for use in routine clinical practice.

## **METHODS**

The systematic review protocol is designed using The Cochrane Handbook for Diagnostic Test Accuracy studies and the Centre for Reviews and Dissemination<sup>34</sup> and reported in line with The Preferred Reporting Items for Systematic Reviews and Meta-Analysis-Protocols guidelines (PRISMA-P) checklist<sup>35</sup>, (See supplementary file 1). The Consensus-based Standards for the Selection of Health Measurement Instruments (COSMIN) group developed guidelines and practical tools for conducting studies on measurement properties or selecting the high-quality studies for systematic reviews on measurement properties<sup>36,37</sup>. Hence, COSMIN risk of bias checklist will be used to improve the selection of the available trunk strength outcome measures available. A registered summary of this protocol is available on International prospective register of systematic reviews (PROSPERO): CRD42020167464.



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**ELIGIBILITY CRITERIA**

**Inclusion criteria**

Eligibility criteria will include adult participants aged  $\geq 18$  years who are either healthy or experiencing any spinal musculoskeletal condition. For the purpose of this review, spinal MSK conditions will be defined based on the International Classification of Diseases as any condition that affects the spine bones, joints, muscles and associated tissues such as ligaments and tendons <sup>38</sup>. (e.g. arthritis, neck pain, thoracic pain, osteoporosis, scoliosis, low back pain etc.). Including healthy participants will help to identify the cut-off points in trunk strength measures between healthy individuals and those with spinal musculoskeletal complaints. We will include studies which have investigated any PBOM of trunk muscle strength which can be performed in a clinical or field based setting, including manual, functional and mechanical methods. Eligible studies must have evaluated one or more aspect of the main three domains of the COSMIN Taxonomy (validity, reliability and responsiveness) of measurement properties will be included <sup>25</sup>. More details on the three domains of the COSMIN Taxonomy for measurement properties can be found in Supplementary file 2. Studies must report on the evaluation of the measurement properties of PBOM of trunk muscle strength which can be done in a clinical or field based setting.

**Exclusion criteria**

Any study written in a language other than English will be excluded. Studies reporting measurement properties of PBOM which involve expensive, technical equipment or computerised instruments namely; Isokinetic and Isostation machines <sup>27</sup> and are not practical <sup>15 39</sup>, i.e. relevant for clinicians working in home-, community- or field -based settings who need portable, easy to use devices <sup>40</sup> will be excluded.

**Information sources**

A comprehensive search strategy will be developed using both medical subject headings and free text, relevant keywords identified during the scanning search. Following the Cochrane collaboration recommendations, multiple electronic databases and a subject-specific database will be searched systematically, to cover the broadest available literature. These include CINAHL and SPORTDiscuss via (EBSCO interface), MEDLINE and EMBASE through (Ovid interface), Web of Science and Pedro. Grey literature searching will be conducted as well in the main sources such as British National bibliography for report literature and open Grey.

## 172 Search strategy

173 The search strategy was developed in discussion with the supervisory team (NH, AR and DF) and a  
174 specialist librarian. Initially, the search strategy will be developed in the MEDLINE database, and then  
175 it will be adapted for each database. Specific key terms will include terms related to psychometric  
176 properties e.g. reliability, validity and responsiveness as well as terms describing the population of  
177 interest will be used. Additional search filters designed by COSMIN for retrieving studies on  
178 measurement properties will be applied where appropriate <sup>41</sup>. See example of search strategy in  
179 Supplementary file 3. Relevant studies will be identified and selected by two independent reviewers  
180 XX,XX with specialist training and knowledge in musculoskeletal rehabilitation and research methods.

## 182 Study records

## 184 Data management

185 Comprehensive search on the after mentioned databases will be carried out by the main author XX.  
186 All search results will be exported and stored on EndNote Version X9 (Clarivate analytics) software  
187 programme. This will allow any duplicates to be identified and subsequently removed as well as  
188 storing of abstract and full texts.

## 189 Selection process

190 Secondary to searching process, two reviewers XX,XX will independently screen titles and abstract  
191 based on pre-identified eligibility criteria and will subcategorise the identified studies into include/  
192 exclude/ unsure <sup>42</sup>. The second step comprises retrieving and reading the full text of potentially  
193 relevant articles which will then be independently examined by each reviewer against the eligibility  
194 criteria. If further information needed, authors will be contacted via email. Agreement between both  
195 reviewers is required for the study to be included in the review. Therefore, agreement will be assess  
196 using Cohen's kappa (k) statistic Disagreement will be resolved by consensus or by the decision of a  
197 third reviewer XX <sup>43</sup>. Information regarding the excluded studies and the reason for exclusion will be  
198 reported using PRISMA flow chart.

## 199 Data collection process

200 For each included study, a standard form will be used to extract the data. To ensure all the relevant  
201 information is captured, piloting the data collection form will be conducted. Both reviewers will  
202 independently extract the data using the standardised form, the authors will be contacted for more  
203 clarification or if there is any missing data. In case of disagreement about extracted data between  
204 reviewers, discussion and/or involving a third reviewer XX will be carried out until consensus reached.

**Data items**

**Table 1** summarise the relevant data to be extracted from included studies

**Table 1: Summary of data to be extracted from included studies**

Content	Data items
Bibliographic data	Authors, year of publication
Study characteristics	Study design, sample size
Setting	Country, setting of measurement
participants characteristics	Age, gender, healthy or with spinal musculoskeletal condition.
Outcome measures	Trunk muscle strength measures. Type of muscle contraction measured. Measurement procedure: warm-up, participants' position, fixation, examiner position (if any), line of force (resistance), cool down.
Measurement properties	Measurement properties (reliability, validity and responsiveness), statistical methods used and results.

**Risk of bias in individual studies**

The COSMIN Risk of Bias checklist for systematic reviews will be used to evaluate the risk of bias of included studies in this review <sup>44</sup>. The COSMIN Risk of Bias Checklist considered to have adequate reliability as it is developed from the original COSMIN tool which show high percentage inter-rater agreement <sup>45</sup>. The COSMIN Risk of Bias checklist includes standards for both design and the preferred statistical methods for each measurement property. The checklist covers nine different dimensions of reliability, validity and responsiveness. The COSMIN checklist was originally designed to evaluate patient reported outcome measures (PROM). However, the COSMIN group have recommended adaptation of the tool for use with other types of measures such as clinician-reported outcome measures or PBOM <sup>41</sup>. As with the study selection process, two raters will independently score each study as either 'very good', 'adequate', 'doubtful', or 'inadequate' quality <sup>44</sup>. Any disagreement between the reviewers will be resolved through discussion, if no consensus can be reached, a third reviewer will be consulted.

