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Acute and Short-Term Neuromuscular and Perceptual Responses to Isometric vs. Dynamic Strength Training in Youth Soccer Players: A Randomized Crossover Trial

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ABSTRACT

This study aimed to compare the short-term neuromuscular impairments resulting from a single session of isometric and dynamic strength training in youth soccer players. Twenty-one male youth soccer players (aged 16.8 ± 0.9 years) participated in this counterbalanced crossover trial, and were randomly assigned to a training sequence, starting with either a dynamic (3 sets of 4 repetitions of squats and deadlifts at 75% and 80% of 1RM, respectively) or an isometric training session (3 sets of 4 maximal 4-second repetitions of isometric squats and mid-thigh pulls) with protocols standardized for the number of exercises, sets, repetitions, and recovery intervals. A one-week washout period was allowed before participants switched training conditions. A repeated-measures ANOVA was used to assess the differences in countermovement jump (CMJ) height, bar velocity during half-squats, and perceived soreness and fatigue across different time points (baseline, 30 minutes, and 24 hours post-exercise). CMJ height was significantly greater in the isometric condition 30 minutes post-exercise compared to the dynamic condition ($d = 0.71$; $p < .001$). Additionally, the isometric condition exhibited significantly higher bar velocity 24 hours post-exercise ($d = 0.69$; $p < .001$). While no significant differences were detected in perceived soreness between groups at any time point, perceived fatigue was significantly reduced in the isometric condition at the 24-hour mark ($d = 0.70$; $p < .05$). These findings suggest that dynamic strength training may impair neuromuscular function to a greater extent than isometric training.

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Strength training is a key component of soccer players' physical conditioning (Darragi et al., 2024), aiming to enhance performance and reduce the risk of non-contact musculoskeletal injuries (Darragi et al., 2024; Lauersen et al., 2018). The timing of these sessions within a microcycle is strategically planned to maximize physiological adaptations—and therefore, performance—while minimizing potential interference with the demands of technical-tactical training sessions and matches. However, implementing strength training sessions during the microcycle often poses challenges, due to the need to balance neuromuscular adaptations with technical-tactical training and adequate recovery before competition (Lovell et al., 2018). Although fixture congestion is particularly relevant in professional soccer, youth academy players also require careful planning of training loads within the weekly planning, to optimize performance and minimize residual fatigue.

Within a microcycle, strength training sessions (e.g., eccentric exercises) are most often prescribed on match day minus four (MD-4), followed to a lesser extent by MD-3 and MD + 2 (Douchet et al., 2023). For instance, the study by Lovell et al. (Lovell et al., 2018) administered an injury prevention program based on eccentric exercise, suggesting that such programs should be implemented as early as possible within a microcycle to avoid compromising physical performance in subsequent matches.

Both dynamic strength training (DST) and isometric strength training (IST) are considered reliable methods for improving neuromuscular functional performance (Lum et al., 2023). However, the acute and short-term effects of these types of training on neuromuscular function and recovery remain unclear. Although both training modalities have been extensively investigated in isolation, direct comparisons of their acute recovery profiles using ecologically valid strength-training protocols in high-level youth soccer players remain scarce. Consequently, practitioners still lack evidence to support the selection of the most appropriate strength-training modality when rapid recovery is required within the weekly microcycle.

DST, in particular, is widely used to develop strength, power, and muscle hypertrophy (McLeod et al., 2024). This type of training involves concentric and eccentric muscle contractions throughout a range of motion (McLeod et al., 2024). Common exercises in soccer DST programs include squats, deadlifts, and hip thrusts, which may contribute to the development of lower-body strength (Styles et al., 2016; Zweifel, 2015)—crucial for actions such as jumping, sprinting, and change of direction (Boraczynski et al., 2020; Spiteri et al., 2014; Styles et al., 2016). However, the repeated concentric-eccentric contractions that are characteristic of DST may lead to muscular fatigue and soreness, potentially impairing

performance for 48–72 hours (Pareja-Blanco et al., 2017; Shigeta et al., 2023). These potential drawbacks raise concerns regarding the optimal placement of DST sessions within the weekly training schedule, as excessive residual fatigue may compromise the quality of subsequent technical-tactical sessions and readiness for competition (Drury et al., 2021; Nédélec et al., 2013).

