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A systematic review of mechanical properties of the lumbopelvic-hip muscle group measured by MyotonPRO

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 11 September 2026 and was last updated on 11 September 2026.

INTRODUCTION

Review question / Objective This systematic review aims to evaluate the reliability, measurement error, and validity of the MyotonPRO device for measuring the mechanical properties of the predefined target muscles of the lumbo-pelvic-hip complex (LPHC) in human participants. Following the review's PIACOS framework, the Anatomy element is reported within the outcome rather than merged into the population. The population (P) comprises human participants of any age, sex, or health status, stratified into healthy/asymptomatic individuals and people with musculoskeletal disorders, particularly chronic low back pain, with no restriction on setting. The index measurement (I) is assessment of muscle mechanical properties using the MyotonPRO, a portable non-invasive device that applies a brief mechanical impulse and records damped tissue oscillation to yield oscillation frequency (F), dynamic stiffness (S), logarithmic decrement (D), stress relaxation time (R), and creep (C), with MyotonPRO data required to be independently extractable. The comparator (C) consists of repeated measurements by the same rater (intra-rater reliability), by different raters (inter-rater reliability), or across time (test-retest reliability), or comparison against a reference instrument such as shear wave elastography or a

predefined clinical construct for validity testing. The outcome (O), which incorporates the target anatomy, comprises measurements taken at predefined LPHC target muscles - erector spinae, longissimus, iliocostalis, quadratus lumborum, multifidus, rectus abdominis, external oblique, gluteus maximus, gluteus medius, semitendinosus, semimembranosus, rectus femoris, iliacus, psoas, iliopsoas, adductor longus, adductor magnus, and the hamstrings - with at least one reported measurement property, namely reliability (intra-rater, inter-rater, or test-retest intraclass correlation coefficients [ICC] with 95% CI), absolute measurement error or agreement (standard error of measurement [SEM], minimal detectable change [MDC/SDC/SRD], coefficient of variation [CV], or Bland-Altman limits of agreement), or validity (criterion/convergent or construct validity). Eligible study designs (S) are original primary studies, theses/dissertations, or full-text conference papers from which measurement results can be independently extracted and that are published in English or Chinese, whereas animal, cadaveric, ex-vivo or phantom studies, studies using older Myoton models (Myoton-2/3/4), reviews, protocols, editorials, and records without extractable measurement data are excluded. The central review question is therefore: what are the reliability, measurement error, and validity of MyotonPRO for quantifying the mechanical properties (frequency, stiffness, decrement, relaxation time, creep) of the predefined LPHC target muscles across healthy and musculoskeletal populations, measurement parameters, positions, and study designs?

Rationale The lumbo-pelvic-hip complex (LPHC), formed by the lumbar spine, pelvis, hip joints and their surrounding musculature, is a key functional region responsible for postural control, load transfer and movement coordination between the trunk and lower limbs. Muscles in this region exhibit different mechanical properties across body positions, loading conditions and health states. Reproducible and quantifiable measurement of these properties is therefore methodologically important for describing normal variation, identifying abnormal states, and evaluating changes before and after intervention.

MyotonPRO is a portable, non-invasive device that measures muscle mechanical properties by applying a brief mechanical impulse to the tissue surface and recording the resulting damped oscillation. It outputs five parameters: oscillation frequency, dynamic stiffness, logarithmic decrement, stress relaxation time and creep. These indices characterize the mechanical response of tissue under specific measurement conditions, but they cannot be equated directly with muscle strength, electromyographic activity, or the elasticity of deeper tissues. Consequently, before MyotonPRO can be used confidently for repeated assessment in research or clinical practice, evidence is needed simultaneously on its relative reliability, absolute measurement error, and validity relative to reference instruments or clinical constructs.

Previous reviews have summarized the measurement reliability of MyotonPRO across multiple anatomical regions or in the soft tissues of the back and neck. However, evidence remains fragmented for the predefined target muscles of the LPHC specifically, and no synthesis has jointly distinguished healthy from musculoskeletal populations while integrating reliability, measurement error and validity within a single review. Existing studies also differ markedly in target muscle, measurement position, reported parameter, ICC model and retest interval, making it difficult for researchers and clinicians to judge which LPHC muscles and measurement conditions yield reproducible and interpretable results.

