

Dynamic Neuromuscular Stabilization on Endurance, Flexibility, and Thoracic Mobility in Adolescent Sprinters: A Scoping Review

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ABSTRACT

Background

Dynamic Neuromuscular Stabilization (DNS) is a developmental kinesiology-based intervention that restores coordinated deep muscle activation, breathing patterns, and postural stabilization. Adolescent sprinters face unique physiological demands requiring integrated neuromuscular control, thoracic mobility for respiratory efficiency, and musculoskeletal flexibility for optimal sprint mechanics. Despite the theoretical alignment between DNS principles and sprint performance requirements, no comprehensive scoping review has mapped the evidence on DNS effects across the outcome domains of endurance, flexibility, and thoracic mobility, particularly in adolescent populations.

Objective

To systematically map the existing evidence on the effects of Dynamic Neuromuscular Stabilization and core stability training on endurance, flexibility, and thoracic mobility, with specific relevance to adolescent sprinters, and to identify intervention characteristics, assessment methods, key outcomes, developmental considerations, and gaps in the literature.

Eligibility Criteria

Studies were included if they involved DNS training, core stability training, or related neuromuscular interventions; reported outcomes related to endurance, flexibility, thoracic mobility, neuromuscular control, or postural stability; and involved athletic or youth populations. Textbooks, reviews, experimental studies, RCTs, meta-analyses, and descriptive analyses were eligible. Studies unrelated to athletic populations, DNS, or the three primary outcome domains were excluded.

Information Sources

Evidence was sourced from 31 references spanning databases including PubMed, Scopus, Web of Science, SPORTDiscus, and CINAHL, covering the period 1952 to 2025. Sources included textbooks, peer-reviewed original articles, reviews, RCTs, meta-analyses, and descriptive analyses.

Charting Methods

Data were charted using a standardized extraction form capturing author, year, country, study design, population, sample size, intervention characteristics, outcome measures, key results, assessment tools, and study limitations. Thematic categorization was applied to map evidence across five domains: physiological foundations, core stability and neuromuscular control, DNS specific interventions, assessment methodology, and developmental considerations.

Results

Thirty one sources were included. DNS training consistently demonstrated improvements in postural stability, balance, neuromuscular coordination, and trunk stability across intervention durations of 4 to 12 weeks. Endurance was assessed using the Yo-Yo Intermittent Recovery Test, flexibility via the Sit-and-Reach Test, and thoracic mobility through chest expansion measurement — all validated tools present in the evidence base. However, no study directly investigated DNS training in adolescent sprinters, and no DNS intervention study used endurance, flexibility, or thoracic mobility as primary outcome measures concurrently. Significant research gaps were identified in paediatric sprint-specific DNS application.

Conclusion

DNS training demonstrates evidence-based effectiveness for neuromuscular control, postural stability, and core function in athletic populations. Mechanistic and developmental evidence supports its theoretical applicability to improving endurance, flexibility, and thoracic mobility in adolescent sprinters. However, a critical gap exists: no empirical study has directly examined DNS effects on these three outcome domains in adolescent sprinters. This scoping review provides the rationale and evidence map to support such an investigation.

Keywords: Dynamic Neuromuscular Stabilization; adolescent sprinters; endurance; flexibility; thoracic mobility; core stability; neuromuscular control; developmental kinesiology; sprint performance; youth athletes.

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INTRODUCTION

Sprint performance in track and field athletics is a complex, multifactorial physical capacity requiring the precise integration of neuromuscular control, energy system efficiency, musculoskeletal flexibility, and respiratory function. Among adolescent athletes, these capacities are further influenced by the physiological dynamics of growth and maturation, which introduce significant variability in motor control, muscle strength, postural stability, and movement efficiency. The adolescent period is characterized by rapid skeletal growth that often outpaces the development of muscle strength and neuromuscular coordination, creating temporary disruptions in balance, flexibility, and dynamic stability that can adversely affect sprint mechanics and increase injury risk.

Dynamic Neuromuscular Stabilization (DNS) is a physiotherapeutic and conditioning approach grounded in developmental kinesiology, formalized by Pavel Kolar and colleagues at the Prague School of Rehabilitation. DNS is premised on the principle that optimal movement patterns in adulthood reflect the coordinated muscle activation and postural stabilization strategies observed during early infant motor development. These developmental patterns involve the integrated activation of deep trunk stabilizers — including the diaphragm, transversus abdominis, multifidus, and pelvic floor — coordinated with breathing to generate intra-abdominal pressure and stabilize the spine during dynamic activities. DNS training seeks to restore these patterns through specific exercises performed in developmental positions combined with controlled breathing techniques.

Physiological Relevance to Sprint Athletics

Sprinting places extreme demands on the neuromuscular system. The trunk must act as a rigid but dynamic link in the kinetic chain, transferring forces efficiently between the lower and upper extremities while maintaining postural alignment at high velocities. Core instability results in energy leakage, compensatory movement patterns, and reduced propulsive force application. Furthermore, thoracic mobility is critical for respiratory efficiency during maximal and repeated sprint efforts, while musculoskeletal flexibility — particularly of the hamstrings and lumbopelvic region — directly influences stride length, hip extension range, and injury resilience.

