Beyond the Legs: Reconsidering Sprint Performance through the Lens of Spinal Engine Theory

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Abstract

Traditional sprint models have advanced understanding of lower-limb force production, but they do not fully explain the active contribution of the trunk and lumbo-pelvic system to sprint performance. This thesis aimed to examine the role of lateral trunk flexion in sprinting by first reviewing the relevant biomechanical literature and then testing whether isometric lateral trunk flexion strength was associated with 40-m sprint times and discrete performance variables. The narrative review identified that conventional models, including the SMM and 2MM, largely represent the upper body or above the lower leg as a single passive mass, whereas emerging imaging, kinetic, morphological, and coordination evidence suggests that the trunk contributes actively to sprinting through muscle activation, pelvic rotation, COM control, and integrated arm-trunk-leg coordination. This evidence provided the rationale for the experimental study, as the literature describes what the trunk does during sprinting but has rarely tested whether lateral trunk flexion strength is directly related to sprint performance. Eighteen trained sprint and field-sport athletes (age 18.9 ± 2.9 years; body mass 84.2 ± 8.9 kg) completed isometric lateral trunk flexion testing using fixed dynamometry and maximal 40-m sprints. Split times over 0–10 m, 10–20 m, 20–40 m, and 0–40 m, peak acceleration, peak velocity, and distance to peak velocity were recorded. The lateral flexion peak force protocol demonstrated good-to-excellent intrasession reliability across sides (ICC = 0.84–0.90; CV = 7.81–9.15%). Pearson product-moment correlations showed that greater lateral flexion peak force was associated with faster 0–10 m ($r = -0.63$, $p = .007$), 10–20 m ($r = -0.56$, $p = .018$), and 0–40 m sprint times ($r = -0.70$, $p = .002$). The association with 20–40 m sprint time was moderate but non-significant ($r = -0.48$, $p = .054$), and no significant relationship was observed with distance to peak velocity ($r = .41$, $p = .101$). These findings suggest that lateral trunk flexion strength may be most relevant to acceleration and early sprint performance rather than later, higher-velocity sprinting. However, the results should be interpreted with caution because the study was cross-sectional, involved a small and predominantly male sample, and did not include concurrent kinematic or GRF data to explain the mechanism underpinning the observed relationships. Practically, lateral trunk flexion strength may be worth assessing and developing in athletes whose performance depends on acceleration, but further research with larger samples using predictive experimental designs is required to elucidate the contribution of lateral trunk flexion strength to linear sprinting performance.

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Attestation of Authorship

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person except where due acknowledgement has been made in the text. This thesis has not been submitted, either in whole or in part, for the award of any other degree or diploma at this or any other tertiary institution.

I certify that all sources of information have been acknowledged and that any assistance received in the preparation of this thesis has been appropriately identified.
I further declare that the research presented in this thesis was conducted in accordance with the ethical approval granted by the Auckland University of Technology Ethics Committee (AUTEC Approval No. 25/236).

William McTaggart

AI Declaration

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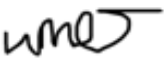
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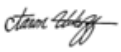
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STUDENT AND SUPERVISOR APPROVALS

By signing you are confirming that the co-author contributions stated in the table(s) below are accurate.

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AUTHOR SURNAME: (order as per manuscript)	CONTRIBUTION (May copy from the guidelines above)
McTaggart	Conceptualization of methodology of this project; data acquisition, data analysis, and interpretation, drafting research outputs and implementing feedback/revisions
Uthoff	Conceptualized methodology, feedback and revision
Spence	Conceptualized methodology, feedback and revision

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Ethics Approval

The Auckland University of Technology Ethics Committee (AUTEC) granted ethical approval for this master's thesis research on:

- 31st of July 2025, AUTEC reference number 25/236 (Appendix A)

Glossary of Terms and Abbreviations

Abbreviation	Term
2MM	Two-mass model
CI	Confidence interval
COM	Centre of mass
CSV	Comma-separated values
CV	Coefficient of variation
GRF	Ground reaction force
HIMA	Holding isometric muscle action
ICC	Intraclass correlation coefficient
MRI	Magnetic resonance imaging
PIMA	Pushing isometric muscle action
RPE	Rating of perceived exertion
SD	Standard deviation
SEM	Standard error of measurement
SMM	Spring-mass model

Term	Definition
Anterior oblique sling	A myofascial chain formed by the external oblique, opposite-side internal oblique, abdominal fascia, and hip adductors.
Axial rotation	Twisting of the trunk about its long (vertical) axis.
Distance to peak velocity	The distance over which a sprinter accelerates before reaching maximal running speed.
Ground reaction force	The force exerted by the ground on the body during foot contact.
Isometric	A muscle action that produces force without a change in muscle length.
Lateral flexion	Side-bending of the trunk in the frontal (side-to-side) plane; the primary trunk action assessed in this thesis.
Lumbo-pelvic region	The functional unit formed by the lower (lumbar) spine and the pelvis, acting together during movement.
Posterior oblique sling	A myofascial chain connecting the gluteus maximus to the opposite-side latissimus dorsi through the thoracolumbar fascia.
Spinal engine theory	Gracovetsky's model proposing that locomotion is driven by lateral flexion and axial rotation of the spine, with the legs amplifying and transmitting these movements.
Spring-mass model	A simplified model representing the runner as a point mass supported by a single massless, elastic leg spring.
Thoracolumbar fascia	A sheet of connective tissue linking the spine, pelvis, and limbs, proposed to transmit force and store elastic energy.
Two-mass model	A refinement of the spring-mass model dividing the body into a distal mass (foot and shank) and a proximal mass (the rest of the body).

Chapter 1 Introduction

Sprinting is among the most studied expressions of human athletic performance. It is decisive in track and field and a primary determinant of success across many field and court sports (Pryer et al., 2025; Haugen & Buchheit, 2016; Healy et al., 2022). Decades of biomechanical research have framed sprint performance through the action of the lower limbs, identifying horizontal force production, ground contact time, stride frequency and leg stiffness as the principal determinants of velocity (Morin et al., 2006; Brughelli et al., 2011). This understanding has been formalised in two influential models. The spring-mass model (SMM) idealises the runner as a single mass supported by a compliant leg-spring that compresses under load and recoils to project the body forwards, capturing vertical stiffness and a bouncing gait through a small set of spatiotemporal variables (Blickhan, 1989; McMahon & Cheng, 1990). The two-mass model (2MM) refines this picture by separating the shank from the rest of the body, enabling the interpretation of braking and propulsion force asymmetries that the SMM cannot resolve (Clark & Weyand, 2014). Both models have been pivotal in advancing sprint science, yet both share a common limitation: because the upper body is modelled as one lumped mass, the trunk and pelvis have no distinct mechanical role within either framework for sprint performance.

Lumbo-pelvic mechanics describes the coordinated interaction between the lower spine and pelvis. During sprinting, this system stabilises the trunk and controls pelvic tilt and rotation, supporting stride length and leg recovery (Sado et al., 2016). A growing body of work indicates that the trunk and pelvis are active contributors to sprint performance rather than a passive load carried by the legs. Coordination between the lumbar spine and pelvis involves movements of lateral flexion, axial rotation and pelvic tilt; these each modulate the trajectory of the centre of mass (COM; the weighted average position of body mass) and the application of ground reaction force (GRF), while the arms operate alongside this system to manage angular momentum and stabilise the torso (Slawinski et al., 2022; Vellucci & Beaudette, 2023).

Asymmetries in these movements, such as imbalance in lateral-flexion torque or axial torsion, have been shown to disrupt stride rhythm and reduce propulsive efficiency (Sado et al., 2023; Nagahara, Matsubayashi, et al., 2018). Alongside this kinematic evidence, a parallel body of research links trunk strength and morphology directly to sprint outcomes. Meta-analytic results indicate that targeted trunk muscle training produces moderate improvements in linear sprint

performance (standardised mean difference [SMD] = 0.66), supporting a functional role for the trunk in sprinting (Saeterbakken et al., 2022).

Morphological studies provide complementary evidence, demonstrating that greater relative cross-sectional area of the lateral abdominal wall is associated with faster 400-m sprint times (r = −0.60) and greater mechanical energy efficiency (r = 0.60), while larger psoas major cross-sectional area is associated with faster 100-m sprint performance (r = −0.36 to −0.39) (Muratomi et al., 2025; Tottori et al., 2021). Strong lateral flexors are thought to enhance sprint performance by stabilising the trunk and regulating pelvic motion, facilitating efficient transfer of force between the lower limbs and the ground (Sado et al., 2020). Direct evidence from T2-weighted magnetic resonance imaging (MRI) further demonstrates substantial activation of the lateral abdominal wall and erector spinae during maximal sprinting, indicating that these muscles actively contribute to lumbo-pelvic stability and force transmission at high running velocities (Yoshimoto et al., 2025). Collectively, this evidence positions the lateral flexors and broader lumbo-pelvic system as plausible contributors to sprint performance, a role that conventional biomechanical models of sprinting do not explicitly capture.

This limitation in conventional sprint models, combined with the converging evidence for an active lumbo-pelvic contribution, suggests that sprint performance is shaped by more than what current models can articulate. An alternative framework, the spinal engine model (Gracovetsky, 1997), has been proposed to account for these proximal contributions and has received interest within some applied sprinting and strength and conditioning environments. It posits that lateral flexion of the lumbar spine and rotation of the pelvis act as drivers of human locomotion, rather than as passive responses to leg actions. On this account, the thoracolumbar fascia and surrounding musculature transmit and recycle force between segments. While the spinal engine remains a proposed mechanism rather than an established model of sprinting, it offers a useful lens through which to reconsider trunk contribution to high-speed running.

Even so, direct empirical investigation of lateral trunk strength and its association with sprint performance remains scarce. Intervention studies and recent meta-analytic evidence indicate that trunk muscle training can improve linear sprint performance (Saeterbakken et al., 2022; Gao et al., 2025). Those studies evaluate the effects of training programmes, however, rather than whether lateral trunk strength itself is associated with sprint performance. Likewise, while

morphological and biomechanical studies demonstrate relationships between trunk musculature, lumbo-pelvic mechanics, and sprint performance, no study has directly examined whether isometric lateral trunk flexion strength is associated with sprint running performance. Consequently, these themes have not been integrated. Work on trunk strength, lumbo-pelvic mechanics, and force transmission between the trunk and lower limbs has not been brought together in a way that gives researchers and practitioners practical insight into how lateral trunk function influences sprint performance. Addressing this gap would extend traditional leg-centric frameworks of sprinting and provide both researchers and coaches with a more integrated view of sprint biomechanics, one that reflects the contribution of the whole body rather than the legs alone.

1.1 Thesis Aim

The primary aim of this thesis is therefore to synthesise the available literature on the contribution of the trunk to sprint performance, with particular focus on lumbar lateral flexion and lumbo-pelvic mechanics, and to assess the relationship between lateral flexion strength and sprint performance.

Research Question 1. Is there a significant relationship between lateral trunk flexion strength, measured isometrically, and sprint performance over 40 m?