Scheduling strength sessions within the weekly microcycle remains challenging because coaches must balance physical development with technical-tactical objectives while minimizing residual fatigue before competition (Lovell et al., 2018; Thorpe et al., 2017). Recent evidence also suggests that manipulating training structure, including exercise format, number of players, and bout duration, can influence both psychophysiological responses and technical performance, further emphasizing the importance of carefully optimizing training prescription within the weekly microcycle (Farhani et al., 2025). As a result, coaches often limit or eliminate the implementation of strength-based sessions throughout the microcycle, as the emphasis shifts toward optimizing recovery and reducing the risk of injury (or, in some instances, nonfunctional overreaching). Consequently, the optimization or maintenance of strength-related physical qualities might be compromised, potentially affecting long-term athletic performance (Rønnestad et al., 2011).

IST is gaining popularity and is being increasingly adopted as an alternative or complementary strength training modality (Lum et al., 2023). Isometric exercise involves producing maximal forces against an immovable resistance, without joint movement during the contraction (James et al., 2023). This approach has been suggested as an effective method for increasing strength, particularly at specific joint angles, while minimizing muscle fatigue (Lum & Barbosa, 2019). Therefore, the static nature of IST is hypothesized to reduce the acute neuromuscular impairments typically associated with eccentric-concentric loading (Tornero-Aguilera et al., 2022). Additionally, IST requires less technical proficiency, making it a reliable option for younger or beginner athletes, as well as for those recovering from injuries (Kadlec et al., 2024; Lum & Barbosa, 2019; Oranchuk et al., 2019). Despite its potential, IST has been underexplored in soccer training programs, possibly due to limited evidence supporting its acute and chronic effects on sports performance (Brynzak et al., 2023).

The distinction in acute neuromuscular responses between DST and IST holds particular significance in sports such as soccer, where athletes face elevated psychophysiological demands that affect their training outcomes and competitive performance (Brynzak et al., 2023; Nédélec et al., 2013). Effective recovery becomes crucial during periods of high-intensity training and competition, as compromised neuromuscular function can diminish performance and increase the risk of injury (Eckard et al., 2018; Nédélec et al., 2013). Research suggests that the neuromuscular impairments following strength training are influenced by various factors, including exercise modality, contraction type, volume, intensity, and individual training history (McLeod et al., 2024). DST has been shown to induce muscle soreness and fatigue due to high mechanical and metabolic demands (Pareja-Blanco et al., 2020; Shigeta et al., 2023). In contrast, IST is hypothesized to

be associated with less muscle damage and faster recovery (Allen et al., 2018), potentially enabling athletes to maintain performance levels during subsequent training sessions or competitions.

As such, this study aims to directly compare the acute and short-term impairments caused by both DST and IST on neuromuscular performance and subjective recovery markers in high-level youth soccer players. Specifically, this study analyzes changes in CMJ height, bar velocity during the half-squat exercise, and perceived soreness and fatigue up to 24 hours following strength training. We hypothesize that IST will lead to reduced neuromuscular impairment and perceptual responses compared with DST.

Methods

Participants

Twenty-one male youth soccer players (age: 16.8 ± 0.9 years; body mass: 71.7 ± 9.7 kg; height: 1.79 ± 0.10 m), competing in the Portuguese Under-19 top division Tier 3—according to the classification of McKay et al. (2022) were included in this study. On average, players completed 4 training sessions per week (approximately 8 hours in total) and played one competitive match per week.

As eligibility criteria, participants were required to be male, soccer players in the highest under-19 Portuguese division, be free from current or recent musculoskeletal injuries, and have completed all familiarization sessions. This study was approved by the University of Maia Ethics Committee (ID: 240/2024), and written informed consent was obtained from all participants and their legal guardians (if under 18 years of age) prior to participation. The protocol of the study was registered at ClinicalTrials.gov under the code NCT06692608.