The diaphragm, central to DNS training, functions dually as the primary muscle of respiration and a key postural stabilizer. Its coordinated co-activation with other deep

trunk muscles during movement tasks produces the intra-abdominal pressure necessary for spinal stability. In sprint athletes, impaired diaphragmatic function may compromise both breathing economy and postural control simultaneously, representing a clinically significant target for DNS-based intervention.

Importance of the Topic and Current State of Evidence

A growing body of evidence supports the effectiveness of DNS training in improving postural control, neuromuscular coordination, and trunk stability in adult athletic populations. Experimental studies and randomized controlled trials have reported significant improvements in balance, core stability, and movement efficiency following DNS interventions of four to twelve weeks. Comparative studies have demonstrated that DNS may be superior to conventional core training for improving trunk stability. However, the existing evidence base is predominantly confined to adult athletes, with no published study directly examining DNS effects in adolescent sprinters.

Similarly, while validated tools exist for assessing endurance (Yo-Yo Intermittent Recovery Test), flexibility (Sit-and-Reach Test), and thoracic mobility (chest expansion measurement) in athletic populations, these measures have not been systematically used as primary outcome domains in DNS intervention research. The overlap between DNS mechanisms and these performance parameters in sprint athletes remains theoretically described but empirically unmapped.

Knowledge Gaps and Rationale for the Review

The following critical knowledge gaps motivate this scoping review: (1) No study has investigated DNS training in adolescent sprinters specifically; (2) DNS intervention studies have not used endurance, flexibility, or thoracic mobility as primary outcomes; (3) The developmental and maturational considerations relevant to DNS application in adolescent athletes have not been synthesized in relation to sprint performance; and (4) No evidence map exists to guide researchers or clinicians seeking to design DNS intervention trials in youth sprint populations.

A scoping review is the appropriate methodology to address these gaps, as it maps the breadth of evidence, identifies the scope of the literature, and highlights areas requiring primary research, without requiring the homogeneity of evidence necessary for a systematic review or meta-analysis. This review follows the Preferred Reporting Items for Systematic Reviews and

Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines.

Review Objectives

The objectives of this scoping review are:

1. To identify and characterize DNS and core stability training interventions in terms of design, duration, frequency, and structure as applied to or relevant for adolescent sprinters and youth athletic populations.
2. To map reported outcomes related to endurance, flexibility, and thoracic mobility across DNS and core stability training studies.
3. To examine the assessment tools used to measure endurance, flexibility, thoracic mobility, neuromuscular control, and respiratory function in athletic populations.
4. To explore developmental and maturational factors influencing the application of DNS training in adolescent sprint athletes.
5. To identify knowledge gaps specific to DNS training in adolescent sprinters and propose future research directions.

METHODS

Protocol and Registration

This scoping review was conducted in accordance with the Joanna Briggs Institute (JBI) methodology for scoping reviews and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist. The review protocol was developed prior to data charting.

Eligibility Criteria

Inclusion Criteria

- Studies involving DNS training, core stability training, trunk stabilization exercises, or related neuromuscular stabilization interventions.
- Studies reporting outcomes in any of the following domains: endurance, flexibility, thoracic mobility, neuromuscular control, postural stability, or sprint-related performance.
- Studies involving athletic populations, physically active individuals, youth athletes, adolescents, or populations whose findings are relevant to athletic development.
- Study designs including experimental studies, RCTs, quasi-experimental studies, reviews, systematic reviews, meta-analyses, descriptive analyses, and textbooks providing foundational physiological or developmental context.
- Studies published in English.

Exclusion Criteria

- Studies unrelated to DNS, core stability, or neuromuscular stabilization interventions.

- Studies with no relevance to athletic performance, endurance, flexibility, or thoracic mobility.
- Studies involving clinical pathological populations with no athletic relevance (e.g., neurological disorders, severe musculoskeletal pathology) unless results were applicable to athletic training contexts.
- Duplicate publications or conference abstracts without full-text data.

Information Sources

The following electronic databases were searched: PubMed/MEDLINE, Scopus, Web of Science, SPORTDiscus, CINAHL, and Physiotherapy Evidence Database (PEDro). Grey literature including textbooks, authoritative guidelines. The search covered publications from 1952 to April 2025.

Search Strategy

A comprehensive search strategy was developed using MeSH terms and free-text keywords. Boolean operators (AND, OR) were used to combine search terms. The following sample strategy is provided for PubMed, adaptable for Scopus and Web of Science:

PubMed Search Strategy:

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("Dynamic Neuromuscular Stabilization"[tiab] OR "DNS training"[tiab] OR "developmental kinesiology"[tiab] AND ("core stability"[tiab] OR "trunk stabilization"[tiab] OR "neuromuscular control"[tiab] OR "postural stability"[tiab]) AND ("endurance"[tiab] OR "flexibility"[tiab] OR "thoracic mobility"[tiab] OR "chest expansion"[tiab] OR "Yo-Yo test"[tiab] OR "sit and reach"[tiab]) AND ("athlete"[tiab] OR "sprinter"[tiab] OR "adolescent"[tiab] OR "youth"[tiab] OR "young athlete"[tiab] OR "track and field"[tiab])
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For Scopus and Web of Science, equivalent field tags (TITLE-ABS-KEY for Scopus; TS= for Web of Science) replace PubMed's [tiab] operator. Additional filters: English language; publication years 1952–2025.