Research Question 2. What evidence exists to support a role for trunk and lumbo-pelvic function in sprint performance?

1.2 Conceptual Framing

In addition to traditional models of sprint biomechanics, this thesis considers the spinal engine as a proposed conceptual model of trunk contribution to locomotion (Gracovetsky, 1997). The spinal engine is treated throughout as a candidate framework for interpreting findings rather than as an established mechanism of sprinting, and its applicability to high-speed running is examined alongside the empirical evidence reviewed in Chapter 2. Where findings appear consistent with the spinal engine framework, this is noted; where they are equivocal or contradict it, this is also noted. The intent is to use the model as an analytical lens, not to test or validate it.

The structure of this thesis is outlined in Table 1. Following this general introduction, Chapter 2 is a narrative literature review that examines the traditional models of sprint biomechanics, the evidence for an active trunk and lumbo-pelvic contribution to sprint performance, and spinal engine theory as a framework for interpreting that evidence. Chapter 3 is an experimental study, which investigates whether isometric lateral trunk flexion strength is associated with sprint performance over 40 m in sprint-trained athletes. Finally, Chapter 4 discusses the findings in an applied context, considers the limitations of the thesis, and outlines directions for future research.

Table 1

Outline of Each Chapter Within This Thesis

Chapter	Title	Purpose
1	Introduction	General introduction to the thesis
2	A literature review on traditional models of sprint biomechanics and a proposed role for trunk and upper-body mechanics in sprint performance	Narrative literature review on traditional sprint models, the contribution of the trunk and lumbo-pelvic system to sprint performance, and the spinal engine as an interpretive framework
3	The relationship between sprint performance and isometric lateral flexion trunk strength	A cross-sectional study assessing the association between isometric lateral trunk flexion strength and 40-m sprint performance in sprint-trained athletes
4	Summary, practical applications, limitations, future research directions	Overall discussion, in which the findings from Chapter 3 are applied to practice and directions for future research are proposed

Note. This table summarises the thesis structure and the purpose of each chapter.

Chapter 2 A Literature Review on Traditional Models of Sprint Biomechanics and a Proposed Role for Trunk and Upper-Body Mechanics in Sprint Performance

2.0 Prelude

Chapter 1 established that sprint performance has traditionally been understood through the action of the lower limbs. It showed that the dominant biomechanical frameworks treat the upper body as a single lumped mass with no distinct mechanical role. These frameworks are the SMM and the 2MM. Chapter 1 then introduced a growing body of evidence that the trunk and pelvis are active contributors to sprinting. This evidence indicated that lumbo-pelvic mechanics, lateral flexion strength and trunk morphology are important for sprint outcomes. It also linked them to the transmission of force from the lower limbs to the ground. Chapter 1 further introduced the spinal engine as a proposed conceptual framework for interpreting these proximal contributions. In doing so it identified a clear gap. Direct empirical investigation of lateral trunk flexion strength and its relationship to sprint performance remains scarce. The themes of trunk strength, lumbo-pelvic mechanics and force transmission have not yet been drawn together in a way that offers researchers and coaches practical insight.

This chapter progresses understanding of that gap through a narrative review of the literature. It examines in greater detail the issues introduced in Chapter 1. It begins with a critical evaluation of the traditional leg-centric models of sprint biomechanics and their limitations. It then synthesises current research on trunk and upper-body mechanics. This includes lumbo-pelvic coordination, lateral flexor function and the evidence linking trunk strength and morphology to sprint performance. Finally, it considers the spinal engine as a lens for interpreting this evidence. In doing so the chapter establishes the conceptual foundation for the empirical investigation that follows. It also clarifies how lateral trunk flexion and related trunk functions may influence sprint performance.

2.1 Introduction

Sprint biomechanics has traditionally been explained through mechanical models that focus on the lower limbs. Conventional frameworks such as the SMM emphasise lower-limb stiffness and vertical force production. A growing body of evidence suggests that these approaches do not fully account for the segmental interactions, asymmetries and multi-planar trunk-pelvis mechanics observed in elite sprinting. The interactions they overlook point to a broader limitation in how leg-centric models represent the contribution of the upper body. Emerging work points instead to trunk and whole-body contributions to high-speed running. Kinetic, kinematic and morphological evidence indicates a role for the trunk in propulsion and in the control of the centre of mass (COM). Alternative frameworks such as spinal engine theory and myofascial slings have therefore been proposed to explain aspects of sprint biomechanics not captured by traditional models. This review examines the biomechanical models underpinning sprint performance and considers how these frameworks may be expanded to account for the arms, trunk and spinal engine theory within whole-body sprint mechanics. From this broader basis, the present study's focus on lateral trunk flexion strength emerges as a logical application.

2.2 Literature Search

2.2.1 Search Strategy

This narrative review was informed by a structured literature search. A systematic-style search was used to identify the primary literature on trunk and lumbo-pelvic contributions to sprinting, which was subsequently supplemented by foundational, theoretical, anatomical, and review sources identified through citation tracking of the retrieved articles. A hybrid approach was chosen deliberately to balance comprehensive literature identification with the inclusion of foundational conceptual and anatomical works. Although a purely systematic search captures the primary biomechanical literature, it may exclude conceptual and anatomical work, such as the original spinal engine literature and descriptions of the myofascial slings, which are necessary to conceptualise and interpret the available evidence.

The structured search was conducted across four electronic databases: PubMed, Web of Science (including MEDLINE), SPORTDiscus, and Scopus. Search terms were organised into three concept blocks using Boolean operators: (1) trunk and lumbo-pelvic structures, (2)

sprinting performance, and (3) biomechanical mechanisms of interest. The full search string was:
("lateral trunk" OR "trunk strength" OR "core strength" OR “trunk rotation” OR “lumbo-pelvic” OR “oblique sling”) AND (sprint* OR "maximal velocity sprint*" OR "sprint performance") AND ("biomechanics" OR "running mechanics” OR “lumbo-pelvic mechanics" OR "spinal engine" OR "force transmission").

Searches were limited to peer-reviewed articles published in English between 2000 and 2026, reflecting the period in which contemporary three-dimensional motion capture, inverse-dynamics, and advanced imaging techniques became widely established within biomechanical research. Reference lists of included articles and relevant reviews were hand-searched to identify additional primary studies and foundational conceptual literature. Foundational works that predated the search window, including Gracovetsky’s (1997) spinal engine theory and anatomical descriptions of myofascial sling systems by Vleeming et al. (1995) and Willard et al. (2012), were retained where they directly informed the conceptual framework of this review.

2.2.2 Study Selection

Priority was given to primary studies involving human participants performing sprinting or running tasks, trunk or lateral trunk flexion strength assessment, or both, with outcomes related to sprint performance, trunk and lumbo-pelvic function, or force transmission through the trunk and pelvis. Kinematic, kinetic, electromyographic, morphological, and imaging studies examining trunk function during high-speed running were considered relevant, reflecting the multidisciplinary nature of the evidence synthesised within this review. Where direct sprint-specific evidence was limited, closely related running studies were included and their relevance to maximal-velocity sprinting was explicitly acknowledged within the text.

As this was a narrative rather than a systematic review, theoretical, anatomical, modelling, and review articles were retained where they were necessary to develop and contextualise the conceptual arguments presented. These sources were used to frame and interpret the primary evidence, with distinction between empirical findings and conceptual or model-based propositions identified throughout the review, where appropriate.

2.3 Traditional Models of Sprint Biomechanics

2.3.1 The Spring-Mass Model

In its simplest form, the SMM describes running as a bouncing system in which the body's COM is supported by a massless elastic leg spring (Blickhan, 1989; McMahon & Cheng, 1990). During stance, the leg spring compresses as the foot contacts the ground, vertical ground reaction force (GRF) rises, and the COM lowers; the spring then recoils to help redirect the body into the next flight phase. This simplified model has been influential because it can reproduce key force and displacement patterns during running and hopping and reduces complex multi-segment motion to measurable variables such as leg stiffness, natural frequency, ground contact time, and aerial time (Clark et al., 2017).

Within this framework, spatiotemporal variables such as contact time, flight time, step length, and step frequency are understood as outcomes of how the leg spring interacts with body mass and running speed. Step frequency has been identified as an important determinant of sprint performance, in some contexts more so than step length (Ito et al., 2006; Salo et al., 2011). The SMM provides one mechanical explanation for this relationship: when cadence is closer to the natural bouncing frequency of the leg-COM system, the muscle-tendon units may store and return elastic energy more effectively, helping to regulate vertical stiffness, contact time, braking forces, and the direction of mechanical work (Debaere et al., 2013). However, step length and step frequency determine running speed in any model of locomotion; the specific contribution of the SMM is that it explains how leg-spring behaviour may shape these variables.

However, the same simplifications that make the SMM useful also limit its ability to explain sprinting as a whole-body movement. The model treats the trunk and head as a passive mass and the leg as a single linear spring of constant stiffness, implying that the upper body simply follows lower-limb dynamics. Two-mass analyses suggest that reproducing the full range of vertical GRF waveforms across speeds, body sizes, and foot-strike patterns requires at least two anatomically distinct masses: the stance foot and shank, and the remaining mass above the lower leg (Clark et al., 2017). Similarly, comparisons between spring-mass simulations and experimental data show that a point mass on a linear spring can overestimate COM vertical

displacement and underestimate vertical GRF, while models that include knee and ankle segments show closer agreement with measured kinematics and kinetics (Gill et al., 2018; Lipfert et al., 2012). Further, force-length behaviour during running suggests that a near-linear force-length relationship, and therefore a single contact “leg stiffness”, is present only in some runners and conditions, varying with speed and foot-strike pattern (Gill et al., 2020). Therefore, while the SMM provides a useful starting point for understanding spring-like lower-limb behaviour, its assumptions constrain its ability to explain pelvis and upper-body contributions to sprint performance. These limitations provide the basis for considering refined models such as the 2MM.

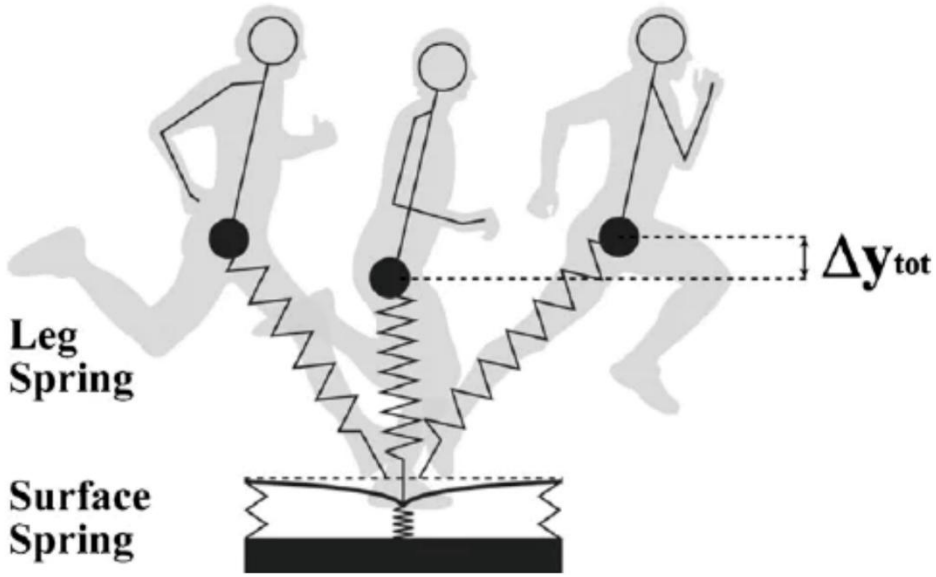


Figure 1

Simplified Spring-Mass Model of Running

Note. The head and trunk are represented as a single rigid mass located at the body's centre of mass, shown by the black dot, while the supporting leg is represented as the spring.