Sample size was calculated a priori based on previous research (Lum & Howatson, 2023), assuming an effect size of $d = 0.87$ for CMJ height, with an α level of 0.05, and 80% statistical power (G*Power, version 3.1.9.7).

Experimental design

The study was conducted over three weeks and comprised five sessions. Participants were randomly assigned to one of two sequences, completing both the DST and IST protocols in a counterbalanced order separated by a one-week washout period. During the first week, participants completed familiarization sessions to ensure proper execution of all exercises and adaptation to both the DST and IST protocols.

In the second week, participants performed an experimental session to establish the load–velocity relationship for the squat and deadlift exercises. Progressive loads (~40%, ~60%, ~70%, and ~80% of estimated 1RM) were used, with two repetitions performed at each load. The mean velocity of the two repetitions was recorded for analysis, allowing for load prescription while minimizing fatigue.

These data were used to estimate the loads corresponding to specific bar velocities: $1 \text{ m}\cdot\text{s}^{-1}$ for testing, and $\sim 0.58 \text{ m}\cdot\text{s}^{-1}$ (squat) (Gantois et al., 2023) and $\sim 0.57 \text{ m}\cdot\text{s}^{-1}$ (deadlift) (Benavides-Ubric et al., 2020) for training. These velocities

corresponded to approximately 75% (half-squat) and 80% (deadlift) of 1RM. Although an initial target of 85% 1RM was considered, loads were reduced following pilot observations of suboptimal technique under higher intensities, prioritizing safe and consistent execution.

All sessions began with a standardized warm-up consisting of 5 minutes of low-intensity running, joint mobility exercises, core and lower-limb activation drills, and five submaximal countermovement jumps (CMJs).

During the intervention phase, the DST protocol consisted of 3 sets of 4 repetitions in the squat and deadlift exercises at ~75% and 80% of 1RM, respectively. During the half-squat exercise, participants were instructed to descend until the thighs were approximately parallel to the floor (~90° knee flexion) before performing the concentric phase as explosively as possible. Deadlift repetitions were performed from the floor using a conventional technique, ensuring full hip and knee extension at the end of each repetition. Participants were instructed to perform each repetition with an approximately 2-second eccentric phase followed by a 2-second concentric phase. This cadence was intended to provide a similar time under tension to the IST protocol (4 s per repetition), although it was guided by verbal instruction rather than objectively monitored. The IST protocol consisted of 3 sets of 4 maximal isometric contractions (4 seconds each) in the isometric squat knee flexion angle of 85–95° (Pareja-Blanco et al., 2020) and mid-thigh pull knee flexion angle of 125°–145° (Lum & Howatson, 2023) exercises. A 3-minute rest interval was provided between sets in both protocols.

Following each training session, participants underwent a 30-minute passive recovery period. Subsequently, subjective markers (DOMS and perceived fatigue and exertion) and neuromuscular performance (CMJ height and bar velocity in the squat using individualized loads) were assessed. The same test battery was repeated 24 hours post-exercise.

Assessment procedures

Countermovement jump

Countermovement jump height was assessed using an A3-sized Chronojump mat (Boscosystem, Barcelona, Spain). Each athlete performed 3 attempts, and the highest jump was considered for subsequent analysis (Al Haddad et al., 2015). Before jumping, participants started in an upright position with their hands on their hips and their feet hip-to-shoulder width apart. During the jump, they were instructed to rapidly squat using a preferred countermovement depth and jump as high as possible, while maintaining full ankle, knee, and hip extension during the flight and their hands on the hips throughout the movement. Each jump was interspersed with one minute of passive rest.

Bar velocity

The bar's mean propulsive velocity (MPV) was measured using the Vitruve wireless linear encoder (Speed4lift, Madrid, Spain) with a sampling frequency of 100 Hz. The device was connected to its respective application (version: 4.29.2), which was installed on an iPhone 12 (Apple Inc., Cupertino, CA, USA).

