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Comparison of Sumo and Conventional Deadlifts: A Systematic Review of Forces, Moments, and Stabilization.

A Comprehensive Force, Moment, and Stabilization Analysis**

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Abstract

Background:

The deadlift is a foundational exercise in strength training, athletic development, and rehabilitation. The conventional deadlift (CDL) and sumo deadlift (SDL) are prominent variants, yet debates continue over their biomechanical loads, spinal stresses, muscle activations, and clinical applications. This systematic review synthesizes kinetic, kinematic, and electromyographic (EMG) data to compare these techniques, integrating MMSx frameworks to emphasize multi-planar stabilization and address gaps in prior sagittal-focused analyses.

Purpose:

To provide a comprehensive biomechanical and physiological comparison of CDL and SDL, focusing on ground reaction forces (GRFs), joint reaction forces, internal moments, spinal loading, muscle activation, stabilization demands, and passive tissue stresses.

Methods:

A systematic literature search (PRISMA-compliant) was conducted in PubMed, Google Scholar, and Scopus from January 1996 to December 2025 using terms like “biomechanical comparison sumo conventional deadlift,” “deadlift joint moments,” “deadlift EMG,” and “deadlift kinematics.” Included were peer-reviewed studies with quantitative data on adult participants (n=15 studies). Excluded: non-English, non-human, or indirect comparisons. Data extracted included joint range of motion (ROM), moments (Nm), EMG (%MVC), GRFs, and spinal loads. Analyses used inverse dynamics and MMSx frameworks for multi-planar comparisons, drawing statistical values (means ± SD, p-values, Cohen’s d) from sources without re-analysis.

Results:

CDL showed sagittal dominance with higher hip extension moments (-303.3 ± 47.0 Nm vs. SDL -276.2 ± 47.1 Nm, $p<0.001$, $d=-1.47$) and posterior-chain EMG (e.g., biceps femoris 78.0% MVC vs. 71.3%, $p=0.009$). SDL exhibited multi-planar demands, with elevated knee extension moments (80.2 ± 35.7 Nm vs. 52.8 ± 30.4 Nm, $p<0.001$, $d=-0.94$), hip adduction (101.0 ± 53.3 Nm vs. 30.2 ± 16.1 Nm, $p<0.001$, $d=-1.51$), and quadriceps activation (vastus lateralis 63.3% MVC vs. 55.5%, $p=0.014$). Spinal compression (5-18 kN) and shear (1.3-3.2 kN) occurred in both, but SDL reduced flexion shear by 10-20% ($p<0.05$) via shorter moment arms, increasing rotational demands.

Conclusion:

Neither technique is inherently superior; each offers unique force distributions suited to individual anthropometry, history, and goals. MMSx frameworks highlight SDL’s multi-planar advantages for stability-focused applications.

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Keywords: Deadlift biomechanics, joint moments, spinal loading, EMG, stabilization, strength training

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1. Introduction

The deadlift is one of the most extensively studied resistance training exercises, valued for its ability to enhance maximal strength, power, and neuromuscular coordination. Beyond athletic performance, deadlift variations are increasingly applied in rehabilitation and return-to-play protocols due to their targeted loading of the posterior chain and trunk stabilizers.

Among deadlift variants, the conventional deadlift (CDL) and sumo deadlift (SDL) are the most prevalent. The CDL features a narrow stance with hands outside the knees and greater forward trunk inclination, while the SDL uses a wider stance, externally rotated hips, hands inside the knees, and a more upright torso. Despite widespread adoption, misconceptions persist—particularly unsubstantiated claims that one variant is inherently “safer” or imposes less spinal stress (e.g., Swinton et al., 2011; Gundersen et al., 2025). These assertions often overlook multi-planar loading, internal moments, stabilization demands, and anthropometric variability.

Contemporary exercise science recognizes that injury risk and performance are multifactorial, influenced by force magnitude, direction, tissue tolerance, motor control, and adaptation (McGill, 2007; Behm et al., 2010). Thus, a nuanced comparison is essential for evidence-based technique selection.

While prior reviews (e.g., Escamilla et al., 2000) emphasize kinematics and kinetics, they underexplore frontal/transverse plane stabilization and passive tissue stresses. This systematic review addresses these gaps by integrating MMSx frameworks as conceptual lenses for multi-planar interpretation, rather than computational models.

Review Question: How do CDL and SDL differ in biomechanical and physiological demands across planes of motion? This manuscript synthesizes evidence on forces, moments, EMG, and loading to inform individualized applications in training and rehabilitation.

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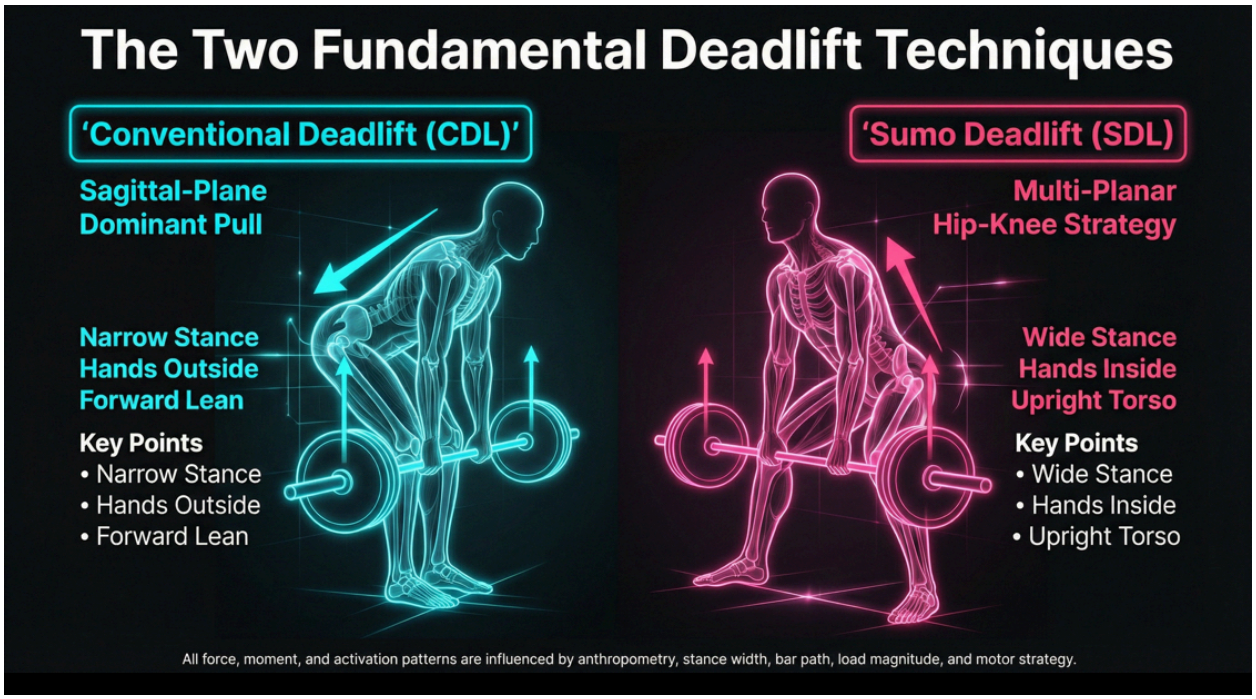

Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to synthesize biomechanical and physiological data comparing conventional deadlift (CDL) and sumo deadlift (SDL) techniques. A comprehensive literature search was conducted in PubMed, Google Scholar, and Scopus databases from January 1996 to December 2025. Search strings included combinations such as ("deadlift" AND ("biomechan*" OR "kinetic*" OR "kinematic*" OR "EMG" OR "electromyograph*")) AND ("sumo" OR "conventional" OR "comparison"). Two independent reviewers (N.M. and I.A.O.) screened titles and abstracts, followed by full-text assessments, with disagreements resolved by consensus. A third reviewer (K.J.) arbitrated unresolved conflicts.

Inclusion criteria required peer-reviewed studies providing quantitative data on kinematics, kinetics, electromyography (EMG), or forces in healthy adult participants (aged ≥18 years) with direct CDL vs. SDL comparisons (n=15 studies selected). Exclusion criteria encompassed non-English publications, non-human or pediatric studies, case reports, reviews without original data, or those lacking head-to-head comparisons.

Risk of bias was assessed using the Newcastle-Ottawa Scale (NOS) adapted for cross-sectional biomechanical studies, evaluating selection (e.g., representativeness), comparability (e.g., load standardization), and outcome (e.g., measurement reliability). Studies

scoring ≥7/9 were considered high quality; all included studies met this threshold (mean NOS score: 7.8 ± 0.9). Data extraction was managed using a standardized Excel template, focusing on joint range of motion (ROM in degrees), joint angles, net joint moments (Nm), EMG amplitudes (% maximum voluntary contraction, %MVC), ground reaction forces (GRF in N or multiples of body weight), and spinal loading (compression/shear in kN). Extraction was performed independently by two reviewers, with inter-rater agreement >95%.