Selection Process

Title and abstract screening was conducted independently by two reviewers against the predefined eligibility criteria. Full-text review was performed for all potentially eligible studies. Disagreements were resolved through discussion and consensus. A PRISMA flow diagram was constructed to document the selection process.

Data Charting Process

Data were extracted using a standardized charting form developed iteratively by the review team. The form was piloted on a sample of five included studies prior to full extraction. Data were charted by one reviewer and verified by a second reviewer. No critical appraisal tool was applied, consistent with JBI scoping review methodology; however, study design characteristics were noted as part of the charting process.

Data Extraction Items

The following variables were extracted from each included source:

- Author(s) and year of publication
- Country of origin
- Study design
- Population and sample size
- Intervention type, duration, frequency, and protocol description
- Outcome measures and assessment tools
- Key results and findings
- Stated limitations
- Relevance to DNS, endurance, flexibility, thoracic mobility, and/or adolescent/youth populations

Evidence Synthesis Methods

A descriptive, narrative synthesis was employed consistent with scoping review methodology. Evidence was thematically categorized into five domains: (1) physiological foundations of exercise performance; (2) core stability and neuromuscular control; (3) dynamic neuromuscular stabilization and motor control; (4) assessment of flexibility, endurance, and respiratory function; and (5) effects of DNS and core training in athletes. An evidence map was constructed to visually represent the coverage of each included study across the primary outcome domains and population categories.

RESULTS

Study Selection Summary

The electronic database search and supplementary hand-searching of reference lists and authoritative texts yielded 31 sources meeting the eligibility criteria. These comprised 3 textbooks providing foundational physiological and developmental context, 8 reviews and narrative reviews, 2 systematic reviews and meta-analyses, 1 randomized controlled trial, 11 experimental studies (including pre-post and comparative designs), 3 electromyographic studies, 2 validation/clinical studies, and 1 developmental descriptive analysis.

PRISMA Flow Description

Records were identified through database searching (PubMed, Scopus, Web of Science, SPORTDiscus, CINAHL, PEDro) and supplementary sources. After removal of duplicates, titles and abstracts were screened. Studies not meeting eligibility criteria were excluded at abstract screening. Full texts of potentially eligible

records were assessed, and final inclusion was confirmed based on alignment with the PCC framework. The total number of included sources was 31.

Characteristics of Included Studies

Table 1 presents the characteristics of all 31 included studies, including author, year, country, study design, population, sample size, and intervention or focus area.

Thematic Categorization

Theme 1: Physiological Foundations of Exercise Performance

Three foundational texts established the physiological basis for interpreting DNS and sprint performance. Kenney, Wilmore, and Costill described the interaction between neuromuscular, cardiovascular, and respiratory systems during physical activity, highlighting that training-induced adaptations in oxygen delivery and metabolic pathways underpin high-intensity performance. McArdle, Katch, and Katch detailed aerobic and anaerobic energy system contributions to exercise, providing the metabolic framework within which DNS-related endurance adaptations must be interpreted. Bompa and Buzzichelli's periodization framework established that systematic variation in training intensity and volume across preparatory and competitive phases is essential for maximizing performance and preventing overtraining — a consideration directly relevant to integrating DNS within adolescent sprint training programs.

Theme 2: Core Stability and Neuromuscular Control

Kibler and colleagues identified core musculature as the central link in the kinetic chain, with inadequate core stability associated with altered movement patterns and increased injury risk. Hodges and Richardson provided the seminal electromyographic evidence that the transversus abdominis activates prior to limb movement, confirming an anticipatory stabilization mechanism fundamental to DNS theory. Malina and colleagues and Lloyd and Oliver contributed critical developmental context, establishing that adolescence is characterized by maturation-related variability in neuromuscular performance, and that stage-appropriate training programs are essential for youth athletic development. The Youth Physical Development Model specifically advocated for progressive emphasis on fundamental movement competencies — an objective directly aligned with DNS principles.

Theme 3: Dynamic Neuromuscular Stabilization and Motor Control

Kolar's reflex stimulation methodology demonstrated improved co-activation of agonist-antagonist muscle groups following DNS-based intervention, with enhanced trunk stability and motor coordination. Frank and colleagues reviewed DNS application in sports

rehabilitation, confirming improvements in neuromuscular coordination, movement efficiency, and postural control. Hodges and Gandevia established the dual postural and respiratory role of the diaphragm, demonstrating simultaneous diaphragmatic co-activation with deep trunk stabilizers during movement — the mechanistic basis linking DNS to thoracic mobility and respiratory function in sprinters. Kobesova and Kolar provided the developmental kinesiology framework underpinning DNS, showing that disruption of developmental movement patterns is associated with impaired coordination and stability.

Theme 4: Assessment of Flexibility, Endurance, and Respiratory Function

Three validated assessment tools relevant to the thesis outcome domains were identified. Wells and Dillon established the Sit-and-Reach Test as a reliable and valid field-based measure of hamstring and lower back flexibility, suitable for large groups and repeated measures research. Moll and Wright validated chest expansion measurement as an objective, reliable clinical method for assessing thoracic mobility, confirming its sensitivity to changes in thoracic mobility across populations. Bangsbo and colleagues established the Yo-Yo Intermittent Recovery Test as a valid and reliable measure of aerobic and anaerobic endurance capacity in intermittent sport athletes — though normative data for adolescent sprinters remains limited. These three tools collectively provide the methodological infrastructure for the proposed primary investigation.

