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ORIGINAL INVESTIGATION

Higher Eccentric Strength Mitigates Deceleration Performance Decline During Repeated Deceleration Tasks

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Purpose: This study aimed to (1) examine the relationship between eccentric strength and the ability to maintain deceleration performance following running, (2) investigate changes in deceleration kinematics during repeated deceleration tasks, and (3) explore associations between the changes in lower-limb mechanical capacities during jump tests and deceleration capacity under load. ***Methods:*** Twenty male athletes participated. Maximal eccentric and concentric strength were assessed via back squat protocols. Participants completed the repeated acceleration–deceleration task consisting of 50 repetitions of a 10-m run followed by maximal deceleration with 45-second rest between repetitions. The ability to sustain deceleration performance was quantified as percentage change in deceleration metrics between the averaged first and last 5 repetitions. Several jump tests were performed before and after the repeated acceleration–deceleration task. ***Results:*** Paired *t*-test showed repeated decelerations significantly increased time from peak to half-peak velocity (TT50%V_{Peak}) (+2.55%, $P = .014$, $d = -0.60$) and decreased deceleration in this phase (DEC_{Early}) (−3.71%, $P = .012$, $d = -0.62$). Correlational analyses revealed that eccentric strength was significantly associated with changes in TT50%V_{Peak} ($P < .01$, $r = -.59$) and DEC_{Early} ($P = .012$, $r = .55$). Changes in DEC_{Early} were significantly correlated with changes in power during squat jump ($P < .05$, $r = .53$). ***Conclusions:*** Repeated deceleration actions impair early-phase deceleration performance; however, greater eccentric strength mitigates this decline. Additionally, the ability to sustain concentric mechanical capacities appears relevant to sustaining deceleration capacity. These findings highlight the importance of eccentric strength in supporting performance under repeated high-load deceleration demands.

Keywords: change-of-direction, fatigue, kinematic measure, jump performance, back squat

Rapid deceleration from high-speed sprinting and the ability to quickly change direction are critical physical attributes in team sports where evading or pursuing opponents is frequent.[1] Several studies have reported the high volume of deceleration actions during match play in various team sports,[2,3] and recent evidence links in-game deceleration performance to match outcomes.[4,5] Accordingly, understanding the physical attributes that enable athletes to sustain high deceleration performance is essential.

While it is well-established that deceleration capacity declines during the latter stages of competition,[6,7] the mechanisms driving this decline are not fully understood. In recent years, investigations into factors influencing single-repetition deceleration performance have increased, providing valuable insights into the mechanical demands of isolated deceleration actions.[8–11] However, these studies do not address how deceleration performance deteriorates under repeated loading, which more closely reflects match-play demands. One proposed mechanism involves the accumulation of muscle damage caused by repeated eccentric contractions, which are inherent to deceleration movements.[12] Eccentric muscle damage has been linked to disrupted sarcomere structure, excitation–contraction coupling impairments, and reductions in force production capacity.[13,14] This damage is typically more pronounced following eccentric loading than concentric or isometric contractions,[15] suggesting that repeated deceleration actions may cause significant muscle damage, thereby contributing to decreased deceleration performance. However, prior exposure to eccentric exercise induces protective adaptations, such as the addition of serial sarcomeres, which help distribute mechanical stress and reduce subsequent muscle damage.[16,17] Consequently, athletes with higher eccentric strength may be better prepared to withstand repeated eccentric demands, preserving performance during accumulated deceleration exposure.

Supporting this posit, long-term eccentric resistance training has been shown to increase eccentric strength and attenuate strength loss following acute fatiguing eccentric protocols.[18] Thus, higher eccentric strength may contribute to maintaining high deceleration performance. Despite the support for this notion, the relationship between an individual's maximal eccentric strength and their ability to sustain deceleration performance under repeated high-load conditions has not been directly examined.

When monitoring the decline in deceleration performance, most of the existing literature has relied on gross external load measures, such as total deceleration distance or event counts to quantify performance decline.[6,7] While these measures provide useful insights, they do not capture the kinematic changes that occur during actual deceleration movements. In addition, little attention has been given to identifying which changes in mechanical qualities contribute to this decline. Consequently, there remains a need to examine how repeated decelerations affect kinematic changes during deceleration

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movement and identify the changes in mechanical qualities that underpin the ability to sustain deceleration performance.

Therefore, the aims of this study were to (1) determine whether individual maximal eccentric strength is associated with the decline in deceleration performance caused by repeated deceleration tasks; (2) examine how deceleration performance, quantified through kinematic metrics, changes during repeated deceleration tasks; and (3) investigate whether the ability to maintain deceleration performance during repeated deceleration tasks is associated with changes in mechanical qualities during jump tests following the task.