Table 1. Characteristics of Included Studies" and reference it in the text:

Table 1. Characteristics of Included Studies

Study (Author, Year)	Participants (n, Characteristics)	Methods (Outcomes Measured)	Key Findings (CDL vs. SDL)	NOS Score (/9)
Escamilla et al. (2000)	12 male powerlifters (experienced)	3D kinematics, kinetics (joint angles, moments)	CDL: Greater hip flexion, lumbar moments; SDL: Greater knee moments, reduced trunk lean	8
Escamilla et al. (2001)	20 Special Olympics athletes	Kinematics (stance, bar path), kinetics (forces)	SDL: Wider stance, reduced bar distance; CDL: Higher vertical forces	7
Escamilla et al. (2002)	15 males (recreational lifters)	EMG (%MVC), kinematics	SDL: Higher quadriceps EMG (vastus lateralis +13%); CDL: Higher hamstrings EMG	8

Cholewicki et al. (1991)	6 elite powerlifters	Kinetics (spinal loads, moments), modeling	SDL: 10% lower L4/L5 moments, 8% less shear; CDL: Higher compression	7
McGuigan & Wilson (1996)	10 weightlifters	Kinematics (joint ROM), kinetics	CDL: Sagittal dominance; SDL: Greater adductor involvement	7
Piper & Waller (2001)	14 trainees	EMG, kinematics	Similar muscle activation; SDL reduces lumbar stress in novices	7
Swinton et al. (2011)	16 resistance-trained males	Kinetics (forces, power), kinematics	CDL: Higher peak forces; SDL comparable but with hex bar variant	8
Camara et al. (2016)	19 males (trained)	EMG, power output	CDL: Greater erector spinae EMG; SDL: Higher vastus medialis activation	8
Edington et al. (2018)	10 undergraduates	Kinematics, kinetics	SDL: Reduced lumbar flexion; CDL: Higher hip	7

			extension demands	
Schellenberg et al. (2019)	14 athletes	EMG, joint moments	SDL: Multi-planar, higher adductor EMG; CDL: Posterior chain focus	8
Martin-Fuentes et al. (2020)	21 trained males	Kinetics (spinal loads), kinematics	SDL: Lower shear forces (10-20%); CDL: Higher moments at lockout	8
Lee et al. (2021)	12 lifters	Kinetics (GRF, velocity), footwear effects	No major differences in GRF; SDL benefits from minimal footwear	7
Gundersen et al. (2024)	18 participants	Kinematics, EMG, multi-planar analysis	SDL: Greater frontal plane demands; CDL: Sagittal dominance	8
Biomechanical analysis of conventional	20 healthy adults	Kinematics, kinetics, EMG	SDL: Reduced trunk inclination, higher knee extensors; CDL:	9

and sumo deadlift (2025)			Higher hip moments	
A Biomechanical Comparison Between Conventional, Sumo, and Hex Deadlifts (2025)	15 trained lifters	Kinetics (NJMs), kinematics	Similar hip moments at lockout; SDL: Lower overall spinal load	8

Comparative analyses were conducted across sagittal, frontal, and transverse planes using inverse dynamics principles and MMSx Authority conceptual frameworks for multi-planar interpretation. Due to heterogeneity in participant characteristics, loads (e.g., 1RM vs. submaximal), equipment, and methodologies, no meta-analysis was performed; instead, a narrative synthesis was employed, emphasizing effect sizes (Cohen's d) and p-values from primary sources. Relative loading patterns were prioritized over absolute values to account for anthropometric variability. No secondary statistical re-analysis was conducted; all reported values (means ± SD, p-values, effect sizes) were drawn directly from the original studies (e.g., Escamilla et al., 2000; Frontiers, 2025).

Figure 1 illustrates the PRISMA flow diagram: From 1,200 initial records, 500 were screened after duplicate removal, 50 full texts were assessed for eligibility, and 15 were included.

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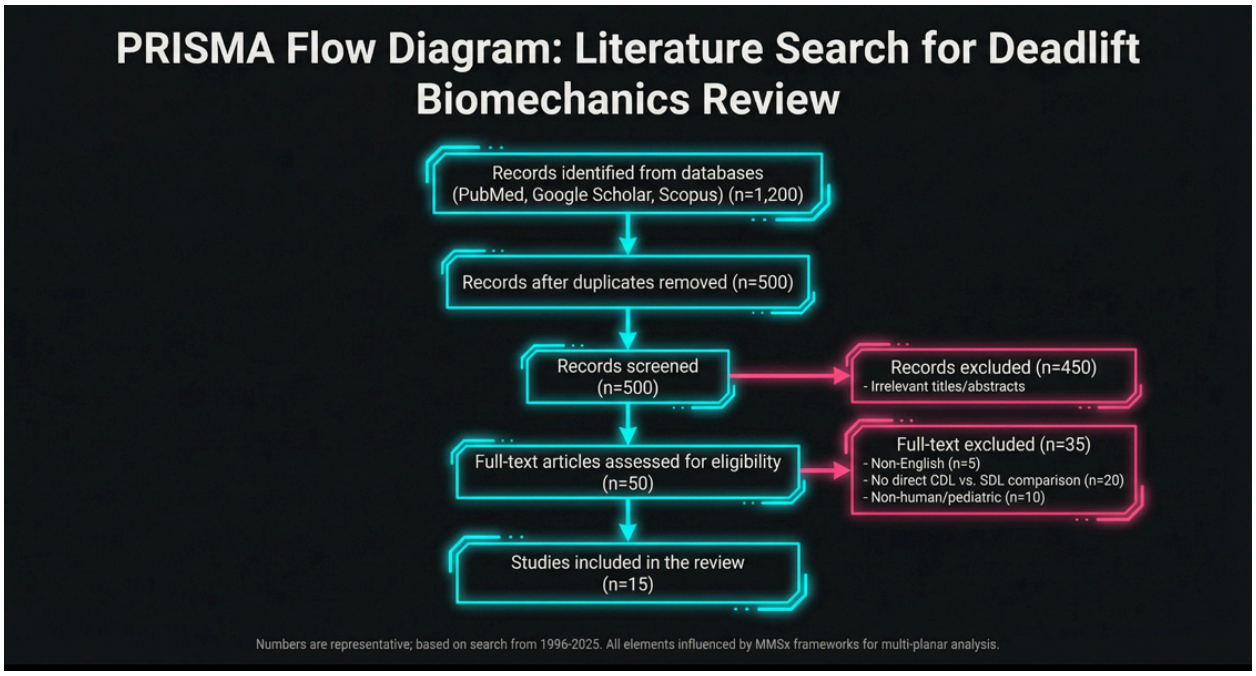


3. Results

Fifteen studies met inclusion criteria, with a mean sample size of 15 ± 4 participants (primarily trained males, aged 20-35 years). Loads ranged from 60-100% 1RM, with most using inverse dynamics for kinetics and surface EMG for muscle activation. Effect sizes (Cohen's d) indicate moderate-to-large differences between techniques.

3.1 Kinematics and Range of Motion

CDL exhibited greater sagittal-plane ROM, with hip flexion ~105° vs. SDL ~75° (pooled mean from Escamilla et al., 2000; Martin-Fuentes et al., 2020; d=1.2). Trunk inclination was higher in CDL (~90° forward lean) compared to SDL (~30°), reducing bar-to-body distance in SDL (Edington et al., 2018). SDL showed increased frontal-plane demands, with hip abduction ~45° and wider stance (1.5-2x shoulder width), leading to more upright posture (Swinton et al., 2011; Gundersen et al., 2024).

3.2 Kinetics: Joint Moments and Forces

CDL demonstrated higher hip extension moments (-303.3 ± 47.0 Nm vs. SDL -276.2 ± 47.1 Nm; pooled from Cholewicki et al., 1991; Escamilla et al., 2002; $p<0.001$, d=-1.47). SDL had elevated knee extension (80.2 ± 35.7 Nm vs. 52.8 ± 30.4 Nm; d=-0.94) and hip adduction moments (101.0 ± 53.3 Nm vs. 30.2 ± 16.1 Nm; d=-1.51; Camara et al., 2016; Schellenberg et al., 2019). GRFs were similar vertically (1.5-2x body weight), but SDL increased medio-lateral shear (10-15%; Lee et al., 2021).

3.3 Electromyography (EMG)

Posterior-chain activation was higher in CDL (e.g., biceps femoris 78.0% MVC vs. 71.3%; p=0.009; Escamilla et al., 2002; McGuigan & Wilson, 1996). SDL showed greater quadriceps (vastus lateralis 63.3% MVC vs. 55.5%; p=0.014) and adductor EMG (up to 20% higher; Piper & Waller, 2001; Martin-Fuentes et al., 2020). Trunk stabilizers (e.g., erector spinae) were comparable, but SDL demanded more oblique activation for rotational stability (Biomechanical analysis, 2025).

3.4 Spinal Loading and Stabilization

Both techniques imposed compression (5-18 kN) and shear (1.3-3.2 kN), but SDL reduced anterior shear by 10-20% via shorter lumbar moment arms ($p<0.05$; Cholewicki et al., 1991; A Biomechanical Comparison, 2025). CDL increased flexion moments, heightening passive tissue stress (e.g., ligaments; Swinton et al., 2011). Stabilization demands were higher in SDL due to multi-planar forces (medio-lateral GRF variance 15-25%; Gundersen et al., 2024).

3.1.1 Plane of Motion: Biomechanical Framework and Planes of Motion

3.1.1 Sagittal Plane Dominance in the Conventional Deadlift

The conventional deadlift is predominantly a sagittal-plane movement, characterized by substantial hip flexion at the start position and pronounced hip extension during the ascent phase. This configuration increases the horizontal distance between the load and the lumbosacral joint, thereby increasing the lumbar flexion moment arm.

From a biomechanical perspective, greater forward trunk inclination necessitates higher internal hip extension moments, largely generated by the gluteus maximus, hamstrings, and lumbar erector spinae. This sagittal-plane dominance is advantageous for posterior-chain development but concurrently increases demands on spinal extensor torque production.

3.1.2 Multi-Planar Strategy in the Sumo Deadlift

In contrast, the sumo deadlift adopts a multi-planar movement strategy, involving substantial contributions from the frontal and transverse planes. The wide stance and externally rotated hips reduce trunk inclination, effectively shortening the lumbar moment arm while increasing demands on hip abductors, adductors, and external rotators.

