International Journal of Strength and Conditioning

Harper, D. J., Cervantes,C., Van Dyke, M., Evans, M., McBurnie, A. J., Dos Santos, T., Eriksrud, O., Cohen, D. D., Rhodes, D., Carling, C., & Kiely, J. (2024). The Braking Performance Framework: Practical Recommendations and Guidelines to Enhance Horizontal Deceleration Ability in Multi-Directional Sports. International Journal of Strength and Conditioning
https://doi.org/10.47206/ijsc.v4i1.351

The Braking Performance Framework: Practical Recommendations and Guidelines to Enhance Horizontal Deceleration Ability in Multi-Directional Sports

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ABSTRACT

Horizontal deceleration is a critical locomotor skill underpinning the many changes of speed and direction performed by athletes in multi-directional sports. Despite its importance there are currently no evidence-based guidelines on how to improve horizontal deceleration ability. Therefore, the aim of this article is to provide practitioners tasked with preparing athletes for the demands of multi-directional sports with practical recommendations and guidelines on how to improve their athlete's horizontal deceleration ability. The article proposes the concept and use of a Braking Performance Framework to help guide the selection of training methods and exercises to target the currently known neuromuscular and biomechanical determinants of horizontal deceleration ability. The Braking Performance Framework provides practitioners with evidence-informed training methods that can be integrated with other important physical, technical, and tactical components to optimize an athlete's horizontal deceleration ability.

INTRODUCTION

The ability to rapidly decelerate in a horizontal direction is a critical locomotor skill underpinning the many changes of speed and direction performed by athletes in multi-directional sports (66). Greater horizontal deceleration permits quicker reductions in whole-body momentum, enabling athletes to reduce their velocity over shorter distances and/or times (152). This means that athletes with greater horizontal deceleration can approach change of directions (COD) at higher velocities due to generating greater horizontal net braking forces in less time (i.e., horizontal braking impulse). As such, this results in less distance to decelerate prior to COD and faster overall COD performance times (43,84). In competitive match play, this also means that those with greater horizontal deceleration can gain advantages in offensive and defensive situations. From an offensive perspective, athletes should be able to spend less time close to their opponent leading to greater time to execute sport-specific technical skills, while from a defensive perspective be able to respond more quickly to their opponents' actions. Furthermore, it might provide a greater decision-making time to correct tactical errors if they approach opponents at higher sprinting speeds than required. Indeed, studies have reported that athletes attain a higher frequency and magnitude of intense decelerations (> -3 m.s^{-2}) in games that have been won compared to those that are drawn or lost (119,129), and a high frequency of decelerations preceding goals in both attacking and defensive players (105). Therefore, improving an athlete's horizontal deceleration ability in multiple directions could have significant implications for achieving successful match performance outcomes for athletes and teams competing in multi-directional sports.

The braking forces associated with horizontal decelerations are uniquely characterised by high impact peak forces and loading rates (97,114,144). For example, in comparison to initial acceleration (~2.2 × body mass) and maximum velocity sprinting (~4.4 × body mass), the peak impact forces during the initial braking steps of a maximal horizontal deceleration (~5.9 × body mass) are up to 2.7 to 1.3 times greater in magnitude, respectively (15,144). Similarly, when compared to other high-intensity activities such as the plant step of a 90° and 180° COD and a 30 cm drop jump (DJ), the initial braking steps of horizontal deceleration have considerably higher loading rates and resultant ground reaction forces (GRF) (97). Accordingly, Lozano-Berges (97) described the initial braking steps of a maximal horizontal deceleration to be "the most demanding task in terms of impact force characteristics". Consequently, during match play, deceleration activities are associated with the highest mechanical forces (90) and the highest accumulation of forces per meter of activity (35). Therefore, to reduce the chances of tissue damage, neuromuscular fatigue, and injury, athletes must be able to skillfully attenuate and distribute the forces associated with deceleration throughout the lower limbs during each braking step (69,109). This will require precise positioning of the lead limb braking foot to orientate and apply the required magnitude of braking force, and a distal to proximal distribution of forces through the ankle, knee, and hip, with the ankle and knee structures attenuating a high percentage (up to ~80%) of the forces should the player have the required strength capacities (53,108). As such, horizontal deceleration is a situational pattern commonly associated with anterior cruciate ligament (ACL) (98,145) and hamstring strain (61,88) injuries in multi-directional sports, in addition to contributing to lower-limb overuse injuries if exposure is not carefully managed (i.e., rapid spikes in braking loads) or if players are sub-optimally prepared to decelerate (18,82). Considering both the match performance and injury-risk implications, horizontal deceleration ability has been defined by Harper et al. (70) as "a player's ability to proficiently reduce whole body momentum, within the constraints, and in accordance with the specific objectives of the task (i.e., braking force control), whilst skilfully attenuating and distributing the forces associated with braking (i.e., braking force attenuation)".

Based upon the match performance implications and potentially damaging nature of horizontal decelerations to athletes involved in multi-directional sports, there is a need to develop evidence-based guidelines on how best to develop an athlete's horizontal deceleration ability and physically prepare them for the unique physiological and biomechanical demands associated with intense horizontal decelerations. Currently, however, from a multi-directional speed perspective, guidelines on effective training strategies only exist for improving sprint acceleration (27,74) and COD performance (36,39,40). Although horizontal deceleration is a critical component of COD, it is an element of performance that has historically received much less attention in empirical research despite its apparent importance and prevalence in training and competition (89). Accordingly, the aim of this article was to provide practitioners tasked with preparing athletes for the demands of multi-directional sports with practical recommendations and guidelines on how to improve their athlete's horizontal deceleration ability to enhance performance and reduce susceptibility to injury. The concept and use of a 'Braking Performance Framework' is proposed to help guide the selection of training methods and exercises to target the currently known neuromuscular and biomechanical determinants of horizontal deceleration ability (70) (Figure 1). For this article, horizontal decelerations refer to

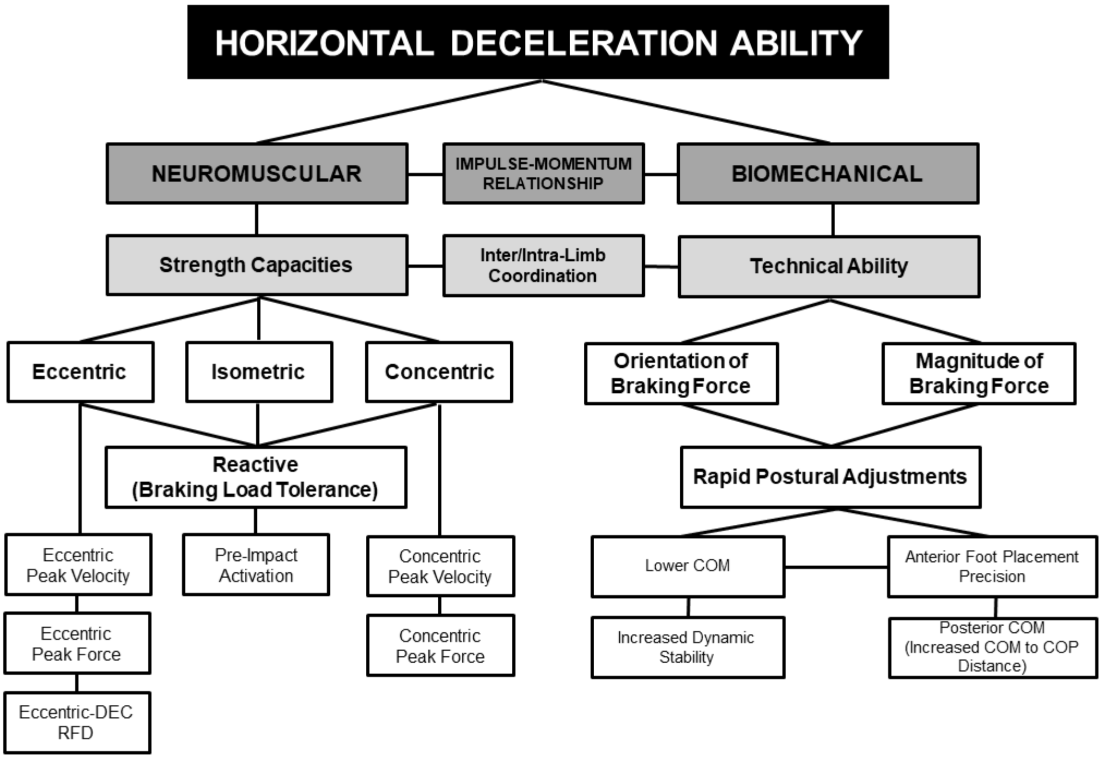

Figure 1. Neuromuscular and biomechanical determinants of horizontal deceleration ability. Modified from Harper et al. (70). DEC = deceleration, RFD = rate of force development, COM = centre of mass, COP = centre of pressure.

any locomotor activity performed parallel to the horizontal plane. Therefore, horizontal decelerations include decelerations performed from forwards, sideways and backward directions that may have differential frontal, sagittal and transverse plane joint movement demands.

THE BRAKING PERFORMANCE FRAMEWORK

The definition of horizontal deceleration ability identified previously (70) highlights two important goals of the Braking Performance Framework: 1) improving braking force control and 2) improving braking force attenuation (Figure 2).

Braking force control requires the athlete to position their centre of mass posterior to the lead foot (i.e., base of support) braking limb to ensure anterior foot placement and the required posterior orientation of the braking force. This is illustrated in Figure 2 with a negative shin angle, upright to posterior trunk lean, and forces directed opposite to the direction of motion to reduce forward momentum. The precise positioning of the lead limb braking foot requires a complex sequence of muscle activation and relaxation strategies to ensure optimal coordination between the trailing and lead foot braking limbs (i.e., inter/intra-limb coordination) (16). A lower vertical and more posterior centre of mass position is also key to dynamic stabilisation and maintaining the centre of mass behind the lead limb braking foot, thereby prolonging the time in which braking forces can be applied (i.e., greater impulse and thus greater reduction of momentum, reflecting the impulse-momentum relationship) (70). Theoretically, these aspects of braking force control will fundamentally increase the rate of deceleration preceding a COD and facilitate effective re-acceleration into a new intended direction. Another key aspect of braking force control reflected in the definition of horizontal deceleration ability is the requirement to decelerate within the constraints, and in accordance with the specific objectives of the task. This reflects the perceptual-cognitive demands of decelerating during competitive match play, whereby players must perform rapid braking actions based on a dynamic, emerging environment that considers their teammates, ball or implement, and opponent's actions. Therefore, developing braking perceptual-cognitive and decision-making qualities is another important feature of the Braking Performance Framework to enhance the transfer to in-game competitive performance. Consequently, task constraints should be designed using "cues" (i.e., perceptual variables) that are representative of the performance environment in which deceleration actions are to be performed (128).

The braking force attenuation component can be considered critical to the reduction of soft-tissue

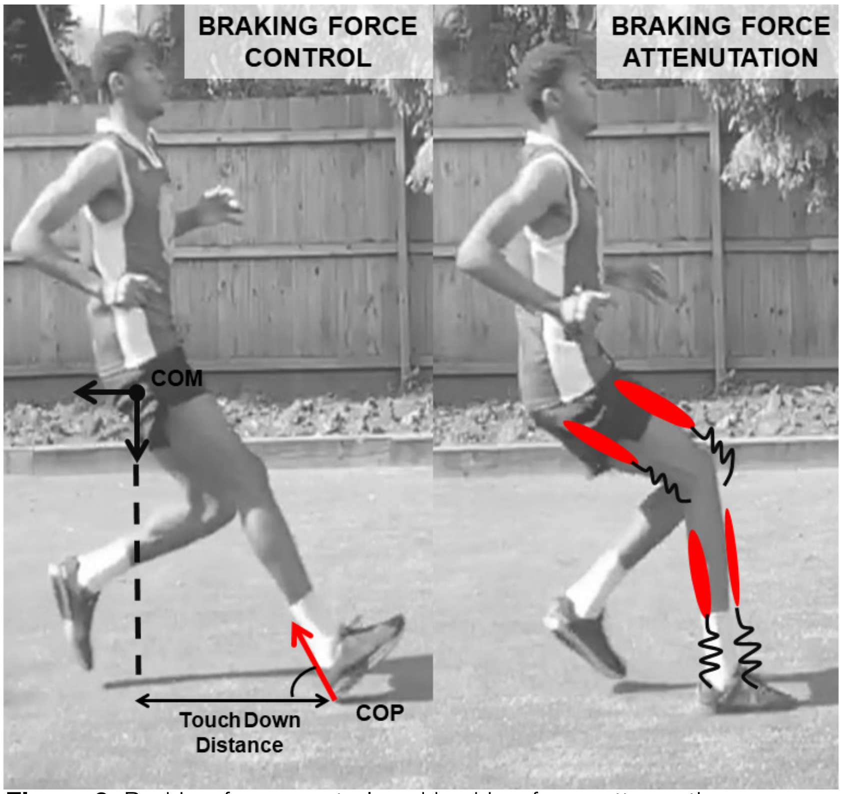

Figure 2. Braking force control and braking force attenuation components of horizontal deceleration ability. Modified from Harper et al. (70). COM = centre of mass, COP = centre of pressure.

damage and neuromuscular fatigue resulting from intense horizontal decelerations that can impose high muscular tensions arising from eccentric (i.e., active muscle lengthening) muscle actions (69,109). Figure 2 highlights the potential critical role of tendons acting as force attenuators upon ground contact during intense deceleration. The lengthening of the tendon during intense braking actions can function to attenuate peak forces and rate of active muscle fascicle lengthening (130). Accordingly, increasing a tendon's structural capacity to attenuate and tolerate mechanical forces, alongside rapid muscle activation ability, could reduce eccentrically induced muscle strains. This provides a 'protective' mechanism against muscle damage that is commonly experienced when decelerating rapidly, along with mitigating a myriad of other performance and health-related factors associated with intense decelerations and muscle damage (55,77,78,143,154,155). Therefore, developing 'damage-resistance' of tissue structures commonly exposed to high eccentric-braking forces is an important player health-related feature of the Braking Performance Framework, highlighted in Figure 3 (69). Indeed, horizontal deceleration training has been advocated as a potential 'vaccine' against soft-tissue injury risk and neuromuscular fatigue due to horizontal decelerations providing a means to provide eccentric overload that could lead to biomechanical and physiological adaptations associated with eccentric muscle actions (109).