Methods

Subjects

Twenty healthy male university students (age: 20 [1] y, height: 176.8 [7.6] cm, body mass: 72.3 [9.5] kg) who regularly participated in sports involving change-of-direction movements (ie, lacrosse, basketball, soft tennis, and soccer) and had 10.3 (5.3) years of competitive experience were recruited. They also had 3.6 (2.0) years of resistance training experience and trained at least twice per week. Participants were instructed to maintain their normal physical activity, diet, and hydration habits, and avoid depressant substances (eg, alcohol) and ergogenic aids (eg, caffeine) within 24 hours before each testing session. All participants provided written informed consent after receiving oral and written explanations of the study's purpose, procedures, risks, and benefits. The study was approved by the Waseda University Ethics Review Committee on Human Research (approval number: 2024-384) and was conducted in accordance with the Declaration of Helsinki.

Study Design

The experimental procedures consisted of 3 sessions separated by at least 24 hours. In session 1, participants performed a back squat to assess their concentric one-repetition maximum (1RM) strength during the ascending phase only. Additionally, they practiced an eccentric-only squat and established objective failure criteria, the details of which described later. In session 2, using the failure criteria established in session 1, participants performed eccentric-only squats to assess their maximal eccentric strength. Session 3 began with preassessments of squat jump (SJ), countermovement jump (CMJ), and drop jump (DJ) performance. Participants then completed a repeated acceleration–deceleration (RAD) task, followed by jump performance assessments conducted again 5 minutes after task completion.

Maximum Strength Assessment

Concentric maximum strength was measured using a back squat exercise that included only the ascending phase. The experimenter assisted the lowering phase to avoid additional loading. The safety rack was adjusted for each participant to ensure a knee flexion angle of 90° when racking the barbell. After this setup, participants completed warm-up sets at 50% (5 repetitions), 80% (3 repetitions), and 90% (1 repetition) of their self-reported back squat 1RM, then increased the load in 5-kg increments until they failed. Each set were separated by 3 minutes of recovery.

The measurement of maximal eccentric strength, based on the approach used by Douglas et al,[19] was determined from the 1RM achieved during an eccentric-only squat performed on a Smith machine (EPIC Smith Machine F211, FreeMotion Fitness) with the counterweights removed (barbell weight: 32.9 kg). The experimenter assisted the lifting phase to ensure that the participant was only exposed to the eccentric load. The target depth corresponding to 90° of knee flexion was predetermined using a goniometer and standardized by positioning a rubber band so that it would contact the posterior thigh when the participant squatted to the specified depth. Participants were instructed to descend over 3 seconds (~30°/s) in time with an external metronome, ensuring contact between the posterior thigh and the rubber band at the target depth. In session 1, participants performed warm-up sets for the eccentric-only squat at 50% (5 repetitions), 80% (3 repetitions), and 110% (1 repetition) of their self-reported back squat 1RM, after which the load was increased in 5-kg increments until the prescribed descent velocity could no longer be maintained. Each set were separated by 3 minutes of recovery. The decent velocity was obtained by a linear position transducer (PT-101, Celesco Transducer Products) fitted to the bar, and live velocity–time data were displayed on a digital screen in front of participants to provide feedback. In session 2, following warm-up sets at 50% (5 repetitions), 75% (1 repetition), and 85% (1 repetition) of the weight used in the final successful trial from session 1, the load was increased in 5-kg increments until participants were unable to control the descent velocity. The failure criterion was defined by calculating the SD of barbell velocity during the final 3 successful eccentric-only squat trials in session 1 for each knee joint range (30°–60° and 60°–90°), averaging these values, and multiplying the result by 4. The 0° to 30° range was excluded because preliminary testing showed considerable variability in barbell velocity during the initial descent, with substantial intraindividual differences that could confound failure threshold determination. By setting the failure criterion in session 1 according to each participant's barbell descent velocity variability, we aimed to achieve a more accurate 1RM measurement that takes individual differences into account. Based on previous reports indicating that loss of barbell velocity control occurs at approximately an 80° knee angle during a squat,[20] the eccentric-only squat trial was considered a failure if the change in barbell velocity within the 60° to 90° range exceeded the failure threshold.[19]

Jump Performance

Jump performance was assessed following a standardized warm-up consisting of a 3-minute jog and 10 minutes of dynamic stretching. Vertical ground reaction force data were collected using a force platform (type 9281E, Kistler) and digitized at 1000 Hz via an analog-digital converter (PowerLab, ADInstruments) and recorded using LabChart software (version 8, ADInstruments); the signals were low-pass filtered at 50 Hz. Prior to jump testing, body mass was measured over a 3-second period, and the start of the SJ and CMJ was defined as 30 millisecond before vertical ground reaction force exceeded body mass ± 5 SD. The order of the jump tests was fixed as follows: SJ, CMJ, and DJ.