2.3.2 The Two-Mass Model

The limitations of the SMM motivated the development of refined models that preserve its simplicity while better representing how anatomical segments contribute to GRF. The most influential of these is the 2MM, which divides the body into a distal mass representing the foot and shank, approximately 8% of body mass, and a proximal mass representing the remaining body segments, approximately 92% of body mass (Clark & Weyand, 2014). This allows the 2MM to separate the high-frequency impact component of the vertical GRF waveform,

produced by rapid deceleration of the foot and shank early in stance, from the broader support and push-off component generated by the rest of the body. Vertical GRF waveforms can then be reconstructed using body mass, contact time, aerial time, and lower-limb vertical acceleration at impact.

The strength of the 2MM is that it improves anatomical representation without losing practical simplicity. Clark et al. (2017) validated the model across 500 footfalls from 42 runners, spanning speeds from 3.0 to 11.1 $m \cdot s^{-1}$ and both rearfoot and forefoot strike patterns. The model reproduced measured GRF waveforms with a mean correlation of 0.95 ± 0.04, despite forces varying more than two-fold in amplitude and duration. This suggests that two moving masses and three stride inputs can capture the major features of the vertical force-time waveform, including both the early impact and late-stance support components, while remaining more accessible than complex multi-mass models.

However, the 2MM remains a descriptive model of vertical GRF rather than a mechanistic explanation of whole-body sprinting. Although it can support contact-by-contact interpretation of sprint mechanics, including changes in force, power, and GRF orientation across acceleration (Rabita et al., 2015), it still collapses the trunk, pelvis, and upper limbs into a single proximal mass (Clark & Weyand, 2014; Clark et al., 2017). As a result, the model cannot explain how arm swing, trunk rotation, lateral trunk flexion, axial torsion, or pelvic tilt contribute to force transmission and COM control during sprinting. Therefore, while the 2MM improves on the SMM by representing distal and proximal mass contributions to vertical GRF, it still does not capture the active upper-body mechanics that may influence sprint performance. This limitation provides the rationale for considering the arms, trunk, and pelvis more directly in the following sections.

2.4 The Upper Body's Role

Traditional sprint models, including the SMM and 2MM, do not fully reflect how athletes coordinate the upper and lower body at high speed. Recent biomechanical evidence suggests that arm swing contributes less to direct propulsion and more to postural control, angular momentum regulation, and trunk-pelvis coordination during sprinting (Vellucci & Beaudette, 2023; Macadam et al., 2018). Experimental restriction studies support this interpretation, suggesting that limiting arm motion produces measurable reductions in sprint performance.

With the main effect appearing to be on how force is regulated and coordinated across the body rather than on the amount of propulsive force produced across sprint phases. Across restriction studies, the magnitude of performance change is small to moderate. For example, when arm swing was restricted during running in Miller et al. (2009), peak vertical GRF fell by approximately 10–13% of body weight. Similarly, Otsuka et al. (2016) observed that arm restriction in the early-acceleration phase reduced first-step sprint speed by 3%, and maximal velocity by 7%. Although modest in percentage terms, changes of this size are unlikely to be trivial in sprinting, where performances are often separated by hundredths of a second; the practical importance of an effect should therefore be judged against the margins that decide sprint outcomes rather than by its percentage magnitude alone. Despite lower GRF and longer ground contact times in these conditions, flight time seems to remain unchanged (Nagahara, 2021). At maximal velocity, the effects appear even smaller, with self-restricted arm action changing speed, acceleration, and total sprint time by less than 2% (Clark & Weyand, 2014). Collectively, these findings suggest that the arms do not act as a primary source of forward propulsion. Instead, they appear to help regulate posture, angular momentum, stride rhythm, and trunk-pelvis coordination. In each case, lower-leg and foot motion changed relatively little, while performance was maintained through compensatory adjustments in the lower limbs, trunk, and lumbo-pelvic region, including reduced forward trunk lean, altered hip extension at take-off, and increased trunk rotation and arm-trunk coordination.

This is supported by full-body musculoskeletal simulation, indicating that natural arm swing reduces longitudinal trunk rotation, improves whole-body stability, and lowers metabolic cost compared with fixed-arm conditions (Koo et al., 2025). Taken together, these findings suggest that arm swing influences sprint performance indirectly by helping organise the movement of the trunk, pelvis, and lower limbs rather than by producing forward propulsion itself. This interpretation is supported by a systematic review of 30 studies showing that arm action primarily regulates angular momentum and stabilises the trunk and pelvis during high-speed running (Macadam et al., 2018). For coaches, the practical implication is that arm action should not be viewed as an isolated driver of speed, but as part of a coordinated trunk-pelvis-limb system that helps maintain posture, rhythm, and efficient force transfer during sprinting.

Strength and conditioning research offers a complementary perspective on the upper body as more than a passive mass. A scoping review of upper-body and trunk strength qualities identified seven studies reporting associations with high-intensity running and jumping actions,

with preliminary evidence that greater upper-body maximal strength-generating capacity may positively influence repeated sprint ability; however, no intervention studies were identified (Curovic et al., 2024). More recently, in 63 male professional soccer players, upper-body isometric strength qualities, particularly handgrip rate of force development, showed large correlations with faster 30-m sprint times in analyses that controlled for leg power (Curovic et al., 2026). These findings are cross-sectional and drawn from team-sport athletes, but they suggest that upper-body force-generating capacity, and not only arm motion, may be relevant to sprint performance.

Viewed within a whole-body framework, the arms operate in unison with the shoulders, trunk and pelvis to balance the opposing rotations of the upper and lower segments. In doing so, they help coordinate the lumbo-pelvic contribution to sprinting through the trunk, with counterrotation of the shoulders and pelvis distributing rotational forces across the kinetic chain. This coupling is consistent with broader proposals about how proximal segments contribute to locomotion, including Gracovetsky's spinal engine model, which suggests counterrotation of the shoulders and pelvis helps distribute and recycle rotational energy during gait (Gracovetsky, 1997). That framework is examined in depth in subsequent sections; the key is that arm motion cannot be understood in isolation from trunk mechanics. Understanding the trunk therefore becomes essential to explaining how arm motion contributes to efficient sprinting, the focus of the next section.

2.5 Trunk and Whole-Body Contributions to Sprint Performance

During sprinting, the trunk does not act as a passive mass that simply follows lower-limb movement. Instead, it undergoes coordinated motion relative to the pelvis, including trunk flexion and extension, lateral flexion toward the stance leg during swing-leg recovery, and axial rotation of the thorax relative to the pelvis. These movements do not occur independently but form an integrated lumbo-pelvic strategy that links arm and leg motion, influences COM movement, and contributes to force production. Recent work by Yoshimoto et al. (2025) highlights the scale of this contribution, showing that the head and trunk account for approximately 40–46% of total body kinetic energy during 40 m sprint acceleration, with this contribution increasing as acceleration progresses. From this perspective, the trunk is not simply a bridge between the upper and lower body but an active contributor to sprint performance.

Evidence from imaging and electromyography further supports an active role for the trunk and lumbo-pelvic system during sprinting. Using T2-weighted MRI before and after repeated 60 m sprint efforts, Yoshimoto et al. (2025) identified pronounced activation of the lateral abdominal wall, psoas major, erector spinae, gluteus maximus, gluteus medius, tensor fasciae latae, and pectineus. Notably, the lateral abdominal wall and erector spinae were among the most highly activated muscles, indicating that structures responsible for lumbo-pelvic stability and trunk motion contribute substantially during maximal sprinting rather than serving only a passive postural role. This physiological evidence complements previous biomechanical findings by demonstrating that the muscles implicated in trunk control are heavily recruited during sprinting and therefore possess the capacity to influence sprint mechanics.

Complementary evidence is provided by muscle synergy analyse**s**, which demonstrate how these muscles are coordinated during sprinting. Kakehata et al. (2024) reported that although fatigue during a maximal 400 m sprint resulted in significant reductions in running speed, step frequency, and step length, the overall number of muscle synergies remained unchanged. Instead, fatigue was accompanied by selective alterations in the weighting of several proximal muscles, including the rectus femoris, tensor fasciae latae, and gluteus maximus, while the overall coordination structure was largely preserved. These findings suggest that sprint performance is maintained not through wholesale changes in movement organisation but through subtle adaptations in the contribution of proximal musculature, highlighting the importance of coordinated trunk and hip function for sustaining high-speed running.

The trunk also appears to contribute directly to the mechanical demands of sprinting through its role in controlling and generating lumbo-pelvic motion. Muscles such as the lateral abdominals and erector spinae help control trunk position, pelvic orientation, and rotational movements of the trunk and pelvis throughout the sprint cycle. Consistent with the importance of these proximal actions, Nagahara and Murata (2024) reported that faster sprinters at maximal velocity demonstrated greater hip flexion and extension torque, as well as greater plantar-flexor torque and power, while knee extension velocity was lower. These findings suggest that sprint propulsion is driven primarily through the hip and ankle rather than the knee. Supporting a direct mechanical role for the trunk, the largest contributor to pelvic rotation was not a hip torque but lumbosacral torsional torque. The angular impulse generated

at the lumbosacral junction was more than four times greater than that produced by any individual hip torque (Sado et al., 2017) and acted to rotate the pelvis toward the swing leg from mid-stance through to flight. This rotational action not only repositions the pelvis but also contributes to hip joint force production and delivers substantial positive joint-force power to the stance-leg hip, assisting propulsion into the subsequent step.

Morphological evidence further supports the importance of the trunk region. In male 400 m sprinters, larger relative cross-sectional areas of the lateral abdominal wall and hip adductors were associated with faster sprint times and greater mechanical-energy efficiency (Muratomi et al., 2025). Intervention studies also suggest that trunk function may be trainable, with recent evidence demonstrating improvements in sprint performance following 6–12 weeks of core training, and some instability-based programmes producing greater gains than traditional approaches (Gao et al., 2025).