The Braking Performance Framework acknowledges that optimal transfer can be achieved through a programme of structured, interconnected exercises that aim to combine the principles of traditional and coordinative overload, also referred to as a 'mixed-methods' training approach (21). Accordingly, the exercise categories and training methods move on a continuum from local (i.e., braking elementary exercises) to global (i.e., braking performance exercises) specificity, focusing on either upgrading braking-specific structural and functional properties or coordination skills. The Braking Performance Framework delineates three main exercise categories: 1) braking elementary exercises, 2) braking development exercises, and 3) braking performance exercises. Within each exercise category, practitioners have the flexibility to choose several training methods to develop their athlete's horizontal deceleration ability.

BRAKING ELEMENTARY EXERCISES

A key focus of the braking elementary exercises is to target specific adaptations to muscle-tendon neuromechanical structural properties to enable

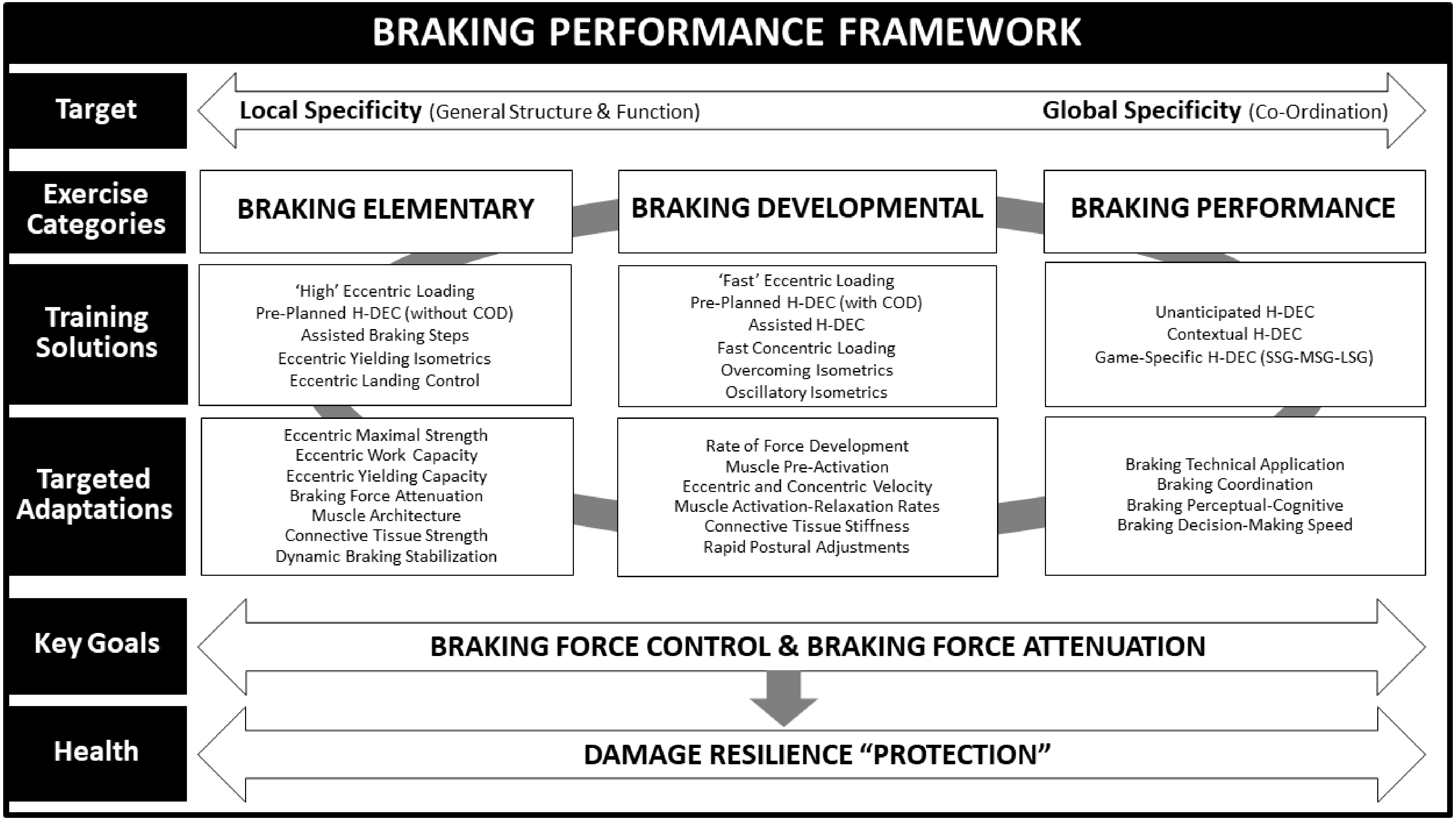

Figure 3. The Braking Performance Framework. H-DEC = horizontal deceleration; COD = change of direction; SSG = small-sided games; MSG = medium-sided games; LSG = large-sided games.

players to produce and tolerate higher horizontal braking forces that must be counteracted and controlled by high internal (i.e., muscle) forces. Accordingly, an important goal is to increase the ability to attenuate shock throughout the lower limbs since substantial impact forces are experienced upon each foot-ground contact during intense braking activities. To assist in effective shock attenuation and to reduce the likelihood of injury when braking, a further goal is to enhance limb and trunk sensorimotor control (i.e., dynamic stabilisation of multiple segments). Eccentric strength training is a potent stimulus for enhancing muscle-tendon neuromechanical function (e.g., strength, power, stiffness, stretch-shortening cycle) and for signalling positive structural adaptations (e.g., muscle and tendon cross-sectional area, type II fast-twitch muscle fibre size) (46). Therefore, eccentric strength training methods are pivotal to the braking elementary exercise category, along with other exercise categories within the Braking Performance Framework. Training methods within the braking elementary exercise category include 1) high eccentric loading, 2) pre-planned horizontal decelerations, 3) assisted horizontal braking steps, 4) eccentric yielding-isometrics, and 5) eccentric landing control.

High Eccentric Loading

High eccentric loading takes advantage of the superior force capabilities possible with eccentric compared to concentric muscle actions by utilising resistance training approaches that place an accentuated demand on the eccentric phase of an exercise (147). Indeed, eccentric strength training has been recommended for enhancing braking load tolerance and for facilitating rapid horizontal deceleration and COD abilities (28,95). Furthermore, new technologies have provided practitioners with various eccentric exercise modalities (i.e., isoweight, isoinertial, and isokinetic) to prescribe safe, progressive, and precise high eccentric loading (52,139). Additionally, variable eccentric loading which comprises exercises such as horizontal decelerations, downhill running, and stair descent should also be considered important eccentric exercise modalities (32). Variable eccentric loading is unique compared to other eccentric modalities in that it requires precise and rapid modification of muscle tensions and forces to optimise locomotor kinematics and reduce the likelihood of eccentrically induced muscle strains (32,48). Table 1 provides an overview of the different equipment options and training methods that can be utilised for each high eccentric loading exercise modality, together with the associated advantages and disadvantages for their application.

Using a high eccentric loading exercise modality and respective training method (i.e., accentuated eccentric loading, 2-1 technique, tempo, eccentric only, two movement, assisted concentric/eccentric action) can elicit greater eccentric muscle activation (115,116,133,142), preferential recruitment of high-threshold motor units (8), neural drive (13), stress of passive elastic structures (i.e., tendon, titin) (4), eccentric peak moments (4), eccentric work (4,146), and mechanical tension (4,146) compared to traditional isoweight constant load resistance training regimes where eccentric force demands are submaximal and underloaded. These heightened neural and mechanical demands generated through high eccentric loading interventions can result in greater maximal concentric (65,125), eccentric (58,65,100,125,149), isometric (65,149) and dynamic strength (47), lower limb vertical and muscle stiffness (13,47), fatigue resistance (136,149), rate of force development (RFD) (58,120,125,146) and muscle hypertrophy (115,116) leading to enhanced braking capabilities, and thus performance of rapid horizontal deceleration and COD manoeuvrers (31,79,99,141).

These findings also align with perceptions of practitioners. For example, over two-thirds (71%) of professional soccer practitioners agreed that flywheel training could chronically enhance a player's COD performance (87). The development and widespread use of technologies like flywheels provide practitioners with more portable, cost-effective, and safe options to prescribe high eccentric loading to target development of their athletes' braking capabilities. Videos in supplementary digital content (SDC) 1, 2, and 3 depict flywheel hand-supported squats with bilateral, split, and rear foot elevated stances, respectively. Furthermore, technologies like a flywheel, through the use of pulley devices, permit high eccentric loading to be more easily performed in the horizontal direction with multi-planar joint movement demands (i.e., frontal, sagittal and transverse), which is more specific to the braking demands of horizontal deceleration, and thus may also have a better transfer to COD performance (57,117) (Figure 4). This also has the advantage of training unilateral braking qualities to facilitate rapid horizontal deceleration and COD performance from both limbs, which might not be achieved when using bilateral vertical flywheel exercises (117).

Table 1. Considerations for application of high eccentric loading (modified from Franchi & Maffiuletti, 2019 & Coratella et al., 2019).

