INPLASY

INPLASY2025100050
doi: 10.37766/inplasy2025.10.0050
Received: 14 October 2025
Published: 14 October 2025

Musculotendinous Stiffness Characteristics of Elite Sprinters: A Systematic Review

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ADMINISTRATIVE INFORMATION

Support - This review received no financial support.

Review Stage at time of this submission - Data extraction.

Conflicts of interest - None declared.

INPLASY registration number: INPLASY2025100050

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 14 October 2025 and was last updated on 14 October 2025.

INTRODUCTION

Review question / Objective Research Question: What is the normative or comparative musculotendinous mechanical stiffness across joints in elite sprinters?
Objective: To determine how musculotendinous mechanical stiffness differs among competitive short-sprint athletes (60–400 m), classified by performance calibre according to the McKay et al. (41) framework, by synthesising evidence from peer-reviewed studies that report direct quantitative measures of musculotendinous stiffness alongside documented sprint performance (time or IAAF point score), training status, or competition level.

Rationale To synthesise current evidence on joint-specific musculotendinous mechanical stiffness in elite sprinters.
Understanding MTU contributions is a complex issue that requires refined terminology and approaches capable of isolating tissue-specific mechanics. With this in mind, the primary aim of this review is to synthesise the existing research on musculotendinous mechanical stiffness characteristics across the lower limb joints (hip, knee, and ankle) in elite sprinters. Exploring the relationship between these localised mechanical properties and their interactions with maximal sprint speed, as determined by 100-m performance, facilitates a more profound understanding of sprinting mechanics and offers insights into performance optimisation and, consequently, injury prevention. A secondary aim is to critically evaluate the reliability, reproducibility, and usefulness of the measurement tools and techniques that permit accurate direct assessment of MTU mechanical stiffness characteristics.

Condition being studied Musculotendinous mechanical stiffness in competitive short-distance sprinters (60–400 m). This physiological characteristic reflects the resistance of muscle–tendon units to deformation under load and is linked to force transmission efficiency, stretch–shortening cycle performance, and potential injury risk in high-speed running.

METHODS

Search strategy The search strategy was designed to identify studies that investigated the mechanical stiffness characteristics of the musculotendinous complex in the context of sprinting. Key terms were searched within the article title, abstract, and keywords using conjunctions "OR" and "AND" with truncation "*." The search terms consisted of combinations of the following Boolean phrases: (muscle* OR tendon* OR mechanical* OR neuromuscular OR active* OR passive*) AND (stiffness* OR compliance* OR elasticity*) AND (sprint* OR athlete* OR sport*). No filters or limiters were applied within the initial database search. Additionally, the reference lists of the identified articles were reviewed to ensure that no relevant studies were omitted during the search process. Subsequently, any missing studies were included manually.

Participant or population The review will include healthy adult short-sprint athletes (60–400 m) explicitly classified as sprinters and further categorised by performance calibre according to the McKay et al. (41) framework (e.g., trained/developmental, highly trained/national, elite/international). Eligible participants must have documented sprint performance (time or IAAF point score), training status, or competition level, and be assessed using direct quantitative measures of musculotendinous mechanical stiffness.
Studies will be excluded if they involve non-sprinter athletic groups, youth (35 years) cohorts unless classified as actively competing at a highly trained or national level, or if stiffness was measured indirectly (e.g., via joint, leg, or vertical stiffness proxies without tissue-specific isolation).

Intervention Not applicable — observational studies only (no intervention).

Comparator No experimental intervention comparator is used, as all eligible studies are observational in nature.

Study designs to be included Cross-sectional, cohort, or comparative observational studies that provide direct quantitative measures of musculotendinous mechanical stiffness in eligible sprint athletes. Experimental or intervention studies will be included only if baseline data meet inclusion criteria. Case reports, reviews, conference abstracts, and in vitro or simulation-based studies will be excluded.