Beyond force production, trunk function appears to be central to whole-body coordination. Using wearable motion and muscle activity sensors combined with machine-learning analysis, Vellucci and Beaudette (2023) identified several features that distinguished faster from slower sprinters, including the timing of contralateral arm and leg swing, stance-leg mechanics during ground contact, active trunk extension at toe-off, controlled left-right asymmetries, and altered timing of posterior-chain activation. The key finding was that faster sprinting was not explained by any single segment, but by coordinated interactions across the arms, trunk, stance leg, and swing leg. Follow-up work showed that faster sprinters also minimise side-to-side COM displacement through coordinated control of the limbs and trunk across all three planes of movement (Vellucci & Beaudette, 2024). Longitudinal evidence supports this interpretation. Ota et al. (2024) observed that as sprinters improved over time, increases in velocity and step frequency were accompanied by reduced pelvic tilt, altered stance-leg positioning, and increased lumbosacral torsional loading during ground contact. Collectively, these findings suggest that improvements in sprint performance are not solely a consequence of producing greater force but also reflect increasingly refined coordination of the trunk and pelvis.

Taken together, the available evidence identifies the trunk and lumbo-pelvic system as an important contributor to sprint performance. Imaging and electromyography demonstrate substantial trunk activation, kinetic analyses reveal meaningful contributions to force

production and pelvic rotation, morphology and training studies suggest that trunk capacity is associated with sprint performance, and coordination studies indicate that faster sprinting is characterised by more effective whole-body integration. Despite this, no study has directly examined the relationship between lateral trunk flexion strength and maximal sprint performance. Furthermore, current biomechanical models such as the 2MM continue to treat the upper body as a single rigid segment and therefore cannot explain how individual trunk actions contribute to sprinting. This limitation provides the rationale for exploring alternative frameworks, including spinal engine (SE) theory and myofascial sling models, which attempt to explain how rotational and lateral trunk actions contribute to locomotion.

2.6 Support for Spinal Engine Theory

The preceding sections established that traditional sprint models, including the SMM and 2MM, do not fully account for the three-dimensional contribution of the arms, trunk, and pelvis during sprinting. Although these models describe important aspects of force production and COM behaviour, they largely treat the upper body as a passive mass rather than an active contributor to locomotion. One framework proposed to address this limitation is the spinal engine theory developed by Gracovetsky (1997). This theory proposes that locomotion is influenced by coordinated lateral flexion, axial rotation, and pelvic motion generated through the spine, with the lower limbs acting partly as amplifiers and transmitters of these movements. Central to this model is the idea that side-bending of the trunk and pelvis can produce axial rotation through coupled spinal motion, contributing to pelvic rotation and forward progression. It should be stated at the outset, however, that the spinal engine remains a conceptual model rather than an established mechanism of sprint performance. Most of the evidence supporting the theory comes from walking and standing, with little direct investigation in running and no direct test, to the author's knowledge, in maximal sprinting.

The anatomical mechanism most used to support the spinal engine is the oblique sling system. These myofascial pathways integrate the trunk, pelvis, and limbs through the thoracolumbar fascia and provide a potential route for force transmission across the body. The posterior oblique sling links the gluteus maximus on one side of the body with the contralateral latissimus dorsi through the posterior layer of the thoracolumbar fascia (Vleeming et al., 1995; Willard et al., 2012). The anterior oblique sling provides a complementary pathway through the external oblique, contralateral internal oblique, abdominal fascia, and hip adductors (Willard et al., 2012). Together, these structures form an interconnected fascial system capable of

transferring load between the upper and lower body while contributing to lumbo-pelvic stability. As such, the sling systems provide a plausible anatomical explanation for how trunk motion could influence pelvic and limb mechanics during locomotion.

Evidence increasingly suggests that these fascial pathways contribute to load transmission rather than functioning solely as passive anatomical structures. Vleeming et al. (1995) demonstrated that tension generated by the gluteus maximus can be transmitted across the thoracolumbar fascia to the contralateral latissimus dorsi. More recent in vivo work has extended this concept to running populations, with Carvalhais et al. (2013) reporting that activation of the latissimus dorsi altered lumbar stiffness and the passive mechanical properties of the contralateral hip in trained runners, but not in sedentary controls. Broader reviews of fascial biomechanics have also shown that connective tissue can transmit force between muscles that are not directly attached and can influence intermuscular coordination (Wilke et al., 2017). These findings provide a biomechanical basis for the idea that force can be transmitted across the trunk and pelvis through myofascial structures, which is a key requirement of the spinal engine framework.

Although direct tests of spinal engine theory in sprinting are lacking, several sprint-specific findings reviewed earlier are broadly consistent with its predictions. These include evidence of substantial lumbosacral torsional loading during maximal sprinting (Sado et al., 2017), and substantial torque generation and mechanical work performed by the lumbo-pelvic-hip complex during block starts (Sado et al., 2020), substantial activation of the lateral abdominal wall and spinal musculature during sprinting (Yoshimoto et al., 2025), and coordinated thorax-pelvis motion associated with COM control and sprint technique (Schache et al., 2014; Vellucci & Beaudette, 2024). Collectively, these findings support the broader view that the trunk and pelvis are active contributors to sprint mechanics rather than passive structures carried by the lower limbs. However, they should be interpreted as evidence that is consistent with the spinal engine, not as evidence that directly confirms it.

Several limitations temper the application of spinal engine theory to sprinting. First, alternative explanations exist for many of the same observations. For example, anti-phase motion between the trunk and pelvis during running may reflect a momentum-management strategy that minimises unnecessary COM movement and improves locomotor efficiency, rather than evidence that the spine actively drives the legs (Preece et al., 2016). Second, much of the direct support for the spinal engine originates from walking, where movement speeds, loading

rates, ground contact times, and muscular demands differ substantially from sprinting. Third, lateral trunk flexion and axial rotation observed in sprinters may reflect individual technique, compensation strategies, fatigue responses, or postural control demands rather than a direct propulsive mechanism. These considerations mean that the spinal engine should not be presented as an established explanation for sprint performance.

Within these constraints, spinal engine theory remains useful as an interpretive framework. It provides a coherent way to organise evidence showing that trunk muscle activation, lumbosacral torsion, thorax-pelvis coordination, myofascial force transmission, and proximal control are relevant to sprinting. It also helps explain why lateral trunk flexion strength may be worth investigating, not as an isolated strength quality, but as part of a broader lumbo-pelvic system involved in force transmission, pelvic control, and whole-body coordination. Therefore, the spinal engine is best treated in this thesis as a conceptual lens that helps frame the research question, rather than as a confirmed mechanism. Its theoretical claims remain hypotheses that require direct testing in sprinting populations.

2.7 Conclusion

The evidence reviewed throughout this chapter suggests that sprinting is best understood as a coordinated whole-body movement rather than a task driven exclusively by the lower limbs. While traditional models such as the SMM and 2MM provide valuable descriptions of force production and COM behaviour, they do not fully account for the active contributions of the trunk and pelvis. Emerging evidence from biomechanical, imaging, morphological, and coordination studies indicates that the trunk plays an important role in force transmission, pelvic rotation, COM control, and the integration of upper- and lower-body motion during sprinting.

Frameworks such as spinal engine theory and myofascial sling concepts offer plausible explanations for how these trunk and lumbo-pelvic contributions may occur, although direct evidence supporting these mechanisms during maximal sprinting remains limited. Nevertheless, the consistent findings of substantial trunk muscle activation, significant lumbosacral torsional loading, and coordinated thorax–pelvis motion collectively support the view that trunk function is relevant to sprint performance.

Despite this growing body of literature, a critical gap remains. While trunk function appears important for sprinting, no study has directly examined the relationship between lateral trunk

flexion strength and maximal sprint performance. Therefore, the extent to which an individual's capacity to generate lateral trunk force is associated with sprint ability remains unclear. Addressing this gap is the focus of the next chapter, which investigates the relationship between isometric lateral trunk flexion strength and sprint performance.

Chapter 3 The Relationship Between Sprint Performance and Isometric Lateral Flexion Trunk Strength

3.0 Prelude

The preceding review followed how sprint biomechanics has come to rethink the trunk. The main models treat everything above the lower leg as a single passive mass. This captures ground reaction force (GRF) well, but it says nothing about how the trunk and pelvis help produce that force. The evidence reviewed alongside those models tells a different story. The trunk carries a large share of the body's energy during acceleration, and its muscles are highly active at top speed. How well an athlete controls it across all three planes, not just the sagittal, appears to set the faster sprinters apart. Lateral trunk flexion appeared repeatedly throughout this work, both as a motion the trunk performs while sprinting and as a possible contributor to propulsion. Yet all this evidence describes what the trunk does while sprinting, and none of it answers whether the force an athlete can produce in lateral trunk flexion relates to how fast they sprint. That is the question the present chapter sets out to address.

3.1 Introduction

Two of the most adopted models of sprinting, used by scientists and practitioners alike, are the spring-mass model (SMM) and the two-mass model (2MM). Both treat the body above the lower leg as a single passive mass carried by the legs. The SMM is valuable for describing the spring-like behaviour of the leg during contact, reducing sprinting to measurable variables such as leg stiffness, contact time and aerial time, while the 2MM separates the foot and shank from the remaining mass and thereby allows the vertical GRF waveform to be reconstructed (Clark & Weyand, 2014; Clark et al., 2017). Each therefore describes global force application well, but neither distinguishes the trunk and pelvis from the mass the legs support. This emphasis also reflects the direction of sprint research to date. Since sprint speed depends on the magnitude, direction, and timing of the force applied to the ground (Weyand et al., 2000; Kugler & Janshen, 2010; Nagahara, Mizutani, et al., 2018), and since lower-body power is a major determinant of that force, research has concentrated on the hip, knee, and ankle as its source. The trunk, by contrast, has largely been viewed as a structure to be stabilised rather than one that contributes to propulsion.

A growing body of evidence indicates that the trunk and lumbo-pelvic musculature actively contribute to sprint performance rather than being passively carried by the legs. The head and trunk account for a substantial proportion of total-body kinetic energy during sprinting (Slawinski et al., 2022), while the lateral abdominal, spinal, and hip musculature are highly active during maximal sprint efforts (Yoshimoto et al., 2025). Faster sprint performance has also been associated with greater trunk and lumbo-pelvic muscle size (Muratomi et al., 2025), trunk-focused training (Gao et al., 2025), and superior control of the trunk and centre of mass (COM) across all three planes of movement (Vellucci & Beaudette, 2024). Together, these findings suggest that the trunk plays an active role in sprint performance rather than serving solely as a passive link between the upper and lower body.

Within the literature, the frontal plane has received comparatively little direct attention. During each support phase, the athlete is in single-leg stance, and the trunk laterally flexes toward the stance limb while the opposite leg recovers. Controlling this motion, through resisting pelvic drop (Sado et al., 2019) and limiting side-to-side movement of the COM (Vellucci & Beaudette, 2024), requires the lateral trunk flexors to act both as stabilisers of the trunk over the stance limb and as contributors of propulsive energy (Sado et al., 2018), a demand these models cannot represent, since collapsing everything above the lower leg into a single passive mass leaves frontal-plane trunk action outside the model altogether. Accordingly, the spinal engine framework treats this motion as central to the generation of locomotion, proposing that lateral flexion of the trunk, coupled with axial rotation of the spine and pelvis, contributes to propulsion rather than simply following passively from leg motion (Gracovetsky, 1997). The same framework couples the arms to the legs through the trunk, with counterrotation of the shoulders against the pelvis distributing rotational load across the kinetic chain, so that arm and leg action form part of one coordinated pattern rather than separate contributions (Macadam et al., 2018; Vellucci & Beaudette, 2023). Whether or not this proposal extends to sprinting, it identifies lateral trunk flexion as a plausible contributor to performance.