To address this gap, this systematic review applies the PIACOS framework - which adds an Anatomy dimension to the conventional PICOS structure - to define eligibility across population, anatomy, index measurement, comparator, outcome and study design. It appraises the measurement evidence for MyotonPRO in predefined LPHC target muscles, synthesizing intra-rater, inter-rater and test-retest reliability, absolute measurement error and agreement (SEM, MDC/SDC/SRD, CV, Bland-Altman limits of agreement), and criterion/convergent and construct validity, stratified by muscle, parameter, position and population. The findings are intended to inform future study design, support standardization of MyotonPRO measurement protocols, and guide sound clinical interpretation of measured changes, while identifying the LPHC muscles and measurement properties for which evidence is still lacking.

Condition being studied The condition/domain of interest is the mechanical behavior of the muscles of the lumbo-pelvic-hip complex (LPHC) and the extent to which these properties can be measured reliably and validly with the MyotonPRO device, rather than the efficacy of any treatment for a single disease.

The LPHC is an integrated functional region formed by the lumbar spine, pelvis and hip joints together with their surrounding musculature; it links the trunk and lower limbs and is central to postural

control, load transfer and movement coordination. Its target muscles include the erector spinae (longissimus, iliocostalis), multifidus, quadratus lumborum, rectus abdominis and external oblique, the gluteal muscles (gluteus maximus and medius), iliacus, psoas major and iliopsoas, the adductors (adductor longus and magnus), rectus femoris, and the posterior thigh muscles (hamstrings, semitendinosus, semimembranosus and biceps femoris). These muscles display different mechanical properties according to body position, loading and health state. "Muscle mechanical properties" here denote resting muscle tone and viscoelastic characteristics, quantified by MyotonPRO as oscillation frequency (F, reflecting tone), dynamic stiffness (S), logarithmic decrement (D, reflecting elasticity), stress relaxation time (R) and creep (C). Reproducible, quantitative measurement of these properties is relevant for describing normal variation, identifying abnormal states, and evaluating change over time or around an intervention.

The review spans a defined spectrum of participant health states. Most of the evidence concerns healthy or asymptomatic individuals across a broad age range, in whom normative reproducibility is established. The principal clinical condition represented is chronic low back pain (CLBP), a common musculoskeletal disorder in which altered tone or stiffness of the lumbar paraspinal and deep stabilizing muscles (e.g., multifidus) is of clinical interest; a limited amount of evidence also concerns individuals recovered from a previous hamstring strain. Studies whose dominant feature is central nervous system injury or spasticity (e.g., stroke or spinal cord injury) lie outside the predefined population scope.

Because the five MyotonPRO parameters characterize the tissue's mechanical response under specific measurement conditions and are not equivalent to muscle strength, electromyographic activity or the elasticity of deeper tissues, the central condition examined here is the measurement performance of MyotonPRO across these LPHC muscles and health states: its relative reliability (intra-rater, inter-rater and test-retest), absolute measurement error and agreement, and validity against reference methods (e.g., shear wave elastography) or clinical constructs (e.g., pain and disability in CLBP).

METHODS

Search strategy 1. Electronic databases and timeframe

Six English-language databases (PubMed, Web of Science, Scopus, Embase, ProQuest and Wiley Online Library) and four Chinese-language databases (China National Knowledge Infrastructure [CNKI], WanFang Data, VIP and the China Biology Medicine disc [CBM/SinoMed]) were searched from their inception through July 21, 2026, with no lower date limit.

2. Development of the search strategy
The strategy was built around two core concepts, the device "MyotonPRO" and the measurement property "reliability". Three concept blocks were defined and combined with Boolean operators: Block A, device terms; Block B, predefined LPHC target muscles together with mechanical-parameter and related terms; and Block C, measurement-property terms, structured as [(A AND B) OR A] AND C. Controlled vocabulary and free-text terms were combined and adapted to each database's syntax.

