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LETTER TO THE EDITOR

Rethinking exercise specificity in unilateral resistance training for football: A neuromechanical perspective

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Dear Editor,

Resistance training is a fundamental component of physical preparation in football, where players repeatedly perform explosive accelerations, rapid decelerations, changes of direction (COD), jumps, unilateral braking, kicking, and transitional movements under substantial temporal and mechanical constraints (Harper et al., 2019; Moreno-Azze et al., 2025). Successful execution of these actions depends not only on the ability to generate high levels of force but also on the capacity to absorb, redirect, and coordinate force across multiple planes of movement while maintaining trunk stability, postural control, and movement adaptability (Harper et al., 2019). Consequently, selecting resistance-training exercises that may transfer effectively to football-specific performance remains a central objective of contemporary strength and conditioning practice.

Among available resistance-training strategies, unilateral exercises have become a cornerstone of football conditioning because many decisive football actions involve single-leg support phases. Despite their widespread implementation, however, unilateral resistance training is frequently discussed and investigated as though it represents a single, homogeneous training stimulus. In practice, exercises performed on one limb may differ substantially in their mechanical characteristics, coordinative requirements, and movement constraints (Huang et al., 2024; Junge et al., 2023). For example, a single-leg squat, lateral lunge, unilateral broad jump, and rotational single-leg Romanian deadlift all involve unilateral execution, yet each requires different strategies for force production, braking, stabilisation, and whole-body coordination. Classifying these exercises solely according to limb involvement may therefore obscure meaningful differences in the training stimulus and their potential relevance to football-specific performance.

This simplified classification may partly contribute to the inconsistent findings reported across studies investigating unilateral resistance training. Although improvements in sprint acceleration, jumping, and COD performance have been observed following unilateral training in some investigations, other studies have

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reported smaller, comparable, or highly variable adaptations despite employing apparently similar unilateral programmes (Appleby et al., 2020; Gonzalo-Skok et al., 2017; McCurdy et al., 2005; Moran et al., 2021). These inconsistencies are undoubtedly multifactorial and may reflect differences in training volume, exercise intensity, frequency, density, players' characteristics, methodological process, and outcome measures. Nevertheless, another plausible, yet comparatively underexplored, explanation is the considerable heterogeneity within unilateral exercise selection itself. When mechanically distinct unilateral exercises are interpreted as equivalent interventions, meaningful differences in the training stimulus may be overlooked, limiting the precision with which adaptation and potential transfer are interpreted.

Although the principle of training specificity is well established, current approaches may not fully account for the diversity of unilateral resistance-training tasks. Existing theoretical perspectives have advanced understanding of exercise specificity by emphasising force orientation, movement constraints, and interactions between the performer and the environment (Morin et al., 2011). However, these perspectives have not been commonly integrated within a framework specifically intended to differentiate unilateral exercises according to their combined mechanical, coordinative, and task-related characteristics. This gap suggests a need to consider unilateral exercise specificity beyond limb involvement alone, with greater attention to the integrated neuromechanical demands imposed by individual exercises.

Accordingly, we conceptualise neuromechanical specificity as the extent to which a unilateral exercise approximates the interaction of mechanical demands (e.g., force orientation, braking–propulsion characteristics, and muscular contraction profile), coordinative requirements (e.g., trunk and pelvic control, intermuscular coordination, and postural regulation), and task constraints that collectively characterise a target football action (Dos'Santos et al., 2017; Nimphius et al., 2018). These dimensions are not considered independent characteristics; rather, their interaction is proposed to form an integrated neuromechanical profile of the exercise. Importantly, neuromechanical specificity is presented as an integrative conceptual lens rather than a new standalone theory or validated quantitative measure.

The distinctive contribution of this perspective is therefore not the introduction of a new mechanical, coordinative, or ecological variable, but the proposition that these dimensions should be considered jointly when evaluating unilateral exercise specificity. Force-vector theory emphasises force orientation, whereas ecological dynamics and task-constraint approaches focus on interactions among the performer, task, and environment; traditional specificity principles emphasise correspondence between training and performance demands (Morin et al., 2011). Neuromechanical specificity brings these perspectives together within an exercise-selection lens, helping distinguish unilateral exercises that share similar limb involvement but may impose substantially different integrated training stimuli. The framework thus complements existing theories while generating hypotheses that require empirical verification.