In the SJ, participants began from a stationary position with a 90° knee flexion maintained for 2 seconds and were instructed to jump as high as possible; any trial in which the force waveform dropped more than 5 N below the static baseline was deemed invalid due to the presence of a countermovement. In the CMJ, participants performed a rapid countermovement to the same depth as the SJ and then jumped as quickly and as high as possible. In the DJ, participants stepped off a 45-cm box while minimizing increases in center-of-mass height and knee flexion, with instructions to reduce ground contact time and maximize jump height; all jumps were executed with hands positioned on the hips. The rest interval between different jump type was set at 1 minute, and the rest interval between repetitions was 30 seconds.

Net vertical acceleration was calculated by dividing the force exceeding body mass by the participant's mass. Instantaneous center-of-mass velocity was obtained via numerical integration of the acceleration data. Instantaneous power was then calculated as the product of force and velocity at each time point. For the CMJ, the eccentric phase onset was defined as the point of peak negative vertical velocity following jump initiation and ended when vertical velocity exceeded 0 m/s, marking the start of the concentric phase, which concluded when vertical ground reaction force dropped below 20 N; average power was calculated separately for the eccentric and concentric phases. For the DJ, ground contact was defined as the instant when the vertical force exceeded 20 N and take-off as the moment when it fell below this threshold; jump height was estimated using the flight-time method, reactive strength index was determined by dividing jump height by contact time, and leg stiffness was calculated using the method described by Dalleau et al.[21] All force and power values were normalized to the body mass, and the mean of 3 trials for each jump type was used for subsequent analyses. The intraclass correlation coefficients for the jump performance measures obtained during the pretest of session 3 are shown in Table 1.

Repeated Acceleration–Deceleration Task

Prior to the initiation of the RAD trials, participants completed a warm-up consisting of 8 sets of 10-m runs with 30-second rest intervals, where the intensity began at approximately 60% of self-estimated effort and incrementally increased by 5% per set until reaching ~95% intensity by the eighth set. After a 2-minute rest, participants performed two 10-m sprints from a stationary standing split-stance start position, with the front foot positioned 30 cm behind the timing gate set at 0.8 m height (Speedlight Timing System, Swift Performance Equipment). Sprint times were recorded to the nearest 0.01 second, and the fastest trail was used as the baseline.

For the RAD task, participants used the same start protocol as the 10-m sprint test. They performed a 10-m run at 90% of maximum sprint velocity, followed by an immediate deceleration and a rapid backpedal until crossing the finish line. This facilitated identifying the end of the deceleration phase on the velocity–time curve. One repetition consisted of a 10-m run followed by a rapid deceleration and a rapid backpedal. A total of 50 repetitions was performed, with 45-second rest intervals between repetitions. The deceleration phase was defined as the period beginning immediately after peak velocity (V_{Peak}) was reached during the run and ending when the velocity fell below 0 m/s. This deceleration phase was further subdivided into early and late-phases based on the time at which 50% of V_{Peak} was reached (Figure 1). Instantaneous deceleration (in meters per second squared) was calculated from the change in velocity between successive data points divided by the corresponding time interval. Average deceleration values were calculated for the entire deceleration phase (DEC_{Ave}) as well as separately for the early (DEC_{Early}) and late (DEC_{Late}) phases. Additional variables were calculated, including the time to reach 50% of V_{Peak} ($TT50\%V_{Peak}$), distance to stop, and time to stop (TTS). The decline in deceleration performance was calculated as the percentage difference between the average values from repetitions 46 to 50 and those from repetitions 1 to 5. Radar data were acquired using the LMD301S device (Jenoptik AG), positioned 5 m behind the start line at approximately 1 m above the ground, corresponding to the approximate center of mass height for the participants. Data were sampled at 100 Hz. The intraclass correlation coefficients for the deceleration performance metrics measured during repetitions 1 to 5 are shown in Table 1.