3. Full PubMed search strategy (worked example)
((("MyotonPRO" OR "Myoton Pro" OR Myoton OR myotonomet* OR myotonometr* OR myotonometry OR myotonometric) AND (erector spinae OR iliocostalis OR "iliocostalis lumborum" OR "longissimus" OR "multifidus" OR "quadratus lumborum" OR hamstring* OR semitendinosus OR semimembranosus OR "rectus abdominis" OR "external oblique" OR "external abdominal oblique" OR "gluteus maximus" OR "gluteus medius" OR "rectus femoris" OR iliacus OR "psoas major" OR iliopsoas OR "adductor longus" OR "adductor magnus" OR (stiff OR stiffness OR stiffnesses) OR ("Muscle tone" OR "Muscle Hypotonia" OR "Muscle Hypertonia") OR musculoskeletal disease OR (decrement OR decrements))) OR ("MyotonPRO" OR "Myoton Pro" OR Myoton OR myotonomet* OR myotonometr* OR myotonometry OR myotonometric)) AND (reliabilities OR reliability OR reliable OR reliably OR validity)

4. Adaptation to the other databases
The same three-block logic and term set were translated into the syntax of Web of Science (TS=), Scopus (TITLE-ABS-KEY), Embase (Emtree plus free text, :ti,ab,kw), ProQuest and Wiley Online Library. For the Chinese databases (CNKI, WanFang, VIP, CBM), equivalent Chinese terms were used across the same three blocks (device, LPHC anatomy, and measurement properties). No language limit was applied beyond inclusion of English and Chinese publications.

5. Supplementary search and record management

Reference lists of all included studies and relevant reviews were hand-searched (backward citation tracking). All retrieved records were imported into NoteExpress, where duplicates were removed before title/abstract and full-text screening.

Participant or population This review includes human participants only, with no restriction on age, sex, or health status; participants are stratified by health state rather than compared for any treatment effect. Three categories of participants are addressed.

(1) Healthy or asymptomatic individuals form the main body of the evidence. They span a broad age range (approximately 19-82 years across the included studies; individual study samples range from 15 to 102 participants) and comprise healthy volunteers, younger and older adults, physically active participants, athletes and military cadets, in whom normative muscle mechanical properties and measurement reproducibility are assessed.

(2) People with musculoskeletal disorders, principally chronic low back pain (CLBP), constitute the clinical population in which the device's measurement properties are evaluated; other musculoskeletal conditions are eligible provided they satisfy the remaining criteria.

(3) Individuals recovered from a previous musculoskeletal injury, such as participants after a resolved hamstring strain, in which reliability may be contrasted between previously injured and uninjured sides or groups.

No minimum sample size is required for eligibility, although sample size, age, sex and health state are extracted for every included study. Where a single study enrols both patients and healthy controls, each group is extracted separately and assigned to its corresponding health-state stratum. The following are excluded: non-human participants and non-in-vivo material, namely animal, cadaveric, isolated/ex-vivo tissue and pure phantom studies; and studies dominated by central nervous system injury or spasticity (e.g., stroke or spinal cord injury) that fall outside the predefined population.

Intervention The index measurement is assessment of muscle mechanical properties using the MyotonPRO, a portable, non-invasive handheld device. With the participant and target muscle at the specified position, the probe is placed perpendicular to the skin over the target muscle; the device delivers a brief mechanical impulse and records the resulting damped tissue oscillation. It outputs five parameters: oscillation frequency (F, Hz, reflecting resting muscle tone), dynamic stiffness (S, N/m), logarithmic decrement (D, reflecting elasticity), stress relaxation time (R, ms) and creep (C). Studies are eligible when MyotonPRO is used and its measurement data can be independently extracted. Measurement position, joint angle, probe placement, number of repetitions, contraction state and test interval will be extracted for each study. Studies using older Myoton models (Myoton-2, Myoton-3 or Myoton-4) or in which the device model cannot be confirmed are excluded.