From a mechanistic perspective, different unilateral exercises may impose distinct neuromechanical demands. Horizontally oriented exercises may be relevant to acceleration through horizontal force production and propulsion, whereas vertically oriented exercises may emphasise vertical force production and eccentric control relevant to jumping and unilateral strength demands. Lateral exercises may impose greater frontal-plane braking and force-absorption demands relevant to deceleration and change-of-direction tasks (Morin et al., 2011; Nimphius et al., 2018). Rotational exercises may emphasise trunk–pelvic control during multiplanar movement, while unilateral strength exercises may emphasise lower-limb force production and eccentric control. However, these relationships represent biomechanically informed hypotheses rather than established exercise–performance effects, and their influence on adaptation or transfer remains to be determined empirically.

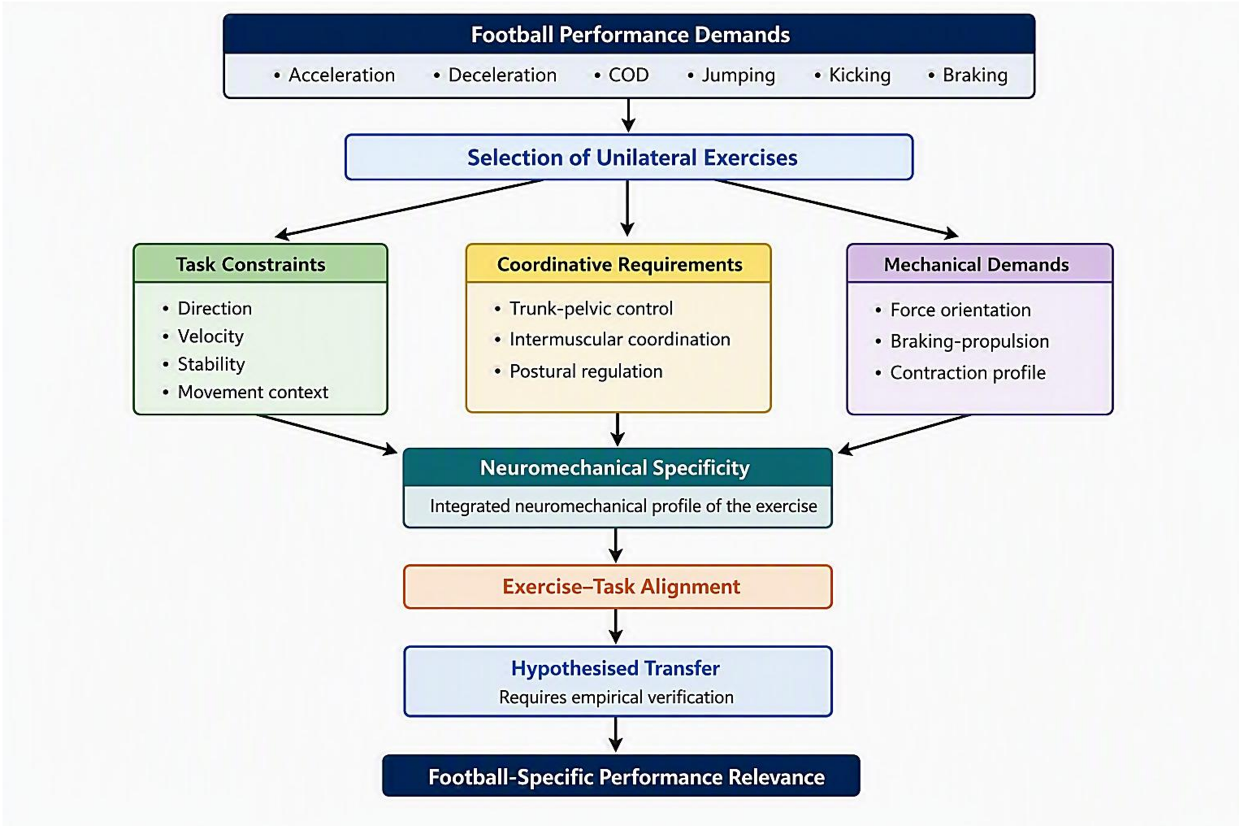

Figure 1. Conceptual framework illustrating neuromechanical specificity as an integrated construct emerging from the interaction among mechanical demands, coordinative requirements, and task constraints within selected unilateral resistance-training exercises. The resulting neuromechanical profile is proposed to inform exercise–task alignment and generate hypotheses regarding potential transfer to football-specific performance. Arrows represent proposed conceptual relationships rather than established causal pathways.

Table 1. Proposed classification of unilateral resistance-training exercises according to their predominant neuromechanical profiles and hypothesised football performance relevance.

Unilateral exercise category	Representative exercise	Predominant neuromechanical profile	Hypothesised football performance relevance
Lower-limb strength	Single-leg squat	Vertical force production and eccentric control	Unilateral force-production capacity
Horizontal propulsion	Single-leg broad jump	Horizontal propulsion and propulsive impulse	Acceleration-related force production
Transitional strength	Step-up jump	Vertical–horizontal force transition and dynamic stability	Transitional acceleration demands
Reactive strength	Single-leg hop	Stretch–shortening cycle function and landing stiffness	Reactive force-production demands
Lateral braking	Lateral lunge	Frontal-plane braking and force absorption	Deceleration and COD-related demands
Rotational control	Rotational single-leg Romanian deadlift	Trunk–pelvic control and anti-rotation stability	Multiplanar movement-control demands

Note. The proposed classification is conceptual and intended for hypothesis generation rather than as a definitive biomechanical taxonomy. Individual exercises may exhibit overlapping characteristics, and their neuromechanical profiles may vary with execution, loading strategy, movement velocity, and task constraints. The listed performance relationships indicate potential relevance rather than established evidence of superior transfer.