Table 1 Reliability of Measurement for Performance Variables

	ICC (95% CI)
Deceleration performance variables	
V_{Peak}, m/s	.940 (.886–.973)
$TT50\%V_{Peak}$, s	.897 (.804–.954)
TTS, s	.908 (.824–.959)
DEC_{Ave}, m/s^2	.909 (.827–.959)
DEC_{Peak}, m/s^2	.832 (.681–.925)
DEC_{Early}, m/s^2	.828 (.672–.923)
DEC_{Late}, m/s^2	.879 (.770–.946)
DTS, m	.920 (.848–.964)
Jump performance variables	
CMJ	
Average braking power, W/kg	.840 (.659–.933)
Average propulsive power, W/kg	.994 (.986–.997)
SJ	
Average propulsive power, W/kg	.974 (.944–.989)
DJ	
RSI, m/s	.955 (.907–.981)
Leg stiffness, $kN \cdot m^{-1} \cdot kg^{-1}$	.925 (.844–.968)

Abbreviations: CI, confidence interval; CMJ, countermovement jump; DEC_{Ave}, average deceleration; DEC_{Early}, average early-phase deceleration; DEC_{Late}, average late-phase deceleration; DEC_{Peak}, peak deceleration; DJ, drop jump; DTS, distance to stop; ICC, intraclass correlation coefficient; RSI, reactive strength index; SJ, squat jump; $TT50\%V_{Peak}$, time to 50% peak velocity; TTS, time to stop; V_{Peak}, peak velocity.

Statistical Analysis

Data normality was assessed using the Shapiro–Wilk test. Paired *t*-tests were used to analyze pretask and posttask changes in jump

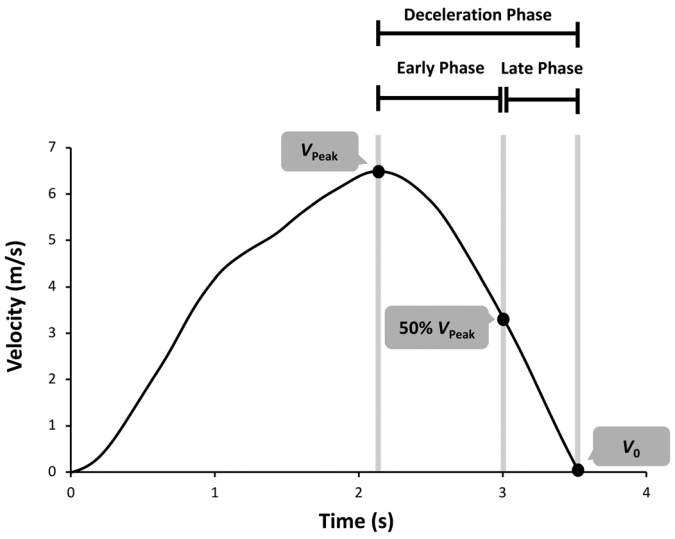

Figure 1 — Example of velocity–time profile showing deceleration phase. $V_{Peak\ indicates}$ peak velocity; 50% V_{Peak}, 50% peak velocity; V_0, the moment the velocity falls below 0.

and deceleration performance. Effect sizes were calculated using Cohen *d,* with thresholds defined as trivial (0.0–0.19), small (>0.2), moderate (>0.5), and large (>0.8).[22] The relationship between the decline in deceleration performance and both muscle strength and the changes in jump performance before and after the RAD task was evaluated using Pearson correlation coefficient. The magnitude of the correlation between variables was determined as trivial (.00–.09), small (.10–.29), moderate (.30–.49), large (.50–.69), very large (.70–.89), and almost perfect (.90–.99).[23] All data are reported as mean (SD), and statistical analyses were conducted using IBM SPSS Statistics (version 30), with significance set at $P < .05$.

Results

Paired *t*-tests showed that posttask V_{Peak} was significantly lower than pretask values paired (Pre: 6.61 [0.20] m/s vs Post: 6.55 [0.21] m/s, $P < .01$, $d = 0.67$). As shown in Figure 2, posttask DEC_{Early} was significantly reduced, while TT50%V_{Peak} was significantly increased compared to pretask values. Correlational analyses revealed that eccentric maximal strength was significantly associated with changes in TT50%V_{Peak}, TTS, DEC_{Ave}, DEC_{Early}, and distance to stop (Figure 3). In contrast, no significant correlations were observed between concentric maximal strength and changes in deceleration performance (Figure 3). As shown in Table 2, average propulsive power in CMJ, as well as reactive strength index and leg stiffness in DJ were significantly reduced after the RAD task. Additionally, Changes in DEC_{Early} were significantly associated with changes in average propulsive power during SJ (Table 3, Figure 4).