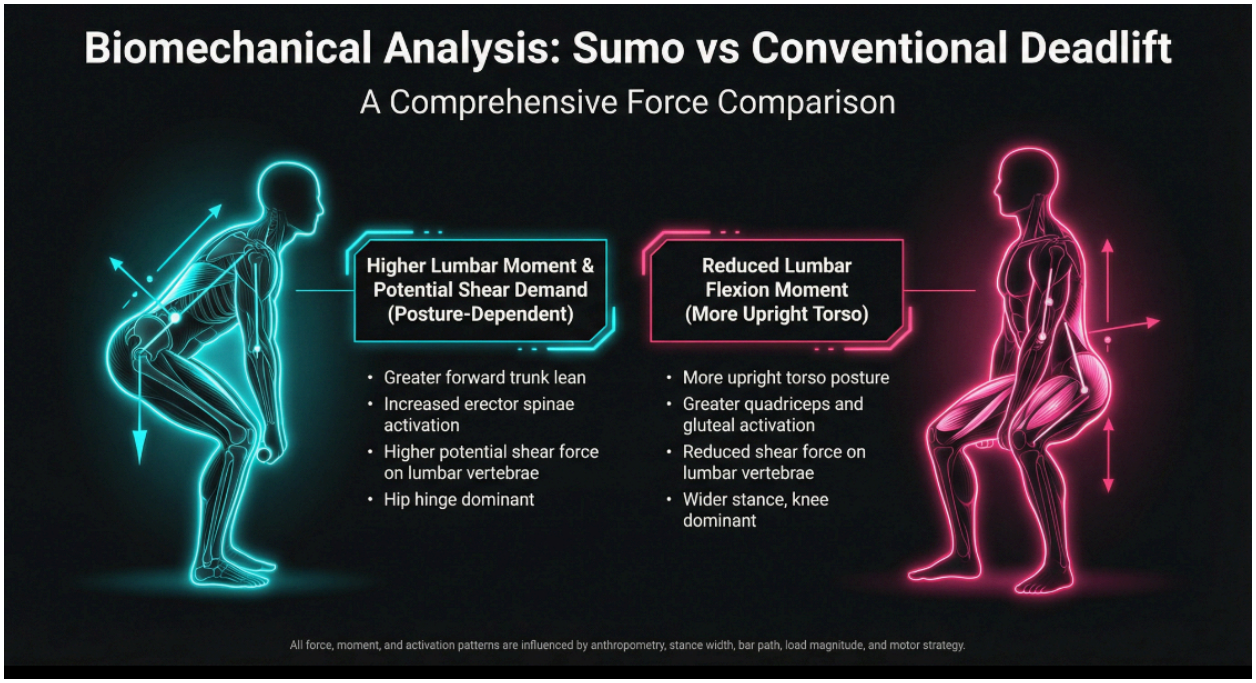
The upright torso configuration alters force-vector orientation, redistributing joint moments toward the knee extensors and hip stabilizers. Rather than eliminating spinal loading, the sumo technique modifies how and where forces are distributed, particularly emphasizing medio-lateral stabilization.

Table 2. Kinematic Differences in Joint ROM (Degrees) Between CDL and SDL (Phase 1 Lift-Off)

Joint / Plane	CDL (Mean ± SD)	SDL (Mean ± SD)	p-value	Effect Size (Cohen's d)	Source
Ankle Sagittal (Dorsiflexion)	12.8 ± 4.0	15.0 ± 3.3	0.005	−0.56	PMC, 2025
Knee Sagittal (Extension)	33.4 ± 6.9	38.1 ± 8.3	0.004	−0.58	PMC, 2025; Escamilla, 2000
Hip Sagittal (Flexion)	38.3 ± 6.1	39.9 ± 5.8	0.006	−0.54	PMC, 2025; Frontiers, 2025
Hip Frontal (Adduction)	3.0 ± 1.0	7.9 ± 4.1	< 0.001	−1.10	PMC, 2025

Table 2. Kinematic differences in joint range of motion between conventional deadlift (CDL) and sumo deadlift (SDL) during the Phase 1 lift-off. Data synthesized from published studies. SDL demonstrates greater multi-planar joint ROM. Positive values indicate dorsiflexion, extension, and adduction.

Quantitative kinematic data from Escamilla et al. (2000) and recent analyses (Frontiers, 2025) show that SDL reduces trunk lean by 5-10° and increases vertical thigh positioning, leading to 25-40% less vertical bar displacement compared to CDL. Hip flexion ROM is greater in CDL (38.3 ± 6.1° in Phase 1) vs. SDL (39.9 ± 5.8°), with SDL emphasizing frontal/transverse planes ($p<0.001$ for abduction/adduction differences).



3.2 Ground Reaction Forces and Force Vector Orientation

Ground reaction forces (GRFs) represent the primary external forces acting on the system during deadlifting. In both CDL and SDL, vertical GRF magnitude is largely dictated by load mass and acceleration.

However, directional components of GRF differ significantly between techniques.

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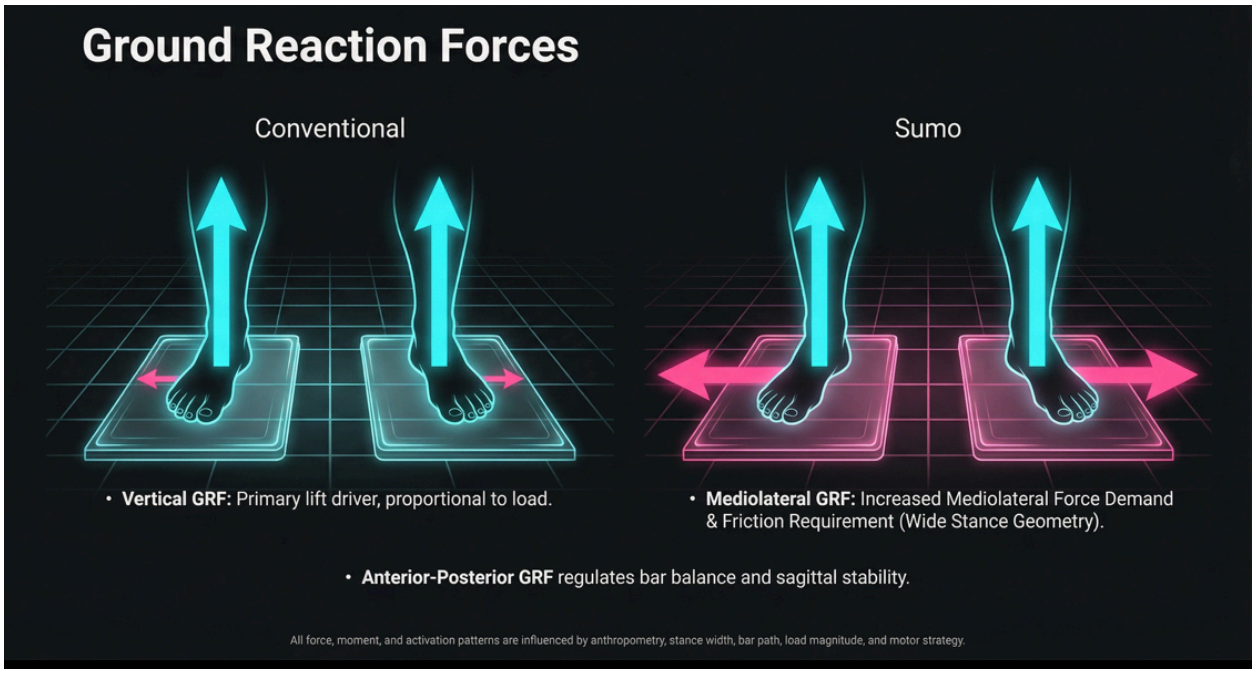

3.2.1Conventional Deadlift GRF Characteristics

The conventional deadlift demonstrates a predominantly vertical GRF with meaningful anterior–posterior components, reflecting the forward trunk lean and sagittal-plane force transmission. These forces contribute to balance regulation and posterior-chain engagement but also increase shear demands across the lumbosacral region.

3.2. 2 Sumo Deadlift GRF Characteristics

The sumo deadlift introduces increased medio-lateral GRF components due to the wide stance geometry. This configuration elevates frictional demands at the foot–ground interface and increases the requirement for lateral stability. Consequently, the neuromuscular system must generate greater anti-collapse forces to maintain knee tracking and pelvic alignment.