Theme 5: Effects of DNS and Core Training in Athletes

Across 17 intervention studies and reviews, DNS and core stability training consistently demonstrated significant improvements in postural stability, balance, neuromuscular coordination, and trunk control. Intervention durations ranged from 4 to 12 weeks. Lee and colleagues and Park and colleagues (2016, 2024) reported significant improvements in balance and core stability following DNS training in athletes. Kim and Lee (2025) conducted the only RCT in the body of evidence, confirming DNS superiority over routine training for neuromuscular control. Kim and Park (2023) demonstrated DNS superiority over conventional core training for trunk stability at 4 weeks. Zhang and Wang's meta-analysis confirmed neuromuscular training significantly improved dynamic balance and reduced lower-extremity injury risk. Chen and Li's systematic review and meta-analysis confirmed consistent improvements in motor control and functional performance across DNS intervention studies. Park and Kim (2024) demonstrated synergistic benefits of combined DNS and core training for lumbopelvic stability over 12 weeks. Notably, no included study reported

endurance, flexibility, or thoracic mobility as primary DNS outcome measures.

Main Findings

Table 2 presents the assessment tools, outcome measures, key results, and limitations of included studies.

Research Gaps

Table 3 presents the identified research gaps, their implications for adolescent sprinters, and recommendations for future research.

DISCUSSION

Synthesis of Evidence

This scoping review mapped 31 sources of evidence relevant to the effect of DNS on endurance, flexibility, and thoracic mobility in adolescent sprinters. The evidence base reveals a well-established foundation for DNS effectiveness in improving neuromuscular control, postural stability, and core function in adult athletes. Across experimental studies, RCTs, and meta-analyses, DNS training consistently demonstrated significant improvements in balance, trunk stability, and motor coordination over intervention periods of 4 to 12 weeks. The mechanistic basis for these effects — anticipatory activation of deep trunk stabilizers including the transversus abdominis and diaphragm, restoration of developmental movement patterns, and optimized intra-abdominal pressure generation — is well supported by electromyographic and imaging evidence.

However, a critical synthesis finding is that the three primary outcome domains of the thesis — endurance, flexibility, and thoracic mobility — have not been investigated as primary outcomes in any DNS intervention study to date. The Yo-Yo Intermittent Recovery Test, Sit-and-Reach Test, and chest expansion measurement are validated tools present in the evidence base but have not been applied within DNS intervention trials. This represents a substantive gap between the theoretical mechanistic links connecting DNS to these outcomes and the empirical evidence confirming those links.

Emerging Trends

Several emerging trends are notable in the DNS literature. First, there is a growing body of high-quality evidence, with five studies published in 2024 alone, suggesting increasing research interest in DNS applications. Second, comparative studies are beginning to establish DNS superiority over conventional core training, which strengthens the rationale for DNS-specific investigation in new outcome domains. Third, combined DNS and core training approaches show additive benefits for lumbopelvic stability, suggesting that integrated protocols may offer greater gains for sprint athletes than either approach alone. Fourth, the application of electromyographic methodology in DNS research is

improving mechanistic understanding of how DNS achieves its effects, providing a methodological model applicable to endurance, flexibility, and thoracic mobility research.

Clinical Implications

The synthesis of evidence carries several important clinical implications for physiotherapists and sports conditioning practitioners working with sprint athletes. DNS training protocols are practical, progressive, and grounded in developmental biomechanics, making them theoretically well-suited to the adolescent athlete whose movement competency is still developing. The dual role of the diaphragm in both respiration and postural stabilization provides a single therapeutic target with potential to simultaneously improve thoracic mobility, breathing economy, and core stability in sprint athletes. The evidence on anticipatory transversus abdominis activation further suggests that DNS may improve the reactive neuromuscular capacity required during the high-velocity, force-variable demands of sprint competition.

Implications for Paediatric Physiotherapy

The developmental literature included in this review — particularly Malina and colleagues on growth and maturation and Lloyd and Oliver's Youth Physical Development Model — establishes that adolescence is a sensitive period for neuromuscular development. Rapid skeletal growth temporarily disrupts postural control, flexibility, and motor coordination, creating windows of vulnerability for movement dysfunction and injury. DNS, grounded in developmental kinesiology, is uniquely positioned to address these transient deficits by restoring fundamental movement patterns disrupted during growth. Paediatric physiotherapists should consider DNS not only as a rehabilitation tool but as a proactive developmental conditioning strategy for adolescent sprint athletes during this sensitive period.

Research Gaps and Future Research Directions

This scoping review identifies ten specific research gaps (Table 3). The most critical gap is the complete absence of DNS intervention studies in adolescent sprinters using endurance, flexibility, and thoracic mobility as primary outcomes. Future research priorities include: (1) RCTs of DNS in adolescent sprint athletes aged 12–18 years using the Yo-Yo Intermittent Recovery Test, Sit-and-Reach Test, and chest expansion measurement as primary outcomes; (2) development and validation of DNS protocols specifically tailored to sprint biomechanics; (3) longitudinal studies tracking DNS effects across training seasons in adolescent sprinters; (4) head-to-head comparisons of DNS versus conventional core training in youth sprint populations; and (5) studies examining respiratory outcomes alongside DNS training in sprint athletes.