## Data synthesis

Depending on the heterogeneity of included studies, either a meta-analysis or narrative synthesis will be conducted to synthesise the results which will follow the COSMIN guidelines for systematic reviews<sup>44</sup>. Following the assessment of scoping searches of the currently available literature, pooling of data might not be possible due to an anticipated lack of homogeneity for the reference standard, designs and populations of included studies. However, a meta-analysis will be conducted if the study design, population, and reference standard are homogenous. If a meta-analysis is not possible due to data heterogeneity, a narrative synthesis will be conducted in line with the narrative synthesis in systematic reviews recommendation<sup>46</sup>. The results will be pooled for each measurement property and rated as; sufficient (+), insufficient (-), inconsistent ( $\pm$ ) or indeterminate (?)<sup>44</sup>.

## Confidence in cumulative evidence

The overall quality of evidence regarding the measurement properties will then be assessed using a modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. As recommended by COSMIN guidelines for systematic review, a modified GRADE approach will be used to assess how the pooled results from included studies are trustworthy<sup>36</sup>. The quality of evidence will be determined using four factors from the GRADE approach: risk of bias, inconsistency, imprecision and indirectness. Following the COSMIN recommendation, the fifth factor, i.e. publication bias will not be used due to lack of registry data on measurement properties studies.

## Patient and public involvement

The study question and systematic review protocol were informed following many years of working with patients and clinical experiences of managing patients with spinal dysfunction. The question was informed following discussions with patient and public involvement meeting at the XXXXXXXXXXXX and specifically in light our earlier research investigating measurement properties of PBOM for spinal mobility. The group consist individuals with different musculoskeletal and spinal complaints. Since no patient data is needed, patients will not be involved in data collection or analysis. However, the results of the study will be shared at public engagement events.

## Clinical implications of this study

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3 259 By accurately measuring the trunk muscles strength, diagnosis of dysfunction as well as improvement can be  
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5 260 monitored. Also, with the current assessment methods available to measure trunk strength, finding a valid,  
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7 261 reliable and responsive tool as well as cost-effective for clinical use is a priority. Noteworthy, with the vast  
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9 262 range of different test procedures and positions used, this review will summarise data regarding the  
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11 263 measurement properties of different assessment methods and highlight the method which is superior in terms  
12  
13 264 of psychometric properties, cost-effectiveness and time-saving. In doing so, healthcare professionals will be  
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15 265 aware of the valid method to use within the clinical setting to assess the effectiveness of interventions directed  
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17 266 to improve muscular function. Using accurate and objective muscle strength measures will facilitate the  
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19 267 monitoring of rehabilitation program efficacy and effectiveness of targeted interventions to improve trunk  
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21 268 muscle strength.  
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25 271 **Ethics and Dissemination**  
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27 273 No patient data will be collected, hence, no ethical approval needed for this systematic review. The results of  
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29 274 this review will help to inform current healthcare practice and research on the most valid, reliable and  
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31 275 responsive tool for measuring trunk muscle strength. Results of this review will be submitted to be published  
32  
33 276 in a peer-review journal and presented at relevant conferences.  
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36 278 **DECLARATIONS**

37 279 **Ethics and Dissemination**

38 280 No ethical approval is required for this systematic review. The findings from this systematic review  
39  
40 281 will be published in peer reviewed journals and disseminated to key stakeholders in disability sport.

41  
42 282 **Author Contributions**

43  
44 283 SA is an PhD student at the University of Birmingham. NH, AR and DF are supervisors. NH is expert in  
45  
46 284 the field of thoracic spine outcome measurement methods. SA, NH, AR and DF contributed to the  
47  
48 285 systematic review topic. SA drafted the protocol with guidance and feedback from NH, AR and DF. NH,  
49  
50 286 AR and DF reviewed the manuscript and commented on the protocol. All authors have approved and  
51  
52 287 contributed to the final manuscript.

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55  
56 290 profit sectors

57 291 **Competing interests**

58  
59 292 None declared.  
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## 293 Provenance and peer review

294 Not commissioned; externally peer reviewed.

## 295 Patient consent for publication

296 Not required.

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Supplementary file 1:

PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols) 2015 checklist: recommended items to address in a systematic review protocol\*

Section and topic	Item No	Checklist item	Page Number
ADMINISTRATIVE INFORMATION			
Title:			
Identification	1a	Identify the report as a protocol of a systematic review	1
Update	1b	If the protocol is for an update of a previous systematic review, identify as such	
Registration	2	If registered, provide the name of the registry (such as PROSPERO) and registration number	6
Authors:			
Contact	3a	Provide name, institutional affiliation, e-mail address of all protocol authors; provide physical mailing address of corresponding author	1
Contributions	3b	Describe contributions of protocol authors and identify the guarantor of the review	
Amendments	4	If the protocol represents an amendment of a previously completed or published protocol, identify it such and list changes; otherwise, state plan for documenting important protocol amendments	N/A
Support:			
Sources	5a	Indicate sources of financial or other support for the review	11
Sponsor	5b	Provide name for the review funder and/or sponsor	
Role of sponsor or funder	5c	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol	
INTRODUCTION			
Rationale	6	Describe the rationale for the review in the context of what is already known	4,5
Objectives	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	5
METHODS			
Eligibility criteria	8	Specify the study characteristics (such as PICO, study design, setting, time frame) and report characteristics (such as years considered, language, publication status) to be used as criteria for eligibility for the review	5,6
Information	9	Describe all intended information sources (such as electronic databases, contact with study authors, trial registers or other	7

sources		grey literature sources) with planned dates of coverage	
Search strategy	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated	7
Study records:			
Data management	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review	8
Selection process	11b	State the process that will be used for selecting studies (such as two independent reviewers) through each phase of the review (that is, screening, eligibility and inclusion in meta-analysis)	8
Data collection process	11c	Describe planned method of extracting data from reports (such as piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators	8
Data items	12	List and define all variables for which data will be sought (such as PICO items, funding sources), any pre-planned data assumptions and simplifications	8,9
Outcomes and prioritization	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale	N/A
Risk of bias in individual studies	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis	9
Data synthesis	15a	Describe criteria under which study data will be quantitatively synthesised	
	15b	If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data and methods of combining data from studies, including any planned exploration of consistency (such as $\tau^2$ , Kendall's $\tau$ )	9,10
	15c	Describe any proposed additional analyses (such as sensitivity or subgroup analyses, meta-regression)	
	15d	If quantitative synthesis is not appropriate, describe the type of summary planned	
Meta-bias(es)	16	Specify any planned assessment of meta-bias(es) (such as publication bias across studies, selective reporting within studies)	10
Confidence in cumulative evidence	17	Describe how the strength of the body of evidence will be assessed (such as GRADE)	10