	HIGH ECCENTRIC LOADING			
Exercise Modalities	**VARIABLE**	**ISOWEIGHT**	**ISOINERTIAL**	**ISOKINETIC**
Environment	Field Based	Gym Based	Field/Gym Based	Field/Gym Based
Equipment Options	• Surfaces (e.g., 3G, grass) • Downhill slopes • Stairs • Motorised resistance devices • Accommodating resistance • Wearable resistance • Partner assisted	• Resistance weights • Free weights • Pneumatic • Motorised resistance devices • Weight releasers • Accommodating resistance	• Flywheel platforms • Flywheel machines • Flywheel pulley • Flywheel with motorised resistance device	• Dynamometer • Motorised resistance devices
Training Methods	• Pre-planned horizontal decelerations • Downhill running • Stair descent	• Supramaximal AEL • Submaximal AEL • AEL 2-1 • Tempo • Eccentric-only • Two-movement • Assisted concentric/eccentric action	• Delayed eccentric action • AEL 2-1 • Two-movement • *Assisted concentric action	• Tempo • Eccentric-only (concentric performed in passive mode) • Supramaximal AEL (MRD only) • Submaximal AEL (MRD only)
Advantages	✓ Easily implemented in any field-based environment ✓ Intra- and inter-limb co-ordination (technical ability) ✓ Easily progressed by manipulating momentum through speed, distance, slope, weight or COD angle ✓ Time effective	✓ Multi-joint and single joint options ✓ Can perform during eccentric phase only ✓ Precise prescription of loads and movement speeds possible ✓ Potential for biofeedback through external devices (e.g., VBT, force plates)	✓ Multi-joint and single joint options ✓ Inertia and eccentric velocity can be manipulated using different flywheel sizes ✓ Can be performed without a spotter ✓ Equipment is typically portable ✓ Potential for biofeedback through external devices or in-built machine sensors (e.g., VBT, force plates). ✓ Time effective	✓ Multi-joint and single joint options ✓ Eccentric forces constant throughout full ROM ✓ Can target specific joint angular velocities and specific ROM ✓ Can be performed without a spotter ✓ Potential for biofeedback through in-built machine sensors (e.g., force and power)
Disadvantages	× Compensation strategies may lead to asymmetrical braking × Multi-joint only making difficult to target specific tissue adaptations × Difficult to monitor mechanical stress on specific tissues	× Eccentric overload not constant through full ROM × Requires careful consideration to participant safety during lifting (i.e., spotting) × Often limited to weight room environments	× Eccentric overload not constant through full ROM × Eccentric overload dependent on inertia generated during concentric phase × Difficult to achieve same level of eccentric load as isoweight	× Equipment costs × Time consuming

AEL = accentuated eccentric load, ROM = range of movement, VBT = velocity-based training, RM = repetition maximum, MRD = motorised resistance device, COD = change of direction
Definition of exercise modalities: Variable = variable/unpredictable velocity, weight, and inertia, Isoweight = constant weight, Isoinertial = constant inertia, Isokinetic = constant speed
Definition of training methods: Supramaximal AEL = Coupled eccentric-concentric movement with eccentric loads (>1RM) greater than concentric loads (<1RM), Submaximal AEL = Coupled eccentric-concentric movement with eccentric loads (<1RM) greater than concentric loads (<1RM), AEL 2-1 = Coupled eccentric-concentric movement with loads lifted bilaterally in concentric phase and lowered unilaterally in eccentric phase, Tempo = Coupled eccentric-concentric movement with controlled eccentric tempo and loads <1RM and equal throughout both eccentric and concentric phase, Eccentric-only = Eccentric only exercise with concentric phase assisted via spotters or equipment, Two-movement = Load is lifted concentrically using a compound movement (e.g., deadlift) and then lowered eccentrically using isolation exercise (e.g., straight-leg deadlift), Delayed eccentric action = Delay braking to end of eccentric phase, Assisted concentric/eccentric action = Using self (e.g., hand supported) or other approaches (e.g., spotter assists on concentric phase or adds manual resistance during eccentric phase) to assist with concentric or eccentric phase.

Figure 4. Horizontal braking exercise performed using flywheel pulley device.

Another option with flywheels is to use single-joint knee extension or flexion machines, which could be particularly important given the associations reported between unilateral single-joint maximal eccentric quadriceps and hamstring strength and enhanced maximal horizontal deceleration abilities (70). Furthermore, multi-joint flywheel exercises, like the squat, may lead to inferior activation of important braking muscles such as the rectus femoris and hamstrings (81). A summary of evidence-based guidelines for programming (12) and periodizing (14) flywheel training into pre-season or in-season periods for multi-directional team sports is illustrated in Table 2.

In addition to the different exercise modalities that can be selected for high eccentric loading, practitioners should also make informed decisions on high eccentric loading approaches based on the individual's training experience and strength capabilities (138). For example, Suchomel et al. (138) recommended using sub-maximal eccentric loads with a slow controlled eccentric tempo, or flywheel isoinertial training for players with lower strength and resistance training experience. Conversely, for players with greater strength and resistance training experience, flywheel isoinertial and accentuated eccentric load training were recommended.

Pre-Planned Horizontal Decelerations without a change of direction

Pre-planned horizontal decelerations without a COD require the athlete to reduce and/or stop momentum in various body positions (i.e., parallel stance, split stance, quarter turn stance, half turn stance, single leg stance), and can be performed from different movement directions (i.e., forwards, sideways, backward). An advantage of using pre-planned horizontal decelerations is that intensity can be systematically progressed or regressed by manipulating either, or both, the velocity and distance at which the deceleration is commenced, or the intensity at which the subsequent deceleration is performed (42). Higher approach velocities (i.e., greater forward momentum) prior to deceleration are reflected in greater deceleration distances and the necessity for more braking steps to reduce momentum (59,63). For example, Graham-Smith et al. (59) reported progressively increasing deceleration distances of 2.93 m, 4.94 m, 6.61 m and 7.93 m when performing a maximal sprint to stop at 5 m (54% of maximum velocity [V_{max}]), 10 m (72% V_{max}), 15 m (83% V_{max}) and 20 m (89% V_{max}) distances, respectively. The deceleration demands can also be manipulated by changing the percentage of maximum sprinting velocity (i.e., momentum) at which the deceleration is performed. For example, Jordan et al. (85) reported progressively increasing ankle plantar

Table 2. Evidence-based guidelines for programming and periodizing flywheel isoinertial eccentric training (taken from Beato et al., 2020 and Beato et al., 2021).

Programming Variables	Guidelines
Training Intensity	• Range of inertial settings (0.025 to 0.11 kg/m2) required to target various eccentric-braking force and power capacities • Higher inertial intensities (> 0.05 kg/m2) may be preferable for eccentric-braking strength adaptations • Lower inertial intensities (i.e., 0.025 to 0.05 kg/m2) may be preferable for eccentric-braking power adaptations
Training Volume	• Between 3 to 6 sets • Between 6 to 8 repetitions
Rest Intervals	• Higher inertial loads require longer rest periods (i.e., > 2 mins) • Lower inertial loads require shorter rest periods (i.e., < 2 mins)
Training Frequency & Duration	• 2 to 3 sessions per week • 5 to 10 weeks Note: 1) Positive effects on COD have been reported using just one session per week in-season, 2) Early functional and morphological adaptations have been reported following short-term (4-week) squat protocols (5 sets of 10 repetitions)
Considerations for Periodisation	• Pre-season or periods with single competitive game: Two sessions per week. First session on MD-4 should focus on injury prevention and eccentric-braking strength development, while the second session (MD-2) should have a focus on eccentric-braking power development with lower inertial loads and overall volume (i.e., combination of sets and reps) • In-season periods with one competitive game: 1) Starters (i.e., players who played high minutes of competitive game) could perform two sessions per week. First session on MD-4 could focus on injury prevention and eccentric-braking strength development, with second session on MD-2 focusing on eccentric-braking power using a micro-dosing scheme (i.e., low volume and high-intensity, e.g., 1-2 sets, 2-3 exercises) with low inertial loads. 2) Non-starters (i.e., substitute players with lower game time) could perform three sessions per week. First session on MD+2 could focus on injury prevention and eccentric-braking strength development, second session on MD-4 could focus on eccentric-braking power development with third session using a micro-dosing scheme • In-season periods with two competitive games (i.e., fixture congestion): One session per week on MD-2 focusing on eccentric-braking power development with option to implement a micro-dosing scheme on MD-2 prior to the second match

MD-4 = Four days prior to competitive game, MD-2 = Two days prior to competitive game, MD+2 = Two days following a competitive game, COD = Change of direction

flexion and knee flexion joint angular velocities when deceleration was performed at 50% (ankle = 307°/s, knee = 325°/s), 75% (ankle = 428°/s, knee = 461°/s) and 100% (ankle = 483°/s, knee = 469°/s) of self-perceived 20 m maximal sprinting effort, indicating increased loading severity when decelerations were performed from a higher percentage of maximal sprinting velocity. Similarly, when the deceleration distance to stop is enforced across a shorter distance (i.e., 3 m compared to 6 m zone), Gageler et al. (53) reported increased shock attenuation demands between the ankle and knee, with the earlier braking steps particularly exposed to increased mechanical loading and shock attenuation demands. Accordingly, careful consideration should be made by practitioners as to how pre-planned horizontal decelerations are systematically progressed across a training period, while also being cognizant of the decelerations load (frequency and magnitude) attained during training and match-play. For example, numerous studies have illustrated that repeated enforced horizontal decelerations can increase the susceptibility to eccentric exercise-induced muscle damage, particularly in players who may be less accustomed (24,77,86,154). Importantly, however, following short exposure to repeated pre-planned horizontal decelerations there is evidence that the eccentric exercise-induced muscle damage response could be attenuated resulting in reduced soreness and enhanced ability to perform other high-intensity movement actions (24); signifying a protective adaptive mechanism commonly known as the repeated bout effect (80).

Pre-planned horizontal decelerations have previously been implemented into multi-directional speed training programmes (41,44,96) with Dos'Santos and colleagues (41,44) placing an emphasis on COD and braking technique modification through coaching cues. For example, to encourage a late braking strategy and lowering of COM, athletes were instructed to "slam on the brakes" and "drop the hips", respectively. Following

6-weeks of the COD and braking technique modification training programmes athletes improved their 90° and 180° COD performance by increasing their ability to apply a more horizontally orientated force (i.e., greater deceleration) in the penultimate braking step. Similarly, in the 6-week multi-directional speed programme implemented by Lockie and colleagues (96), the inclusion of pre-planned horizontal decelerations to a split stance stop culminated in greater increases in COD speed, knee extensor and flexor strength, leg power, and DJ reactive strength index (RSI) compared to a group who just performed the multi-directional speed training exercises alone (96). Collectively, these findings highlight the potential importance of pre-planned horizontal decelerations without a COD for teaching horizontal deceleration technique and for enhancing adaptations to specific technical, neuromuscular strength, and tissue qualities known to be important for greater horizontal deceleration ability. Further research into the dose-response relationship for these specific adaptations is needed and how different volumes may influence both horizontal deceleration capacity and the ability to maintain repeated horizontal decelerations. Nonetheless, this is a simple, cost-effective modality that can be simply integrated into field-based training sessions (i.e., warm-ups, cool-downs, technical/technical sessions) for multi-directional sports.

Assisted Horizontal Braking Steps

Resisted and assisted training approaches are extensively used to target specific force-velocity components influencing maximal horizontal acceleration and sprinting speed performances (74). However, the applications of resisted and assisted training for improving horizontal deceleration ability have been largely unexplored despite the potential benefits of manipulating horizontal braking demands (139,140). Assisted horizontal braking steps are different from assisted horizontal decelerations described in the braking developmental exercise category in that they are performed at slower movement velocities with higher assisted (pulling) forces to prolong the time in which braking forces are applied (110). The application of high assisted pulling forces is similar to the concept of heavy or very heavy resisted sprint training that enables athletes to achieve a greater forward trunk lean and more time to apply a horizontally orientated propulsive force (i.e., mechanical effectiveness) to target improvements in the early acceleration phase (i.e., 0-5m) (92,113,126). While there is currently limited research on heavy assisted braking steps, we suggest this training approach would be more conducive to adaptations in the late deceleration phase when longer ground contact times and slower horizontal velocities need to be decelerated, as observed in the preparatory deceleration steps (i.e., antepenultimate and penultimate steps) prior to turning (43,114).

Assisted horizontal braking steps can be performed across a pre-determined distance or a number of steps with assisted force generated via low-cost equipment (e.g., elastic bands, Figure 5) or more precisely programmed using a motorised resistance device (50). Video SDC 4 depicts a 2-step braking sequence with assistance provided by a motorised resistance device (1080 Sprint, 1080 Motion). Using bands or a material (e.g., nylon) with high tensile strength assistance could also be generated through an additional person(s) pulling their partner (i.e., partner assisted). Despite limited research, assisted braking steps have been used in eccentric strength training programmes to increase knee flexor and extensor peak force to longer muscle lengths, potentially signifying a protective effect against muscle strains during actions with a high eccentric loading demand (25). It is also important to acknowledge that from a fatigue management perspective assisted horizontal braking steps do not require the athlete to generate the propulsive impulses required to accelerate to a desired velocity to subsequently decelerate from. Thus, there is a reduced overall physiological and mechanical cost compared to performing unassisted horizontal decelerations, which could be a useful strategy to reduce load in the days immediately following or preceding competitive matches, or to simply focus on targeting improvements in horizontal deceleration ability.