To assess neuromuscular fatigue, the individual load that elicited a MPV of approximately $1 \text{ m} \cdot \text{s}^{-1}$ was determined for each participant during the pre-intervention dynamic squat test, following established procedures (Sánchez-Medina & González-Badillo, 2011). This individualized load was then used as a reference in all subsequent post-intervention assessments (30 min and 24 h). A reduction in bar velocity against this absolute load, compared to baseline, was interpreted as an indicator of neuromuscular fatigue, in line with the well-documented relationship between velocity loss and fatigue accumulation (Sánchez-Medina & González-Badillo, 2011). Conversely, the maintenance or increase of velocity for the same load would suggest a fully recovered or potentially potentiated state. Athletes were verbally encouraged to exert maximal concentric effort during every repetition to ensure the validity and reliability of the velocity measurements.

Perceptual responses

Perceived fatigue was assessed using the Rate of Fatigue (RoF) scale. Briefly, this scale consists of five descriptors and five diagrams to help participants rate their fatigue. Players answered the question “How fatigued do you feel?” from 0 to 10 arbitrary units, ranging from “Not fatigued at all” to “Total fatigue and exhaustion; nothing left,” respectively (Barreira et al., 2025; Micklewright et al., 2017).

Perceived soreness was assessed using a 10-centimeter Visual Analogue Scale, anchored with the numbers 0 and 10 at the left and right ends, respectively (Cleather & Guthrie, 2007). Participants were asked to draw a perpendicular line with a pen at the point that better represented their soreness level. The rating corresponded, in arbitrary units, to the distance (in centimeters) between the beginning of the horizontal line and their mark.

Subjective ratings of perceived exertion (RPE) were collected 30 minutes after the DST and IST sessions using the CR-10 Borg Scale (Zhao et al., 2022).

Statistical analysis

Statistical analyses were conducted using R in RStudio. Data normality was checked using the Shapiro–Wilk test, and homogeneity of variances with Levene's test. To assess the effects of time and mode of exercise (dynamic vs. isometric), a 2 (condition) $\times$ 3 (time) repeated-measures ANOVA was conducted. Bonferroni adjustment was used as a post-hoc test, to assess the changes across time and mode of exercise, both between and within conditions. Effects sizes are reported as partial eta-squared (η^2) for the repeated-measures ANOVA ($\eta^2 \geq 0.01$: small effect; $\eta^2 \geq 0.06$: moderate effect; and $\eta^2 \geq 0.14$: large effect) and as Cohen's d (d) for pairwise comparisons (<0.20: trivial effect; 0.20 to 0.49: small effect; 0.50 to 0.79: moderate effect; and ≥ 0.80 : large effect) (Maher et al., 2013). To assess the differences in perceived exertion across conditions, a paired-samples t-test was conducted. A *p*-value of 0.05 was considered as the threshold to detect statistical significance. The assumption of sphericity was assessed using Mauchly's test.

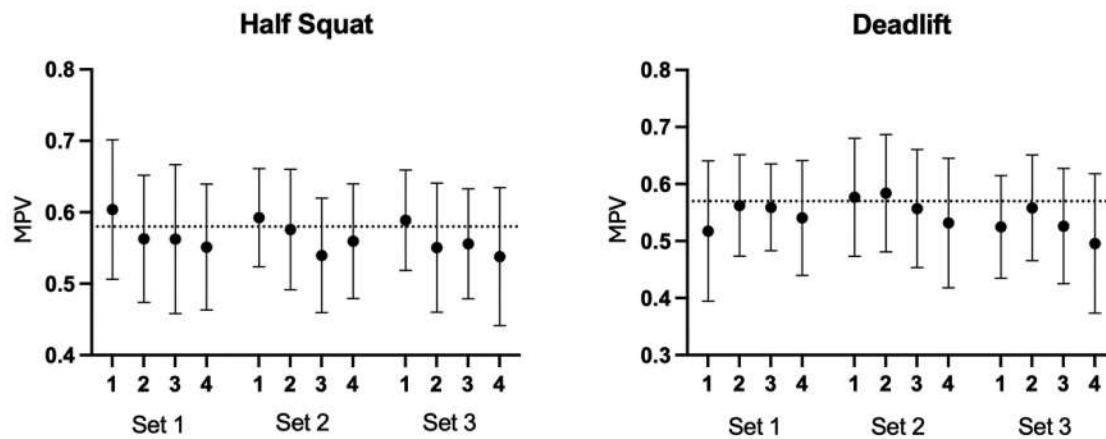


Figure 1. Bar velocities during half-squat and deadlift exercises. Dots represent means and vertical lines represent standard deviations. *Note.* MPV = mean propulsive velocity.