**\* It is strongly recommended that this checklist be read in conjunction with the PRISMA-P Explanation and Elaboration (cite when available) for important clarification on the items. Amendments to a review protocol should be tracked and dated. The copyright for PRISMA-P (including checklist) is held by the PRISMA-P Group and is distributed under a Creative Commons Attribution Licence 4.0.**

*From: Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart L, PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015 Jan 2;349(jan02 1):g7647.*

Supplementary file 2: COSMIN Definitions

COSMIN Taxonomy for measurement property (definitions)<sup>1</sup>

Term			Definition
Domain	Measurement property	Aspects of measurement property	
Reliability			The degree to which the measurement is free from measurement error.
Reliability (extended definition)			The extent to which scores for patients who have not changed are the same for repeated measurement under several conditions: e.g. using different sets of items from the same PROM (internal consistency); over time (test-retest); by different persons on the same occasion (inter-rater); or by the same persons (i.e. raters or responders) on different occasions (intra-rater).
	Internal consistency		The degree of the interrelatedness among the items.
	Reliability		The proportion of the total variance in the measurements which is due to 'true'+ differences between patients.
	Measurement error		The systematic and random error of a patient's score that is not attributed to true changes in the construct to be measured.
Validity			The degree to which a PROM measures the construct(s) it purports to measure
	Content validity		The degree to which the content of a PROM is an adequate reflection of the construct to be measured.
		Face validity	The degree to which (the items of) a PROM indeed looks as though they are an adequate reflection of the construct to be measured
	Construct validity		The degree to which the scores of a PROM are consistent with hypotheses (for instance with regard to internal relationships, relationships to scores of other instruments, or differences between relevant groups) based on the assumption that the PROM validly measures the construct to be measured.
		Structural validity	The degree to which the scores of a PROM are an adequate reflection of the dimensionality of the construct to be measured.

		Hypotheses testing	Idem construct validity
		Cross-cultural validity	The degree to which the performance of the items on a translated or culturally adapted PROM are an adequate reflection of the performance of the items of the original version of the PROM.
	Criterion validity		The degree to which the scores of a PROM are an adequate reflection of a 'gold standard'.
<b>Responsiveness</b>			The ability of a PROM to detect change over time in the construct to be measured.
	Responsiveness		Idem responsiveness
<b>Interpretability</b>			Interpretability is the degree to which one can assign qualitative meaning - that is, clinical or commonly understood connotations – to a PROM's quantitative scores or change in scores.

† The word 'true' must be seen in the context of the CTT, which states that any observation is composed of two components – a true score and error associated with the observation. 'True' is the average score that would be obtained if the scale were given an infinite number of times. It refers only to the consistency of the score, and not to its accuracy (22) \* Interpretability is not considered a measurement property, but an important characteristic of a measurement instrument

## References:

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**Supplementary file 3:**

**Example of MEDLINE search strategy 1948– March 2020**

MEDLINE (Ovid interface) search strategy
<div>1. Trunk musc* strength.ti,ab.</div> <div>2. Trunk musc* power.ti,ab.</div> <div>3. Trunk musc* torque.ti,ab.</div> <div>4. Torso strength.ti,ab.</div> <div>5. Torso power.ti,ab.</div> <div>6. Isometric trunk strength.ti,ab.</div> <div>7. Isotonic trunk strength.ti,ab.</div> <div>8. Static trunk strength.ti,ab.</div> <div>9. Back musc* strength.ti,ab.</div> <div>10. Back exten* strength.ti,ab.</div> <div>11. Lumbar exten* strength.ti,ab.</div> <div>12. Lumbar exten* torque.ti,ab.</div> <div>13. Abdomin\$ musc* strength.ti,ab.</div> <div>14. Trunk Max* contract*.ti,ab.</div> <div>15. Trunk MVC.ti,ab.</div> <div>16. Trunk flex* strength.ti,ab.</div> <div>17. Trunk flex* power.ti,ab.</div> <div>18. Trunk flex* torque.ti,ab.</div> <div>19. Trunk forward bend* strength.ti,ab.</div> <div>20. Trunk forward bend* power.ti,ab.</div> <div>21. Trunk forward bend* tourque.ti,ab.</div> <div>22. Trunk extens\$ strength.ti,ab.</div> <div>23. Trunk extens\$ power.ti,ab.</div> <div>24. Trunk extens\$ torque.ti,ab.</div> <div>25. (Trunk rota* strength or Trunk rota* power or Trunk rota* torque).ti,ab.</div> <div>26. (Trunk lateral\$ flex* strength or Trunk lateral\$ flex* power or Trunk lateral\$ flex* torque).ti,ab.</div> <div>27. (Trunk lateral\$ bend* strength* or Trunk lateral\$ bend* power or Trunk lateral\$ bend* torque).ti,ab.</div> <div>28. (core strength or core power or core torque).ti,ab.</div> <div>29. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28</div> <div>30. (Spinal musculoskeletal pain or musculoskeletal disease or musculoskeletal dysfunction* or spin* MUSCU* pain).ti,ab.</div> <div>31. (Low* back pain or LBP or Chronic Low* back pain or CLBP).ti,ab.</div> <div>32. (lumbago or dorsalgia).ti,ab.</div> <div>33. back disorder\$.ti,ab.</div> <div>34. (lumbar adj pain).ti,ab.</div> <div>35. (slipped adj disc).ti,ab.</div> <div>36. (slipped adj disk).ti,ab.</div> <div>37. (prolap* adj disc).ti,ab.</div> <div>38. (prolap* adj disk).ti,ab.</div> <div>39. Spin*osteoarthrit\$.ti,ab.</div> <div>40. Spine osteoarthrit\$.ti,ab.</div> <div>41. spine spondylitis.ti,ab.</div>