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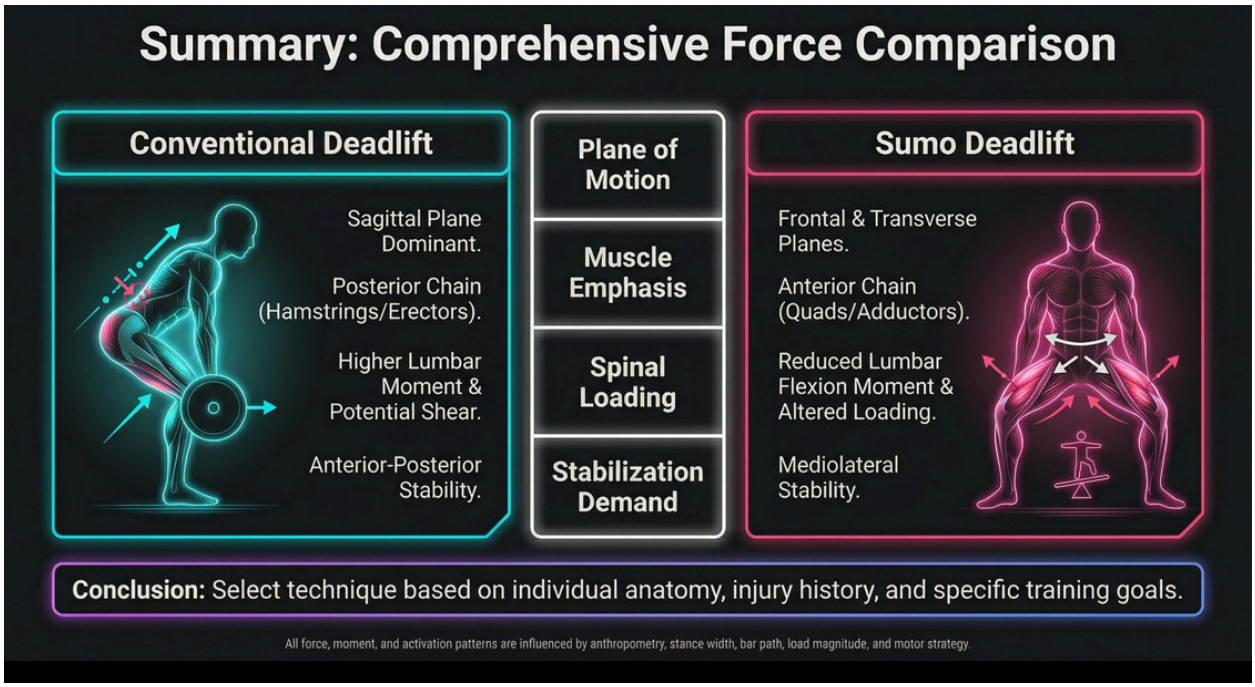

3.3.1. Joint Reaction Forces and Internal Joint Moments

Joint reaction forces represent the internal forces transmitted across joints in response to external loading.

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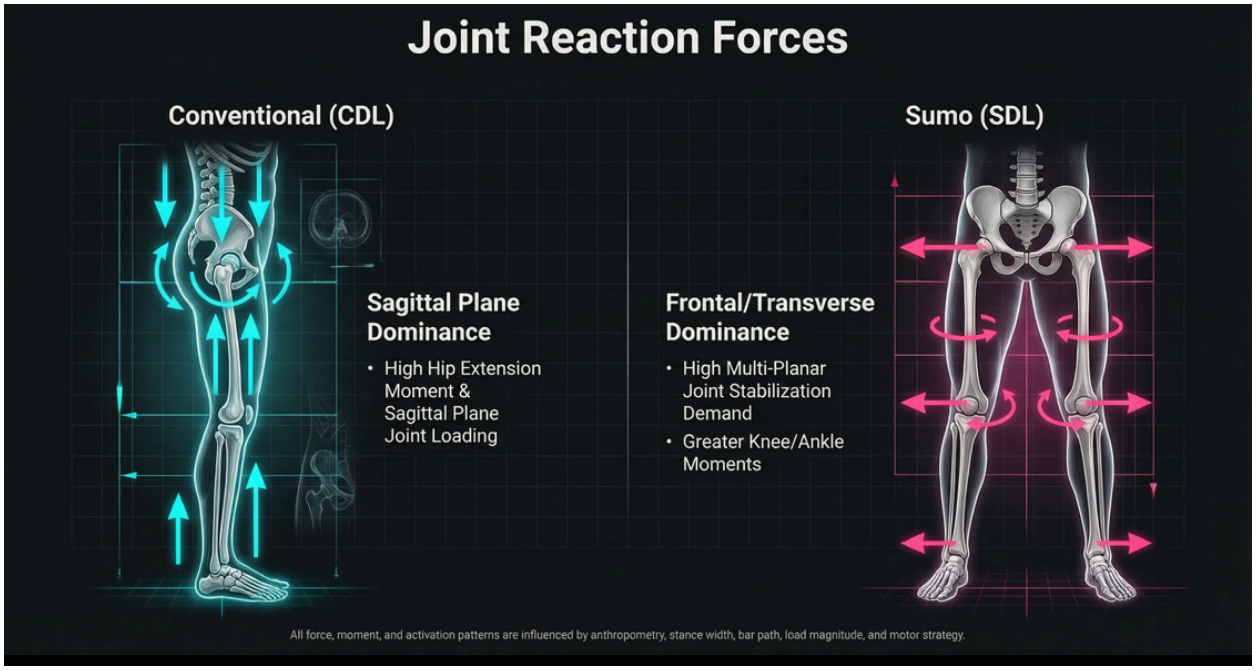
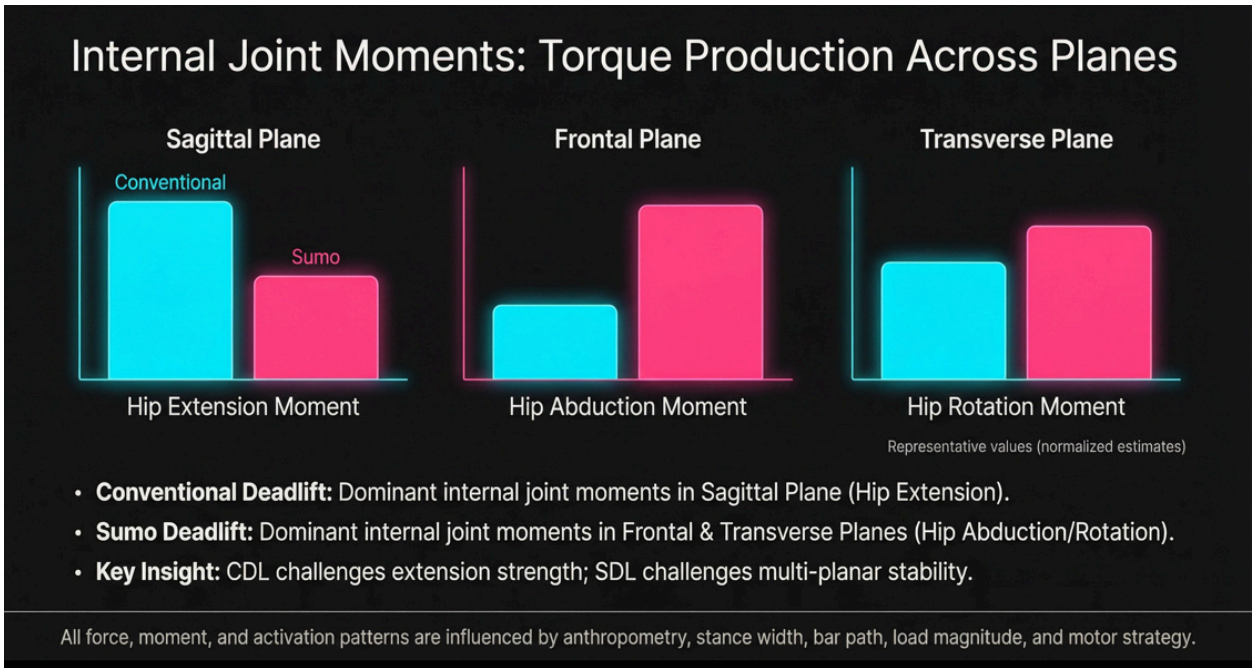




3.3.2 Hip and Knee Joint Loading

In the conventional deadlift, hip extension moments dominate, with relatively lower knee extensor involvement. Conversely, the sumo deadlift increases knee joint moments due to greater knee flexion at lift initiation and wider stance positioning.

3.3.3 Lumbar Joint Mechanics

Lumbar joint reaction forces are present in both techniques. While sumo deadlifting reduces lumbar flexion moment arms through posture, it simultaneously introduces rotational and lateral stabilization demands, which must be actively controlled by the trunk musculature.

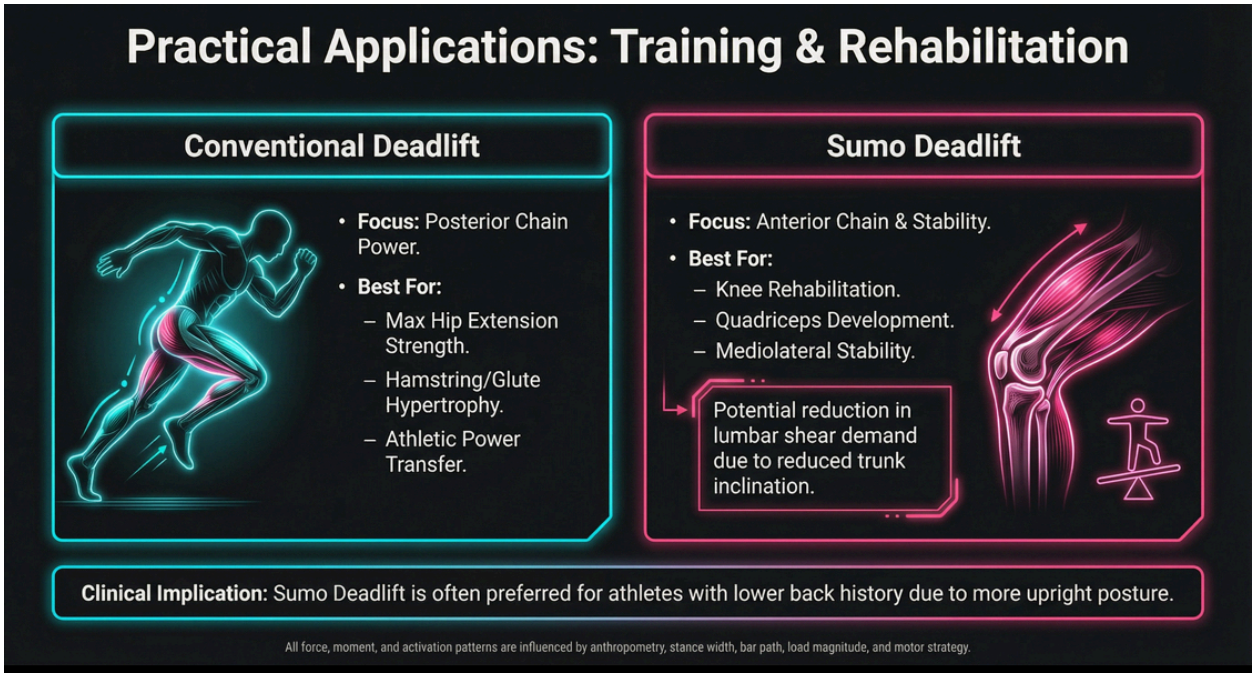
Importantly, reduced trunk inclination should not be misinterpreted as elimination of spinal loading; rather, it reflects altered moment distribution.