Eccentric Yielding Isometrics

Eccentric yielding isometrics (also known as holding isometric muscle action) involve holding a static position that maintains or limits joint range of motion for a desired duration or until isometric failure has occurred due to being unable to resist an external load (134). Following the point of isometric failure, the athlete may also maximally resist the subsequent eccentric phase through a desired range of movement, referred to as an eccentric quasi-isometric loading exercise (124). Eccentric yielding isometrics demand a high level of position control (134) and are effective in generating mechanical tension (i.e., force and active stretch)

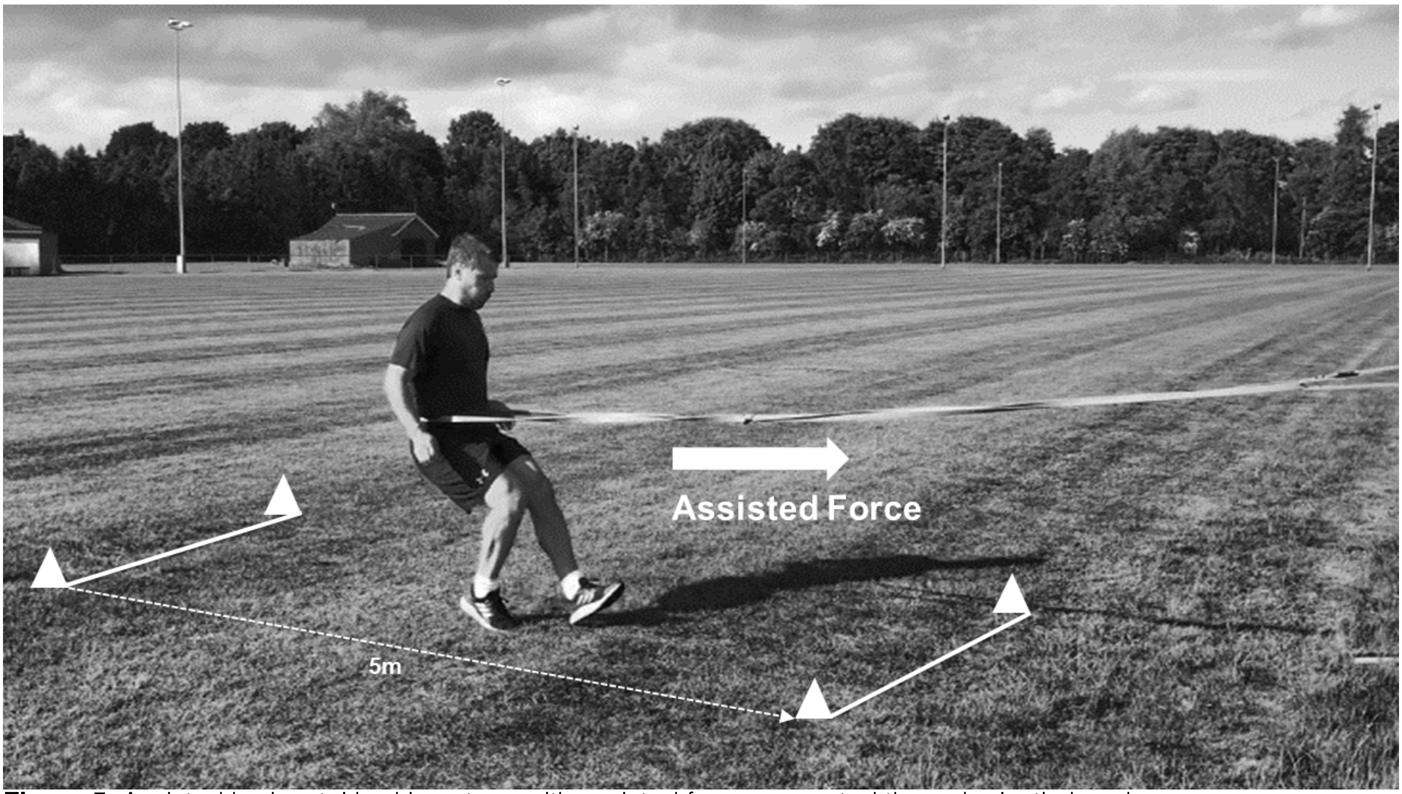

Figure 5. Assisted horizontal braking steps with assisted force generated through elastic bands.

required to promote muscle and connective tissue structural adaptations, with notably less acute muscle soreness than dynamic eccentric muscle actions (122,124). Eccentric yielding isometrics also require a rapid recruitment of the motor-unit pool to sustain the required amount of force, resulting in a significantly quicker time to fatigue than overcoming ("pushing" or "pulling") isometrics described in the braking developmental exercise category (9). Therefore, by increasing the force-sustaining capacity of activated motor units, it could be concluded that motor unit recruitment will be enhanced when resisting loads eccentrically resulting in an enhanced braking force endurance capacity (124).

The similarity of eccentric yielding isometrics to eccentric muscle contractions (134), along with a more prolonged loading duration when compared to overcoming isometrics may also help to optimize gains in muscle hypertrophy, strength, and muscle connective tissue stiffness that is essential for the effective transmission and attenuation of forces during deceleration (7,106). Guidelines for the prescription of eccentric yielding isometrics along with proposed adaptations are illustrated in Table 3.

The ankle, knee and hip extensors have been previously highlighted as important for braking in horizontal decelerations (70). Therefore, eccentric yielding isometric exercises that challenge the ability to resist flexion of these joints (see video SDC 5 and 6) while adopting similar postural positions observed in the different braking steps of horizontal decelerations (e.g., antepenultimate, penultimate, final foot contact) should be carefully selected and used particularly within the general preparatory period (124).

Eccentric Landing Control

Eccentric landing control aims to develop the neuromuscular qualities required to safely attenuate the forces emanating from foot-ground impact when landing from various lunging, jumping, hopping and bounding tasks, while reinforcing optimal neuromuscular control and movement quality to reduce risk of injuries such as ACL. Welch et al. (150) used a single-leg drop landing task from a 30-cm height as a proxy measure of deceleration ability, requiring players to "absorb the landing as fast as possible before holding it for 2 seconds". Players who could generate greater eccentric impulse in the first 25 ms following impact had superior COD ability, but only in a COD task with a substantial deceleration demand requiring high braking forces. The authors concluded that rapid eccentric impulse represented a neural ability to pre-activate muscles prior to impact, which would be a vital neuromuscular performance quality for both unilateral landing and braking. Eccentric box drop and hold exercises performed into low squat and

Table 3. Guidelines for prescription of eccentric yielding and eccentric quasi-isometric (EQI) exercises with proposed adaptations. Taken from Oranchuk et al. (120, 121).

Programming Variables	Long Duration Holds	Light Yielding	Moderate Yielding	Heavy Yielding	Maximal Yielding
Load	Body weight	30-60% 1RM	60-80% 1RM	80-100% 1RM	100-110% 1RM
Time (s)	> 60	30-60	30-60	10-30	3-10
Reps	1	3-5	3-5	1-5	1-5
Sets	1-5	3-5	3-5	3-5	2-4
Main Adaptations	✓ Tendon and connective tissue architecture ✓ Tendon compliance (shock absorbing qualities) ✓ Eccentric yielding endurance capacity ✓ Fatigue resistance ✓ Time and magnitude of force transmission ✓ Muscle hypertrophy ✓ Muscle strength (recruitment of type II motor units) ✓ Co-activation of agonist and synergist muscles ✓ Positional control and joint stabilisation under high metabolic stress (i.e., decreased muscle oxygenation and pH levels) ✓ Increased aerobic and anaerobic enzymes ✓ Improved Ca2+ reuptake that could help protect against muscle damage and DOMS associated with repeated intense decelerations			✓ Tendon and connective tissue architecture (e.g., thickness) ✓ Tendon and connective tissue (i.e., titin) stiffness ✓ Time and magnitude of force transmission ✓ Reductions in electromechanical delay (i.e., increased RFD) ✓ Reduced muscle inhibition ✓ Maximal muscle strength and force production capacity ✓ Co-activation of agonist and synergist muscles	

Other Training Considerations:

1. Performing isometrics at LML reported to promote greater increases in muscle hypertrophy, strength, and tendon and connective tissue stiffness adaptations, with muscle hypertrophy and strength adaptations across a greater joint ROM. LML may also increase susceptibility to muscle damage, but have more profound effects on reducing damage, muscle soreness and declines in force generating potential in subsequent training sessions i.e., have a greater protective effect.
2. Dynamic 'switching' and 'catching' can be performed prior to stabilising in a holding/yielding isometric position. Advanced variations require pre-activation prior to landing due to performing an airborne (jump) phase.

Eccentric Quasi-Isometric (EQI) Training Guidelines

- Brace and maintain joint position
- Following isometric failure resist eccentric yielding for period of 10-30 seconds through desired ROM
- 1-3 sets per exercise with 180s inter-set rest period

1RM = Concentric 1 repetition maximum, CSA = cross sectional area, RFD = rate of force development, ROM = range of movement, LML = long muscle lengths, DOMS = delayed onset of muscle soreness, RFD = rate of force development

lunge landing positions have also been integrated into eccentric training interventions to increase the angle of peak force in both the quadriceps and hamstrings (25,26). To further augment eccentric-braking forces and impact attenuation demands in vertical drop landing exercises, additional resistance can be generated using equipment such as dumbbells (**see videos SDC 7, 8 and 9**) or elastic bands (**see videos SDC 10, 11 and 12**), and have been recommended to be included in a training block prior to DJ fast eccentric loading exercises as described in the braking developmental exercise category (111).

In addition to exercises that challenge eccentric landing control vertically, it is also important to include eccentric horizontal landing control exercises to increase specificity to the forces and postural control demands experienced when braking during horizontal deceleration. One approach to increase horizontal braking force demands is to use assisted load through cable pulley machines (**see videos SDC 13 and 14**), motorised resistance devices (**see video SDC 15**), or elastic resistance bands (**see videos SDC 16 and 17**). For example, significant increases in horizontal braking GRF, with no accompanying increase in vertical GRF, have been observed in a horizontal hop and hold exercise with cable pulley-assisted loads progressing from 4 (608 N), 8 (654 N), 12 (717 N) and 16% (811 N) body mass (34). The authors suggested that horizontal hop and hold exercises would be useful additions to complement other horizontal deceleration exercises (i.e., pre-planned or unanticipated horizontal decelerations) to enhance horizontal deceleration ability, and for injury-risk reduction (e.g., ACL) and rehabilitation purposes. Eccentric landing control exercises can be easily incorporated into field or gym-based warm-up sessions (as typically seen in injury mitigation programmes) or performed within the main resistance training session as part of a braking complex (described later) or during the rest period between sets. Table 4 provides an overview of different variables that can be manipulated to increase the difficulty (i.e., greater dynamic stabilisation and braking demands upon landing) of eccentric landing control exercises.

BRAKING DEVELOPMENTAL EXERCISES

The key aim of the braking developmental exercises is to increase the ability to produce high net braking forces in less time (i.e., 'tall-thin' braking impulse). As previously highlighted, deceleration requires a highly coordinated inter- and intra-limb movement strategy, necessitating rapid joint angular velocities and precise muscle activation and relaxation sequences to facilitate posterior force generation. Accordingly, training interventions that can increase eccentric and concentric joint angular velocities and RFD are important inclusions within the braking developmental exercise category. Training methods within the braking developmental exercise category include 1) fast eccentric loading, 2) pre-planned horizontal decelerations with COD, 3) assisted horizontal decelerations, 4) fast concentric loading, 5) overcoming isometrics, and 6) oscillatory isometrics.

Fast Eccentric Loading

Training approaches for fast eccentric loading include 1) plyometrics (i.e., jumping, bounding and hopping with slow (>0.25 s) and fast (<0.25 s) stretch-shortening cycle demands), 2) Olympic lifting derivatives (i.e., drop snatch, clean, jump shrug), and those described by Handford et al. (64) for increasing eccentric velocities (i.e., deceleration demands) including 3) accelerated eccentric loading (i.e., bands are used to accelerate eccentric phase and released before concentric phase), and 4) submaximal accentuated eccentric loading (eccentric-concentric coupling exercise with greater mass in eccentric than concentric phase. Note: submaximal implies eccentric loads less than concentric 1RM). Similar to high eccentric loading, fast eccentric loading can also be performed with an eccentric-only option, where the load is moved rapidly through the desired eccentric range of movement without (**see videos SDC** 18 **and** 19) or with band assistance (**see videos SDC** 20 **and** 21) before decelerating to an isometric hold. Using this approach, fast eccentric (~1 s) squat training performed with a load (~70% 1RM) that optimised eccentric-braking RFD resulted in significantly greater increases in fascicle length (10%) and isometric RFD (10-19%), when compared to a group who performed slow velocity (~4 s) eccentric only squats. Furthermore, utilising fast eccentric squats in combination with unloaded countermovement jumps (CMJ) in a 6-week low volume (6 x 2 fast eccentric half-squats with CMJ performed on each minute of a 4-minute inter-set rest period) fast

Table 4. Variables that can be manipulated to increase difficulty of eccentric landing control exercises.