Results

The average MPV at which deadlift and squat exercises were performed during the DST protocol is displayed in (Figure 1).

Countermovement jump height showed significant main effects of time ($F = 33.9$; $p < .001$; $\eta^2 p = .453$), group ($F = 16.6$; $p < .001$; $\eta^2 p = .288$), and the time $\times$ group interaction ($F = 11.0$; $p < .001$; $\eta^2 p = .211$). Specifically, significant differences between groups were observed in the 30-minute post-exercise time point (DST: 35.1 ± 5.17 cm vs IST: 38.6 ± 4.72 cm; $d = 0.71$; $p < .001$), but not at 24 hours post-exercise (DST: 38.3 ± 4.67 vs IST: 39.2 ± 5.23 cm; $d = 0.18$; $p = 1.00$).

For bar velocity at the load eliciting a MPV of approximately $1 \text{ m} \cdot \text{s}^{-1}$ a significant effect of time ($F = 13.88$; $p < .001$; $\eta^2 p = .253$), group ($F = 18.58$; $p < .001$; $\eta^2 p = .312$), and time $\times$ group interaction ($F = 4.24$; $p = .018$; $\eta^2 p = .094$) was identified. Post-hoc tests identified significant differences between groups at the 24-hour time point (DST: $0.95 \pm 0.11 \text{ m} \cdot \text{s}^{-1}$ vs IST: $1.02 \pm 0.09 \text{ m} \cdot \text{s}^{-1}$; $d = 0.69$; $p < .001$), but not at the 30-minute time point (DST: $1.01 \pm 0.06 \text{ m} \cdot \text{s}^{-1}$ vs IST: $1.04 \pm 0.10 \text{ m} \cdot \text{s}^{-1}$; $d = 0.36$; $p = .40$).

Delayed onset of muscle soreness showed significant variation over time. Significant main effects were observed for time ($F = 42.03$; $p < .001$; $\eta^2 p = .519$) and group ($F = 6.57$; $p = .014$; $\eta^2 p = .144$), whereas no significant group $\times$ time interaction was detected ($F = 1.84$; $p = .166$; $\eta^2 p = .045$).

Regarding perceived fatigue, significant main effects were observed for time ($F = 95.55$; $p < .001$; $\eta^2 p = .700$), group ($F = 4.43$; $p = .041$; $\eta^2 p = .098$), as well as a significant time $\times$ group interaction ($F = 3.35$; $p = .040$; $\eta^2 p = .076$). Specifically, significant between-group differences were observed at the 24-hour time point (DST: 4.05 ± 1.86 AU vs IST: 2.81 ± 1.63 AU; $d = 0.70$; $p = .024$), favoring the IST group (i.e. lower RoF), whereas no significant differences were identified at the 30-minute time point (DST: 4.57 ± 2.08 AU vs IST: 4.52 ± 2.15 AU; $d = 0.02$; $p = 1.00$).

Finally, perceived exertion did not vary significantly across groups (DST: 6.48 ± 1.79 AU vs IST: 5.90 ± 2.11 AU; $d = 0.29$; $p = .11$), which might indicate participants perceived both training sessions as similarly demanding, despite the inherent mechanical differences between the two training modalities.

Mauchly's test indicated that the assumption of sphericity was met for all outcome variables (all $p > .05$). The graphical synthesis of the results is displayed in (Figure 2).

Discussion

This study compared the acute and short-term effects of IST and DST on the recovery kinetics (i.e., neuromuscular performance and perceptual responses) of youth soccer players. Our findings revealed that IST induced less neuromuscular impairment compared to DST. Specifically, IST resulted in less neuromuscular impairment, as evidenced by higher CMJ performance at 30 minutes post-exercise and greater MPV during the half-squat at 24 hours post-exercise. Furthermore, IST was associated with lower RoF 24 hours post-exercise. Additionally, the absence of significant differences in RPE between conditions suggests that the training load was perceived as similar, strengthening the notion that loads across conditions were comparable.