Discussion

This study aimed to determine whether individual maximal eccentric strength is associated with the ability to maintain deceleration performance, examine how deceleration performance, measured by kinematic metrics, changes during repeated deceleration tasks, and explore the relationships between the capacity to sustain deceleration performance during repeated deceleration tasks and changes in mechanical qualities during jump tests following the task. Our results indicate that repeated deceleration tasks led to a decrease in the early-phase deceleration performance. Moreover, greater eccentric strength was associated with a smaller decline in early-phase deceleration performance, while concentric strength showed no significant relationship. Additionally, large correlations were observed between changes in average propulsive power during SJ and early-phase deceleration. These findings emphasize that maximal eccentric strength is a key determinant of an athlete's ability to maintain early-phase deceleration performance during repeated deceleration tasks, while the ability to sustain SJ-derived mechanical qualities may play a complementary role in supporting overall performance under fatigue.

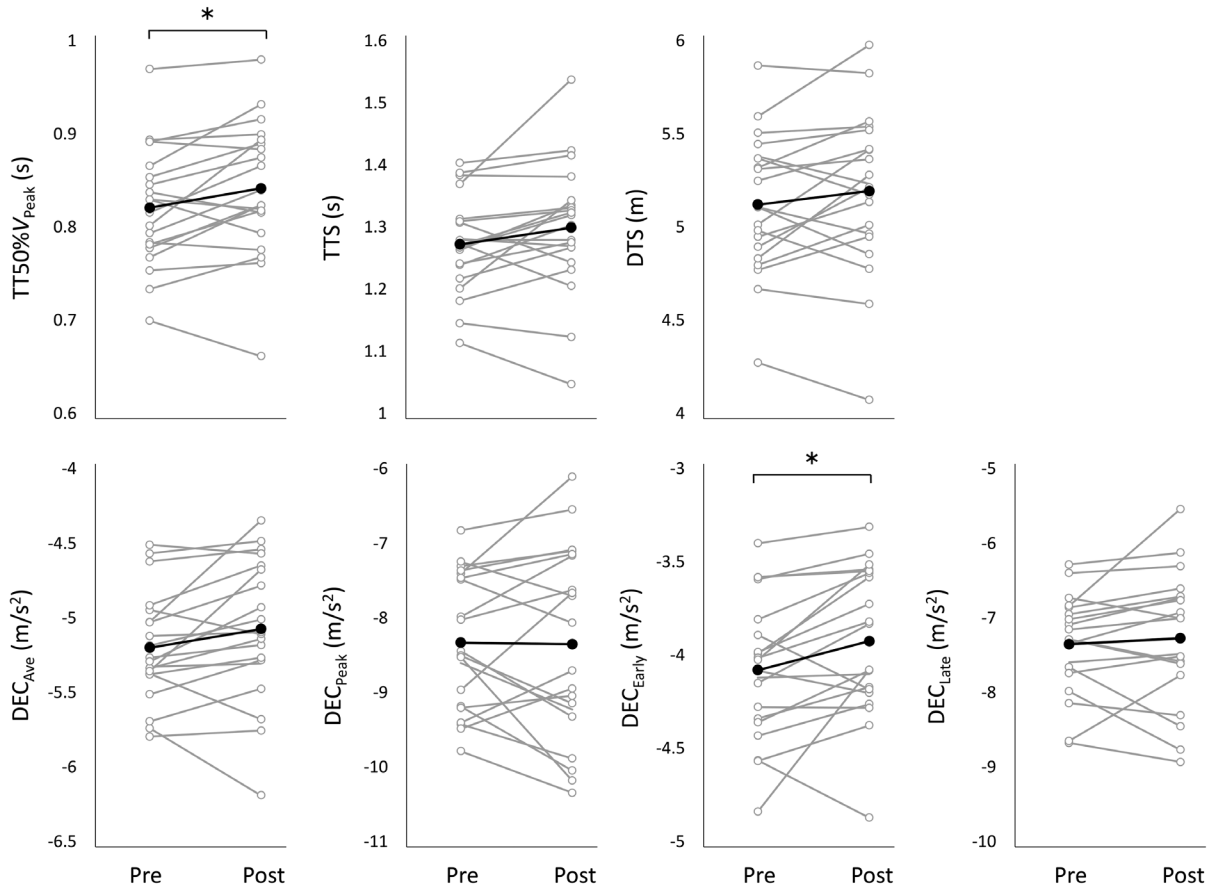

Figure 2 — Changes in deceleration performance variables following the RAD task. DEC_{Ave}, average deceleration; DEC_{Early}, average early-phase deceleration; DEC_{Late}, average late-phase deceleration; DTS, distance to stop; TT50%V_{Peak}, time to 50% peak velocity; TTS, time to stop. *Significant difference (P<.05).