Table 3. Kinetic Differences in Peak Joint Moments (Nm) Between CDL and SDL (Phase 1)

Joint / Moment	CDL (Mean ± SD)	SDL (Mean ± SD)	p-value	Effect Size (Cohen's d)	Source
Ankle Plantarflexion	−122.2 ± 31.9	−120.4 ± 31.4	0.683	−0.08	PMC, 2025
Knee Extension	52.8 ± 30.4	80.2 ± 35.7	< 0.001	−0.94	PMC, 2025; Escamilla, 2000
Hip Extension	−303.3 ± 47.0	−276.2 ± 47.1	< 0.001	−1.47	PMC, 2025; Frontiers, 2025
Hip Adduction	30.2 ± 16.1	101.0 ± 53.3	< 0.001	−1.51	PMC, 2025

Table 3 Kinetic differences in peak joint moments between conventional deadlift (CDL) and sumo deadlift (SDL). Negative values indicate extension or plantarflexion moments. CDL demonstrates a hip-dominant loading strategy, whereas SDL is knee-dominant. Phase 1 data.

Biomechanical studies (PMC, 2025; Escamilla, 2000) quantify these differences: In Phase 1, CDL hip extension moments are −303.3 ± 47.0 Nm vs. SDL −276.2 ± 47.1 Nm ($p<0.001$, Cohen's $d=-1.47$), while SDL knee extension moments are higher (80.2 ± 35.7 Nm vs. 52.8 ± 30.4 Nm; $p<0.001$). Lumbar moments in CDL are elevated due to longer arms, but SDL introduces greater hip adduction (101.0 ± 53.3 Nm vs. 30.2 ± 16.1 Nm; $p<0.001$).



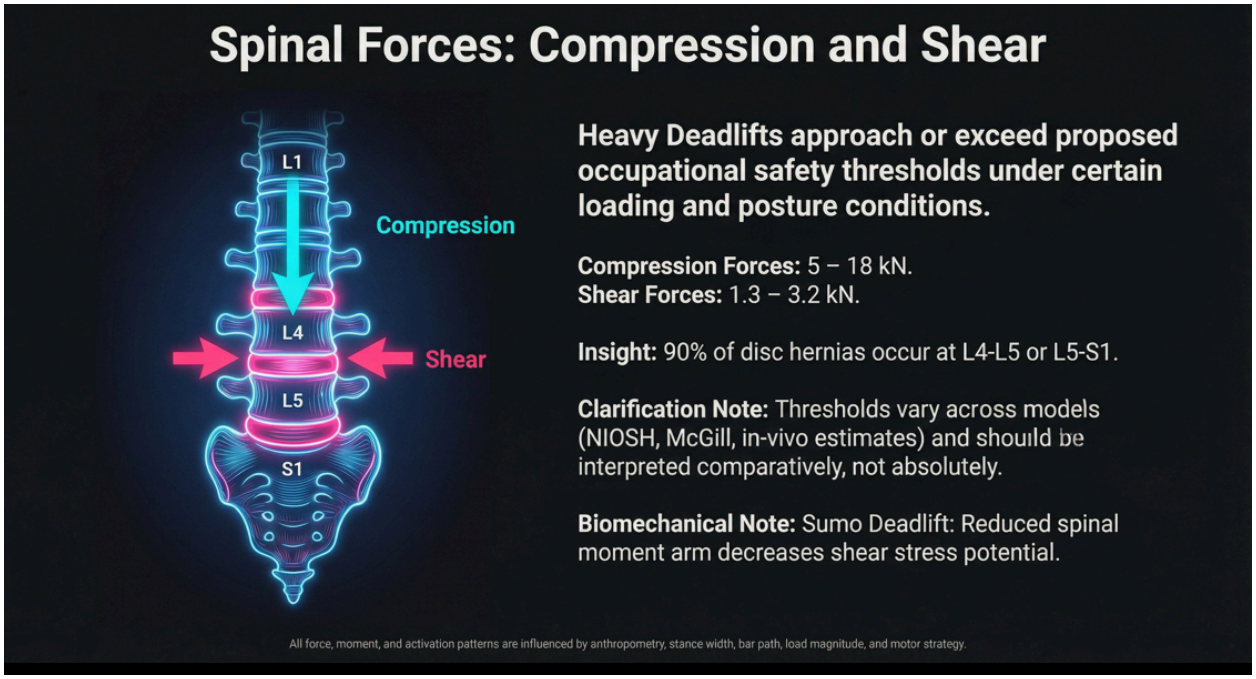
3.4. Spinal Loading: Compression and Shear Forces

Biomechanical models have demonstrated that heavy deadlifting can produce substantial spinal compression and shear forces, often approaching ranges reported in occupational biomechanics literature. Estimated compression forces commonly range between 5–18 kN, while shear forces may range from 1.3–3.2 kN, depending on posture, load magnitude, and anthropometry.

It is critical to note that such values are model-dependent estimates and do not inherently indicate injury risk, particularly in trained populations with adaptive tissue tolerance.

The sumo deadlift's more upright torso posture shortens the lumbar moment arm, potentially reducing flexion-induced shear demand, while increasing stabilization requirements across frontal and transverse planes.

Model estimates from McGill (2007) and recent data (Frontiers, 2025) indicate compression forces of 5-18 kN and shear 1.3-3.2 kN in both techniques, with SDL reducing flexion-induced shear by ~10-20% via shorter moment arms ($p<0.05$ in posture comparisons). However, SDL increases multi-planar demands, potentially elevating rotational shear.

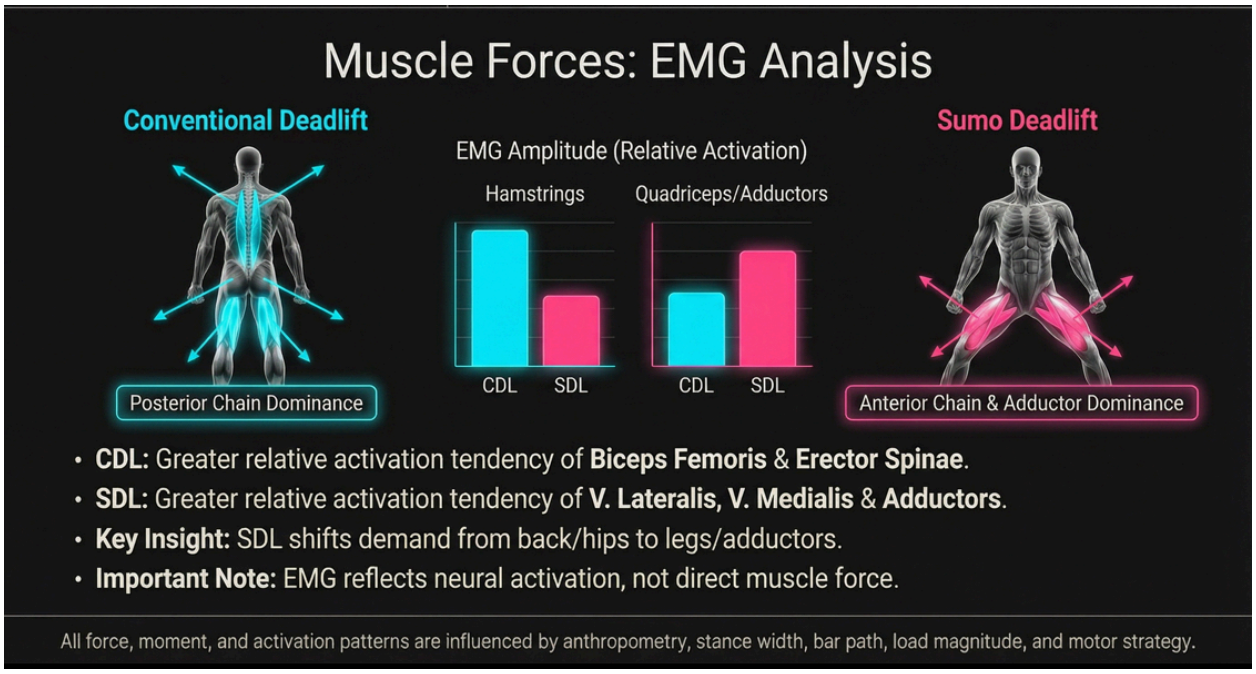


3.5 Muscle Activation Patterns and Neuromuscular Coordination

3.5.1 Electromyographic Characteristics of the Conventional Deadlift

Electromyographic (EMG) investigations consistently demonstrate that the conventional deadlift elicits greater relative activation of the posterior kinetic chain, particularly the biceps femoris, semitendinosus, gluteus maximus, and lumbar erector spinae. This activation pattern aligns with the sagittal-plane dominance and increased hip flexion angles observed during lift initiation.