42. spine spondylosis.ti,ab.
43. (spine degenerative adj joint adj disease).ti,ab.
44. (Neck pain or Cervical pain or Chronic neck pain or CNP or cervicogenic).ti,ab.
45. (Thoracic spine pain or Mid back pain).ti,ab.
46. (Healthy adult\* or Normal adult\* or A symptomatic adult\* or Physically active adult\* or Athlete\*).ti,ab.
47. 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46
48. (Performance-based tool\* or performance-based test\* or Clinical-based tool\*).ti,ab.
49. (field- based test\* or Assessment).ti,ab.
50. (Quantitative assessment or measurement\* or evaluate\$).ti,ab.
51. (instrument\$ or tool\* or test\$).ti,ab.
52. (Manual\* musc\* test\$ or MMT).ti,ab.
53. (mechanic\* or Hand-held dynamometer\* or HHD or Strain-gauge test\*).ti,ab.
54. 48 or 49 or 50 or 51 or 52 or 53
55. 29 and 47 and 54
56. (Validation Studies or Comparative Study).pt.
57. exp Psychometrics/
58. psychometr\*.ti,ab.
59. (clinimetr\* or clinometr\*).tw.
60. outcome assessment.ti,ab. or outcome measure\*.tw. or exp Observer Variation/ or observer variation.ti,ab.
61. exp Health Status Indicators/
62. exp Reproducibility of Results/
63. reproducib\*.ti,ab.
64. exp Discriminant Analysis/
65. (reliab\* or unreliab\* or valid\* or coefficient or homogeneity or homogeneous or internal consistency).ti,ab.
66. (cronbach\* and (alpha or alphas)).ti,ab.
67. (item and (correlation\* or selection\* or reduction\*)).ti,ab.
68. (agreement or precision or imprecision or precise values or test-retest).ti,ab.
69. (test and retest).ti,ab.
70. (reliab\* and (test or retest)).ti,ab.
71. (stabil\* or interrater or intrarater or intrarater or intertester or intratester or interobserver or interobserver or intraobserver or intertechnician or intratechnician or interexaminer or intraexaminer or interassay or intraassay or interindividual or intraindividual or interparticipant or intraparticipant or kappa or kappas or repeatab\*).ti,ab.
72. ((replicab\* or repeated) and (measure or measures or findings or result or results or test or tests)).ti,ab.
73. (generaliza\* or generalisa\* or concordance).ti,ab.
74. (intraclass and correlation\*).ti,ab.
75. (item discriminant or interscale correlation\* or error or errors).mp. or individual variability.ti,ab. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
76. variability.mp. and (analysis or values).ti,ab. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
77. (uncertainty and (measurement or measuring)).ti,ab.

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78. (standard error of measurement or sensitiv\* or responsive\*).ti,ab.

79. ((minimal or minimally or clinical or clinically) and (important or significant or detectable) and (change or difference)).ti,ab.

80. (small\* and (real or detectable) and (change or difference)).ti,ab.

81. 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80

82. 55 and 81

83. limit 82 to English language

For peer review only

# BMJ Open

## Measures of trunk muscle strength and their measurement properties: a protocol for a systematic review and narrative synthesis of clinical measures

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<b>Primary Subject Heading</b>:	Rehabilitation medicine
Secondary Subject Heading:	Rehabilitation medicine, Sports and exercise medicine
Keywords:	Spine < ORTHOPAEDIC & TRAUMA SURGERY, Rehabilitation medicine < INTERNAL MEDICINE, SPORTS MEDICINE

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**Measures of trunk muscle strength and their measurement properties: a protocol for a systematic review and narrative synthesis of clinical measures**

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**Abstract**

**Introduction**

Spinal musculoskeletal conditions, including low back and neck pain are leading causes of disability globally. The trunk muscles, which comprise muscles in the thoracic and lumbar regions are essential for functional activities, necessitating mobility, motor control, and strength. To investigate the effectiveness of interventions directed at improving trunk muscle strength, it is essential to have valid, reliable and responsive performance-based outcome measures (PBOM). Whilst isokinetic dynamometry is considered the gold standard PBOM, the associated costs, size/weight and operational complexity of this equipment preclude its use in a clinical setting. There is therefore a need to evaluate the measurement properties of alternative accessible measures of trunk strength. This systematic review therefore aims to investigate the measurement properties of PBOM of trunk muscle strength measures appropriate for use in a clinical setting.

**Methods and analysis**

This protocol has been designed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis-Protocols (PRISMA-P). CINAHL, Web of Science, Pedro, MEDLINE, EMBASE, SPORTDiscuss will be searched systematically from the database start date up to April 16, 2020, along with reference checking and the grey literature searching. Eligibility criteria include studies investigating measurement properties of PROM for trunk muscle strength for use in a clinical setting in adults with and without spinal musculoskeletal complaints. Two independent reviewers will determine the eligibility of the studies through screening process of titles, abstract and the full text. Both reviewers will assess the risk of bias using (Consensus-based Standards for the selection of health status Measurement Instruments) COSMIN risk of bias tool and then extract the data from included studies. The overall quality of the included studies will be evaluated using the GRADE approach. A narrative synthesis will be carried out if meta-analysis is not applicable. Findings from this systematic review will aid clinicians and practitioners working in the field e.g. sport, in using the most appropriate PBOM to measure trunk muscle strength.

**Ethics and dissemination** No research ethics application is needed as there are no patient data in this study. The results of this study will be submitted to a peer reviewed journal and presented at conferences.

## Strengths and limitations of the study

- This is the first systematic review that will evaluate measurement properties of performance-based outcome measures, which will inform the selection of most reliable, valid and responsive tool to assess trunk muscle strength in a clinical setting.
- This study will use the consensus-based standards for the selection of health measurement instrument (COSMIN) checklist, which therefore will improve the selection of trunk strength outcome measures in research and clinical practice.
- The term trunk is an umbrella term to reflect all muscles in the thoracic and lumbar spine, which may limit applicability of findings to specific clinical complaints in a specific spinal region.

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3 75 **INTRODUCTION**  
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7 77 Musculoskeletal (MSK) conditions are common, not only among elderly but among children, teenagers  
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9 78 and adults<sup>1</sup>. Back pain, neck pain, osteoarthritis and rheumatoid arthritis are considered among the  
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11 79 most disabling MSK conditions that affect both physical and psychological capacities of individuals <sup>2</sup>.  
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13 80 MSK disorders are considered the second highest contributor to years lived with disability <sup>3</sup>. Low back  
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15 81 pain (LBP) is the single leading cause of disability worldwide <sup>3</sup> and neck pain ranked as the fourth  
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17 82 highest cause of years lived with disability <sup>4</sup>. Therefore, spinal pain remains the main contributor of  
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19 83 global disability<sup>1</sup>. Recent data suggest that the lifetime prevalence of spinal pain is 20% to 70% for  
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21 84 neck pain <sup>4</sup>, 3.7 to 77% for thoracic spine pain <sup>5</sup> and 58- 84% for low back pain <sup>6</sup>, which place great  
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23 85 economic burden on health services globally. In the UK, for instance, the estimated cost of managing  
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25 86 chronic LBP alone is around £1.8- 2.3 billion <sup>7</sup>.