Accordingly, the framework may provide a rationale for aligning unilateral exercise selection with the predominant neuromechanical demands of a target football action. For example, horizontally dominant exercises may be considered when training capacities relevant to acceleration, whereas exercises emphasising frontal-plane force absorption and eccentric control may be considered for braking and change-of-direction demands. Rotational exercises may likewise be considered when training objectives involve multiplanar trunk and pelvic control. These examples are intended to illustrate hypothesis generation rather than demonstrate that any exercise category is superior for a particular performance outcome.

Several limitations should be acknowledged. Unilateral exercises may possess overlapping mechanical, coordinative, and task-related characteristics, and hybrid exercises may therefore be difficult to classify within a single predominant category. Moreover, no validated composite measure currently exists to quantify neuromechanical specificity across these dimensions, and the framework has not yet been directly validated experimentally. The proposed categories should consequently be regarded as conceptual and hypothesis-generating rather than definitive.

Future research should directly test whether different neuromechanical profiles produce distinct football-performance adaptations. Longitudinal intervention studies could compare programmes systematically differentiated by force orientation, braking demands, coordinative complexity, or task constraints while controlling training dose. Comparative exercise-selection studies could examine whether greater exercise–task similarity is associated with different adaptations. Biomechanical profiling could quantify force-time characteristics, eccentric braking impulse, trunk–pelvic kinematics, and movement variability, alongside field-based measures such as sprint and COD testing, wearable inertial sensors, and global positioning system (GPS) derived metrics (Dos'Santos et al., 2017; Junge et al., 2023). Such approaches may help operationalise neuromechanical specificity and determine whether it provides explanatory value beyond existing specificity frameworks.

Taken together, unilateral resistance training should not necessarily be treated as a single exercise category given its considerable mechanical, coordinative, and task-related diversity. Exercise specificity may be interpreted more precisely through the integrated neuromechanical profile of individual unilateral exercises rather than unilateral execution alone. Neuromechanical specificity therefore represents a proposed conceptual lens that complements established theories and generates testable hypotheses concerning exercise–task alignment. Its explanatory and practical value remains an empirical question requiring longitudinal, comparative, biomechanical, and integrated laboratory-to-field research.

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CONFLICT OF INTEREST

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