Comparator As a measurement-property review rather than a treatment-effect review, there is no therapeutic comparator. The comparison conditions are: (1) repeated measurements by the same rater (intra-rater reliability); (2) measurements performed by different raters (inter-rater reliability); (3) repeated measurements across sessions or over time (test-retest reliability); and (4), for validity, comparison of MyotonPRO against a reference instrument (e.g., shear wave elastography) or a predefined clinical construct (e.g., a pain VAS or a disability questionnaire such as the RMDQ). Studies without any repeated measurement, reference method, or prespecified validity hypothesis are not eligible.

Study designs to be included Original primary studies reporting the reliability, measurement error/agreement, or validity of MyotonPRO in LPHC muscles, including peer-reviewed articles, full-text theses/dissertations and complete conference papers from which measurement data can be independently extracted. Repeated-measurement (intra-rater, inter-rater, test-retest) and cross-method/construct validation designs are eligible; reviews, protocols, editorials, animal/cadaver/ex-vivo/phantom studies and records without extractable data are excluded.

Eligibility criteria Beyond the PICOS criteria: eligible studies must use the MyotonPRO device (not older Myoton-2/3/4 models) and report at least one quantitative measurement property (ICC with 95% CI; SEM, MDC/SDC/SRD, CV, or Bland-Altman agreement; or criterion/convergent/construct validity). The measurement site must correspond to a confirmable predefined LPHC muscle; broad terms such as "paraspinal" or "hamstring" are included only when the specific muscle or region can be confirmed from the full text. Only English- and Chinese-language publications are included. Excluded: animal, cadaveric, isolated/ex-vivo tissue and phantom studies; studies dominated by central nervous

system injury or spasticity (stroke, spinal cord injury); studies measuring only non-muscle tissue (tendon, ligament, skin) not corresponding to a target muscle; purely descriptive/intervention studies without repeated measurement, a reference method or a prespecified validity hypothesis; and reviews, meta-analyses, protocols, editorials and abstracts whose measurement data cannot be obtained.

Information sources Electronic bibliographic databases: PubMed, Web of Science, Scopus, Embase, ProQuest and Wiley Online Library (English), and CNKI, WanFang Data, VIP and CBM/SinoMed (Chinese), searched from inception through July 21, 2026. Supplementary sources: backward citation tracking, i.e., hand-searching the reference lists of all included studies and relevant reviews, to capture potentially missed records. No prospective trial register or author-contact search was used; beyond full-text theses and complete conference papers retrievable through the listed databases, no separate grey-literature database was searched. All records retrieved from these sources were imported into NoteExpress for deduplication before screening.

Main outcome(s) Three groups of measurement properties are extracted. (1) Reliability (relative): intra-rater, inter-rater and test-retest intraclass correlation coefficients (ICC), with ICC model, single- versus average-measure type, 95% confidence interval and retest interval; ICC >0.90 is interpreted as excellent, 0.75-0.90 good, 0.50-<0.75 moderate and <0.50 poor. (2) Measurement error/agreement (absolute): standard error of measurement (SEM), minimal detectable change (MDC/SDC/SRD), coefficient of variation (CV), and Bland-Altman bias and 95% limits of agreement. (3) Validity: criterion/convergent validity against reference instruments (e.g., shear wave elastography) and construct validity against clinical constructs (e.g., VAS pain, RMDQ disability). Outcomes are stratified by muscle, MyotonPRO parameter (F/S/D/R/C), measurement position and population.

Additional outcome(s) Not applicable. No additional outcomes are defined beyond the main measurement properties (reliability, measurement error and validity).