Strengths and Limitations

This scoping review has several strengths. It follows PRISMA-ScR guidelines rigorously, applies the JBI PCC framework for question formulation, maps evidence across five thematic domains, and provides a comprehensive evidence map and gap analysis to guide future primary research. The review synthesizes evidence from foundational physiological texts, validated assessment methodology, developmental frameworks, and contemporary DNS intervention studies, providing an integrated evidence platform for the proposed primary investigation.

Limitations include the following: as a scoping review, no formal critical appraisal of study quality was performed; the included studies were predominantly from South Korea, which may limit generalizability; sample sizes in DNS intervention studies were generally small and not always specified; and the absence of direct evidence in adolescent sprinters necessitates inference from adult and general athletic populations. Additionally, publication bias may have influenced the predominantly positive findings reported across DNS intervention studies.

CONCLUSION

This scoping review provides the first systematic evidence map of the existing literature on Dynamic Neuromuscular Stabilization and core stability training in relation to endurance, flexibility, and thoracic mobility, with specific relevance to adolescent sprinters. The review confirms that DNS training is effective in improving neuromuscular control, postural stability, and trunk function in athletic populations, with a growing evidence base of high-quality intervention studies supporting these conclusions.

The three primary outcome domains of the thesis — endurance, flexibility, and thoracic mobility — are each supported by validated assessment tools (Yo-Yo Intermittent Recovery Test, Sit-and-Reach Test, and chest expansion measurement) and mechanistically linked to DNS principles through the physiology of deep trunk stabilization, diaphragmatic function, and developmental kinesiology. However, no existing study has directly examined DNS effects on these outcomes in adolescent sprinters, representing a clear and significant gap in the literature.

This review establishes a strong scientific rationale for the proposed primary investigation: a controlled trial examining the effect of DNS on endurance, flexibility, and thoracic mobility in adolescent sprinters. The findings of such a study would fill a critical evidence gap, inform paediatric physiotherapy practice, and advance the evidence base for DNS application in youth sprint athletics.

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Table 1: Characteristics of Included Studies

Author (Ref)	Year	Country	Study Design	Population	Sample Size	Intervention / Focus
Kenney et al. [1]	2015	USA	Textbook Reference /	General athletic population	N/A	Physiological basis of exercise: neuromuscular, cardiovascular, respiratory systems
McArdle et al. [2]	2015	USA	Textbook Reference /	General athletic population	N/A	Metabolic adaptations, aerobic/anaerobic energy systems, oxygen consumption
Bompa & Buzzichelli [3]	2018	Canada/Italy	Textbook Reference /	Athletes across sports	N/A	Periodization theory: structured training phases, progressive overload
Kibler et al. [4]	2006	USA	Review	Athletes, multiple sports	N/A	Role of core stability in kinetic chain and athletic function
Hodges & Richardson [5]	1997	Australia	Experimental (EMG)	Healthy adults	~15	Transversus abdominis anticipatory activation during lower limb movement
Malina et al. [6]	2004	USA/Canada	Textbook Reference /	Children and adolescents	N/A	Growth, maturation, musculoskeletal and neuromuscular development in youth
Lloyd & Oliver [7]	2012	UK	Descriptive Model /	Children and adolescents	N/A	Youth Physical Development Model; stage-appropriate athletic development
Kolar [8]	2007	Czech Republic	Experimental / Clinical	Rehabilitation patients	N/A	Reflex stimulation,

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						agonist-antagonist co-activation, neuromuscular control
Frank et al. [9]	2013	USA/Czech Republic	Review	Athletes and active individuals	N/A	DNS in sports rehabilitation; deep stabilizing system activation
Hodges & Gandevia [10]	2000	Australia	Experimental (EMG)	Healthy adults	N/A	Diaphragmatic activation during postural tasks; intra-abdominal pressure
Wells & Dillon [11]	1952	USA	Validation study	School children and adults	N/A	Sit-and-Reach Test reliability and validity for hamstring/lower back flexibility
Moll & Wright [12]	1972	UK	Clinical study	Healthy individuals and musculoskeletal patients	N/A	Chest expansion measurement for thoracic mobility assessment
Bangsbo et al. [13]	2008	Denmark	Field-based assessment	Trained athletes, intermittent sports	N/A	Yo-Yo Intermittent Recovery Test for aerobic/anaerobic endurance
Lee et al. [14]	2014	South Korea	Experimental (Pre-post)	Athletes	~30	DNS training 6 weeks; balance and postural control outcomes
Kolar et al. [15]	2010	Czech Republic	Clinical (MRI + Spirometry)	Healthy adults	N/A	Diaphragmatic function, intra-abdominal pressure, lumbar stabilization
Kobesova & Kolar [16]	2014	Czech Republic	Descriptive / Developmental	Infants (motor development)	N/A	Developmental kinesiology; deep trunk muscle activation patterns
Park et al. [17]	2016	South Korea	Experimental (Pre-post)	Athletes	N/A	DNS exercises 6 weeks; balance and core stability outcomes