Variables	DIFFICULTY →		
Landing stance (points of contact)	Bilateral	Split stance	Unilateral
Plane of movement	Vertical	Horizontal (F, B, L)	Multi-planar (and rotational)
Speed of movement	Submaximal	Maximal	Overspeed
Compliance (C) / Stiffness (*K*)	High C / Low *K*	Medium C / Medium *K*	Low C / High *K*
Resistance (mass)	Body mass	Body mass +	Body mass ++
Vertical landing distance	Low	Medium	High
Horizontal landing distance	Low	Medium	High
Mechanical perturbation	None	Anticipated	Unanticipated
Neurocognitive demand	Low	Medium	High
Volume	Low	Medium	High
Surface and environment	Soft / Compliant		Hard / Non-compliant

F = forward, B = backward, L = lateral eccentric-braking complex training programme, resulted in significant increases in eccentric-braking RFD (40-107%), CMJ concentric peak power (20-36%) and hypertrophy (8.6-11.6%) of both slow and fast twitch quadricep (vastus lateralis) muscle fibres (17).

While incremental DJ heights have been traditionally used to augment eccentric (negative work) demands, utilisation of elastic bands (i.e., accelerated eccentric loading) and free-weights (i.e., accentuated eccentric loading) can be used as an alternative strategy to un-loaded plyometric DJ (i.e., short GCT and small joint flexion angles) or depth jumps (i.e., longer GCT and greater joint flexion angles). For example, when compared to performing an unloaded DJ from 35 or 50 cm heights, an accelerated eccentric loading approach with band resistance equivalent to 30% body mass (measured at DJ height) had significantly greater eccentric impulse and RFD, along with earlier onsets of quadriceps and soleus pre-landing activation (2). It is important to note that an accelerated eccentric load DJ performed from the lower height (i.e., 35 cm) evoked similar eccentric intensity (i.e., eccentric impulse and RFD) as the unloaded DJ performed from higher DJ heights (i.e., 50 cm), therefore providing an alternative but potentially safer fast eccentric loading approach. Interestingly, a short 4-week training period with accentuated eccentric load DJ performed from a 52cm drop height with a dumbbell load equivalent to 20% body mass resulted in greater improvements in CMJ eccentric peak force, DJ-RSI, and 180° COD performance when compared to a group who completed unloaded DJ from the same height (23). Importantly, both CMJ eccentric peak force and DJ-RSI have been identified as neuromuscular performance qualities associated with greater horizontal deceleration ability (Figure 1). Therefore, these findings highlight the importance of DJ training performed with or without additional load for improving the ability to generate higher braking impulses to increase horizontal deceleration ability. Furthermore, low-volume DJ accentuated eccentric load training through mechanisms aligned to the repeated bout effect, could also be used as an effective micro-dosing strategy to protect players from eccentric exercise-induced muscle damage and associated declines in eccentric and concentric peak force capabilities (22) .

New motorised resistance devices (e.g., 1080 Quantum synchro, 1080 Motion) also enable precise accentuated eccentric loading prescriptions during performance of dynamic plyometric jumping actions (62,72,76). Unlike other forms of accentuated and accelerated eccentric loading approaches that require resistance to be manually adjusted or re-applied following the 1st repetition (thereby not permitting continuous repetitions to be performed), accentuated eccentric loading with motorised resistance devices enable automatic adjustment of loads when transitioning between the eccentric and concentric phases, allowing for repeated reactive vertical jumps to be performed with precisely pre-programmed eccentric and concentric loads. Using repeated reactive accentuated eccentric load CMJs (bilateral and unilateral) alongside slow velocity squats (bilateral and unilateral) across an 8-week training period, both Horwath et al. (76) and Helland et al. (72) reported superior enhancements in DJ performance in comparison to a group who performed the same exercises with constant load, or a group who performed an Olympic style weightlifting training programme, respectively. These superior adaptations in DJ performance are likely due to the high eccentric braking forces and RFD imposed during reactive accentuated eccentric load CMJs, thus generating positive adaptations in the ability to generate and tolerate high braking impulses (62). Indeed, in comparison to non-reactive accentuated eccentric load CMJs (i.e., performed with feet on floor) and traditional repeated CMJs (i.e., performed with constant load throughout eccentric and concentric phases), Gross et al. (62) observed significantly higher braking forces and RFD. These findings have potentially important implications for practitioners looking to programme accentuated or accelerated eccentric load exercises throughout the training year, and highlight the importance of reactive plyometric CMJs for attaining high eccentric braking forces and RFD, similar to those imposed during rapid horizontal decelerations (70).

Performing CMJs with constant load is another viable strategy for attaining eccentric overload through attempting to rapidly accelerate the load as fast as possible through the eccentric (downward) phase before braking as late as possible (73). In this study moderate (50% 1RM) to heavy (75% 1RM) loads generated the highest eccentric overload (4 to 12%) and the longest percentage time spent braking, demonstrating the potential to develop eccentric strength and braking capacity. Braking demands are likely to be further augmented, similar to Gross et al. (62), if loaded CMJs are performed in a repeated reactive format due to the generation of greater potential energy before commencing the descent of the CMJ (i.e., greater eccentric velocity, thus momentum to be decelerated). Using instructions that aim to enhance performance in the eccentric braking phase (e.g., "jump as fast and as high as possible, but focus on reaching 50% of depth as rapidly as possible", "jump as fast and as high as possible, but focus on changing direction as fast as possible by pushing against the ground") could also be applied to other jumping derivatives (e.g., rear foot elevated jump squat, hex bar jump, jump shrug) to target an individual's ability to generate greater magnitude and rate of braking force across different joint angle configurations (91).

Pre-Planned Horizontal Decelerations with Change of Direction

During a pre-planned COD task the deceleration demands are both angle and velocity dependent (42). Greater COD angles and higher approach velocities prior to COD will require a higher magnitude of horizontal braking impulse to decelerate forward momentum, resulting in higher lower limb mechanical loading demands and potential injury risks, particularly at the knee (42). Accordingly, for horizontal deceleration training and improving braking force capabilities, there is a need to focus on COD angles that require significant horizontal deceleration prior to turning. Dos Santos et al. (42) illustrated this using a traffic light system with COD angles greater than 60° requiring substantial braking (i.e., red light) across a number of braking steps prior to turning and re-accelerating in a new direction. It is important to also highlight how approach velocity and distance prior to COD can influence horizontal deceleration demands and the different braking strategies and techniques deployed. For example, a 15 m approach compared to a 5 m approach prior to a 180° COD will require braking to be performed from a higher approach velocity (~83% vs. ~54% V_{max}, respectively) and across a higher number of braking steps (~5-6 vs. ~3 braking steps, respectively) (Figure 6) (51,59).

As such, while horizontal deceleration is a multi-step skill in both these COD tasks, different braking strategies and demands (e.g., GCT, joint angles and forces) will be enforced across each braking step. For example, during a 180° COD test with a 15 m approach Dos'Santos et al. (43) observed a significant association (r^2 = 39-61 %) between horizontal braking forces in the antepenultimate step (i.e., 2 steps prior to COD) and overall COD performance, with the penultimate step (i.e., 1 step prior to COD) having lower horizontal braking demands and a lower importance (r^2 = 4-32 %)

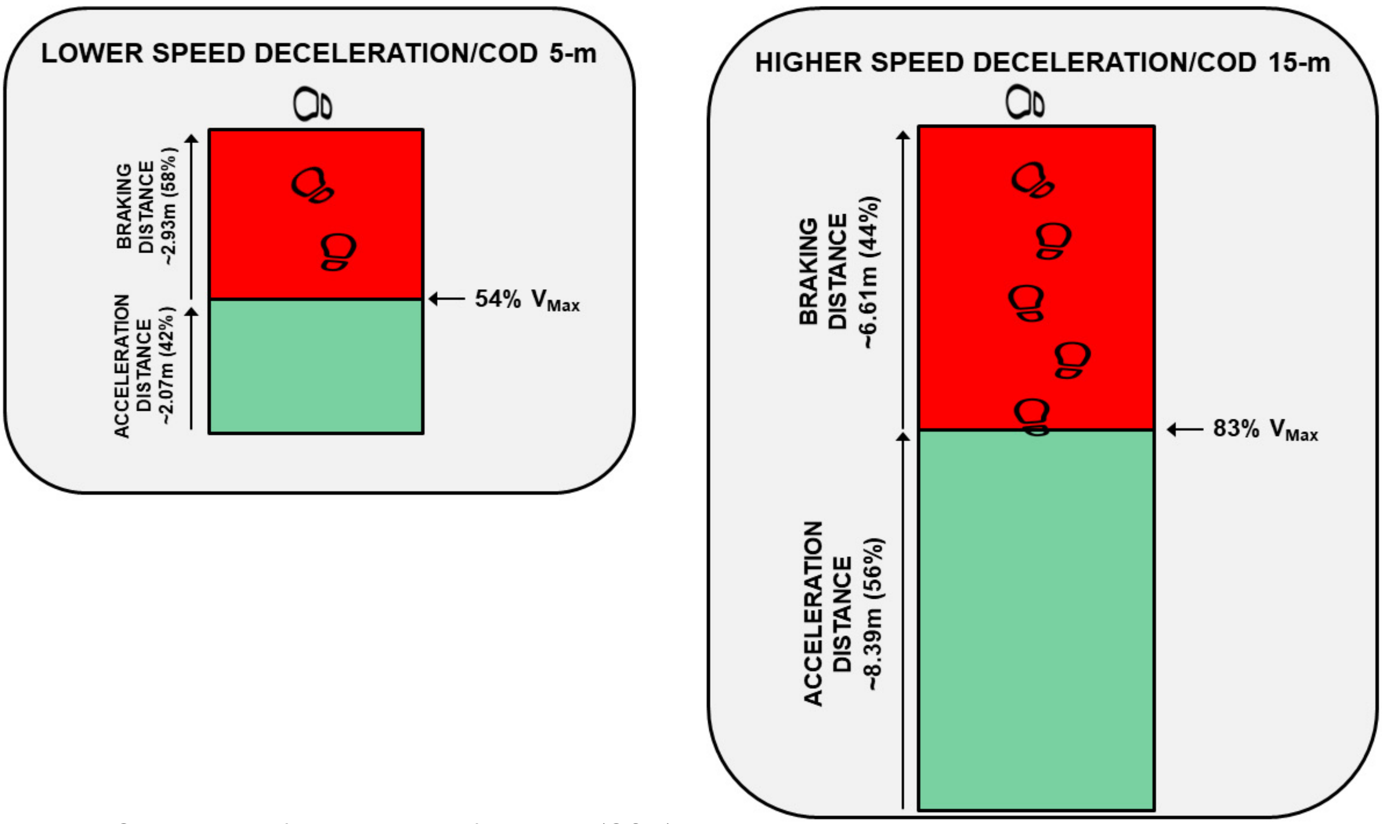

Figure 6. Comparison of 180° change of direction (COD) tasks with 5m and 15m approach. Approximate approach speed, braking distances and number of braking steps taken from Graham-Smith et al. (59) and Falch et al. (51). VMax = Maximal velocity attained prior to deceleration commencing, Green = acceleration distance, Red = deceleration distance.

on overall COD performance, likely due to this step being more of a positional braking step for enhancing re-acceleration in the subsequent final foot plant step. Conversely, in a 180° COD test with a 5 m approach the penultimate step seems to have a much more significant role on horizontal deceleration and overall COD performance, although the ante-penultimate step was not investigated in this study and should be investigated in future research (45). These findings highlight the importance of training sharp COD angles (>60°) from both lower (<80% V_{max}) and higher (>80% V_{max}) sprinting speeds and entry distances to ensure athletes are exposed to varying braking demands and develop the braking strategies unique to each COD task. Practitioners should also be aware many sharp CODs (and decelerations) during match play are performed from sub-maximal speeds (49,101,118,132). Therefore, it is recommended that athletes are also exposed to sharp CODs during training from sub-maximal speeds. Furthermore, while the main focus of this article is on forwardly initiated decelerations and CODs, it is important to note that decelerations and CODs can also be commenced or followed from varying body positions (i.e., sideways, backward or different combinations) (112). Therefore, following a thorough needs analysis of the multi-directional sport, relevant priority should be placed on developing deceleration and COD skills from the various body positions most likely encountered in that sport and playing position.

Assisted Horizontal Decelerations

Similar to assisted horizontal braking steps as described in the braking elementary category, assisted horizontal decelerations are performed with assisted pulling loads (i.e., using elastic bands and motorised resistance devices) to increase horizontal deceleration and braking demands. However, unlike assisted braking steps, assisted horizontal decelerations require braking forces to be generated at faster movement speeds and with shorter GCTs, thereby challenging the speed of inter- and intra-limb coordination and horizontal braking RFD. Assisted horizontal decelerations can be progressed or regressed by manipulating the approach distance and velocity attained prior to decelerating, COD angle, or with assisted or resisted load (42). New motorised resistance devices also enable assisted load to be prescribed in the deceleration phase, before changing to a lighter resisted load in the re-acceleration phase of a COD task (Figure 7). This prescription is similar to applications of accentuated eccentric load training in the vertical plane to accentuate the deceleration (eccentric) phase before moving to a lighter resisted load in the re-acceleration (concentric) phase.