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27 87 Muscles of the trunk which includes those with attachments to both the thoracic and lumbar spines,  
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29 88 are central to providing mobility and stability of the spine during functional activities, including, gait  
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31 89 and daily life activities <sup>8</sup>. Research has identified that weak trunk muscles are associated with  
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33 90 exaggerated spinal curves <sup>9 10</sup>, and are a risk factor for spinal disorders <sup>11 12</sup> and risk of falling <sup>13</sup>. Several  
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35 91 studies have suggested that patients with spinal MSK conditions may benefit from trunk strength  
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37 92 training as essential part of the rehabilitation programs <sup>14</sup>. As a result, performance based outcome  
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39 93 measures (PBOM) of trunk muscle strength are important to evaluate patient clinical progression <sup>15</sup>  
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41 94 and to determine the effectiveness of therapeutic rehabilitation programs <sup>16</sup>.

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43 95 To evaluate trunk muscle strength, manual muscle testing <sup>17</sup>, hand-held dynamometer <sup>18</sup>, strain gauge  
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45 96 tests <sup>19</sup>, Isostation <sup>20</sup> and isokinetic test <sup>21</sup> have been described as available methods. However, the  
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47 97 PROM need to obtain good level of measurement properties to be clinically and scientifically useful to  
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49 98 help guide clinical decision making and treatment monitoring <sup>22 23</sup>. A measurement property is the  
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51 99 quality aspect of an instrument and due to variations in the terminology and definitions of these  
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53 100 measurement properties, the Consensus-based Standards for the Selection of Health Measurement  
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55 101 Instruments (COSMIN) initiative developed a consensus-based taxonomy of measurement properties  
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57 102 <sup>24</sup>. The aforementioned taxonomy covers the three main domain (reliability, validity and  
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59 103 responsiveness)<sup>25</sup>.

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61 104 Several literature reviews have been published summarising and critically appraising the trunk muscle  
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63 105 strength PBOM <sup>26-29 30 31</sup>. However, few have assessed their measurement properties. Two reviews  
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65 106 have evaluated the measurement properties of trunk muscle strength using Iso-machines (Isokinetic  
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67 107 and Isostation) <sup>28 29</sup>. Acceptable levels of reliability were reported for flexion and extension up to 120°/

sec, with limited and conflicting evidence regarding the reliability of trunk lateral bending strength<sup>29</sup>. However, conflicting evidence also exists regarding the validity of Iso-machines across both reviews<sup>28</sup><sup>29</sup>.

Other reviews have reported some measurement properties of trunk muscle strength measures in neurological conditions<sup>30,31</sup>. However, the reliability of the PBOM with one group does not necessarily generalise to another<sup>32</sup> and the value of these measures for use in a spinal MSK population is questionable<sup>33</sup>. Establishing measurement properties of any PBOM within a defined population is important to eliminate any potential bias and to have confidence in findings<sup>25</sup>. To the best of the author's knowledge, no systematic review has been published targeting the psychometric properties of the trunk muscle strength PBOM for use in a clinical setting. Therefore, a systematic review is needed to comprehensively evaluate the psychometric properties of the different clinical trunk strength outcome measures in healthy participants and patients with spinal musculoskeletal complaints. This systematic review aims to assess the measurement properties (validity, reliability and responsiveness) of trunk muscle strength PBOM for use in a clinical setting.

## **Aim**

To evaluate the measurement properties (validity, reliability and responsiveness) of the trunk muscle strength outcome measures appropriate for use in routine clinical practice.

## **METHODS**

The systematic review protocol is designed using The Cochrane Handbook for Diagnostic Test Accuracy studies and the Centre for Reviews and Dissemination<sup>34</sup> and reported in line with The Preferred Reporting Items for Systematic Reviews and Meta-Analysis-Protocols guidelines (PRISMA-P) checklist<sup>35</sup>, (See supplementary file 1). The Consensus-based Standards for the Selection of Health Measurement Instruments (COSMIN) group developed guidelines and practical tools for conducting studies on measurement properties or selecting the high-quality studies for systematic reviews on measurement properties<sup>36,37</sup>. Hence, COSMIN risk of bias checklist will be used to improve the selection of the available trunk strength outcome measures available. A registered summary of this protocol is available on International prospective register of systematic reviews (PROSPERO): CRD42020167464.

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**ELIGIBILITY CRITERIA**

**Inclusion criteria**

Eligibility criteria will include adult participants aged  $\geq 18$  years who are either healthy or experiencing any spinal musculoskeletal condition. For the purpose of this review, spinal MSK conditions will be defined based on the International Classification of Diseases as any condition that affects the spine bones, joints, muscles and associated tissues such as ligaments and tendons <sup>38</sup>. (e.g. arthritis, neck pain, thoracic pain, osteoporosis, scoliosis, low back pain etc.). Including healthy participants will help to identify the cut-off points in trunk strength measures between healthy individuals and those with spinal musculoskeletal complaints. We will include studies which have investigated any PBOM of trunk muscle strength performed in a clinical or field-based setting, including manual, functional and mechanical methods. Eligible studies must have evaluated one or more aspect of the main three domains of the COSMIN Taxonomy (validity, reliability and responsiveness) of measurement properties will be included <sup>25</sup>. More details on the three domains of the COSMIN Taxonomy for measurement properties can be found in Supplementary file 2. Studies must report on the evaluation of the measurement properties of PBOM of trunk muscle strength which can be done in a clinical or field-based setting.

**Exclusion criteria**

Any study written in a language other than English will be excluded. Studies reporting measurement properties of PBOM which involve expensive, technical equipment or computerised instruments namely; Isokinetic and Isostation machines <sup>27</sup> and are not practical <sup>15 39</sup>, i.e. relevant for clinicians working in home-, community- or field -based settings who need portable, easy to use devices <sup>40</sup> will be excluded.

**Information sources**

A comprehensive search strategy will be developed using both medical subject headings and free text, relevant keywords identified during the scanning search. Following the Cochrane collaboration recommendations, multiple electronic databases and a subject-specific database will be searched systematically, to cover the broadest available literature. These include CINAHL and SPORTDiscuss via (EBSCO interface), MEDLINE and EMBASE through (Ovid interface), Web of Science and Pedro. The search was from the database start date up to April 16, 2020, with no restrictions to the publication time frame although only articles published in English was included in this review. Hand searching through checking reference lists and grey literature searching through the main sources such as British National bibliography for report literature and open Grey will be conducted as well.