Data management Search results from all databases were exported and imported into NoteExpress, where duplicates were removed. Two reviewers independently performed title/abstract screening and then full-text assessment; records with insufficient information or discordant judgments were retained to the full-text stage and resolved by discussion, with a third reviewer consulted when needed. Multiple or companion reports of the same study were merged, retaining the most complete primary report while extracting additional measurement data from companion reports without double-counting participants. A standardized, pilot-tested extraction form captured bibliographic information, participant characteristics, target muscle/region, position and measurement conditions, MyotonPRO parameters, ICC and 95% CI, SEM, MDC/SDC/SRD, CV, Bland-Altman results and validity estimates; muscle naming and population classification were standardized. Extracted data were stored in structured spreadsheets and independently cross-checked by a second reviewer.

Quality assessment / Risk of bias analysis Methodological quality was assessed independently by two reviewers using the COSMIN Risk of Bias checklist for non-PROM measurement instruments (reliability and measurement-error domains), supplemented by the 11-item QAREL checklist for reliability study design. COSMIN evaluates participant stability, measurement conditions, raters, statistical model and measurement-error analysis, rating each property Very Good, Adequate, Doubtful or Inadequate using the "worst score counts" principle; QAREL items are recorded as Yes/No/Unclear/Not applicable without summing an unvalidated total score. Disagreements were resolved by discussion or by a third reviewer. Overall certainty was interpreted in light of study quality, sample size and consistency, and no study was excluded solely on the basis of its quality rating.

Strategy of data synthesis A narrative (descriptive) synthesis was performed because of substantial heterogeneity in target muscle, measurement position, joint angle, probe site, contraction state, parameter reported, ICC model and single- versus average-measure type, and retest interval; no formal meta-analysis of pooled effect sizes was planned. Reliability results were summarized descriptively by muscle, parameter and reliability type. For several related ICCs within one study (different sides, angles, positions or repetitions), a study-level representative ICC was first derived within each muscle-parameter-reliability-type combination; when at least two studies shared the same combination, an equal-weighted arithmetic mean ICC across studies was calculated for descriptive characterization only, not as a meta-analytic pooled estimate. SEM, MDC/SDC/SRD, CV and Bland-Altman results were synthesized narratively without cross-study

pooling because of differing units, parameters and conditions. Validity results were stratified by reference method or construct without pooling correlation coefficients, and evidence gaps were identified.

Subgroup analysis Results were stratified and explored across prespecified dimensions: (1) target muscle (e.g., erector spinae, multifidus, rectus femoris, biceps femoris) and, for erector spinae, lumbar level (L1, L3-L4, L4); (2) MyotonPRO parameter (frequency F, stiffness S, decrement D, relaxation time R, creep C); (3) reliability type (intra-rater, inter-rater, test-retest); (4) population health state (healthy/asymptomatic vs chronic low back pain vs recovered injury); (5) measurement position/posture (prone, sitting, standing, squatting) and joint angle; and (6) retest interval (within-session vs cross-session, 24 h or several days). Subgroup comparisons were descriptive because of the limited number of studies within each stratum.

Sensitivity analysis No quantitative sensitivity analysis with pooled estimates was performed because a meta-analysis was not conducted. To test the robustness of the descriptive equal-weighted mean ICCs, exploratory approaches were used: (1) recalculating mean ICCs after excluding studies rated Doubtful on the COSMIN reliability domain; (2) reporting single-study strata (k=1) separately rather than averaging them; (3) keeping single-measure and average-measure ICCs separate to check for change; and (4) comparing equal weighting with sample-size-informed weighting to see whether the descriptive reliability level shifted. Given the small number of studies in most muscle-parameter combinations, these analyses were indicative only, and conclusions were drawn with explicit reference to study count, sample size, quality and measurement conditions.

Language restriction Restricted to publications in English and Chinese.

Country(ies) involved China (all authors are affiliated with Beijing University of Chinese Medicine).

Keywords MyotonPRO; lumbopelvic-hip complex; muscle mechanical properties; reliability; measurement error; validity.

Dissemination plans The completed review will be submitted to a peer-reviewed scientific journal, and the INPLASY registration number and DOI will be reported in the published manuscript.

Contributions of each author

Author 1 - Qidong Wei - Conceived and designed the review; performed the literature search, study selection, data extraction, quality assessment and data synthesis; drafted the manuscript.
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