Fast Concentric Loading

Although not previously recognised as a potentially important NMP determinant of horizontal deceleration ability, a number of studies have identified associations between concentric force at faster knee joint angular velocities and horizontal deceleration abilities (60,67,68). While it is recognised that enhancing eccentric force can augment concentric force during coupled eccentric-concentric movements, practitioners should also consider, in addition to the accentuated eccentric load training interventions already discussed, strategies that could further augment concentric force at high lower-limb joint angular velocities. One clear strategy would be to utilise assisted jump training approaches that enable much higher lower limb joint angular velocities to be developed when compared to using loads equal to body mass or above (131). Utilising this “overspeed” training stimulus could be particularly effective for players exhibiting a high-velocity deficit, who following an individualised training programme consisting of specific high-velocity training exercises (i.e., assisted squat jumps and CMJ) can demonstrate extremely large changes in maximal lower-limb velocity and jump performance capabilities (83). Practitioners may also look to utilise velocity-based resistance training strategies that aim to maximise the number of repetitions performed with high movement velocity (i.e., low % velocity loss) which are known to be conducive to activities such as decelerating, where rapid force production and lower-limb movements are required (127).

Overcoming Isometrics

Overcoming isometrics also known as “pushing” or “pulling” isometric muscle actions, requires athletes to push or pull actively against a stable object using specific postures and joint angle configurations (134). There are two distinct types of overcoming isometric exercises, including (1) explosive contraction training that involves very short (~1 s) explosive contractions interspersed with short (~5s) relaxation periods, and (2) sustained contraction training that involves longer (~4 s) contraction durations interspersed with varied (2 to 20 s) relaxation periods (7,93,106). Explosive isometric contraction training is a potent stimulus for enhancing early RFD and free-tendon stiffness,

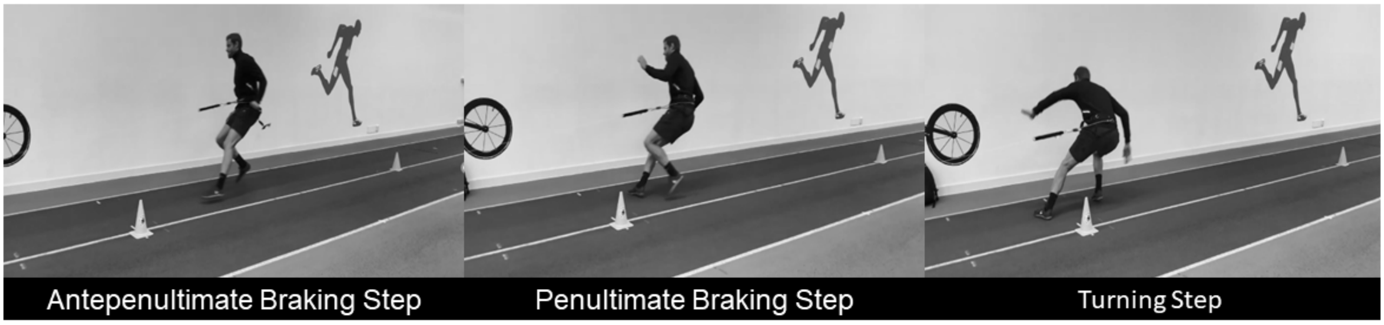

Figure 7. Assisted horizontal deceleration during a 180° change of direction task. Assistance is generated through a motorised resistance device during the deceleration phase, before automatically changing to a lighter resisted load upon executing the turning step and re-accelerating.

while sustained isometric contraction training is more beneficial for muscle hypertrophy and tendon-aponeurosis complex stiffness (106). The neural and connective tissue adaptations unique to explosive and sustained isometric contraction training can be considered crucial for intense braking actions where rapid forces must be generated and attenuated quickly. Indeed, following 10 weeks of explosive contraction training of the ankle plantar flexors, increases in Achilles tendon stiffness and muscle strength were accompanied by reductions in active fascicle lengthening and fascicle lengthening velocity during a high-impact single-leg braking task, potentially mitigating muscle damage caused by fast eccentric muscle actions (151).

Since overcoming isometric training adaptations is deemed more effective at the specific joint angles that are trained (123), practitioners looking to enhance horizontal deceleration ability should target a range of postures and joint positions that closely mimic those seen during the different braking steps of horizontal decelerations (Figure 8). Practitioners may also attempt to perform overcoming isometrics by targeting specific muscles and tendons known to be important for enhancing horizontal deceleration ability. For example, ankle plantar-flexor muscles (i.e., soleus and gastrocnemius) and their associated connective tissue structures are important for attenuating forces upon ground contact and for generating ankle extensor moments that help prevent forward excursion of the COM to prolong braking (107). Using a single-joint overcoming isometric approach, practitioners may also use post-stretch isometric contractions to achieve supramaximal isometric forces (29). Using this approach, a brief explosive isometric contraction (~1s) performed at shorter muscle lengths is followed by an active eccentric stretch before performing a sustained contraction (~5s) at a longer muscle length. Additionally, practitioners may consider using biofeedback devices (e.g., force plates, handheld dynamometers, strain gauges) that are widely accessible and commonly used in practice for providing external feedback (motivation) and monitoring intensity of isometric exercise.

Oscillatory Isometrics

Oscillatory isometrics involve an active, intense, oscillatory pushing and pulling component. Similar to overcoming isometrics these exercises target specific body and joint positions seen when decelerating and involve a rapid recruitment of the motor unit pool (134). The active pushing and pulling motion in oscillatory isometrics generate impulse-like contractions that could help to prevent fatigue by maintaining the transport of substrates thought to be a cause of fatigue in eccentric yielding isometrics (134), while also necessitating a higher discharge rate of motor units that can influence the maximal RFD (9). Furthermore, by performing the oscillations at long muscle lengths, with contractile disadvantage, higher neural activation can be achieved along with increased stress and strain on the passive elastic structures (37). Accordingly, given that horizontal decelerations require rapid muscle activation and relaxation rates, and for connective tissues to assist in attenuating braking forces, oscillatory isometrics provide a useful training option to target these specific neural and mechanical qualities.

BRAKING PERFORMANCE EXERCISES

An important aim of braking performance exercises is to enhance braking skills under constraints specific to the competitive environment (i.e. game-representative braking) (153). Therefore, training options within the braking performance exercise category are designed to enhance horizontal deceleration ability using tasks and constraints

Figure 8. Braking specific overcoming isometric exercise performed in horizontal deceleration position.

more specific to the competitive performance environment, including 1) unanticipated horizontal decelerations, 2) contextual horizontal decelerations, and 3) game-specific horizontal decelerations. All these braking performance exercises require players to utilise perceptual information to make high-speed decisions on the braking strategies that should be deployed to maximise performance outcomes of the task (i.e., game-speed).

Unanticipated Horizontal Decelerations

Unanticipated horizontal decelerations (i.e., agility) are designed with multi-directional, linear or curvilinear movement challenges, or combinations of these, with either, or both, offensive (i.e., to create space/evade) and defensive (i.e., to close down space/pursue) goals, but without the integration of sport-specific technical skills. These can include agility games (i.e., chase and evade drills), dyad partner training (also known as mirror drills), invasion games (i.e., 1vs1, 2vs2) and COD tasks requiring action to an external stimulus (i.e., visual, tactile, and audible). An important requirement of unanticipated horizontal decelerations is anticipating and responding to other human or sport-specific stimuli. This will require the athlete to precisely regulate horizontal braking and deceleration magnitudes against constantly changing movement speeds, and spatial and temporal constraints. Thus, an additional goal of these drills is to enhance anticipatory skills (i.e., advanced cue utilisation) and decision-making speed so that greater preparatory time can be made available to co-ordinate effective body positions and to generate higher, quicker and more precisely orientated braking forces to facilitate faster and more precise horizontal decelerations (137). As mentioned above, it is important to design unanticipated horizontal deceleration challenges with both offensive and defensive situations, since distinct biomechanical and perceptual-cognitive demands are required that could influence braking force capabilities and overall movement performance capabilities (i.e., ability to adapt to surrounding conditions) (137,153).

Practitioners should look to design and progress unanticipated horizontal decelerations by manipulating the key constraints of the practice environment (e.g., rules of the task) to enable the desired type of unanticipated horizontal deceleration to emerge. For example, to progress the intensity of unanticipated horizontal decelerations the practice design could be manipulated to encourage unanticipated horizontal decelerations to be performed from progressively greater movement velocities or COD angles (Figure 9). Furthermore, similar to pre-planned horizontal decelerations, weighted vests or light wearable resistance applied to specific body segments could be used to overload braking neuromuscular and mechanical demands under more highly specific movement conditions (38). Alternatively, to enhance braking load tolerance, practitioners should design training scenarios requiring a high density of unanticipated horizontal decelerations to be performed (i.e., numbers per minute) to ensure athletes are prepared for the peak demands of competitive sport.

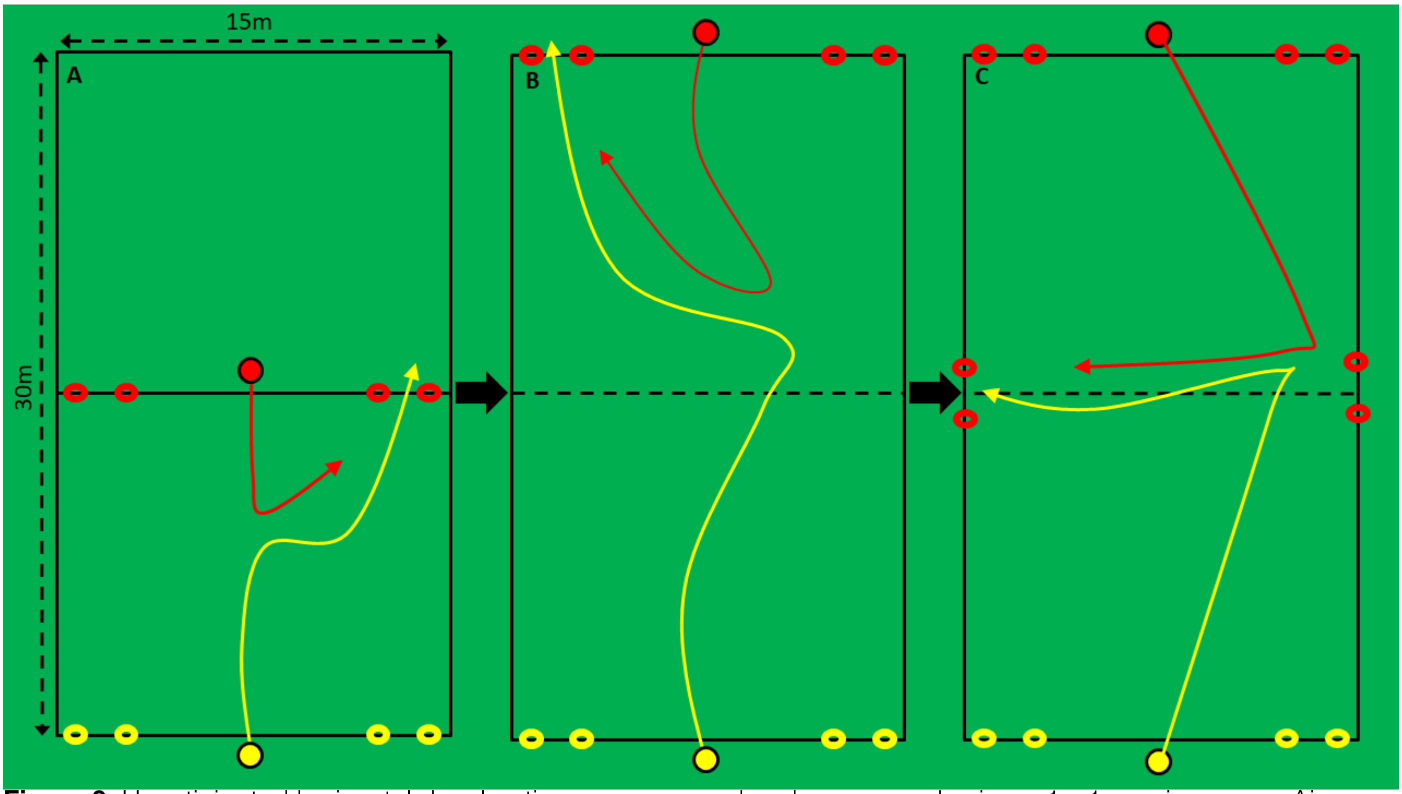

Figure 9. Unanticipated horizontal decelerations programmed and progressed using a 1vs1 evasion game. Aim of the game is for the attacker (yellow circle) to evade the defender (red circle) by running through the red gates (red doughnut). (A) Lower speed horizontal deceleration. Area is constrained to 15 x 15m area. (B) Higher speed horizontal deceleration. Task is progressed by increasing the length of the area to 30m permitting horizontal decelerations and COD to be performed at higher speeds. (C) Higher speed horizontal deceleration with sharper (>60°) COD. Attacker is given more options to evade defender by placing additional gates on the halfway line. Attacker also instructed must pass halfway line to score through these gates, with aim of facilitating higher speeds and more opportunity for rapid horizontal decelerations and sharp (>60°) CODs to be performed.