Collectively, the available evidence suggests that the trunk contributes to sprint performance and that lateral flexion is an important component of sprint mechanics. However, previous work has generally linked performance to trunk morphology or broader trunk-training interventions rather than directly measuring lateral flexion force. The broader core-strength literature, which has more commonly relied on endurance-based or sagittal-plane assessments, has also reported inconsistent associations with sprint performance.

Consequently, it remains unclear whether an athlete's capacity to produce force in lateral trunk flexion is related to sprint performance. Therefore, the purpose of this study was to examine the relationship between isometric lateral trunk flexion strength and sprint performance over 40 m in sprint-trained athletes. It was hypothesised that greater lateral flexion force would be associated with faster sprint times, with the strongest relationship expected during the acceleration phase.

3.2 Methods

3.2.1 Approach to the Problem

An acute cross-sectional, within-subject design was used to examine the relationships between lateral trunk flexion strength and sprint performance. Lateral flexion strength was measured isometrically using belt-stabilised fixed dynamometry (Figure 2) (Bucke et al., 2024). Sprint performance was assessed over 40 m using electronic single-beam timing gates, providing 0–10 m, 10–20 m, and 20–40 m split times, and a motorised resisted pulley device was used to record distance to peak velocity. Each participant attended the laboratory on two occasions separated by at least 48 hours: a familiarisation session and a data-collection session. Both assessments were conducted in an indoor training facility, with the 40-m sprints performed on a synthetic sprint track.

3.2.2 Subjects

A priori sample size estimation was conducted using G*Power 3.1 (Faul et al., 2009; Universität Düsseldorf, Germany) for a correlation analysis examining the association between lateral trunk flexion strength and sprint performance. Assuming a moderate effect size (r = 0.50), statistical power of 0.80, and an alpha level of 0.05 (two-tailed), the required minimum sample size was 23 participants. A total of 18 sprint-trained participants (16 males and 2 females) were recruited for this study (descriptive characteristics in Table 2). This fell short of the a priori target of 23. Recruitment coincided with the competitive season for several of the sports represented, which limited the number of athletes willing to undertake maximal testing during training and competition, and recruitment closed at 18 participants so that testing could be completed within the study timeframe. Participants competed in sprint-based sports, including track and field, rugby union, rugby sevens, and rugby league, ranging from amateur to semi-professional levels. To be eligible, participants were required to be aged 16 years or over, to have prior sprint training experience through track and field, team sport, or recreational training, and to be currently injury-free and able to perform maximal sprinting and maximal

isometric strength testing without pain. Participants were excluded if they reported a current injury, or any medical or physical condition that would prevent the safe completion of maximal sprinting or isometric strength testing. Eligibility was confirmed by participant self-report on the information and consent documentation (Appendix C) prior to the familiarisation session. All participants provided written informed consent prior to participation. Ethical approval for the study was granted by the Auckland University of Technology Ethics Committee (AUTEC; Approval No. 25/236).

Table 2

Descriptive Statistics for Participant Characteristics, Lateral Flexion Strength, and Sprint Performance Variables

Variable	Mean ± SD
Age (years)	18.9 ± 2.9
Body mass (kg)	84.2 ± 8.9
Lateral flexion peak force (N)	2595.6 ± 576.7
Relative lateral flexion force ($N \cdot kg^{-1}$)	30.80 ± 5.80
0–10 m sprint time (s)	1.776 ± 0.083
10–20 m sprint time (s)	1.255 ± 0.051
20–40 m sprint time (s)	2.302 ± 0.096
0–40 m sprint time (s)	5.333 ± 0.182
Distance to peak velocity (m)	38.5 ± 1.6

Note. Values are presented as mean ± standard deviation. SD = standard deviation.

3.2.3 Procedures

The first session was used for familiarisation. Written informed consent was confirmed, body mass was recorded using a calibrated digital scale (Hamburg, Germany), and participants were familiarised with all testing procedures. The second session served as the formal data-collection session and comprised lateral flexion strength and 40-m sprint testing.

Both sessions followed the same standardised warm-up and testing sequence. The warm-up consisted of 5–10 minutes of self-paced cycling on an electronically braked ergometer (Lode Excalibur Sport, Groningen, The Netherlands) at a light intensity (5/10 rating of perceived exertion [RPE]), followed by dynamic trunk and hip mobilisation exercises (torso rotations, side bends, glute bridges, and hip-flexor stretches). Participants then completed the same familiarisation build protocol for both testing assessments, completing gradual builds in intensity at approximately 50%, 70%, and 90% of perceived maximal effort before commencing the sprint or lateral flexion test. All warm-ups were supervised by the primary researcher.

Raw data were exported from the manufacturer software platforms as comma-separated values (CSV) files and screened in Microsoft Excel. Data were checked for completeness and visually inspected for anomalous values prior to analysis. Sprint velocity-time profiles were reviewed to confirm smooth acceleration characteristics and the absence of signal artefacts,

with trials displaying irregular profiles (e.g., signal dropouts or abrupt decelerations) excluded. Lateral flexion force-time outputs were similarly screened to confirm protocol adherence and maximal effort. Where multiple valid trials were available, the highest-performing trial was retained for subsequent analysis, consistent with the approach used in the reliability study underpinning the lateral flexion assessment (Bucke et al., 2024) and with applied sprint-testing practice (Pryer et al., 2025).

3.2.4 Isometric Lateral Trunk Flexion Strength

Isometric lateral flexion strength was assessed using a portable strain gauge (Hawkins Dynamics TruStrength, Westbrook, ME, USA) in conjunction with a 45° Roman chair (Figure 2). A fixed-dynamometer approach was selected because belt-stabilised isometric trunk strength testing, including lateral flexion, has demonstrated excellent between-session reliability in our laboratory (intraclass correlation coefficient [ICC] ≈ 0.98–0.99). The method was chosen to provide a reliable assessment that could be readily implemented within routine athlete testing and monitoring practices. An isometric measure was considered appropriate despite the dynamic nature of sprinting because it isolates the maximal force-generating capacity of the lateral flexors under standardised, externally stabilised conditions. Dynamic trunk tasks, by contrast, are difficult to standardise and are confounded by momentum, movement technique, and force contributions from adjacent segments, which makes the strength of the lateral flexors themselves difficult to resolve. Maximal isometric force was therefore treated as an index of the underlying strength capacity that the lateral flexors must express rapidly and cyclically during sprinting, rather than as a simulation of the sprint action itself. The consequence is that rate- and velocity-dependent qualities of trunk function are not captured by this measure, and this constraint is considered in Section 3.5. Reliability of the present assessment is reported in Table 3.

Participants lay side-on with the trunk aligned to the longitudinal axis of the Roman chair and the pad positioned beneath the level of the anterior superior iliac spine; the side under assessment faced upward (e.g., lying on the left side to test the right lateral flexors). The legs were secured by an inbuilt pad over the distal shank. A non-elastic strap was positioned under the axillae across the trunk and connected to the strain gauge, anchored to a firmly secured metal plate 1.90 m from the Roman chair. With the test-side arm crossed over the chest and the contralateral arm relaxed, participants were instructed, from a neutral trunk position, to

"drive the ribcage towards the ceiling" as hard and as fast as possible and to maintain maximal effort for 3 seconds. Body position was monitored visually by the primary researcher throughout.

After the device was zeroed, participants performed three warm-up contractions per the progression described above (3 s each, 60 s rest), followed by three maximal voluntary isometric contractions (MVICs), each held for 3 s and separated by 60 s of passive rest, with strong verbal encouragement. A 3 s duration was selected because it is sufficient for peak force to be attained and plateau in a maximal isometric trunk effort, while remaining short enough to limit the fatigue, postural drift, and compensatory bracing that accumulate over longer holds and would otherwise degrade both the peak value and its reproducibility. This duration is also consistent with the protocol used in the reliability study underpinning the assessment (Bucke et al., 2024), allowing the present reliability estimates to be compared directly with those reported previously. The full protocol was completed on both sides. Peak force (N) was extracted from each trial, and the highest value from each side was retained. Because the study aimed to quantify overall lateral flexion strength rather than inter-limb asymmetry, the left and right peak forces were summed to form the primary predictor (summed lateral flexion peak force). Summing was considered the more appropriate operationalisation on both theoretical and statistical grounds. Theoretically, lateral flexion is expressed alternately to left and right across successive steps, so total bilateral capacity, rather than the capacity of either side in isolation, is the quantity available to the sprint task. Statistically, retaining separate left and right predictors would have introduced two highly collinear variables and additional comparisons into an already modest sample, whereas a single summed index provided one theoretically grounded predictor per participant. Trials affected by technical error (e.g., hips lifting off the pad, inward collapse of the torso, or knee flexion used to generate additional force) were repeated.

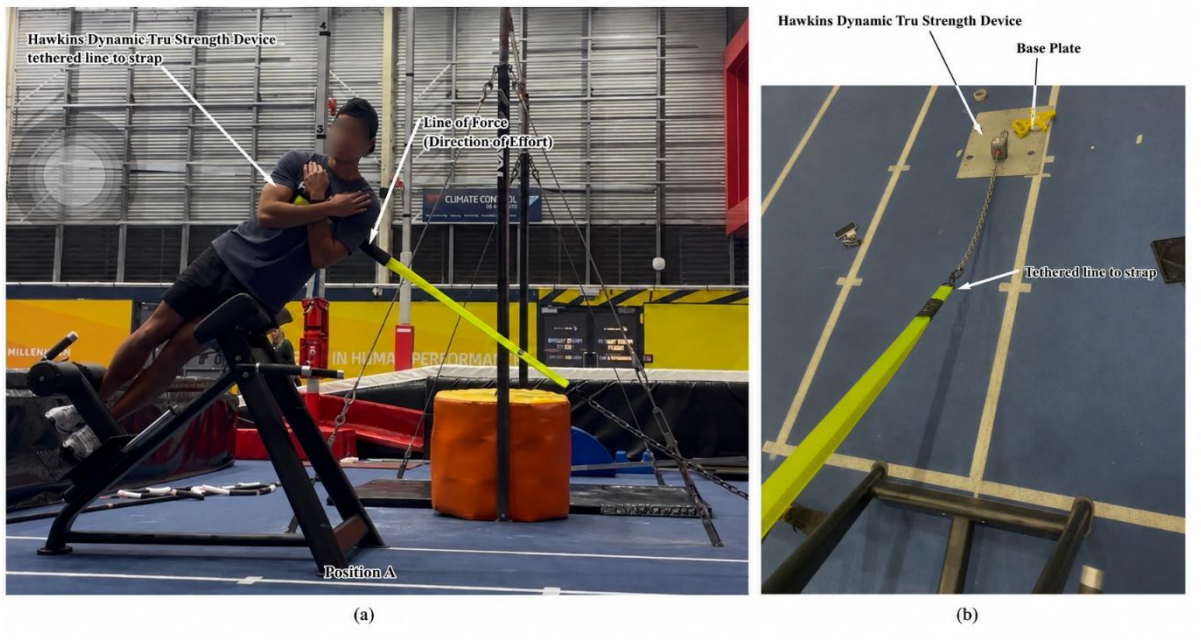


Figure 2

Lateral Flexion Isometric Assessment

Note. Panel A shows the participant positioned for lateral flexion testing, with resistance applied via the portable strain gauge and tethered strap. Panel B shows the device and base plate anchoring the tethered strap to the floor.