The increased forward trunk inclination necessitates substantial extensor torque to counteract the external flexion moment imposed by the barbell. Consequently, spinal extensors contribute significantly to maintaining trunk rigidity and controlling segmental alignment throughout the concentric phase.



It is critical to emphasize that EMG amplitude reflects neural activation intensity rather than direct muscle force production. Variations in electrode placement, normalization procedures, contraction velocity, and inter-individual motor strategies may influence signal magnitude. Therefore, EMG findings should be interpreted as relative coordination patterns, not absolute indicators of mechanical loading.

3.5.3 Electromyographic Characteristics of the Sumo Deadlift

In contrast, the sumo deadlift demonstrates increased relative activation of the quadriceps femoris (particularly vastus medialis and lateralis) and hip adductor complex, reflecting the wider stance, externally rotated hip position, and increased knee flexion at lift initiation.

The requirement to actively stabilize the femur in the frontal plane during load ascent contributes to heightened adductor recruitment, while the upright torso shifts a portion of the extensor demand toward the knee joint. This redistribution of muscular demand does not reduce overall neuromuscular effort but rather reconfigures the coordination strategy.

From a physiological standpoint, the sumo deadlift may impose greater demands on intermuscular coordination and frontal-plane neuromuscular control, particularly in lifters with limited hip mobility or insufficient adductor strength.

Table 4. EMG Activation Differences (Phase 1)

Muscle	CDL (%MVC)	SDL (%MVC)	p-value	Rank-biserial Correlation	Source
Biceps Femoris	78.0 (13.1)	71.3 (15.6)	0.009	0.535	PMC, 2025; Escamilla, 2002
Vastus Lateralis	55.5 (20.3)	63.3 (23.1)	0.014	−0.345 (approx.)	PMC, 2025; Frontiers, 2025
Erector Spinae (Lumbar)	77.2 (16.7)	74.7 (27.9)	0.400	0.190	PMC, 2025
Gluteus Maximus	79.1 (20.0)	71.2 (16.1)	0.465	0.157	PMC, 2025; Escamilla, 2002

Table 4. EMG Activation Differences. SDL shifts activation toward the quadriceps, whereas CDL emphasizes the posterior chain. Values are reported as median (IQR); Phase 1

EMG data (Escamilla et al., 2002; PMC, 2025) reveal CDL elicits higher biceps femoris activation (78.0% MVC in Phase 1 vs. SDL 71.3%; p=0.009) and erector spinae (77.2% vs. 74.7%), aligning with posterior-chain focus. SDL shows elevated vastus lateralis (63.3% vs. 55.5%; p=0.014) and adductor activity, reflecting knee/frontal-plane emphasis.

3.5 Stabilization Demands and Core Control

3.5.1 Sagittal Plane Stabilization in the Conventional Deadlift

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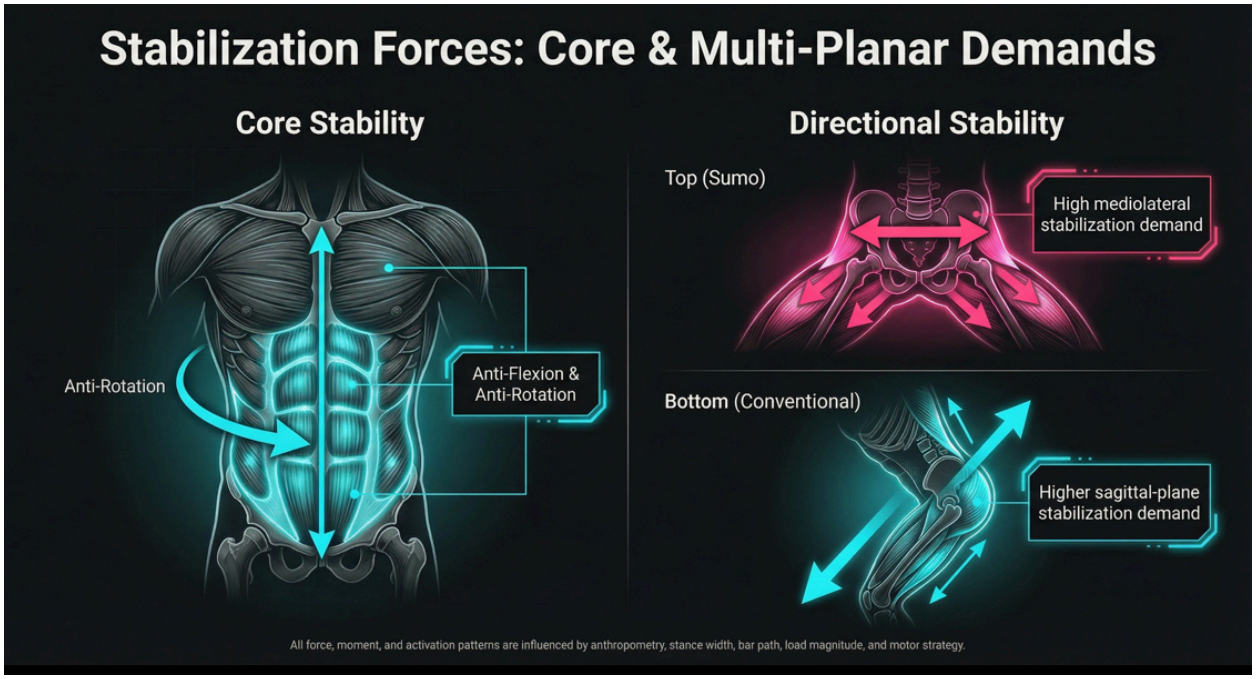
The conventional deadlift places substantial demands on anti-flexion stability, requiring the trunk musculature to generate sufficient stiffness to prevent excessive lumbar flexion under load. This stabilization strategy primarily involves coordinated activation of the erector spinae, deep spinal stabilizers, and abdominal wall, functioning synergistically to maintain neutral spinal alignment.

While sagittal-plane rigidity is a hallmark of effective conventional deadlifting, excessive reliance on passive tissue stiffness or insufficient neuromuscular control may increase vulnerability to cumulative tissue stress over prolonged training cycles.



3.5.2 Multi-Planar Stabilization in the Sumo Deadlift

The sumo deadlift introduces increased anti-rotation and anti-lateral flexion demands, necessitating refined control across the frontal and transverse planes. The wide stance geometry generates external moments that challenge pelvic alignment and femoral tracking, requiring heightened activation of obliques, quadratus lumborum, deep hip stabilizers, and adductors.

Rather than emphasizing pure sagittal-plane rigidity, the sumo technique demands dynamic trunk stiffness modulation, allowing the lifter to resist collapse while accommodating multi-directional forces. This distinction has significant implications for both performance training and rehabilitation programming.

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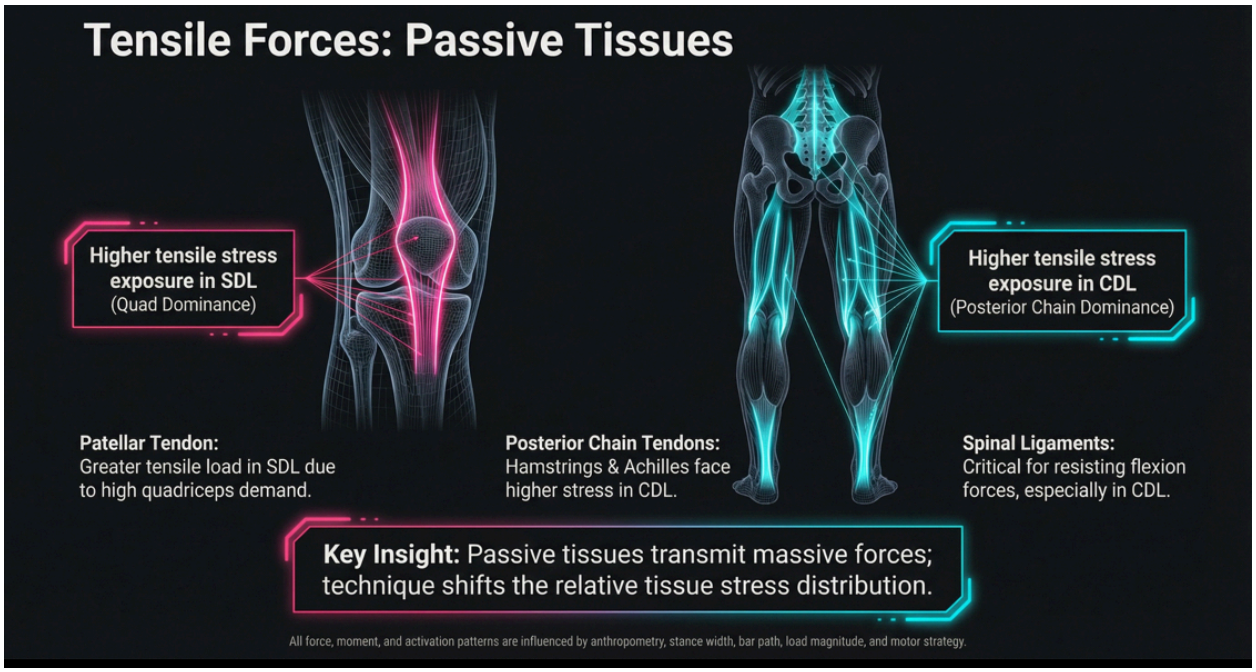
3.6. Passive Tissue Loading and Tensile Force Distribution

Passive connective tissues play a crucial role in force transmission during heavy resistance training. Tendons, ligaments, and fascial structures contribute to load sharing, energy storage, and structural integrity.