Contextual Horizontal Decelerations

Contextual horizontal decelerations aim to re-create movement patterns that incorporate game-specific horizontal decelerations in combination with technical and tactical outcomes encountered when both in and out of possession, also known as the integrated approach (20). Contextual horizontal deceleration sessions can be designed using either a position-specific format, or with a combination format where different positions are worked in unison (19). To specifically target horizontal decelerations performed at higher sprinting speeds, transitional games can also promote quick defensive re-organisation or counterattacking (5,6,11). Furthermore, to ensure players are optimally prepared to perform the intensity ($m.s^{-2}$) and density (i.e., $n.min^{-1}$) of horizontal decelerations that may be encountered during match play and the most demanding passages of play, practitioners should ensure deceleration demands replicate or progressively overload those experienced during match play. For example, in soccer it has been reported that all positional roles may be required to perform between 4 to 5 high-intensity decelerations (> $-3\ m.s^{-2}$) per minute during the most demanding passages of play when examined across a 1-minute rolling time-period (102).

Using the common technical and tactical actions performed by wide midfield soccer players while in and out of possession of the ball (3), an example contextual position-specific drill is illustrated in Figure 10. It is also important to note that this sequence of movements could be broken down into isolated contextual horizontal deceleration drills. This would involve the player performing specific movements within the sequence (e.g., A to C, Figure 10), or integrating different parts of the sequence (e.g., C-D-E-F, Figure 10). These sequences could also be further developed by adding an external stimulus so the player must react to an opponent's actions. For example, in the A-C sequence the defensive press could be made against an opponent who can dribble the ball down the line or inside the field. In this example, this would expose the player to a common scenario (inciting event) that is observed during many ACL injuries

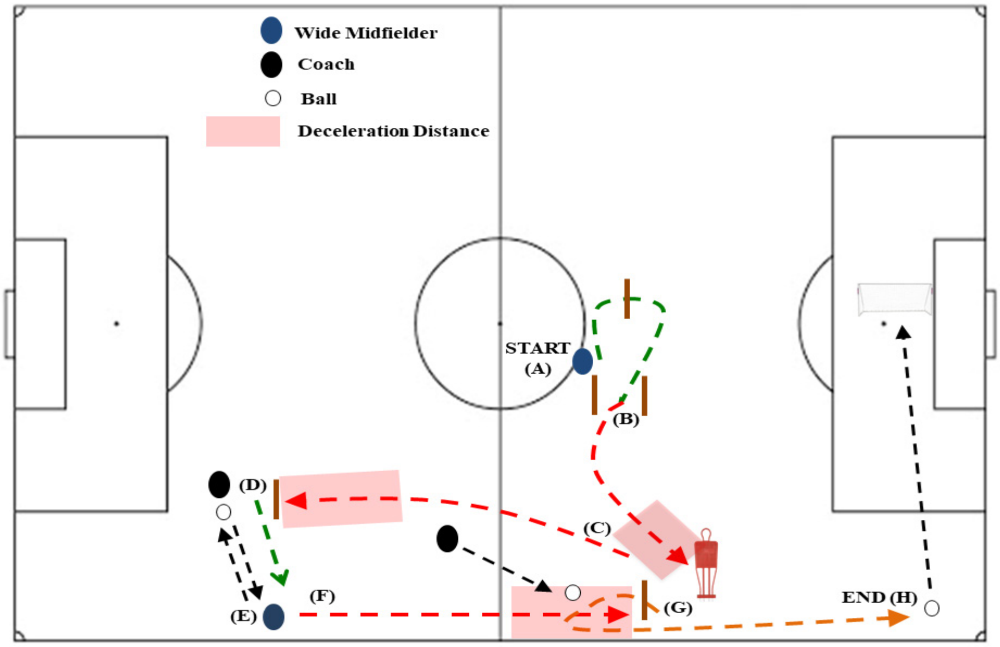

Figure 10. Contextual position-specific deceleration drill for wide midfielder. Movement sequences A, B and C performed when out of possession, and D, E, F, G and H are performed when in possession of the ball. A = start in middle-third of pitch with slow jog to side-shuffle, B = ~90° turn with curvilinear sprint to high-intensity deceleration (tactical aim: close down opposition player), C = ~90-180° turn to curvilinear sprint to high-intensity deceleration (tactical aim: track opposition players drive through middle), D = ~90-180° turn to back pedal, E = quick one touch pass, F = ~90-180° turn to sprint down channel to high-intensity deceleration (tactical aim: overlapping run), G = ~90-180° turn to receive pass and dribble down line, H = end with cross into mini-goal.

in male (145,148) and female (98) soccer players. As such, these contextual horizontal deceleration training activities could help players develop the anticipatory and neurocognitive skills that are required to reduce ACL injury risk when a late visual distracting movement is made by an attacker when close to them.

The tactical and technical contexts of this drill have been informed using an adapted version of the high-intensity movement programme devised by Ade et al. (3), which provides practitioners with a classification system of various contextual specific deceleration drills that can be constructed using various tactical outcomes required to be performed during soccer match play (Table 5). This classification system could easily be adapted and used to inform contextual position-specific horizontal deceleration design for other multi-directional sports.

Game Specific Horizontal Decelerations

Game-specific decelerations are 'modified' versions of the formal competitive game, commonly known as sided games (121). In team sports such as soccer these are often further described as small-sided games (SSG; 1vs1 to 4vs4), medium-sided games (MSG; 5vs5 to 8vs8) and large-sided games (LSG; 9vs9 to 11vs11) dependent on player numbers and size of the playing area. The key aim of game-specific horizontal decelerations is to develop a player's game-specific horizontal deceleration capabilities by utilising tasks highly representative of the competitive environment. Accordingly, sport-specific information sources and individual action capabilities will inform player horizontal deceleration manoeuvres, with the intentions of enhancing sport-specific technical and tactical outcomes. By manipulating game-specific task constraints practitioners can target different horizontal deceleration capabilities that are known to be important for performance in competitive match play while achieving simultaneous technical-tactical development and increased adherence and motivation.

Using soccer as an example, SSG and MSGs with a smaller player number and playing area can overload the frequency of high-intensity (> $-3 m.s^{-2}$) decelerations and associated technical actions in comparison to the average and most demanding passages of play experienced during competitive matches (103,104). However, practitioners should be aware that SSGs (i.e., intensive soccer conditioning) might not provide adequate opportunity for players to perform horizontal decelerations from higher running velocities that may have a different neuromuscular and mechanical demand (71,118). Accordingly, LSGs (i.e., extensive soccer conditioning) with larger playing areas can allow players to attain higher and more frequent maximal deceleration values than SSGs (1,56). An alternative strategy to target higher-speed horizontal decelerations using SSG would be to increase the playing area, allowing players greater space to attain higher running velocities prior to deceleration (75). Furthermore, practitioners should also carefully consider work-to-rest ratios and the number of sets performed since longer continuous durations and a higher frequency of bouts have been reported to reduce the amount of high-intensity decelerations performed (30). Given the potential for large inter- and intra-position variability in high-intensity deceleration frequencies during different formats of sided-games (54), supplementary high-intensity deceleration training may be needed as a "top-up", similar to practices used for high-speed running. However, the minimum effective dosage is currently unknown and is, therefore, an important direction for future research. Thus, practitioners should monitor and be cognizant of the acute and chronic deceleration loads to potentially protect against injury (18).

OTHER PROGRAMMING CONSIDERATIONS

Braking Complexes

A programming strategy that practitioners may consider is the use of 'braking complexes', which sequences together different combinations of exercises and training methods described in the Braking Performance Framework (Figure 3). Braking complexes include those proposed by Cormier et al. (33), including 1) Complex-Contrast, 2) Complex-Ascending, 3) Complex-Descending, and 4) Complex-French Contrast, in addition to 5) Complex-Adaptive proposed by Schaefer and Bittman (135). Complex-Adaptive is different than a lot of the traditional complex training methods in that an isometric muscle action is preceded immediately by an eccentric muscle action to compose a unique

Table 5. Contextual classification system for horizontal decelerations encountered during soccer specific match play scenarios whilst in (offense) and out (defence) of possession of the ball. Adapted from Ade et al. (3)

In Possession (Offensive)	
Break into box	Player runs into penalty box and decelerates to create space
Overlap	Player runs from behind to in front of, or parallel to player on ball before **decelerating** to create space to receive the ball
Push-up pitch	Player runs up the pitch to support the play before **decelerating** to create space to receive ball or attain a tactical position
Drive through middle	Player runs through middle of pitch before **decelerating** to create space or to change direction to penetrate different area of opposition territory
Drive inside the pitch	Player runs to middle of the pitch before **decelerating** to receive pass or change direction to create space
Run the channel	Player runs down the channel to one of the external areas of the pitch before **decelerating**
Run in behind	Player aims to beat opposition offside trap by performing a **deceleration** before sprinting towards opposition goal
Out Of Possession (Defensive)	
Closing down (pressing)	Player runs directly towards opposition player before **decelerating** to attempt to tackle, press, block, or hold up play (delay)
Interception of pass	Player runs before **decelerating** to intercept a pass
Covering	Player runs to cover space or a player on the pitch whilst remaining goal side, before performing a **deceleration** in response to opposition player movement / to maintain defensive line (off-side trap)
Track runner	Player runs alongside opposition player with or without the ball, before **decelerating** in response to opposition movement / to maintain defensive line (off-side trap)
Ball over the top	Player runs after opposition pass over defence through middle of pitch before **decelerating** to retain possession or respond to opposition players
Ball down the side	Player runs after opposition pass over top of downside of the flank before **decelerating** to retain possession or respond to opposition players
Recovery run	Player runs back towards own goal when out of possession before **decelerating** to be goal side / to maintain defensive line (off-side trap)

feature termed the adaptive force. Adaptive force is suggested to be a coordinative sensorimotor quality that can 'boost' eccentric-braking forces and promote the ability to adapt to varying external forces (135). Increased force output has been reported to be due to greater fascicle elongation during active stretch (i.e., eccentric muscle action) compared to eccentric muscle action with no isometric pre-activation. Table 6 provides an overview of each of the braking-complex training strategies, together with an example of a vertically and horizontally orientated exercise sequence for each braking complex.

Damage Resistance

A further important programming consideration within the Braking Performance Framework is to help protect potential diminishes in player health by increasing 'damage-resistance' to braking loads. Accordingly, practitioners should consider programming exercises into micro-cycles that may help reduce the potentially damaging effects of impending fast velocity eccentric loading cycles associated with repeated intense horizontal decelerations (80). For example, lower volumes of accentuated eccentric load DJ performed 2-weeks prior to a larger volume of accentuated eccentric load DJ can attenuate eccentric exercise-induced muscle damage and declines in eccentric peak force (a neuromuscular performance quality previously identified to be important for horizontal deceleration) due to mechanisms proposed to be associated with the repeated bout effect (22). Alternatively, isometric contractions performed at long muscle lengths could be an alternative acute protective strategy potentially implemented in the two-to-four day period prior to match day (i.e., between MD-2 and MD-4), specifically targeting muscles that may be more susceptible to EIMD following intense decelerations (94). Supplementary horizontal deceleration training may also be recommended in the same way 'top-up' work is prescribed for high-speed running and sprinting to ensure regular weekly exposures are attained to help protect players from hamstring strain injuries (10).