Eligibility criteria Criteria for Inclusion and Exclusion
Studies were included in the review based on the following criteria: (a) the full text was available in English; (b) the publications consisted of peer-reviewed journal articles; (c) the subjects were classified explicitly as sprinters who participated in short-sprint events (60-400 m); (d) sprinters could be defined and classified by performance calibre in accordance with the McKay et al. (41) classification framework; (e) performance times or IAAF point equivalent (42), training status, and competition level were identified and documented; and (f) the study included one or more quantitative assessments of musculotendinous mechanical stiffness.
Studies were excluded if they: (a) were conference papers/posters/presentations; (b) were in vitro or in silico; (c) did not provide direct measures of musculotendinous mechanical stiffness; (d) reported functional proxies for musculotendinous stiffness (i.e., joint, leg, or vertical stiffness) without isolating specific mechanical tissue-related components; (e) focused solely on neuromuscular or morphological variables; (f) involved youth participants (35 years), unless clearly classified as actively competing at a highly trained or national level; (g) included the wrong athletic population; and, (h) failed to describe methodological, subject, performance, or training status information necessary to identify the population inclusion criteria.

Information sources A systematic electronic search using PubMed, MEDLINE (via Ovid), SPORTDiscus (via EBSCOhost), and Scopus databases was used. There were no additional sources used.

Main outcome(s) The primary outcome of interest is musculotendinous mechanical stiffness measured directly at the muscle, tendon, or muscle–tendon unit (MTU). Musculotendinous stiffness characteristics included: tendon stiffness/compliance, active muscle stiffness, passive muscle stiffness, tendon elongation, strain, hysteresis.
Measurements may be taken under passive, active, or isometric/quasi-isometric loading conditions. Where applicable, testing context (e.g., joint angle, contraction state, anatomical site) will be recorded to account for methodological variance.

Additional outcome(s) Where available, test–retest reliability metrics such as intraclass correlation coefficients (ICC), coefficients of variation (CV%), standard error of measurement

(SEM), or minimal detectable change (MDC) will be extracted. If studies reference prior validation work rather than reporting reliability directly, the cited reliability data will be documented to evaluate methodological robustness across measurement approaches.

Quality assessment / Risk of bias analysis Studies that met the inclusion criteria underwent a risk of bias and quality assessment based on the Joanna Briggs Institute Critical Appraisal tools (JBI) established for use in systematic reviews of cross-sectional studies (45). Eight items were scored using a yes, no, unclear or not/application system to obtain a quality score to rank the risk of bias. Two independent reviewers completed the quality assessments of each study, with a third reviewer settling any discrepancies in scoring, as recommended by PRISMA (41).

Strategy of data synthesis Given the expected variability in stiffness assessment methods, anatomical sites, and participant classification, a narrative synthesis will be the primary method of data integration. Studies will be grouped and compared based on:
Measurement site (e.g., tendon vs. muscle vs. joint),
Contraction state (passive vs. active / isometric vs. quasi-isometric),
Performance calibre or sprint event groupings, where applicable.
Where at least two studies report comparable stiffness outcomes using consistent units and protocols, descriptive statistics (e.g., mean ± SD ranges, percentage differences) will be tabulated.

Subgroup analysis Where sufficient data are available, subgroup analyses will be conducted to explore whether musculotendinous stiffness differs based on the above strategy of data synthesis. However, limited data is currently available, with the majority of the research involving either non-athletic controls or single studies (2) showing subgroup analysis.

Sensitivity analysis Sensitivity analyses will be conducted to assess the robustness of the findings where sufficient comparable data are available. However, in recognition of the limited number of eligible investigations available in this niche area, sensitivity analysis will be treated as an exploratory procedure rather than a mandatory criterion for interpretation. Sensitivity will instead be assessed qualitatively, by examining whether overall conclusions rely heavily on any single study, high-risk-of-bias source, or methodologically divergent approach.

Language restriction English only.

Country(ies) involved New Zealand, USA.

Keywords muscle; tendon; stiffness; compliance; mechanical properties; sprinting; reliability.

Contributions of each author
Author 1 - David Sturrock - Author 1 drafted the manuscript and led the development of the review protocol.
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