One key observation was the significant reduction in CMJ height following DST at the 30-minute post-exercise time point, compared to IST. This is likely explained by the greater mechanical and metabolic demands associated with repeated eccentric-concentric muscle actions in DST (Schoenfeld, 2013; Spiering et al., 2023). Specifically, eccentric loading has consistently been associated with greater muscle damage, inflammatory responses, and transient impairments in neuromuscular function than training modalities that minimize muscle lengthening under load, although these responses depend on the exercise characteristics and training status of the participants (Cairns & Borrani, 2015; Chaabene et al., 2026; Lum & Barbosa, 2019). In contrast, IST relies solely on static contractions, which appear to limit the degree of muscle damage and maintain neuromuscular function shortly after exercise (Lum & Barbosa, 2019). This may offer a practical advantage when minimizing residual fatigue is desirable, particularly during the latter stages of the weekly microcycle or on training days preceding competition. From a physiological perspective, the lower neuromuscular impairment observed after IST is likely multifactorial. Besides the lower exposure

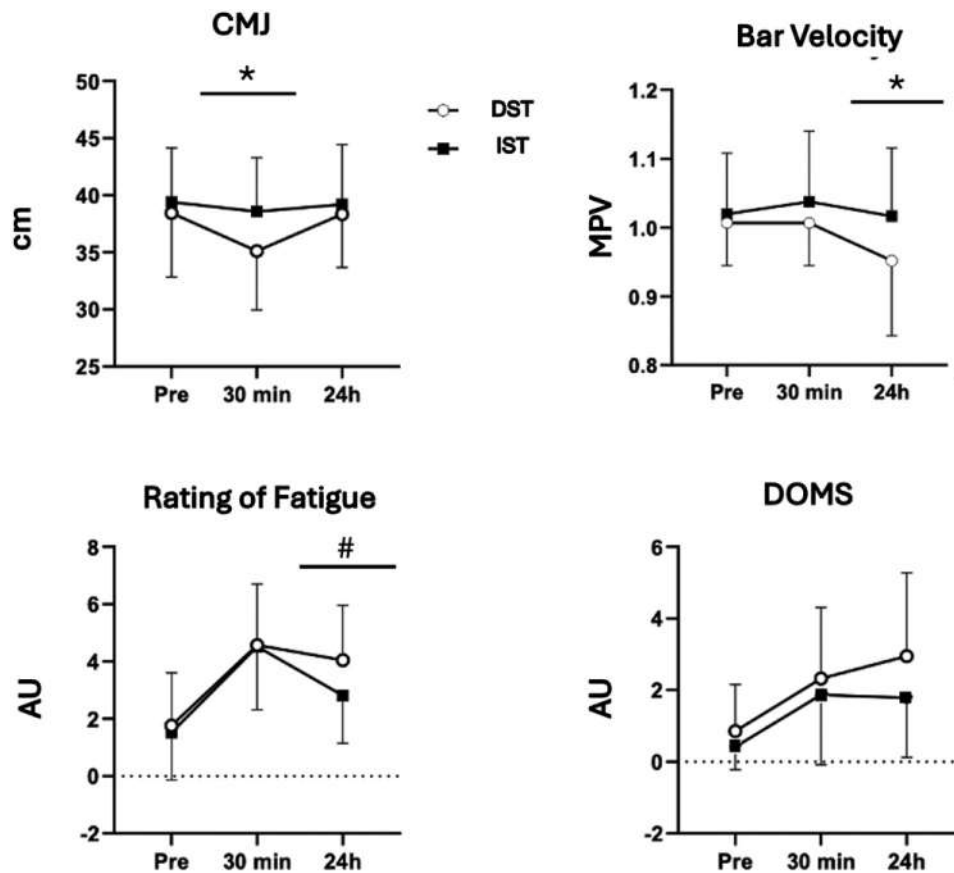


Figure 2. Graphical summary of the results. Note. DST = dynamic strength training; IST = isometric strength training; MPV = mean propulsive velocity; cm = centimeters; AU = arbitrary units. Statistical significance between groups at each time point: * represents $p < .001$ and # represents $p < .05$. Dots represent means and vertical lines represent standard deviations.