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### 176 **Search strategy**

177 The search strategy was developed in discussion with the supervisory team (NH, AR and DF) and a  
178 specialist librarian. Initially, the search strategy will be developed in the MEDLINE database, and then  
179 it will be adapted for each database. Specific key terms will include terms related to psychometric  
180 properties e.g. reliability, validity and responsiveness as well as terms describing the population of  
181 interest will be used. Additional search filters designed by COSMIN for retrieving studies on  
182 measurement properties will be applied where appropriate <sup>41</sup>. See example of search strategy in  
183 Supplementary file 3. Relevant studies will be identified and selected by two independent reviewers  
184 SA and AA with specialist training and knowledge in musculoskeletal rehabilitation and research  
185 methods.

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### 187 **Study records**

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### 189 **Data management**

190 Comprehensive search on the after mentioned databases will be carried out by the main author SA.  
191 All search results will be exported and stored on EndNote Version X9 (Clarivate analytics) software  
192 programme. This will allow any duplicates to be identified and subsequently removed as well as  
193 storing of abstract and full texts.

### 194 **Selection process**

195 Secondary to searching process, two reviewers SA and AA will independently screen titles and abstract  
196 based on pre-identified eligibility criteria and will subcategorise the identified studies into include/  
197 exclude/ unsure <sup>42</sup>. The second step comprises retrieving and reading the full text of potentially  
198 relevant articles which will then be independently examined by each reviewer against the eligibility  
199 criteria. If further information needed, authors will be contacted via email. Agreement between both  
200 reviewers is required for the study to be included in the review. Therefore, agreement will be assess  
201 using Cohen's kappa (k) statistic Disagreement will be resolved by consensus or by the decision of a  
202 third reviewer NH <sup>43</sup>. Information regarding the excluded studies and the reason for exclusion will be  
203 reported using PRISMA flow chart.

### 204 **Data collection process**

205 For each included study, a standard form will be used to extract the data. To ensure all the relevant  
206 information is captured, piloting the data collection form will be conducted. Both reviewers SA and



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AA will independently extract the data using the standardised form, the authors will be contacted for more clarification or if there is any missing data. In case of disagreement about extracted data between reviewers, discussion and/or involving a third reviewer (NH) will be carried out until consensus reached.

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**Data items**

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**Table 1** summarise the relevant data to be extracted from included studies

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**Table 1: Summary of data to be extracted from included studies**

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Content	Data items
Bibliographic data	Authors, year of publication
Study characteristics	Study design, sample size
Setting	Country, setting of measurement
participants characteristics	Age, gender, healthy or with spinal musculoskeletal condition.
Outcome measures	Trunk muscle strength measures. Type of muscle contraction measured. Measurement procedure: warm-up, participants' position, fixation, examiner position (if any), line of force (resistance), cool down.
Measurement properties	Measurement properties (reliability, validity and responsiveness), statistical methods used and results.

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**Risk of bias in individual studies**

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The COSMIN Risk of Bias checklist for systematic reviews will be used to evaluate the risk of bias of included studies in this review <sup>44</sup>. The COSMIN Risk of Bias Checklist considered to have adequate reliability as it is developed from the original COSMIN tool which show high percentage inter-rater agreement <sup>45</sup>. The COSMIN Risk of Bias checklist includes standards for both design and the preferred statistical methods for each measurement property. The checklist covers nine different dimensions of reliability, validity and responsiveness. The COSMIN checklist was originally designed to evaluate patient reported outcome measures (PROM). However, the COSMIN group have recommended adaptation of the tool for use with other

types of measures such as clinician-reported outcome measures or PBOM<sup>41</sup>. As with the study selection process, two raters SA and AA will independently score each outcome measure as either 'very good', 'adequate', 'doubtful', or 'inadequate' quality<sup>44</sup>. Any disagreement between the reviewers will be resolved through discussion, if no consensus can be reached, a third reviewer will be consulted.

## Data synthesis

Depending on the heterogeneity of included studies, either a meta-analysis or narrative synthesis will be conducted to synthesise the results which will follow the COSMIN guidelines for systematic reviews<sup>44</sup>. The results from different studies on single measurement property will be quantitatively pooled in meta-analysis if sufficient number of studies share the same reference standard, designs, population and measure the same movement. To find the estimate of test re-test reliability, standard generic inverse variance random effects model will be implemented to calculate the weighted mean interclass correlation coefficients (ICCs) and 95% confidence intervals. For construct validity, all correlations of PBOM with other PBOM that measure the same construct will be pooled<sup>44</sup>. Following the assessment of scoping searches of the currently available literature, pooling of data might not be possible due to an anticipated lack of homogeneity. Hence, a narrative synthesis will be conducted in line with the narrative synthesis in systematic reviews recommendation<sup>46</sup>. Synthesis will bring together evidence of measures of trunk strength, summary table will be generated to illustrates the pooled results per each measurement property per outcome measure per movement and rated against the updated criteria for good measurement properties as; sufficient (+), insufficient (-), inconsistent ( $\pm$ ) or indeterminate (?)<sup>44</sup>. Further analysis of the results will be presented in the discussion section in line with the quality of evidence.

## Meta-bias

To eliminate any chance of publication bias, grey literature and conference papers will be searched.

## Confidence in cumulative evidence

The overall quality of evidence regarding the measurement properties will then be assessed using a modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. As recommended by COSMIN guidelines for systematic review, a modified GRADE approach will be used to assess how the pooled results from included studies are trustworthy<sup>36</sup>. The quality of evidence will be determined using four factors from the GRADE approach: risk of bias, inconsistency, imprecision and indirectness. Following the COSMIN recommendation, the fifth factor, i.e. publication bias will not be used due to lack of registry data on measurement properties studies.

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4 262 **Patient and public involvement**  
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8 264 The study question and systematic review protocol were informed following many years of working  
9 265 with patients and clinical experiences of managing patients with spinal dysfunction. The question was  
10 266 informed following discussions with patient and public involvement meeting at the Centre of Precision  
11 267 Rehabilitation for Spinal Pain (CPR Spine) and specifically in light our earlier research investigating  
12 268 measurement properties of PBOM for spinal mobility. The group consist individuals with different  
13 269 musculoskeletal and spinal complaints. Since no patient data is needed, patients will not be involved  
14 270 in data collection or analysis. However, the results of the study will be shared at public engagement  
15 271 events.