APPLICATION OF THE BRAKING PERFORMANCE FRAMEWORK

The range of training solutions discussed within each braking exercise category offers practitioners a range of options to target specific physical and technical qualities identified to be important for enhancing maximal horizontal deceleration ability. However, the Braking Performance Framework envisages that to optimise transfer to horizontal deceleration ability a vertically integrated, complementary, 'mixed-methods' training approach will be adopted that combines training solutions from each braking exercise category, with priorities and training densities varying throughout the season dependent on individual player training needs. For example, during the preparatory phase of the season a greater volume of work may be attributed to training solutions within the braking elementary exercise category that develop maximal eccentric strength and muscle-tendon unit structure capacities to attenuate braking forces. This could be attained through coupling field-based deceleration exercises, such as assisted braking steps and pre-planned horizontal decelerations, with exercises such as flywheel and yielding isometrics. Figure 11 provides a hypothetical example of a pre-season preparation micro-cycle encompassing the principles of the Braking Performance Framework for a soccer player wanting to improve multi-directional speed, and who has been identified through testing and training with a need to improve their horizontal deceleration and braking performance capabilities. Thus, the primary emphasis is on training solutions that enhance these qualities.

During the in-season phase, a greater emphasis may be placed on braking developmental and braking performance exercises. The eccentric and isometric strength and muscle-tendon unit adaptations realised from the preparatory block may lay the foundations for exercises, such as 'fast' eccentric loading exercises, alongside contextualised, unanticipated horizontal decelerations involving greater approach velocities (increased distances) and COD angles, which are used to intensify deceleration demands. Figure 12 provides an example of an in-season performance micro-cycle encompassing the principles of the Braking Performance Framework for the same player.

Table 6. Braking complexes with examples of vertical and horizontally focused exercises. Modified from Cormier et al. (32).

TRAINING TERMINOLOGY	Training Description	Exercise Intensity	Recovery Interval	Example Vertical Braking Focus	Example Horizontal Braking Focus
BRAKING COMPLEXES	General aim is to enhance different strength and skill qualities required for braking during horizontal deceleration.				
Contrast	Alternating high-load and low load (higher-velocity) exercises in a set-by-set fashion.	• High load/low speed (0-85%1RM) • Low load/high speed (BM to 60% 1RM)	• Intra-contrast rest: Strong (5-7 mins) Recreational (>8 mins) • Inter-set rest: 3-4 mins	1. RFE SS (80% 1RM) 2. Drop lunge (20% 1RM)	1. Heavy assisted braking steps (50-75% BM) 2. Assisted hop & stick 3. (5% BM)
Ascending	Sets of low-load, higher-velocity exercises before high-load exercises within same session.	• Low load/high speed (BM to 60% 1RM) • High load/low speed (>85% 1RM)	• 3–4 mins between sets	1. Drop lunge (20% 1RM) 2. Drop lunge (20% 1RM) 3. RFE SS (80% 1RM) 4. RFE SS (80% 1RM)	1. Hop & stick (5% BM) 2. Hop & stick (5% BM) 3. Assisted braking steps (75% BM) 4. Assisted braking steps (75% BM)
Descending	Sets of high-load exercise before low-load, higher velocity exercises within same session.	• High load/low speed (>85%1RM) • Low load/high speed (BM to 60% 1RM)	• 3–4 mins between sets	1. RFE SS (80% 1RM) 2. RFE SS (80% 1RM) 3. Drop lunge (20% 1RM) 4. Drop lunge (20% 1RM)	1. Heavy assisted braking steps (50-75% BM) 2. Heavy assisted braking steps (50-75% BM) 3. Hop & stick (5% BM) 4. Hop & stick (5% BM)
French Contrast	Series of four exercises performed in sequence within same session: 1. Heavy compound 2. Plyometric 3. Light-to-moderate compound 4. Plyometric or overspeed	• Heavy compound • (80-90% 1RM*) or variable eccentric • Plyometric/Landing (BM) • Low-to-moderate compound (20-40% 1RM) or variable eccentric • Plyometric/Landing (overspeed/assisted)	• Between exercises (0-20s) • Between series/sets (4-8 mins)	1. Flywheel squat 2. 20cm DJ (BM) 3. Drop squat (30%) 4. ACEL CMJ	1. Flywheel pulley brake step (50-75% BM) 2. Horizontal jump and stick (BM) 3. Heavy assisted braking steps (50-75% BM) 4. Assisted horizontal deceleration (10% BM)
Adaptive	Fast eccentric exercise performed immediately after isometric exercise	• Pushing isometric • (30-100% MVC) • Fast eccentric • (BM-75%1RM)	• Intra-exercise (0-5s) • Between sets (3-5 mins)	1. Isometric RFE SS (90-100% MVC) 2. RFE SS drop (BM-20% 1RM)	1. Isometric braking stance (90-100% MVC) 2. Assisted hop and stick (12% BM assisted)

RM = repetition maximum; BM = body mass; MVC = maximum voluntary contraction; RFE = rear foot elevated; SS = split squat

TRAINING PRIORITY	**BRAKING ELEMENTARY**	
	BRAKING DEVELOPMENTAL	
	BRAKING PERFORMANCE	

	ACTIVE RECOVERY	**INTENSIVE**	**EXTENSIVE**	**TECHNICAL-TACTICAL**	**TECHNICAL-TACTICAL**		
	Monday (MD +2)	**Tuesday (MD -4)**	**Wednesday (MD-3)**	**Thursday (MD-2)**	**Friday (MD-1)**	**Saturday (MD)**	**Sunday (MD+1)**
KEY TRAINING GOALS	• Braking stabilization • Eccentric yielding • Tendon stiffness • ROM • Reduce DOMS	• Braking stabilization • Eccentric-braking strength • Repeated DEC (braking load tolerance) • Braking technical ability • Braking PC • Braking DMS	• Eccentric velocity • Braking RFD • Braking pre-activation • Braking technical ability • Braking PC • Braking DMS	• Braking PC • Braking technical ability • Braking DMS	• Braking PC • Braking technical ability • Braking DMS • Braking RFD	MATCH DAY (GS-DEC)	PASSIVE RECOVERY INTERVENTIONS
BRAKING ELEMENTARY EXERCISES	GYM • ECC landing control (V) • ECC yielding ISO (LY)	GYM • ECC landing control (H) • HEL (flywheel++, V/H/I[b]) • FIELD • Assisted braking steps • PP-DEC (low speeds)	FIELD • PP-DEC (high speeds[d])	GYM • ECC yielding ISO (HY[f]) • HEL (flywheel+, V)			
BRAKING DEVELOP-MENTAL EXERCISES					FIELD • UA DEC (agility/mirror games)		
BRAKING PERFORMANCE EXERCISES	FIELD • Contextual DEC (tempo circuit) • Game specific DEC (MSGs, PO/FL/Z[a])	FIELD • Isolated contextual DEC (lower speeds[c]) • Game specific-DEC (SSGs with GK[c])	FIELD • Contextual DEC (higher speeds –TG[e]) • Game specific DEC (LSGs with GK[e])	FIELD • Game specific DEC (MSG-LSGs with GK)	FIELD • Contextual DEC (team formation, set pieces)		
DECELERATION FREQUENCY							
DECELERATION INTENSITY							

Figure 11. Example pre-season preparatory micro-cycle encompassing the principles of the Braking Performance Framework.

DEC = horizontal deceleration; DMS = decision making speed; DOMS = delayed onset muscle soreness; ECC = eccentric; FL = floaters; GK = with goal keepers; H = horizontal focus; HY = high-yielding (see table 3); ISO = isometric; ; I = isolated single-joint focus; LY = light-yielding load (see table 3); LSG = large-sided games (9v9 to 11v11); MD = match day; MSG = medium-sided games (5v5 to 8v8); PC = perceptual-cognitive; PO = possession-only based; RFD = rate of force development;; ROM = range of movement; PP-DEC = pre-planned horizontal decelerations; SSG = small-sided games (1v1 to 4v4); TG = transitional games; V = vertical focus; Z = zonal restrictions; + = lower isoinertial loads (see table 2); ++ = higher isoinertial loads (see table 2)

[a]Frequency and intensity of high-intensity decelerations are restricted using possession only, floaters or zonal constraints to reduce eccentric forces and facilitate active recovery

[b]Flywheel performed prior to DEC/COD actions can increase braking force capabilities due to enhanced neural drive and muscle stiffness

[c]SSGs and isolated contextual DEC enable players to perform a high-frequency of horizontal DEC/COD to develop tolerance to repeated eccentric-braking forces

[d]PP-DEC are used to ensure all players are exposed to decelerations from higher movement speeds

[e]TGs and LSGs enable players to perform decelerations from higher running speeds to develop ability to brake rapidly with shorter ground contact times (i.e., braking impulse/RFD)

[f]Low volume isometric pre-conditioning protective stimulus at long muscle lengths to help reduce damage potential on MD and accelerate recovery from symptoms of ECC induced muscle damage

TRAINING PRIORITY		
	BRAKING ELEMENTARY	
	BRAKING DEVELOPMENTAL	
	BRAKING PERFORMANCE	

	ACTIVE RECOVERY	INTENSIVE	EXTENSIVE	TECHNICAL-TACTICAL	TECHNICAL-TACTICAL		
	Monday (MD +2)	Tuesday (MD -4)	Wednesday (MD-3)	Thursday (MD-2)	Friday (MD-1)	Saturday (MD)	Sunday (MD+1)
KEY TRAINING GOALS	• ROM • Reduce DOMS	• ECC-braking strength • Tendon stiffness • Repeated DEC (braking load tolerance) • Braking RFD • Braking technical ability • Braking PC • Braking DMS	• Braking pre-activation • Braking RFD (V+H) • Tendon stiffness • ECC velocity • Braking technical ability • Braking PC • Braking DMS	• Braking PC • Braking technical ability • Braking DMS • CON velocity	• Braking PC • Braking technical ability • Braking DMS	MATCH DAY (GS-DEC)	PASSIVE RECOVERY INTERVENTIONS
BRAKING ELEMENTARY EXERCISES		GYM • HEL (flywheel++, V/H)		GYM • ECC Yielding ISO (MY-HY[c])			
BRAKING DEVELOP-MENTAL EXERCISES		GYM • Overcoming ISO[a] • FEL (ACEL/AEL[a])	GYM • Overcoming ISO[b] • FEL (Plyometric[b]) • FIELD • Assisted DEC/COD	GYM • Fast CON load[d]	FIELD • UA DEC (agility/mirror games)		
BRAKING PERFORMANCE EXERCISES	FIELD • Contextual DEC (tempo circuit) • Game specific DEC (MSGs, PO/FL/Z)	FIELD • Contextual DEC (lower speeds) • Game specific-DEC (SSGs with GK)	FIELD • Contextual DEC (higher speeds –TG) • Game specific DEC (LSGs with GK)	FIELD • Game specific DEC (MSG-LSGs with GK)	FIELD • Contextual DEC (team formation, set pieces)		
DECELERATION FREQUENCY							
DECELERATION INTENSITY							

Figure 12. Example in-season performance micro-cycle encompassing the principles of the Braking Performance Framework.

ACEL = accelerated (band) eccentric loading; AEL = accentuated eccentric loading; CON = concentric; DEC = horizontal deceleration; DMS = decision making speed; DOMS = delayed onset muscle soreness; ECC = eccentric; FL = floaters; GK = with goal keepers; H = horizontal focus; HY = high-yielding (see table 3); ISO = isometric; LSG = large-sided games (9v9 to 11v11); MD = match day; MY = moderate-yielding (see table 3); MSG = medium-sided games (5v5 to 8v8); PC = perceptual-cognitive; PO = possession-only based; RFD = rate of force development; ROM = range of movement; SSG = small-sided games (1v1 to 4v4); TG = transitional games; V = vertical focus; Z = zonal restrictions; ++ = higher isoinertial loads (see table 2)

[a]Overcoming ISO can be paired with ACEL/AEL to form a braking adaptive-complex. Overcoming ISO targeting more flexed braking specific joint positions representing DEC performed at lower running speeds

[b]Overcoming ISO can be paired with plyometric to form a braking descending complex. Overcoming ISO targeting more extended braking specific joint positions representing DEC performed at higher running speeds

[c]Low volume ECC yielding ISO used as a protective isometric pre-conditioning stimulus to help reduce damage potential on MD and accelerate recovery from symptoms of ECC induced muscle damage

[d]Fast CON exercises are used to enhance rapid force capabilities at fast lower-limb joint angular velocities, whilst simultaneously unloading eccentric forces to facilitate tapering prior to MD.

CONCLUSION

Horizontal decelerations are performed frequently in multi-directional sports training and competition and are integral to successful performance of many offensive and defensive outcomes. However, unlike horizontal acceleration and COD performance, little attention has been directed towards training strategies aimed at improving an athlete's horizontal deceleration ability. The Braking Performance Framework provides practitioners with a selection of evidence-informed training methods that can be integrated with other important physical, technical, and tactical components to optimize the preparation of individual athlete's ability to perform and tolerate repeated horizontal decelerations during match play.

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