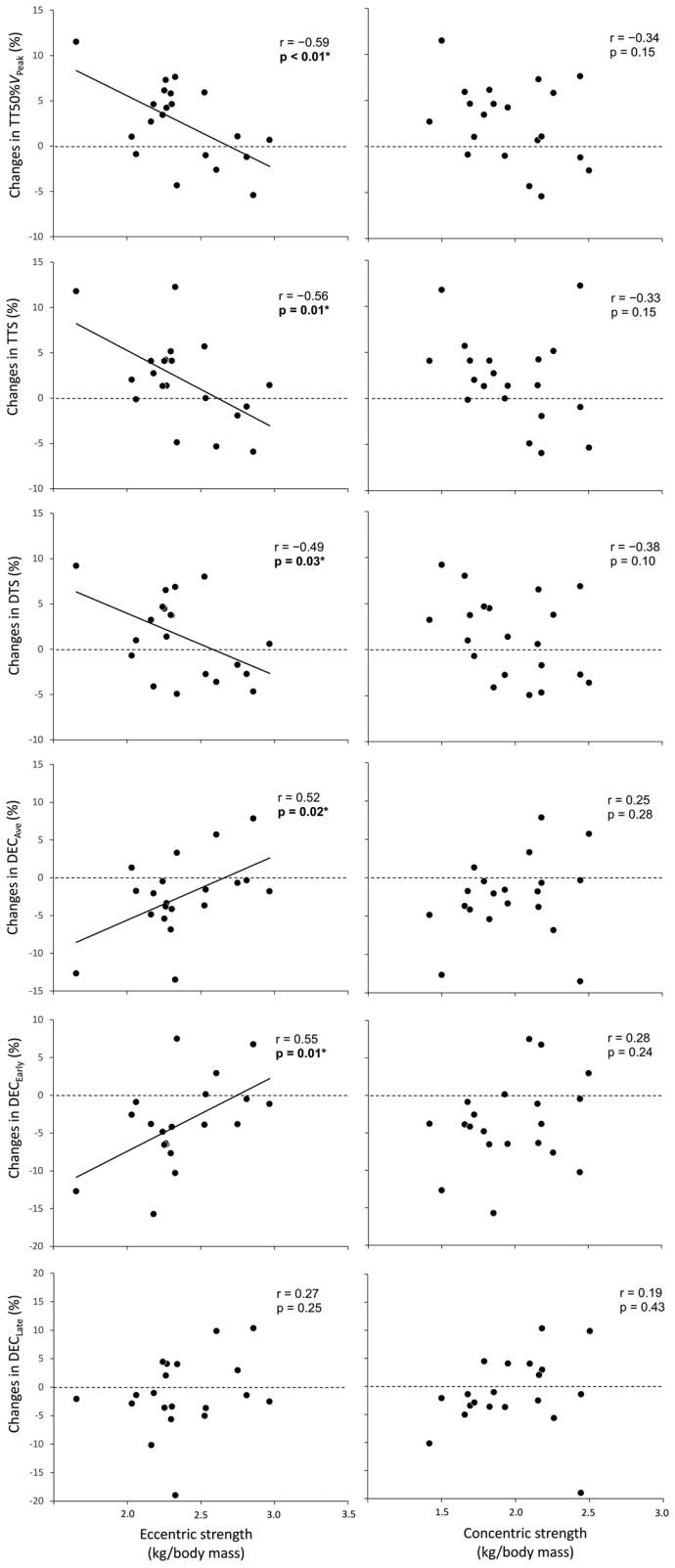

Figure 3 — Correlation between the maximum strength and the changes in deceleration performance variables. DEC_{Ave}, average deceleration; DEC_{Early}, average early-phase deceleration; DEC_{Late}, average late-phase deceleration; DTS, distance to stop; TT50%V_{Peak}, time to 50% peak velocity; TTS, time to stop. Significant *P*-values ($P < .05$) are highlighted in bold.