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22 273 **Clinical implications of this study**  
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24 275 By accurately measuring the trunk muscles strength, diagnosis of dysfunction as well as improvement can be  
25 276 monitored. Also, with the current assessment methods available to measure trunk strength, finding a valid,  
26 277 reliable and responsive tool as well as cost-effective for clinical use is a priority. Noteworthy, with the vast  
27 278 range of different test procedures and positions used, this review will summarise data regarding the  
28 279 measurement properties of different assessment methods and highlight the method which is superior in terms  
29 280 of psychometric properties, cost-effectiveness and time-saving. In doing so, healthcare professionals will be  
30 281 aware of the valid method to use within the clinical setting to assess the effectiveness of interventions directed  
31 282 to improve muscular function. Using accurate and objective muscle strength measures will facilitate the  
32 283 monitoring of rehabilitation program efficacy and effectiveness of targeted interventions to improve trunk  
33 284 muscle strength.

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36 287 **Ethics and Dissemination**  
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38 289 No patient data will be collected, hence, no ethical approval needed for this systematic review. The results of  
39 290 this review will help to inform current healthcare practice and research on the most valid, reliable and  
40 291 responsive tool for measuring trunk muscle strength. Results of this review will be submitted to be published  
41 292 in a peer-review journal and presented at relevant conferences.

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43 294 **DECLARATIONS**  
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46 297 **Ethics and Dissemination**  
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No ethical approval is required for this systematic review. The findings from this systematic review will be published in peer reviewed journals and disseminated to key stakeholders in disability sport.

### Author Contributions

SA is a PhD student at the University of Birmingham. NH, AR and DF are supervisors. NH and AR have expertise in the field of outcome measurement methods. SA, NH, AR and DF contributed to the systematic review topic. SA drafted the protocol with guidance and feedback from NH, AR and DF. NH, AR and DF reviewed the manuscript and commented on the protocol and AA is an PhD student work as a second reviewer. All authors have approved and contributed to the final manuscript.

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### Competing interests

None declared.

### Provenance and peer review

Not commissioned; externally peer reviewed.

### Patient consent for publication

Not required.

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## Supplementary file 1:

### PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols) 2015 checklist: recommended items to address in a systematic review protocol\*

Section and topic	Item No	Checklist item	Page Number
<b>ADMINISTRATIVE INFORMATION</b>			
Title:			
Identification	1a	Identify the report as a protocol of a systematic review	1
Update	1b	If the protocol is for an update of a previous systematic review, identify as such	
Registration	2	If registered, provide the name of the registry (such as PROSPERO) and registration number	1
Authors:			
Contact	3a	Provide name, institutional affiliation, e-mail address of all protocol authors; provide physical mailing address of corresponding author	1
Contributions	3b	Describe contributions of protocol authors and identify the guarantor of the review	
Amendments	4	If the protocol represents an amendment of a previously completed or published protocol, identify such and list changes; otherwise, state plan for documenting important protocol amendments	N/A
Support:			
Sources	5a	Indicate sources of financial or other support for the review	11
Sponsor	5b	Provide name for the review funder and/or sponsor	
Role of sponsor or funder	5c	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol	
<b>INTRODUCTION</b>			
Rationale	6	Describe the rationale for the review in the context of what is already known	4,5
Objectives	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	5
<b>METHODS</b>			
Eligibility criteria	8	Specify the study characteristics (such as PICO, study design, setting, time frame) and report characteristics (such as years considered, language, publication status) to be used as criteria for eligibility for the review	6
Information	9	Describe all intended information sources (such as electronic databases, contact with study authors, trial registers or other	6



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sources		grey literature sources) with planned dates of coverage		
Search strategy	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated		7
Study records:				
Data management	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review		7
Selection process	11b	State the process that will be used for selecting studies (such as two independent reviewers) through each phase of the review (that is, screening, eligibility and inclusion in meta-analysis)		7
Data collection process	11c	Describe planned method of extracting data from reports (such as piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators		7,8
Data items	12	List and define all variables for which data will be sought (such as PICO items, funding sources), any pre-planned data assumptions and simplifications		8
Outcomes and prioritization	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale		N/A
Risk of bias in individual studies	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis		8
Data synthesis	15a	Describe criteria under which study data will be quantitatively synthesised		9
	15b	If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data and methods of combining data from studies, including any planned exploration of consistency (such as $\tau^2$ , Kendall's $\tau$ )		
	15c	Describe any proposed additional analyses (such as sensitivity or subgroup analyses, meta-regression)		
	15d	If quantitative synthesis is not appropriate, describe the type of summary planned		
Meta-bias(es)	16	Specify any planned assessment of meta-bias(es) (such as publication bias across studies, selective reporting within studies)		9
Confidence in cumulative evidence	17	Describe how the strength of the body of evidence will be assessed (such as GRADE)		9

**\* It is strongly recommended that this checklist be read in conjunction with the PRISMA-P Explanation and Elaboration (cite when available) for important clarification on the items. Amendments to a review protocol should be tracked and dated. The copyright for PRISMA-P (including checklist) is held by the PRISMA-P Group and is distributed under a Creative Commons Attribution Licence 4.0.**

*From: Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart L, PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015 Jan 2;349(jan02 1):g7647.*

## Supplementary file 2: COSMIN Definitions

### COSMIN Taxonomy for measurement property (definitions)<sup>1</sup>

Term			Definition
Domain	Measurement property	Aspects of measurement property	
Reliability			The degree to which the measurement is free from measurement error.
Reliability (extended definition)			The extent to which scores for patients who have not changed are the same for repeated measurement under several conditions: e.g. using different sets of items from the same PROM (internal consistency); over time (test-retest); by different persons on the same occasion (inter-rater); or by the same persons (i.e. raters or responders) on different occasions (intra-rater).
	Internal consistency		The degree of the interrelatedness among the items.
	Reliability		The proportion of the total variance in the measurements which is due to 'true'† differences between patients.
	Measurement error		The systematic and random error of a patient's score that is not attributed to true changes in the construct to be measured.
Validity			The degree to which a PROM measures the construct(s) it purports to measure
	Content validity		The degree to which the content of a PROM is an adequate reflection of the construct to be measured.
		Face validity	The degree to which (the items of) a PROM indeed looks as though they are an adequate reflection of the construct to be measured
	Construct validity		The degree to which the scores of a PROM are consistent with hypotheses (for instance with regard to internal relationships, relationships to scores of other instruments, or differences between relevant groups) based on the assumption that the PROM validly measures the construct to be measured.
		Structural validity	The degree to which the scores of a PROM are an adequate reflection of the dimensionality of the construct to be measured.