3.2.5 40-m Sprint

Single-beam SmartSpeed timing gates (VALD Performance, Brisbane, Australia) were positioned at 0, 10, 20, and 40 m to record 0–10 m, 10–20 m, and 20–40 m split times, as well as total 0–40 m sprint time. Each timing gate and its paired reflector were positioned approximately 2 m apart and perpendicular to the running direction, with the infrared beam aligned at approximately hip height (~1.0 m) (van den Tillaar et al., 2022).

Continuous velocity-time data were captured using a motorised resisted pulley device (MuscleLab, Ergotest Technology AS, Stathelle, Norway). The unit was positioned 5 m behind the start line and connected via a retractable motorised cable to a waist belt worn by the participant, applying a constant tracking load of 0.5 kg throughout each sprint. A low constant preload was used to maintain cable tension and minimise cable slack during data collection, thereby improving the accuracy of position and velocity measurements while imposing

negligible external resistance, consistent with previous motorised encoder methodologies (Fornasier-Santos et al., 2022).

Participants performed three maximal 40-m sprints, each separated by 5 minutes of passive recovery, with the instruction to "run as fast as possible." Sprints were initiated from a standing two-point start, with the front foot placed on a marked line positioned 0.5 m behind the first timing gate. This starting distance was selected to prevent premature triggering of the timing system by a swinging arm or elevated knee, consistent with established sprint-timing recommendations (Haugen et al., 2019). Participants self-initiated each sprint, and timing began when the first beam was broken.

As the participant accelerated, the device continuously tracked cable displacement and velocity, enabling continuous measurement of running velocity and distance throughout the sprint. These data were used to identify the distance to peak velocity, which was included alongside sprint performance variables in the subsequent analyses. Trials affected by technical error or incorrect protocol execution (e.g., submaximal effort, premature deceleration, or loss of balance) were excluded.

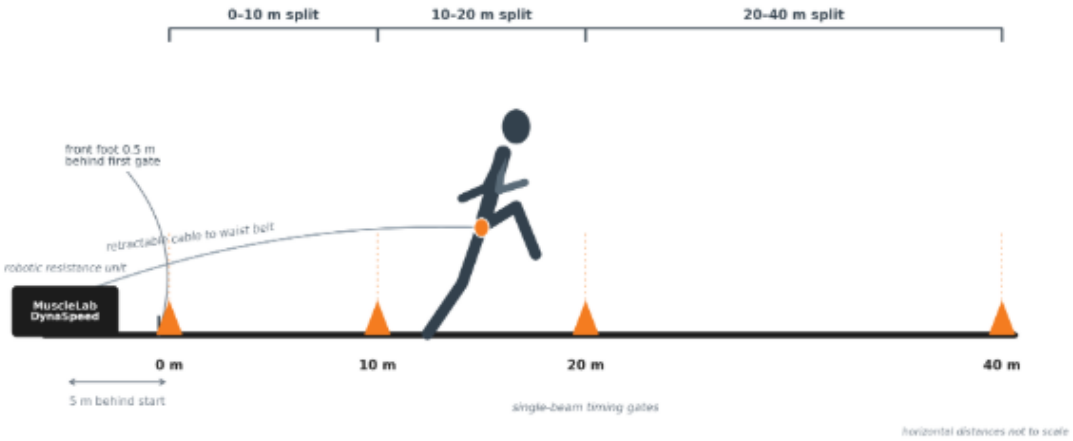


Figure 3

Schematic of the 40-m Sprint Assessment Setup

Note. Timing gates were positioned at 0, 10, 20, and 40 m, with the motorised resisted pulley device positioned behind the start line to record continuous velocity-time data across the sprint.

3.2.6 Statistical Analysis

The final dataset was analysed using JASP (Version 0.18.1; JASP Team, Amsterdam, Netherlands). Descriptive statistics are presented as mean ± standard deviation. Normality was assessed using the Shapiro-Wilk test and visual inspection of Q-Q plots. As the analyses were correlational, assumptions of linearity and homoscedasticity were evaluated through visual inspection of bivariate scatterplots.

Intrasession reliability of lateral flexion peak force was assessed using a single-measure, absolute-agreement, two-way mixed-effects ICC consistent with the recommendations of Koo and Li (2016). Absolute reliability was expressed as the standard error of measurement (SEM), and relative variability was expressed as the coefficient of variation (CV), with values <10% considered acceptable. Prior to summation, left and right lateral flexion peak force values were examined to determine whether they could be combined into a single measure. The two sides were strongly correlated ($r = .76$, $p < .001$) and did not differ significantly $t(17) = 0.56$, $p = .585$), supporting the use of summed lateral flexion peak force in subsequent analyses.

The primary analysis examined the relationships between summed lateral flexion peak force and sprint performance variables (0–10 m, 10–20 m, 20–40 m, and 0–40 m sprint times). Associations between distance to peak velocity and sprint-performance variables were also examined using Pearson product-moment correlation coefficients (r). Correlation magnitudes were interpreted as small (.10), moderate (.30), and large (.50) according to Cohen (1988). Statistical significance was set at $p < .05$.

3.3 Results

Descriptive statistics for participant characteristics, lateral flexion strength, and sprint-performance variables are presented in Table 2. All variables were normally distributed (Shapiro-Wilk, all $p > .05$), and visual inspection of bivariate scatterplots supported the assumptions of linearity and homoscedasticity for all variable pairs. Lateral flexion peak force demonstrated excellent intrasession reliability on the left side (ICC = 0.90, 95% CI = 0.80–0.95; SEM = 50.67 N; CV = 7.81%) and good reliability on the right side (ICC = 0.84, 95% CI = 0.60–0.94; SEM = 58.68 N; CV = 9.15%) (Table 3).

Table 3

Intrasession Reliability of Isometric Lateral Flexion Peak Force

Variable	ICC (95% CI)	SEM (N)	CV (%)
Lateral flexion peak force (L)	0.90 (0.80–0.95)	50.67	7.81
Lateral flexion peak force (R)	0.84 (0.60–0.94)	58.68	9.15

Note. ICC = intraclass correlation coefficient; CI = confidence interval; SEM = standard error of measurement; CV = coefficient of variation.

Significant large negative relationships were observed between lateral flexion peak force and both the 0–10 m sprint split ($r = −.63$, $p = .007$) and 0–40 m sprint time ($r = −.70$, $p = .002$). Relationships between lateral flexion peak force and the 10–20 m split time were moderate and statistically significant ($r = −.56$, $p = .018$), whereas relationships with the 20–40 m split time and distance to peak velocity were small-to-moderate and non-significant ($r = −.48$ to $.41$, $p = .054$ to $.101$). Correlations between all variables are presented in Figure 4.

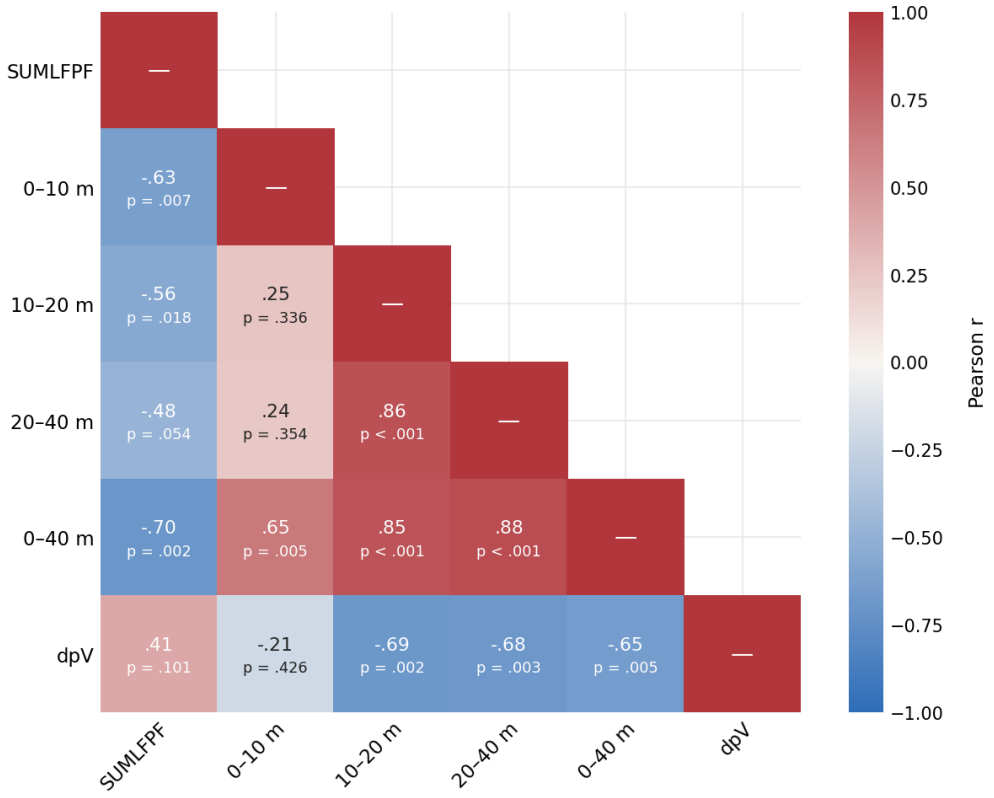


Figure 4

Correlation Matrix for Lateral Flexion Strength, Sprint Split Times, and Sprint-Derived Velocity Variables

Note. Correlation coefficients (*r*) are displayed for relationships between summed lateral flexion peak force (SUMLFPF), sprint split times (0–10 m, 10–20 m, 20–40 m, and 0–40 m), and distance to peak velocity (dPV). Red shading indicates positive and blue shading negative relationships, with darker shading indicating stronger relationships. The p-value for each correlation is shown beneath its coefficient; significance was set at $p < .05$.

3.4 Discussion

The present study examined the relationship between isometric lateral trunk flexion strength and sprint performance over 40 m in sprint-trained athletes. In alignment with our hypothesis, greater lateral flexion peak force was associated with faster sprint performance during acceleration, with the strongest relationship observed over 0–10 m. Significant relationships were also observed for the 10–20 m split and total 0–40 m sprint time, whereas no significant relationships were found for the 20–40 m split or distance to peak velocity. Together, these findings suggest that lateral flexion strength may contribute to sprint ability and be most relevant during the early stages of sprint acceleration.