The decline in early-phase deceleration performance observed in this study demonstrates that repeated deceleration efforts impair an athlete's capacity to effectively dissipate momentum during the initial braking phase. Given the crucial role of early-phase deceleration in managing high-speed momentum, a reduction in this capacity likely forces greater braking demands onto the later phases of the deceleration sequence.[8] To mitigate the substantial mechanical load that arises in this phase, athletes adopt a self-regulated strategy in which they gradually dissipate momentum over the initial steps of the deceleration phase. Producing a greater braking impulse during early-phase deceleration allows braking demands to be more evenly distributed across the entire deceleration phase, thereby reducing the magnitude of impact experienced later in the deceleration process. A decline in early-phase deceleration performance may increase the demand for braking in the later phase.[24] Consistent with these findings, our data showed nonsignificant trends toward declines in TTS and distance to stop, suggesting that early-phase deceleration impairments may contribute to broader reductions in deceleration capacity.[9]

In contrast, maximum eccentric strength exhibited strong correlations with changes in early-phase deceleration performance, indicating that athletes with greater eccentric capacity are better able to maintain braking performance under repeated eccentric loading. This association likely reflects superior neuromuscular fatigue resistance in individuals with greater eccentric strength, potentially underpinned by long-term adaptations to eccentric training, such as additional sarcomeres in series that shifts the length–tension curve toward longer lengths, thereby reducing exposure to the unstable descending limb,[16,17] and/or improved motor unit synchronization that may distribute mechanical loading and attenuate muscle damage.[16] Given that creatine kinase concentration has been shown to be associated with decline in force-generating performance during repeated eccentric exercise,[25] these adaptations may contribute to reduced susceptibility to muscle damage and maintained eccentric performance. Previous study showed that athletes with higher eccentric strength exhibit superior neuromuscular fatigue resistance following repeated eccentric contractions.[18] During early deceleration, when ground contact time is short, rapid preactivation of the lower-limb muscles is required to optimize braking force at initial contact.[1] These findings suggest that while neuromuscular impairments contribute to early-phase deceleration performance decline, greater eccentric strength may help attenuate fatigue-induced deterioration.

Changes in average propulsive power from the SJ demonstrated large correlations with changes in DEC_{Early}, suggesting that the ability to maintain concentric mechanical capacities during SJ contributes to sustaining early-phase deceleration performance. Previous research has shown that concentric contractions are superior to isometric and eccentric contractions in their ability to generate rapid force due to superior neural activation.[26] During early deceleration, rapid concentric contraction immediately before ground contact would be essential to increase joint stiffness and produce high forces during the following short ground contact time.[1,10] This indicates that the ability to sustain concentric measures derived from the SJ may reflect capacities essential for effective braking in early deceleration during repeated deceleration tasks.

Repeated eccentric loading is known to impair neuromuscular control during both rapid eccentric and concentric contractions.[27] Consequently, athletes with higher eccentric strength may better preserve concentric mechanical capacities resulting from greater resistance to muscle damage. Collectively, these results suggest that while concentric mechanical capacities contribute to early-phase deceleration, maintaining this function under fatigue is partly

Table 2 Changes in Jump Performance Variables Before and After RAD Task

Variables	Pre Mean (SD)	Post Mean (SD)	Change Δ % ± SD	Effect size (descriptor)	*P*
CMJ					
Average braking power, W/kg	−15.84 (2.33)	−15.16 (2.68)	−4.30 (8.48)	−0.45 (small)	.058
Average propulsive power, W/kg	32.53 (6.09)	31.31 (5.86)	−3.64 (4.15)	0.91 (large)	**<.001**
SJ					
Average propulsive power, W/kg	17.36 (3.61)	17.27 (4.06)	−0.54 (11.52)	−0.40 (small)	.848
DJ					
RSI, m/s	3.26 (0.53)	3.06 (0.52)	−5.88 (6.77)	0.89 (large)	**<.001**
Leg stiffness, $kN \cdot m^{-1} \cdot kg^{-1}$	0.40 (0.09)	0.37 (0.09)	−9.88 (8.21)	1.11 (large)	**<.001**

Abbreviations: CMJ, countermovement jump; DJ, drop jump; RSI, reactive strength index; SJ, squat jump. Note: Significant *P*-values ($P < .05$) are highlighted in bold.

Table 3 Correlation Between the Changes in Deceleration Performance Variables and the Changes in Jump Performance Variables

	Δ TT50%V_{Peak}		Δ TTS		Δ DEC_{Ave}		Δ DEC_{Early}		Δ DEC_{Late}		Δ DTS	
	r	Effect	*r*	Effect	*r*	Effect	*r*	Effect	*r*	Effect	*r*	Effect
CMJ												
Δ Average braking power	−.01	Trivial	−.21	Small	.23	Small	−.02	Trivial	.39	Moderate	−0.12	Small
Δ Average propulsive power	.25	Small	.19	Small	−.26	Small	−.17	Small	−.03	Trivial	0.24	Small
SJ												
Δ Average propulsive power	−.25	Small	−.29	Small	.26	Small	**.53**	**Large**	.31	Moderate	0.02	Trivial
DJ												
Δ RSI	−.39	Moderate	−.25	Small	.29	Small	.32	Moderate	.05	Trivial	−0.30	Moderate
Δ Leg stiffness	−.30	Moderate	−.19	Small	.24	Small	.22	Small	.04	Trivial	−0.26	Small