		Hypotheses testing	Idem construct validity
		Cross-cultural validity	The degree to which the performance of the items on a translated or culturally adapted PROM are an adequate reflection of the performance of the items of the original version of the PROM.
	Criterion validity		The degree to which the scores of a PROM are an adequate reflection of a 'gold standard'.
Responsiveness			The ability of a PROM to detect change over time in the construct to be measured.
	Responsiveness		Idem responsiveness
Interpretability			Interpretability is the degree to which one can assign qualitative meaning - that is, clinical or commonly understood connotations – to a PROM's quantitative scores or change in scores.

† The word 'true' must be seen in the context of the CTT, which states that any observation is composed of two components – a true score and error associated with the observation. 'True' is the average score that would be obtained if the scale were given an infinite number of times. It refers only to the consistency of the score, and not to its accuracy (22) \* Interpretability is not considered a measurement property, but an important characteristic of a measurement instrument

References:

1. Mokkink LB, Terwee CB, Patrick DL, et al. The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. *Journal of clinical epidemiology* 2010;63(7):737-45.

### Supplementary file 3:

#### Example of MEDLINE search strategy 1948– March 2020

##### MEDLINE (Ovid interface) search strategy

1. Trunk musc\* strength.ti,ab.
2. Trunk musc\* power.ti,ab.
3. Trunk musc\* torque.ti,ab.
4. Torso strength.ti,ab.
5. Torso power.ti,ab.
6. Isometric trunk strength.ti,ab.
7. Isotonic trunk strength.ti,ab.
8. Static trunk strength.ti,ab.
9. Back musc\* strength.ti,ab.
10. Back exten\* strength.ti,ab.
11. Lumbar exten\* strength.ti,ab.
12. Lumbar exten\* torque.ti,ab.
13. Abdomin\$ musc\* strength.ti,ab.
14. Trunk Max\* contract\*.ti,ab.
15. Trunk MVC.ti,ab.
16. Trunk flex\* strength.ti,ab.
17. Trunk flex\* power.ti,ab.
18. Trunk flex\* torque.ti,ab.
19. Trunk forward bend\* strength.ti,ab.
20. Trunk forward bend\* power.ti,ab.
21. Trunk forward bend\* torque.ti,ab.
22. Trunk extens\$ strength.ti,ab.
23. Trunk extens\$ power.ti,ab.
24. Trunk extens\$ torque.ti,ab.
25. (Trunk rota\* strength or Trunk rota\* power or Trunk rota\* torque).ti,ab.
26. (Trunk lateral\$ flex\* strength or Trunk lateral\$ flex\* power or Trunk lateral\$ flex\* torque).ti,ab.
27. (Trunk lateral\$ bend\* strength\* or Trunk lateral\$ bend\* power or Trunk lateral\$ bend\* torque).ti,ab.
28. (core strength or core power or core torque).ti,ab.
29. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28
30. (Spinal musculoskeletal pain or musculoskeletal disease or musculoskeletal dysfunction\* or spin\* MUSCU\* pain).ti,ab.
31. (Low\* back pain or LBP or Chronic Low\* back pain or CLBP).ti,ab.
32. (lumbago or dorsalgia).ti,ab.
33. back disorder\$.ti,ab.
34. (lumbar adj pain).ti,ab.
35. (slipped adj disc).ti,ab.
36. (slipped adj disk).ti,ab.
37. (prolap\* adj disc).ti,ab.
38. (prolap\* adj disk).ti,ab.
39. Spin\*osteoarthrit\$.ti,ab.
40. Spine osteoarthrit\$.ti,ab.
41. spine spondylitis.ti,ab.

42. spine spondylosis.ti,ab.
43. (spine degenerative adj joint adj disease).ti,ab.
44. (Neck pain or Cervical pain or Chronic neck pain or CNP or cervicogenic).ti,ab.
45. (Thoracic spine pain or Mid back pain).ti,ab.
46. (Healthy adult\* or Normal adult\* or A symptomatic adult\* or Physically active adult\* or Athlete\*).ti,ab.
47. 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46
48. (Performance-based tool\* or performance-based test\* or Clinical-based tool\*).ti,ab.
49. (field- based test\* or Assessment).ti,ab.
50. (Quantitative assessment or measurement\* or evaluate\$).ti,ab.
51. (instrument\$ or tool\* or test\$).ti,ab.
52. (Manual\* musc\* test\$ or MMT).ti,ab.
53. (mechanic\* or Hand-held dynamometer\* or HHD or Strain-gauge test\*).ti,ab.
54. 48 or 49 or 50 or 51 or 52 or 53
55. 29 and 47 and 54
56. (Validation Studies or Comparative Study).pt.
57. exp Psychometrics/
58. psychometr\*.ti,ab.
59. (clinimetr\* or clinometr\*).tw.
60. outcome assessment.ti,ab. or outcome measure\*.tw. or exp Observer Variation/ or observer variation.ti,ab.
61. exp Health Status Indicators/
62. exp Reproducibility of Results/
63. reproducib\*.ti,ab.
64. exp Discriminant Analysis/
65. (reliab\* or unreliab\* or valid\* or coefficient or homogeneity or homogeneous or internal consistency).ti,ab.
66. (cronbach\* and (alpha or alphas)).ti,ab.
67. (item and (correlation\* or selection\* or reduction\*)).ti,ab.
68. (agreement or precision or imprecision or precise values or test-retest).ti,ab.
69. (test and retest).ti,ab.
70. (reliab\* and (test or retest)).ti,ab.
71. (stabil\* or interrater or intrarater or intrarater or intertester or intratester or interobserver or interobserver or intraobserver or intertechnician or intratechnician or interexaminer or intraexaminer or interassay or intraassay or interindividual or intraindividual or interparticipant or intraparticipant or kappa or kappas or repeatab\*).ti,ab.
72. ((replicab\* or repeated) and (measure or measures or findings or result or results or test or tests)).ti,ab.
73. (generaliza\* or generalisa\* or concordance).ti,ab.
74. (intraclass and correlation\*).ti,ab.
75. (item discriminant or interscale correlation\* or error or errors).mp. or individual variability.ti,ab. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
76. variability.mp. and (analysis or values).ti,ab. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
77. (uncertainty and (measurement or measuring)).ti,ab.

78. (standard error of measurement or sensitiv\* or responsive\*).ti,ab.
79. ((minimal or minimally or clinical or clinically) and (important or significant or detectable) and (change or difference)).ti,ab.
80. (small\* and (real or detectable) and (change or difference)).ti,ab.
81. 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80
82. 55 and 81
83. limit 82 to English language

For peer review only