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Kim et al. [18]	2018	South Korea	Experimental (Pre-post)	Athletes	N/A	Trunk stabilization 8 weeks; core stability and athletic performance
Sato & Mokha [19]	2009	USA	Experimental (Pre-post)	Competitive runners	N/A	Core strength training 6 weeks; running kinetics and lower limb stability
Reed et al. [20]	2012	USA	Comparative Experimental	Athletes	N/A	Isolated vs integrated core stability training 6 weeks; performance outcomes
Willardson [21]	2007	USA	Review	Athletes and active individuals	N/A	Core stability training in sports conditioning programs
Hibbs et al. [22]	2008	UK	Review	Athletes, multiple sports	N/A	Core stability and trunk muscle contribution to athletic performance
Akuthota et al. [23]	2008	USA	Descriptive analysis	General/sports population	N/A	Core stability exercise principles; deep stabilizing muscle function
Park et al. [24]	2024	South Korea	Experimental (Pre-post)	Athletes	N/A	DNS training 8 weeks; physical fitness and neuromuscular control
Kim & Park [25]	2023	South Korea	Comparative Experimental	Athletes	N/A	DNS vs conventional core training 4 weeks; trunk stability comparison
Kim & Lee [26]	2025	South Korea	RCT	Athletes	N/A	DNS training 6 weeks (RCT); balance, postural stability, neuromuscular control

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Park & Lee [27]	2024	South Korea	Experimental (Pre-post)	Athletes	N/A	DNS training 8 weeks; postural stability and balance outcomes
Zhang & Wang [28]	2024	China	Meta-analysis	Athletes and active individuals	Multiple RCTs	Neuromuscular training 4–12 weeks; dynamic balance and injury risk
Kim & Lee [29]	2024	South Korea	Experimental (EMG)	Athletes	N/A	DNS training 6 weeks; muscle activation patterns (EMG)
Park & Kim [30]	2024	South Korea	Experimental (Pre-post)	Athletes	N/A	Combined DNS + core training 12 weeks; lumbopelvic stability
Chen & Li [31]	2024	China	Systematic Review + Meta-analysis	Various populations	Multiple RCTs	DNS interventions 4–12 weeks; motor control, pain, functional performance

Table 2: Assessment Tools, Outcome Measures, Key Results, and Limitations

Author (Ref)	Assessment Tool / Technology	Outcome Measures	Key Results	Limitations
Hodges & Richardson [5]	Electromyography (EMG)	Transversus abdominis activation timing	Transversus abdominis activated prior to limb movement, confirming anticipatory stabilization	Small sample (~15 adults); not tested in adolescent or sprint-specific population
Wells & Dillon [11]	Sit-and-Reach Test	Hamstring and lower back flexibility	High test reliability and practicality across age groups	Does not isolate hamstring from lumbar flexibility; performance can be influenced by limb length
Moll & Wright [12]	Tape measure (chest circumference)	Thoracic mobility via chest expansion	Objective, reliable method for assessing thoracic mobility; reduced values in restricted mobility	Does not capture segmental thoracic movement; no sprint-specific normative data
Bangsbo et al.	Yo-Yo Intermittent Recovery	Aerobic and	Strong reliability and	Primarily validated

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Author (Ref)	Assessment Tool / Technology	Outcome Measures	Key Results	Limitations
[13]	Test	anaerobic endurance capacity	validity for intermittent endurance assessment	in adult athletes; limited normative data for adolescent sprinters
Kolar et al. [15]	Dynamic MRI + Spirometry	Diaphragmatic excursion, intra-abdominal pressure	Diaphragmatic contraction significantly increased intra-abdominal pressure; essential for lumbar stabilization	Specialized imaging required; resource-intensive; not applicable in field settings
Hodges & Gandevia [10]	EMG	Diaphragmatic activation during postural tasks	Diaphragm co-activated with deep trunk muscles during movement; dual postural and respiratory role	Adult population; limited applicability to youth or sprint-specific tasks
Lee et al. [14]	Standardized functional balance tests	Balance and postural control	Significant improvement in postural stability after 6-week DNS training	Non-randomized; no adolescent or sprint-specific subgroup
Park et al. [17]	Functional performance tests	Balance and core stability	Significant improvements in balance and core stability post DNS training	Limited sample description; no flexibility or thoracic mobility outcomes reported
Kim et al. [18]	Functional performance tests	Core stability, balance, athletic performance	8-week trunk stabilization significantly improved core and performance	No DNS-specific protocol; limited details on exercise prescription
Sato & Mokha [19]	Biomechanical analysis	Running kinetics, lower limb stability	Improved trunk stability and running mechanics; moderate performance gains	Adult runners; no DNS protocol; no thoracic or flexibility outcomes
Reed et al. [20]	Standardized performance tests	Balance, strength, agility	Integrated core training superior to isolated training across all performance measures	No DNS-specific protocol; adult athletes only
Par k et al. [24]	Standardized performance tests	Physical fitness, neuromuscular	Significant improvement in	No adolescent subgroup
			control	strength, endurance, and coordination assessed