The strongest relationship was between lateral flexion peak force and 0–10 m sprint time ($r = -.63$, $p = .007$). Athletes who produced greater lateral flexion force accelerated faster during the first 10 m, suggesting that lateral flexion strength may contribute to the control and transfer of force through the trunk and pelvis during early acceleration. This interpretation is consistent with recent evidence highlighting the active role of the trunk during sprinting. The trunk contributes substantially to whole-body mechanical output during acceleration, while faster sprinters appear to display superior trunk-pelvic coordination and reduced unnecessary COM movement (Vellucci & Beaudette, 2023, 2024; Yoshimoto et al., 2025). Improvements in sprint performance have also been accompanied by changes in trunk-pelvic mechanics over time (Ota et al., 2024). Collectively, this evidence supports the present finding and suggests that greater lateral flexion strength may contribute to faster acceleration by improving trunk-pelvic control and force transmission. A direct mechanical contribution is also possible, as the lateral trunk flexors have been shown to perform meaningful work during single-support tasks (Sado et al., 2018, 2020). However, because trunk kinematics and GRF were not measured, the specific mechanism remains unclear.

A second important finding was the progressive reduction in the magnitude of the relationship across the sprint. The relationship decreased from 0–10 m ($r = -.63$) to 10–20 m ($r = -.56$) and then to 20–40 m ($r = -.48$, $p = .054$). This suggests that lateral flexion strength may be more important during acceleration than during later phases of sprinting. Early acceleration is characterised by greater propulsive demands, larger trunk inclination, and wider step placement, all of which likely increase the requirement for frontal-plane trunk control. As velocity increases, performance becomes increasingly dependent on rapid force production, elastic energy utilisation, stiffness, and technical efficiency (Weyand et al., 2000; Struzik et al.,

2021). Consequently, the influence of maximal lateral flexion strength may diminish as other qualities become more important determinants of performance. This interpretation aligns with the present findings, whereby the strongest relationship was observed during the first 10 m and progressively weakened across subsequent sprint phases.

Lateral flexion peak force was also significantly related to total 0–40 m sprint time ($r = -.70$, $p = .002$). However, this relationship was likely driven by acceleration performance rather than by an independent contribution across the entire sprint. Significant relationships were present during both the 0–10 m and 10–20 m splits, whereas no significant relationship was observed during the 20–40 m split. Therefore, the association with total sprint time appears to reflect the influence of lateral flexion strength during the first half of the sprint. Put simply, athletes with greater lateral flexion strength achieved faster 40 m sprint times largely because they accelerated more effectively during the opening phases of the sprint.

Interestingly, no significant relationship was observed between lateral flexion peak force and distance to peak velocity ($r = .41$, $p = .101$), which contrasts with the strong relationship observed between lateral flexion strength and acceleration performance. The lateral flexors contribute meaningful joint work during the single-support phase of a block start (Sado et al., 2020), and this demand appears greatest across the wide-stance early steps, easing as step width narrows and the athlete rises into an upright posture (Nagahara & Zushi, 2017). One plausible reading is therefore that their contribution is front-loaded, and that a maximal isometric test, reflecting force applied slowly rather than the reactive qualities thought to sustain acceleration, relates to the first steps rather than to the distance over which velocity continues to rise (Brady et al., 2020). Rather than influencing how long acceleration is maintained, lateral flexion strength appears to be more closely related to how effectively velocity is generated during the initial stages of a sprint.

In summary, greater isometric lateral trunk flexion strength was associated with faster sprint performance, particularly during the first 10 m. The relationship weakened across successive sprint phases and was likely responsible for the observed association with total sprint time. These findings suggest that lateral flexion strength may be more relevant to acceleration than to later phases of sprinting and support its consideration as a potential monitoring variable in sprint-trained athletes.

3.5 Limitations

Several limitations should be considered when interpreting these findings. The cross-sectional design allows conclusions regarding association but not causation, and therefore, cannot determine whether greater lateral flexion strength contributed to faster acceleration or simply accompanied it. The final sample of 18 participants fell short of the a priori target of 23, which reduced statistical power and widened the confidence intervals around the reported correlations. Genuine moderate associations may therefore have gone undetected, and the magnitude of the relationships that did reach significance should be regarded as provisional rather than precisely estimated. The sample was also drawn from sprint-trained athletes representing a range of sporting backgrounds, which may have introduced variability in sprint mechanics and training histories. In addition, the sample was predominantly male, meaning the findings are most appropriately applied to male sprint-trained athletes. Further, lateral flexion strength was assessed using a single maximal isometric measure, which may not fully reflect the dynamic and velocity-specific functions of the trunk during sprinting. Isometric force-time measures show correlations with dynamic performance ranging from small to very large depending on the test and task (Lum et al., 2020), and a rate-of-force-development measure or a standing, single-support test position may have better matched the demands of sprinting. Summing left and right peak forces also meant that side-to-side imbalance was not retained, and future work pairing separate left and right measures with sprint kinematics could test whether such imbalance is reflected in step asymmetries. Sprint performance was also evaluated without concurrent kinematic or GRF measurements, meaning the proposed mechanism relating to trunk-pelvic control and force transmission remains inferential rather than directly observed. Finally, the spinal engine framework used to assist interpretation has been investigated primarily in walking and has received limited examination in sprinting; as such, it should be viewed as an interpretive framework rather than an established explanation of sprint mechanics.

3.6 Practical Applications

Greater isometric lateral trunk flexion strength was associated with faster acceleration performance over the first 20 m of a sprint and with faster overall 40 m sprint time. Coaches working with athletes whose performance depends on acceleration may consider monitoring lateral flexion strength alongside established measures of lower-body strength, power, and sprint performance. The assessment used in the present study is simple to implement in a gym-based environment, using relatively portable and accessible equipment rather than

sophisticated laboratory-based instrumentation. Although the present findings do not establish a causal relationship, lateral flexion strength may represent a physical quality relevant to acceleration performance and may warrant inclusion within a comprehensive athlete monitoring programme.

Chapter 4 Summary, Practical Applications, Limitations, Future Research Directions

4.1 Summary

This thesis set out to examine the contribution of the trunk to sprint performance, with particular focus on lumbar lateral flexion, and to test directly whether the force an athlete can produce in lateral trunk flexion relates to how fast they sprint. The review in Chapter 2 established that conventional models of sprinting, the SMM and 2MM, treat the whole upper body as a single passive mass and therefore give the trunk and pelvis no distinct mechanical role. It then drew together a converging body of evidence that the trunk is in fact an active contributor to accelerated sprinting through its share of whole-body kinetic energy, the recruitment of the lateral abdominals and spinal musculature, the role of lumbosacral torsion in pelvic rotation, and the associations between trunk size and sprint times (Sado et al., 2017, 2020; Fujita et al., 2019; Yoshimoto et al., 2025). The review identified a clear gap within this evidence. The literature described what the trunk does during sprinting but had not tested whether lateral flexion strength itself relates to sprint performance. Chapter 3 set out to explore this empirical gap.

Chapter 3 found that isometric lateral trunk flexion strength was associated with faster early acceleration and faster overall 40 m time in sprint-trained athletes, but not with the higher-velocity phases of the sprint. The relationship was therefore phase-specific, concentrated in the initial steps where propulsive demand, trunk lean and frontal-plane control are greatest. Read alongside the review, this result does two things. It provides the direct, strength-based evidence the literature was previously lacking and suggests that this relationship is most evident during the acceleration phase, where the trunk's contribution is mechanically most plausible. However, given the correlational design and the absence of concurrent kinematic or kinetic measures, this interpretation should be considered supportive rather than conclusive. Taken together, the review and the study support the broader case running through this thesis, that the trunk is an active contributor to acceleration rather than a passive mass carried by the legs, while showing that this contribution is specific rather than general and is best understood phase by phase.

The study was cross-sectional and collected no kinematic or GRF data, so the reason lateral flexion strength relates to early acceleration remains inferred rather than explained, and the spinal engine framework used to interpret it throughout the thesis remains a lens rather than a tested mechanism.

4.2 Practical Applications

For the coach, the central message is that lateral trunk flexion strength is a quality worth measuring and considering in athletes whose performance depends on acceleration. The assessment used in this thesis is simple to administer, uses portable equipment rather than sophisticated laboratory-based instrumentation, and is reliable enough to monitor change over time, which makes it practical for applied settings.

The findings support lateral flexion strength as a potential monitoring variable in sprint-trained athletes, but they do not show that training this quality improves sprint performance. The lateral flexion and oblique work that many practitioners already build into warm-ups and supplementary training is consistent with these findings, but whether it enhances early acceleration remains an untested proposition that requires intervention research. Any such work should complement rather than replace lower-limb and whole-body training, since the legs remain the primary propulsive mechanism. Table 4 is presented in the same spirit: as a conceptual framework to structure future intervention studies, not as an evidence-based training prescription.

Table 4

Proposed Conceptual Framework for Classifying Spinal Engine Training

System	Isometric	Dynamic	Ballistic/reflexive
Lateral flexion	Lateral flexion PIMA/HIMA	Flywheel lateral flexion	Drop-catch lateral flexion
Rotation	Rotational PIMA/HIMA	Split-stance rotations	MB side toss
Oblique sling	Contralateral ISO holds	Loaded sling patterns	Sling throw variations

Integrated	Acceleration lunge ISO with dowel lateral flexion	Seated gait walks	Stick/dowel accelerations
Oscillation/elasticity	—	Speed ball patterns	Sprinting

Note. PIMA = pushing isometric muscle action; HIMA = holding isometric muscle action; ISO = isometric; MB = medicine ball. Exercises are organised according to a proposed progression from force-capacity development, to force production through range, and finally reflexive force transfer and sprint-specific expression. This framework is conceptual and speculative. It was adapted from spinal engine training concepts presented in supporting training materials, and no element of it was implemented, tested, or evaluated in this thesis. The progression reflects a theoretical rationale rather than empirical evidence of training efficacy, and the exercises listed should not be interpreted as validated means of improving sprint performance. The framework is presented to structure future intervention research.

4.3 Limitations

The limitations specific to the experimental study are reported in Section 3.5. Considered together, they define the boundary of what this thesis can claim.

The cross-sectional design and the absence of concurrent kinematic and GRF data mean that the contribution of the lateral flexors to trunk-pelvic control and force transmission is established here at the level of association, with the underlying mechanism proposed on the basis of these relationships rather than measured directly. The single maximal isometric task, while a practical and reliable measure of force-producing capacity, does not reflect the dynamic, rate-dependent, or velocity-specific qualities likely expressed by the trunk during sprinting, which may partly explain why the relationships were strongest during acceleration. The findings are therefore most appropriately read as evidence that trunk lateral flexion strength warrants inclusion in models of acceleration performance in male sprint-trained athletes, rather than as an established account of the trunk's contribution to sprinting more broadly.

More broadly, the spinal engine framework that informed much of the interpretation offers a useful perspective through which to consider the potential contribution of the trunk to sprint performance. However, the framework has been investigated primarily in walking locomotion,

with relatively limited evidence available in running and virtually none in maximal sprinting. The present findings may therefore be viewed as providing preliminary support for exploring these concepts in sprint performance, rather than as confirmation of the spinal engine model itself.