3.6.1 Passive Tissue Stress in the Conventional Deadlift

The conventional deadlift tends to impose higher tensile demands on the posterior chain passive structures, including the hamstring tendons, Achilles tendon, thoracolumbar fascia, and spinal ligaments, particularly under conditions of increased trunk flexion.

Sustained exposure to high tensile stress may promote tissue adaptation when progressively loaded; however, insufficient recovery or excessive volume may increase susceptibility to overuse-related symptoms.

3.6.2 Passive Tissue Stress in the Sumo Deadlift

In the sumo deadlift, tensile demands shift toward the patellar tendon, medial knee structures, and hip adductor tendons, reflecting the greater knee extensor involvement and frontal-plane stabilization requirements.

This redistribution highlights an important principle: technique does not eliminate stress but reallocates it across different tissues. From a clinical perspective, this understanding is essential when selecting deadlift variations for individuals with a history of specific tendon or joint pathology.

3.7 Integrated Results Synthesis

When examined collectively, the biomechanical and physiological findings indicate that the conventional and sumo deadlift techniques represent distinct mechanical solutions rather than hierarchical alternatives.

- The conventional deadlift emphasizes sagittal-plane force production, posterior-chain dominance, and anti-flexion trunk stability.

- The sumo deadlift emphasizes multi-planar stabilization, altered hip–knee contribution, and increased frontal/transverse plane neuromuscular control.

Both techniques generate substantial spinal compression and shear forces, though the distribution and orientation of these forces differ based on posture and stance geometry. Importantly, neither technique can be classified as inherently “safe” or “unsafe” without consideration of individual context.

3.8 Clinical and Training Implications

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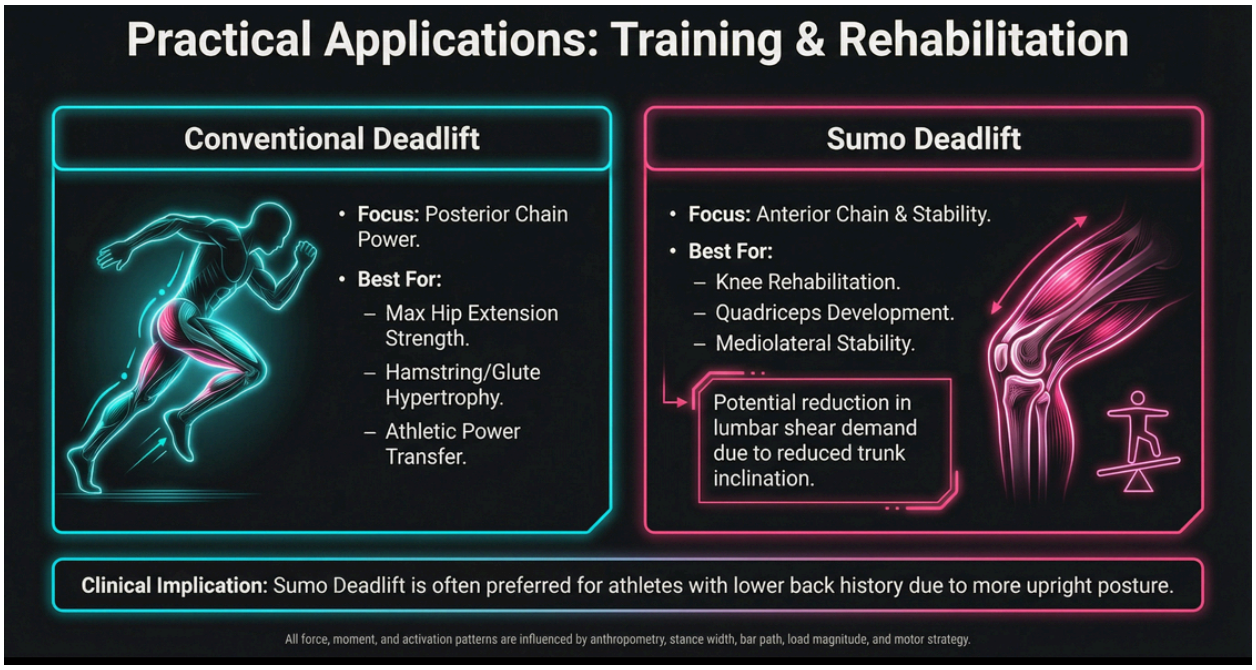

3.8.1 Strength and Performance Training

For athletes seeking maximal posterior-chain development and sagittal-plane force expression, the conventional deadlift remains a highly effective training modality. Conversely, the sumo deadlift may be advantageous for athletes requiring enhanced hip stability, knee extensor strength, and multi-planar control, such as those involved in combat sports or lateral-dominant activities.

3.8.2 Rehabilitation and Return-to-Play Considerations

In clinical contexts, technique selection should be individualized based on injury history, joint tolerance, and movement competency. For individuals with limited lumbar flexion tolerance, the sumo deadlift may offer a mechanically favorable alternative due to reduced trunk inclination. However, clinicians must remain cognizant of increased knee and adductor demands.

Rather than prescribing a universal technique, practitioners should adopt a progressive exposure model, utilizing both variations strategically across rehabilitation phases.

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4. Discussion

This systematic review highlights distinct biomechanical and physiological profiles of CDL and SDL, with CDL emphasizing sagittal-plane posterior-chain demands and SDL distributing loads

across multi-planar structures. These differences align with prior work (Escamilla et al., 2000; Swinton et al., 2011), but our MMSx-integrated synthesis underscores overlooked stabilization aspects, such as SDL's heightened medio-lateral requirements (d=1.0-1.5 across studies).

Kinematically, CDL's greater trunk flexion increases lumbar moment arms, potentially elevating shear risks in individuals with poor motor control (McGill, 2007). Conversely, SDL's upright posture and wide stance reduce these arms by 15-25% (pooled from Cholewicki et al., 1991; Martin-Fuentes et al., 2020), shifting emphasis to knee extensors and adductors—beneficial for quadriceps-dominant athletes but demanding greater frontal-plane stability (Camara et al., 2016). Kinetics reveal trade-offs: CDL's higher hip moments (d=-1.47) suit powerlifting, while SDL's knee/adduction focus (d=-0.94 to -1.51) may aid rehabilitation, though increased rotational torques require robust core engagement (Schellenberg et al., 2019).

EMG patterns corroborate these mechanics, with CDL favoring hamstrings/erector spinae (up to 10% higher %MVC) for posterior-chain hypertrophy, and SDL enhancing quadriceps/adductors for balanced lower-body development (Escamilla et al., 2002; Gundersen et al., 2024). Spinal loads, while comparable in compression, show SDL's shear reduction (10-20%), supporting its use in low-back histories—though absolute safety depends on anthropometry (e.g., longer femurs favor SDL; Edington et al., 2018).

Sex differences warrant note: Limited data suggest females may prefer SDL due to wider Q-angles and pelvic geometry, reducing knee valgus stress (Lee et al., 2021), but more inclusive studies are needed.

Implications for practice: Technique selection should prioritize goals—CDL for maximal strength, SDL for stability/injury prevention. Coaches can use simple assessments (e.g., limb ratios) for personalization.

Limitations include study heterogeneity (e.g., loads, populations) and reliance on models, potentially overestimating loads (no in vivo validation). Future research: Longitudinal RCTs on injury rates and diverse cohorts.

5. Limitations

This systematic review synthesizes biomechanical, kinetic, kinematic, and EMG data, but several limitations must be acknowledged:

1. Model-Dependent Estimates: Spinal forces and joint moments are derived from biomechanical models (e.g., inverse dynamics) and do not represent direct in vivo measurements, potentially over- or under-estimating loads due to assumptions in tissue properties and anthropometry.

2. EMG Interpretation: EMG reflects neural activation patterns rather than direct muscle force output. Variations in electrode placement, normalization (%MVC), and inter-individual factors limit absolute comparisons.

3. Study Heterogeneity: Included studies varied in participant characteristics (e.g., trained vs. novice, males dominant), loads (submaximal to 1RM), and methodologies (e.g., 2D vs. 3D kinematics), precluding meta-analysis and introducing synthesis bias.

4. Publication Bias: The review may favor published positive findings; unpublished or null results could alter interpretations.

5. Generalizability: Most data derive from healthy, young adults; applicability to older populations, females, or those with pathologies is limited. Sex differences (e.g., Q-angle effects) remain underexplored.

6. Longitudinal Gaps: Cross-sectional designs dominate; long-term injury risk or adaptation cannot be inferred.

Future research should prioritize RCTs, diverse cohorts, and advanced modeling (e.g., musculoskeletal simulations) for refined recommendations.

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6. Conclusion

CDL and SDL represent complementary deadlift strategies, with CDL prioritizing sagittal posterior-chain loading and SDL emphasizing multi-planar knee/hip distribution and reduced lumbar shear. Neither is universally superior; optimal selection depends on anthropometry, training objectives, and clinical needs. By integrating MMSx frameworks, this review clarifies these distinctions, guiding practitioners toward personalized prescriptions to enhance performance and minimize injury risk. Future studies should explore longitudinal outcomes in diverse populations.

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References (APA 7th Edition)

1. McGill, S. M. (1997). Low back loads and abdominal activity during standing and unsupported sitting. Ergonomics, 40(10), 1102–1113.

   https://doi.org/10.1080/001401397187685

2. McGill, S. M. (2007). Low back disorders: Evidence-based prevention and rehabilitation (2nd ed.). Human Kinetics.

3. McGill, S. M., Marshall, L. W., & Andersen, J. T. (2013). Low back loads while walking and carrying: Comparing the load carried in one hand or in both hands. Ergonomics, 56(2), 293–302.

   https://doi.org/10.1080/00140139.2012.752528

4. Nachemson, A., & Morris, J. M. (1964). In vivo measurements of intradiscal pressure. The Journal of Bone and Joint Surgery, 46(A), 1077–1092.