Abbreviations: CMJ, countermovement jump; DEC_{Ave}, average deceleration; DEC_{Early}, average early-phase deceleration; DEC_{Late}, average late-phase deceleration; DJ, drop jump; DTS, distance to stop; RSI, reactive strength index; SJ, squat jump; TT50%V_{Peak}, time to 50% peak velocity; TTS, time to stop. Note: Significant *P*-values ($P < .05$) are highlighted in bold.

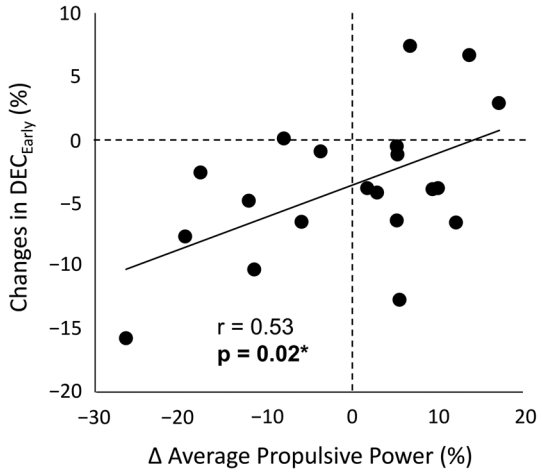

Figure 4 — Correlation between the changes in average early-phase deceleration and the changes in average propulsive power during squat jump. DEC_{Early} indicates average early-phase deceleration.

dependent on eccentric strength. However, it should be noted that Figure 4 shows that some subjects increased SJ power after the RAD task. Although the warm-up included a 3-minute jog, muscle temperature—which enhances ballistic performance—typically plateaus around 10 minutes postexercise.[28] Therefore, additional temperature increase during the RAD task likely helped offset the performance decline. Although the CMJ and DJ indices significantly decreased following the RAD task (Table 2), this might reflect that repeated eccentric contractions impair eccentric force output more than concentric force output.[15]

While this study provides important insights into the role of eccentric strength and mechanical capacities in maintaining deceleration performance, several limitations should be acknowledged. Although the relationship between eccentric strength and early-phase deceleration performance decline was statistically significant, the association was moderate, suggesting that additional factors, such as cardiopulmonary function or technical adaptations may also contribute to performance deterioration during repeated deceleration tasks. Furthermore, while we infer that muscle damage and neuromuscular fatigue underpin the observed declines, direct measures of muscle damage (eg, creatine kinase levels, muscle imaging) were not collected, limiting mechanistic conclusions. Finally, the present study focused solely on a physically constrained deceleration task. In competitive settings, athletes frequently perform decelerations under unpredictable and cognitively demanding conditions, likely exacerbating performance decline. Future research should therefore investigate the interplay between eccentric strength, neuromuscular fatigue, and cognitive load on deceleration performance to better reflect sport-specific scenarios.

Practical Applications

The demonstrated relationship between eccentric strength and early-phase deceleration performance underscores the practical importance of targeted eccentric strength development for athletes exposed to frequent deceleration demands. A decline in early-phase deceleration not only impairs braking efficiency but may also compromise change-of-direction performance by increasing mechanical load in latter stages of deceleration. Consequently, eccentric-focused training interventions, such as eccentric squats, flywheel exercises, and deceleration-specific drills, may help athletes tolerate repeated eccentric loads encountered in competition. By enhancing eccentric capacity, athletes can improve their ability to maintain deceleration performance under fatigue, potentially optimizing overall game performance. Future longitudinal controlled trial are needed to confirm the causal link between eccentric-focused training and the ability to maintain deceleration performance.

Conclusions

In conclusion, the present study demonstrated that repeated deceleration tasks significantly impair deceleration performance, with the most pronounced decline occurring during early-phase of braking. The magnitude of this decline significantly associated with maximal eccentric strength, indicating that athletes with greater eccentric capacity are better able to maintain deceleration performance under repeated load. In contrast, maximal concentric strength showed no significant relationship with deceleration performance decline, suggesting that eccentric strength is a more critical determinant of an athlete's ability to sustain deceleration capacity in fatigue-inducing conditions.

Acknowledgments

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