4.4 Future Research Directions

The clearest priority is to integrate step-resolved kinematic and kinetic data with the strength measure, so that the mechanism behind the acceleration relationship can be examined directly rather than inferred. This would establish whether stronger lateral flexors are associated with larger propulsive impulses and greater horizontal and vertical GRF during early acceleration, with longer step lengths and wider step widths, and identify if lateral flexion strength relates to ground contact time and step frequency across the opening steps. Beyond this, the single isometric measure should be extended to rate of force development and include a range of motion, so that the specific qualities of the lateral flexors that matter, and the phases at which they matter, can be separated. A larger sample would allow these relationships to be examined with greater confidence, and a more even distribution of male and female participants would allow potential sex differences to be assessed, which the present sample could not address. Finally, because this thesis tested an association rather than a training effect, intervention studies are needed to determine whether developing lateral flexion strength improves acceleration, and prospective work in maximal-velocity sprinting would help establish whether the SE framework holds as a mechanism rather than serving only as an interpretive lens.

4.5 Conclusion

Isometric lateral trunk flexion strength demonstrated significant relationships with both 0–10 m and 0–40 m sprint performance in sprint-trained athletes. These relationships were confined to the acceleration phase, suggesting that lateral trunk strength may be particularly important during the high-force demands of early sprinting. The assessment demonstrated excellent reliability and may provide practitioners with a practical method for monitoring frontal-plane trunk strength. Further research should investigate whether targeted improvements in lateral trunk strength can directly enhance sprint performance and explore the mechanisms underpinning this relationship.

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Appendices

Appendix A – Ethics Application

AUT
TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

20 August 2025

Aaron Uthoff
Faculty of Health and Environmental Sciences

Dear Aaron

Re Ethics Application: **25/236 Investigating the association between maximal lateral isometric trunk flexion strength and sprint running performance**

Thank you for your responses to AUTEC's conditions.

Your ethics application has been approved for three years until 20 August 2028.

Non-Standard Conditions of Approval

1. Assurance that the storage of research data and consent forms are under the control of the applicant.
2. Changes to the advertisement flyer:
    a. Indicate that this study is for Master's research. A heading of "MASTER RESEARCH" has been added which may be misleading to the public. Please also revise reference to the student researcher as the "Head" researcher as again this could be misleading;
    b. Revise the inclusion criteria to reflect the response given in the correspondence to condition 8;
3. Changes to the Information Sheet:
    a. Include the exclusion criteria to reflect the response given in the correspondence to condition 9;
    b. Remove the indicative cost of the "performance report ($100)" and the repetition of receiving a personalised performance report;
    c. Include the subsection "what opportunity do I have to consider this invitation".

Non-standard conditions do not need to be submitted to or reviewed by AUTEC unless requested but must be completed before commencing your study.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC.
2. All public facing documents must have the AUTEC approval number and be of a high standard of spelling and grammar. Dates on the Information Sheet(s) and Consent Form(s) must be consistent.
3. Any amendments to the project must be approved by AUTEC prior to being implemented.
4. A progress report is due annually on the anniversary of the approval date.
5. A final report is due at the expiration of the approval period, or, upon completion of project.
6. Any serious or adverse events must be reported to AUTEC, this includes unforeseen issues that might affect continued ethical acceptability of the project.
7. AUTEC grants ethical approval only. You are responsible for obtaining management permission for access from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

The application number and title need to be referenced on all correspondence related to this project.

All forms are available online http://www.aut.ac.nz/research/researchethics

For any enquiries, please contact the Secretariat at ethics@aut.ac.nz
(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: willmct01@gmail.com;ztw6773@autuni.ac.nz; Alyssa-joy.spence@aut.ac.nz

Auckland University of Technology, D-88, Private Bag 92006, Auckland 1142, New Zealand.
T: +64 9 921 9999 ext. 8316: E: ethics@aut.ac.nz: www.aut.ac.nz/researchethics

Appendix B – Recruitment Flyer



Appendix C – Information Sheet & Consent Form

Participant Information Sheet

Everything you need to know before you sign

Date produced: 12 July 2025

Date that data collection will start: *26th of May 2026*

Project Title

Beyond the Legs: Reconsidering Sprint Performance through the Lens of Spinal Engine Theory

Working title: Trunk Strength and Sprint Performance Study

Kia ora,

You are invited to take part in a research study looking at whether trunk strength is linked to sprint performance. This study is being conducted by William McTaggart from Auckland University of Technology (AUT), New Zealand. The research team also includes Dr Alyssa-Joy Spence (Supervisor) and Dr Aaron Uthoff (Co-Supervisor). The study is being carried out as a requirement for William's *Master of Sport, Exercise and Health* degree.

At a glance

What we're studying	Whether strong trunk muscles (your lateral flexors and obliques) are linked to sprint performance, and how reliable a new way of measuring this strength is.
Who can take part	Aged 16+, with sprint training experience (track, team sport, or recreational), and currently injury-free.
What you'll do	Two visits to AUT Millennium: a familiarisation session, then trunk strength testing on a 45° Roman chair and 40 m sprints on an indoor track.
How long	Two sessions at least 2 days apart — around 30–45 minutes for familiarisation, and 60–90 minutes for testing.

Cost to you	None — just your time (around 2–2.5 hours in total).
What you get back	A full athlete performance profile, plus a sprint force–load profile sheet with programming recommendations and specific loads to use to improve.

Why we're doing this

We want to understand whether strong trunk muscles — specifically your lateral flexors and obliques (the muscles that control sideways bending and rotation) — are linked to sprint performance and technique. This sits within a broader idea called the ‘spinal engine theory’, which suggests the trunk plays a bigger part in running than it's often given credit for. The study has two goals:

- **Test a new strength test.** We're checking how reliable a new way of measuring lateral trunk flexion strength is — whether it gives consistent results when repeated.
- **Link strength to sprinting.** We'll compare your strength scores against your 40 m sprint performance — including your times over the first 10 m, 20 m, and full 40 m — to see whether stronger trunk muscles tend to mean faster, more efficient sprints.

Why are you being invited?

You've expressed interest in the study and meet the criteria: aged 16 or over, with previous sprint experience, and currently able to sprint and do strength testing without injury or pain.

How do I agree to take part?

Taking part in this study is entirely voluntary — it's your choice, and choosing not to take part won't disadvantage you in any way. On arrival for your first session, you can ask us anything, and once you're comfortable, you'll sign a consent form before any testing begins. See ‘Your privacy’ below for how withdrawing affects your data.

What will actually happen?

You'll attend two sessions with William at AUT Millennium (17 Antares Place, Rosedale), at least 2 days apart and at around the same time of day each visit. Please avoid eating for 2 hours before each session, and try to keep up your normal training in between.

Session 1: Familiarisation

We'll record your height and weight, confirm your written consent, and walk you through every test so you know exactly what to expect. This session is just practice — it doesn't count towards your results.

Session 2: Testing

Both sessions begin with the same warm-up: 5–10 minutes of easy cycling, followed by dynamic stretches for your trunk and hips, all supervised by the research team. You'll then complete:

1. Trunk strength test

Lying on your side on a padded 45° Roman chair, with a strap around your trunk connected to a strength-measuring device, you'll drive your ribcage toward the ceiling as hard and fast as you can, holding for 3 seconds. After a few lighter practice efforts, you'll perform three maximal pushes with a minute's rest between each.

2. 40 m sprint testing

Three maximal 40 m sprints, with 5 minutes' rest between each. You'll wear a lightweight waist belt attached to a cable that tracks your speed and distance, and run through timing gates that record your times at 10 m, 20 m, and 40 m.

All testing is run by qualified researchers under standardised conditions to keep you safe and the data reliable.

Benefits of taking part

- You'll get a full athlete performance profile based on your trunk strength and sprint performance, useful for shaping your own training.
- You'll receive a sprint force–load profile sheet with programming recommendations and specific loads to use to improve.
- You'll see how scientific testing methods are used in real sports performance research.
- Your data helps improve our understanding of how trunk strength links to sprint performance, which can inform coaches and strength & conditioning practice.

- The findings will support William's *Master's* thesis and may lead to academic publications and presentations. You won't be identifiable in any published output.

Risks and discomfort

We don't expect any significant risk. The strength test is isometric, and the sprint uses only a very light cable tension (0.5 kg) with a standardised setup, so you shouldn't experience soreness or fatigue that would affect your training. If anything is uncomfortable at any stage, tell us straight away and we'll address it.

If something goes wrong

In the unlikely event of a physical injury caused by participation, rehabilitation and compensation may be available through the Accident Compensation Corporation (ACC), provided the incident meets ACC's requirements.

Your privacy

Your data will be de-identified. We'll assign you a unique participant ID and remove your name from all records.

You can withdraw at any point. If you do, you can choose whether to have your identifiable data removed or to allow it to keep being used. Once the findings are published, removal may no longer be possible.

Costs and feedback

There are no monetary costs — only your time (around 2–2.5 hours across both sessions). We'd appreciate hearing back within one working week if you'd like to take part. If you tick the relevant box on the consent form, we'll email you a summary of the findings and/or your personal performance profile after your session.

Concerns or questions

Any concerns about the nature of this project should be raised in the first instance with the Project Supervisor or Co-supervisor. Concerns about how the research is being conducted should go to the Executive Secretary of AUTEC. Please keep this Information Sheet and a copy of your signed Consent Form for your future reference.

Researcher	William McTaggart +64 020 4068 1051 · willmct01@gmail.com
Supervisor	Dr Alyssa-Joy Spence +64 021 025 93012 · alyssa-joy.spence@aut.ac.nz
Co-supervisor	Dr Aaron Uthoff +64 27 231 9585 · aaron.uthoff@aut.ac.nz
AUTEC Executive Secretary	For concerns about the conduct of the research +64 9 921 9999 ext 6038 · ethics@aut.ac.nz
Wellbeing support	AUT Counselling & Mental Health (free & confidential for AUT students) 09 921 9292 (Mon–Fri, 8:30am–4:30pm)

Approved by the Auckland University of Technology Ethics Committee on *31/07/25.* **AUTEC Reference:** *[25/236]***.**

Consent Form

Project title: **Beyond the Legs: Reconsidering Sprint Performance through the Lens of Spinal Engine Theory**

Project Supervisor: Dr. Aaron Uthoff & Dr. Alyssa-Joy Spence

Researcher: William McTaggart

- ○ I have read and understood the information provided about this research project in the Information Sheet dated dd mmmm yyyy.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ○ I understand that if I withdraw from the study then I will be offered the choice between having any data or tissue that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ○ I am not suffering from I am currently injury-free and do not have any medical or physical condition that would prevent me from safely performing maximal sprinting and isometric strength testing. I have completed at least one year of resistance training, regularly participate in sprint-based activities (minimum 1–2 times per week), and am between 16 and 30 years of age
- ○ I agree to participate in the performance testing procedures outlined in this study, including maximal-effort sprint testing and isometric strength assessments.
- ○ I agree to take part in this research.
- ○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: .....

Participant's name:

..... Participant's Contact

Details (if appropriate):

.....

.....

.....

.....

Date:

Approved by the Auckland University of Technology Ethics Committee on 31/07/25 AUTEC

Reference number 25/236 *Note: The Participant should retain a copy of this form.*