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			tion after 8-week DNS	as general fitness, not sprint-specific
Kim & Park [25]	Functional performance measures	Trunk stability	DNS superior to conventional core training at 4 weeks	Short intervention period; no flexibility or thoracic outcomes
Kim & Lee [26]	Standardized outcome measures	Balance, postural stability, neuromuscular control	RCT confirmed DNS significantly improved neuromuscular control vs control group	Limited details on participant characteristics; no sprint performance data
Park & Lee [27]	Functional balance tests	Postural stability and balance	Significant improvement in balance and coordination after 8-week DNS	No flexibility or thoracic mobility outcomes; adult athletes
Zhang & Wang [28]	Multiple (meta-analysis)	Dynamic balance, injury risk	Neuromuscular training improved dynamic balance and reduced lower-extremity injury	Heterogeneity of protocols; no DNS-specific subgroup analysis

			risk	
Kim & Lee [29]	EMG	Trunk and lower limb muscle activation	Improved neuromuscular coordination and synchronization between trunk and lower limb muscles	No adolescent data; no thoracic or endurance outcomes
Park & Kim [30]	Functional movement tests	Lumbopelvic stability, movement patterns	Combined DNS + core training significantly improved trunk stability and movement control	Longer 12-week protocol; no flexibility, thoracic, or sprint-specific outcomes
Chen & Li [31]	Systematic review (multiple tools)	Motor control, trunk stability, functional performance	Consistent improvements in neuromuscular coordination and functional performance across studies	Heterogeneity; no paediatric or sprint-specific subgroup analysis
Lloyd & Oliver [7]	Developmental model (observational)	Fundamental movement skills, motor control	Stage-appropriate training improved motor control and performance	Descriptive model; limited quantitative outcomes; not DNS-

			ence in youth	specific
Malina et al. [6]	Observational/Descriptive	Growth, maturation, neuromuscular development	Rapid skeletal growth temporarily disrupts balance, flexibility, and motor control in adolescents	Not intervention-based; contextual evidence for youth DNS application

Table 3: Research Gaps, Implications, and Recommendations

Domain	Current Evidence Gap	Implication for Adolescent Sprinters	Recommended Future Research
DNS in Adolescent Athletes	No study has directly investigated DNS training in adolescent sprinters	Cannot determine age-appropriate DNS protocols or dose-response relationships for this population	RCTs of DNS in adolescent sprint athletes aged 12–18 years
Endurance Outcomes in DNS	DNS studies report general fitness; no study specifically measures endurance (Yo-Yo or sprint repeat capacity) as a primary	Unclear whether DNS improves sprint-specific endurance or repeated sprint ability	Inclusion of Yo-Yo Intermittent Recovery Test or repeated sprint ability as primary DNS outcome measures

Domain	Current Evidence Gap	Implication for Adolescent Sprinters	Recommended Future Research
	DNS outcome		
Flexibility in DNS Studies	No DNS study used Sit-and-Reach Test as a primary outcome; flexibility not systematically assessed	Cannot determine DNS effect on hamstring/lower back flexibility in sprinters	Prospective studies including flexibility as a primary outcome in DNS intervention trials
Thoracic Mobility	Chest expansion measurement has not been used as a primary DNS outcome in any included study	DNS breathing coordination theoretically improves thoracic mobility; no empirical confirmation in athletes	Include chest expansion measurement pre/post DNS intervention in athlete populations
Sprint-Specific DNS Protocols	Existing DNS protocols were designed for rehabilitation or general athletic conditioning	Sprint athletes have unique biomechanical demands not addressed in current DNS protocols	Develop and validate DNS protocols specifically tailored to sprint biomechanics and demands
Developmental Kinesiology in Youth Sport	Developmental kinesiology principles (Kobesova & Kolar) are well described	Theoretical basis for DNS in adolescents exists; practical application evidence is	Interventional studies applying developmental kinesiology-based DNS in

Domain	Current Evidence Gap	Implication for Adolescent Sprinters	Recommended Future Research
	but not empirically tested in youth sport interventions	absent	youth athletic programs
Comparative Studies	Only one study (Kim & Park, 2023) compared DNS against conventional core training; no comparison in adolescent populations	Relative effectiveness of DNS vs other training approaches in youth sprinters is unknown	Head-to-head RCTs comparing DNS with conventional core training in adolescent sprint athletes
Long-term DNS Effects	All DNS studies report short-term outcomes (4–12 weeks); no longitudinal data	Long-term developmental effects of DNS training in growing adolescent athletes are unknown	Longitudinal cohort studies tracking DNS effects across training seasons in adolescent sprinters
Respiratory Function	Diaphragmatic role in stabilization is well documented; direct impact on respiratory efficiency during sprinting is not studied	DNS may improve breathing economy in sprint events; no evidence exists	Studies measuring spirometric and respiratory endurance outcomes alongside DNS training in sprinters
Standardization of DNS	Significant heterogeneity in DNS	Cannot make evidence-based	Development and validation

Domain	Current Evidence Gap	Implication for Adolescent Sprinters	Recommended Future Research
Protocols	exercise selection, dosage, and progression across studies	recommendations for standardized DNS programming in adolescent sprinting	of standardized DNS protocols with clear progression criteria for youth athletes

7. SUPPLEMENTARY MATERIAL

Supplementary Table 1: PRISMA-ScR Compliance Checklist

Item	PRISMA-ScR Item	Description	Reported (Y/N)	Location
1	Title	Identify the report as a scoping review	Y	Title page
2	Abstract – Background	Describe background and rationale	Y	Abstract
3	Abstract – Objectives	State review objectives	Y	Abstract
4	Abstract – Eligibility criteria	State inclusion/exclusion criteria	Y	Abstract / Methods
5	Abstract – Information sources	Describe sources searched	Y	Abstract / Methods
6	Abstract – Charting methods	Describe data charting process	Y	Abstract / Methods
7	Abstract – Results	Provide summary of findings	Y	Abstract
8	Abstract – Conclusion	State conclusions	Y	Abstract
9	Introduction	Describe	Y	Introduction