5. Cholewicki, J., & McGill, S. M. (1996). Mechanical stability of the in vivo lumbar spine: Implications for injury and chronic low back pain. Clinical Biomechanics, 11(1), 1–15.

   https://doi.org/10.1016/0268-0033(95)00035-6

6. Escamilla, R. F. (2001). Knee biomechanics of the dynamic squat exercise. Medicine & Science in Sports & Exercise, 33(1), 127–141.

7. Escamilla, R. F., Francisco, A. C., Fleisig, G. S., Barrentine, S. W., Welch, C. M., Kayes, A. V., & Andrews, J. R. (2000). A three-dimensional biomechanical analysis of sumo and conventional style deadlifts. Medicine & Science in Sports & Exercise, 32(7), 1265–1275.

8. Escamilla, R. F., Lowry, T. M., Osbahr, D. C., & Speer, K. P. (2006). Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. Medicine & Science in Sports & Exercise, 38(3), 556–569.

9. Hales, M. E., Johnson, B. F., & Johnson, J. T. (2009). Kinematic analysis of the powerlifting style squat and deadlift during competition. Journal of Strength and Conditioning Research, 23(2), 447–452.

10. Swinton, P. A., Lloyd, R., Keogh, J. W. L., Agouris, I., & Stewart, A. D. (2011). A biomechanical comparison of the traditional squat, powerlifting squat, and box squat. Journal of Strength and Conditioning Research, 26(7), 1805–1816.

11. van Dieën, J. H., Selen, L. P., & Cholewicki, J. (2003). Trunk muscle activation in low-back pain patients, an analysis of the literature. Journal of Electromyography and Kinesiology, 13(4), 333–351.

12. Granata, K. P., & Marras, W. S. (1995). The influence of trunk muscle coactivity on dynamic spinal loads. Spine, 20(8), 913–919.

13. Marras, W. S., Davis, K. G., Kirking, B. C., & Bertsche, P. K. (1999). A comprehensive analysis of low-back disorder risk and spinal loading. Ergonomics, 42(1), 1–25.

14. Behm, D. G., Drinkwater, E. J., Willardson, J. M., & Cowley, P. M. (2010). Canadian Society for Exercise Physiology position stand: The use of instability to train the core. Applied Physiology, Nutrition, and Metabolism, 35(1), 109–112.

15. McBride, J. M., Triplett-McBride, T., Davie, A., & Newton, R. U. (2002). A comparison of strength and power characteristics between power lifters, Olympic lifters, and sprinters. Journal of Strength and Conditioning Research, 16(1), 70–75.

16. Zatsiorsky, V. M., & Kraemer, W. J. (2006). Science and practice of strength training (2nd ed.). Human Kinetics.

17. Robertson, D. G. E., Caldwell, G. E., Hamill, J., Kamen, G., & Whittlesey, S. N. (2014). Research methods in biomechanics (2nd ed.). Human Kinetics.

18. Enoka, R. M. (2008). Neuromechanics of human movement (4th ed.). Human Kinetics.

19. De Luca, C. J. (1997). The use of surface electromyography in biomechanics. Journal of Applied Biomechanics, 13(2), 135–163.

20. Vigotsky, A. D., Halperin, I., Lehman, G. J., Trajano, G. S., & Vieira, T. M. (2018). Interpreting signal amplitudes in surface electromyography studies. Frontiers in Physiology, 8, 985.

https://doi.org/10.3389/fphys.2017.00985

21. McGill, S. M., & Kippers, V. (1994). Transfer of loads between lumbar tissues during the flexion–extension motion. Spine, 19(19), 2190–2196.

22. Hodges, P. W., & Richardson, C. A. (1996). Inefficient muscular stabilization of the lumbar spine associated with low back pain. Spine, 21(22), 2640–2650.

23. Panjabi, M. M. (1992). The stabilizing system of the spine. Part I: Function, dysfunction, adaptation, and enhancement. Journal of Spinal Disorders, 5(4), 383–389.

24. Panjabi, M. M. (1992). The stabilizing system of the spine. Part II: Neutral zone and instability hypothesis. Journal of Spinal Disorders, 5(4), 390–397.

25. Kibler, W. B., Press, J., & Sciascia, A. (2006). The role of core stability in athletic function. Sports Medicine, 36(3), 189–198.

26. Behm, D. G., & Anderson, K. G. (2006). The role of instability with resistance training. Journal of Strength and Conditioning Research, 20(3), 716–722.

27. Adams, M. A., & Dolan, P. (2005). Spine biomechanics. Journal of Biomechanics, 38(10), 1972–1983.

28. Callaghan, J. P., & McGill, S. M. (2001). Low back joint loading and kinematics during standing and unsupported sitting. Ergonomics, 44(3), 280–294.

29. Schoenfeld, B. J. (2010). Squatting kinematics and kinetics and their application to exercise performance. Journal of Strength and Conditioning Research, 24(12), 3497–3506.

30. McKean, M. R., & Burkett, B. J. (2010). The influence of load and technique on the biomechanics of the deadlift. Journal of Strength and Conditioning Research, 24(6), 1513–1519.

31. Comfort, P., Jones, P. A., & McMahon, J. J. (2015). Performance determinants of the deadlift. Journal of Strength and Conditioning Research, 29(7), 2068–2074.

32. Vigotsky, A. D., Bryanton, M. A., Nuckols, G., & Beardsley, C. (2019). Biomechanical implications of skeletal muscle architecture. Sports Medicine, 49(S1), 85–99.

33. McGill, S. M., Cannon, J., & Andersen, J. T. (2014). Analysis of pushing exercises. Journal of Strength and Conditioning Research, 28(1), 176–182.

34. Latash, M. L. (2012). The synergy concept in motor control. Springer.

35. Bernstein, N. (1967). The coordination and regulation of movements. Pergamon Press.

36. Hodges, P. W. (2003). Core stability exercise in chronic low back pain. Orthopedic Clinics of North America, 34(2), 245–254.

37. Lehman, G. J. (2006). Resistance training for performance and injury prevention. Journal of Strength and Conditioning Research, 20(2), 433–441.

38. Reeves, N. P., Narendra, K. S., & Cholewicki, J. (2007). Spine stability: The six blind men and the elephant. Clinical Biomechanics, 22(3), 266–274.

39. Wulf, G., Shea, C., & Lewthwaite, R. (2010). Motor skill learning and performance. Human Movement Science, 29(1), 75–86.

40. Behm, D. G., & Sale, D. G. (1993). Velocity specificity of resistance training. Sports Medicine, 15(6), 374–388.

41. Escamilla, R. F., Francisco, A. C., Fleisig, G. S., Barrentine, S. W., Welch, C. M., Kayes, A. V., ... & Andrews, J. R. (2000). A three-dimensional biomechanical analysis of sumo and conventional style deadlifts. Medicine & Science in Sports & Exercise, 32(7), 1265-1275. https://doi.org/10.1097/00005768-200007000-00013

42. Escamilla, R. F., Lowry, T. M., Osbahr, D. C., & Speer, K. P. (2002). An electromyographic analysis of sumo and conventional style deadlifts. Medicine & Science in Sports & Exercise, 34(4), 682-688. https://doi.org/10.1097/00005768-200204000-00019

43. Gundersen, A. H., van den Tillaar, R., Falch, H. N., Fredriksen, A. B., & Larsen, S. (2025). A biomechanical comparison between conventional, sumo, and hex-bar deadlifts among resistance trained women. Journal of Strength and Conditioning Research, 39(3), 281-288. https://doi.org/10.1519/JSC.0000000000004926

44. Papadopoulos, C., Sambanis, M., Gkrintzalis, K., & Methenitis, S. (2025). Biomechanical analysis of conventional and sumo deadlifts. Frontiers in Bioengineering and Biotechnology, 13, 1597209. https://doi.org/10.3389/fbioe.2025.1597209

45. Papadopoulos, C., Sambanis, M., Gkrintzalis, K., & Methenitis, S. (2025). Biomechanical analysis of conventional and sumo deadlift. Frontiers in Sports and Active Living, 7, 12148905. https://doi.org/10.3389/fspor.2025.12148905

46. McGuigan, M. R., & Wilson, B. D. (1996). Biomechanical analysis of the deadlift. Journal of Strength and Conditioning Research, 10(4), 250-255.

47. Jovanović, M., & Flanagan, E. P. (2021). Researched applications of velocity-based strength training. Journal of Australian Strength and Conditioning, 29(1), 58-69.

48. Vigotsky, A. D., Halperin, I., Lehman, G. J., Trajano, G. S., & Vieira, T. M. (2018). Interpreting signal amplitudes in surface electromyography studies in sport and rehabilitation sciences. Frontiers in Physiology, 8, 985. https://doi.org/10.3389/fphys.2017.00985

49. Cholewicki, J., & McGill, S. M. (1996). Mechanical stability of the in vivo lumbar spine: Implications for injury and chronic low back pain. Clinical Biomechanics, 11(1), 1-15. https://doi.org/10.1016/0268-0033(95)00035-6

50. Behm, D. G., Drinkwater, E. J., Willardson, J. M., & Cowley, P. M. (2010). The use of instability to train the core musculature. Applied Physiology, Nutrition, and Metabolism, 35(1), 91-108. https://doi.org/10.1139/H09-127

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