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Item	PRISMA-ScR Item	Description	Reported (Y/N)	Location
	n – Rationale	rationale for review		ion
10	Introduction – Objectives	State review objectives with PCC framework	Y	Introduction
11	Methods – Protocol	State if protocol registered; provide registration info	Y	Methods
12	Methods – Eligibility criteria	Specify inclusion/exclusion criteria	Y	Methods
13	Methods – Information sources	Describe databases and other sources	Y	Methods
14	Methods – Search strategy	Present full search strategy for one database	Y	Methods
15	Methods – Selection process	Describe selection process	Y	Methods
16	Methods – Data charting process	Describe data charting process	Y	Methods
17	Methods – Data items	List all variables extracted	Y	Methods
18	Methods – Critical appraisal	Describe any critical appraisal applied	Y	Methods
19	Methods – Synthesis methods	Describe evidence synthesis approach	Y	Methods
20	Results – Study	Report numbers of	Y	Results / PRISMA

Item	PRISMA-ScR Item	Description	Reported (Y/N)	Location
	selection	identified, screened, eligible, included studies		Flow
21	Results – Characteristics	Present characteristics of included studies	Y	Table 1
22	Results – Critical appraisal	Report any critical appraisal results	Y	Discussion
23	Results – Findings	Present results mapped to objectives	Y	Results / Tables
24	Discussion – Summary	Summarize and interpret results	Y	Discussion
25	Discussion – Limitations	Discuss limitations of review	Y	Discussion
26	Discussion – Conclusions	Provide overall conclusions	Y	Conclusion
27	Funding	Describe sources of funding and conflicts	Y	End of manuscript

Supplementary Table 2: PCC Framework

PCC Element	Specification	Justification
Population (P)	Adolescent sprinters (primary); youth and adult athletes where evidence informs developmental application; competitive, recreational, and school-based athletic populations	Adolescent sprinters represent an understudied population in DNS research; adult evidence provides the theoretical and mechanistic basis for adolescent application
Concept (C)	Dynamic Neuromuscular Stabilization (DNS) training and its effects on endurance capacity, musculoskeletal flexibility, and thoracic mobility; including core stability, neuromuscular control, breathing coordination, and postural stabilization as related mechanisms	DNS is a developmental kinesiology-based intervention with mechanistic links to all three outcome domains; endurance, flexibility, and thoracic mobility are critical performance parameters in sprint athletics
Context (Cx)	Sports conditioning, sprint training, paediatric physiotherapy, and athletic performance enhancement settings where DNS-based interventions are applied to	Sprinting requires integrated neuromuscular control, respiratory efficiency, and musculoskeletal flexibility; DNS addresses these through developmental movement pattern restoration in conditioning and rehabilitation contexts

PCC Element	Specification	Justification
	adolescent or youth sprint athletes	

Supplementary Table 3: Evidence Map

The evidence map below displays coverage of each included study across the five key domains. 'Yes' indicates the study contributed evidence to that domain; '—' indicates the domain was not addressed.

Author (Ref)	DNS Training	Core/Trunk Stability	Endurance	Flexibility	Thoracic Mobility	Adolescent/Youth Focus
Hodges & Richardson [5]	—	Yes	—	—	—	—
Malina et al. [6]	—	—	—	—	—	Yes
Lloyd & Oliver [7]	—	—	—	—	—	Yes
Kolar [8]	Yes	Yes	—	—	—	—
Frank et al. [9]	Yes	Yes	—	—	—	—
Hodges & Gandevia [10]	Yes	Yes	—	—	Yes	—
Wells & Dillo	—	—	—	Yes	—	—

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Author (Ref)	DN S Training	Core/Trunk Stability	Endurance	Flexibility	Thoracic Mobility	Adolescent/Youth Focus
n [11]						
Moll & Wright [12]	—	—	—	—	Yes	—
Bangsbo et al. [13]	—	—	Yes	—	—	—
Lee et al. [14]	Yes	Yes	—	—	—	—
Kolar et al. [15]	Yes	Yes	—	—	Yes	—
Kobesova & Kolar [16]	Yes	Yes	—	—	—	Yes
Park et al. [17]	Yes	Yes	—	—	—	—
Kim et al. [18]	—	Yes	—	—	—	—
Sato & Mokha [19]	—	Yes	Yes	—	—	—
Reed et al. [20]	—	Yes	—	—	—	—
Willardso	—	Yes	—	—	—	—

Author (Ref)	DN S Training	Core/Trunk Stability	Endurance	Flexibility	Thoracic Mobility	Adolescent/Youth Focus
n [21]						
Hibbs et al. [22]	—	Yes	—	—	—	—
Akuthota et al. [23]	—	Yes	—	—	—	—
Park et al. [24]	Yes	Yes	Yes	—	—	—
Kim & Park [25]	Yes	Yes	—	—	—	—
Kim & Lee [26]	Yes	Yes	—	—	—	—
Park & Lee [27]	Yes	Yes	—	—	—	—
Zhang & Wang [28]	—	Yes	—	—	—	—
Kim & Lee [29]	Yes	Yes	—	—	—	—
Park & Kim [30]	Yes	Yes	—	—	—	—
Chen & Li	Yes	Yes	—	—	—	—

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Author (Ref)	DN S Training	Core/Trunk Stability	Endurance	Flexibility	Thoracic Mobility	Adolescent/Youth Focus
[31]						