to eccentric loading, isometric contractions involve minimal muscle length changes, which may reduce mechanical disruption of muscle fibers and contribute to a faster restoration of force-producing capacity (Oranchuk et al., 2019). Nevertheless, because no mechanistic assessments were included in the present study, these explanations should be regarded as plausible rather than definitive.

Bar velocity during the half-squat provided further insight into the recovery time course following both training modalities. Specifically, the reduction in bar velocity observed 24 hours after DST indicates that neuromuscular performance had not fully recovered at this time point (Lum & Barbosa, 2019). In contrast, the maintenance of bar velocity following IST may reflect a lower degree of residual fatigue, potentially due to the absence of eccentric loading and the associated muscle damage (Barreira et al., 2024; Macintosh & Rassier, 2002; Moura et al., 2024). From an applied perspective, maintaining movement velocity against a standardized absolute load is particularly relevant because velocity loss is considered a sensitive indicator of neuromuscular readiness (Barreira et al., 2024). Consequently, the superior maintenance of MPV following IST may indicate a greater readiness to perform subsequent explosive or strength-oriented training sessions (Barreira et al., 2024). These findings may therefore assist practitioners in selecting strength training modalities according to the available recovery time within the weekly microcycle. More broadly, recent evidence suggests that optimizing

the structure and loading characteristics of training interventions in youth athletes can positively influence neuromuscular performance and training quality, reinforcing the importance of carefully selecting exercise modalities according to the objectives and timing of the weekly microcycle (Cherni et al., 2025).

The present findings partially contrast with previous literature (Barreira et al., 2024), in which CMJ performance required a longer recovery period than half-squat MPV following official soccer matches. However, this discrepancy may be explained by the substantially different physiological demands imposed by competitive match play compared with an isolated strength training session. Moreover, because no direct physiological assessments (e.g., electromyography, twitch interpolation, or muscle damage biomarkers) were performed in the present study, the mechanisms underlying the different recovery patterns observed for CMJ and MPV cannot be determined with certainty. These interpretations should therefore be considered exploratory and confirmed by future studies incorporating mechanistic assessments.

Moreover, although no statistically significant between-condition differences were observed in perceived muscle soreness, IST demonstrated numerically lower DOMS values than DST, particularly at 24 hours. While the observed effect size at this time point was moderate ($d = 0.59$), the absence of a statistically significant interaction precludes firm conclusions regarding the superiority of one training modality over the

other. Therefore, these findings should be interpreted cautiously.

Perceived fatigue (i.e., RoF) was significantly higher following DST at the 24-hour mark. This aligns with previous research indicating that dynamic contractions, involving eccentric-concentric loading, can induce a prolonged inflammatory response and delayed recovery (James et al., 2023). In contrast, the static nature of IST appears to mitigate these effects, possibly due to a reduced dependence on stretch-shortening cycles, which are more demanding on the musculotendinous unit (Lum & Barbosa, 2019; Lum & Howatson, 2023). From a practical point of view, our results highlight the potential of IST as a reliable alternative to DST in scenarios where rapid recovery is essential. These findings may assist practitioners in organizing strength training within the weekly microcycle. Importantly, these findings do not suggest that IST should replace DST. Rather, they indicate that both training modalities may have complementary roles within the weekly microcycle depending on the desired balance between strength stimulus and recovery. For example, when sufficient recovery time is available (e.g., MD-4), DST may remain the preferred option because of its well-established benefits for maximal strength, power, and hypertrophy adaptations (McLeod et al., 2024). Conversely, when strength training must be scheduled closer to competition (e.g., MD-2 or MD-1) or alongside demanding technical-tactical sessions, IST may represent a practical alternative to provide a strength stimulus while minimizing residual neuromuscular fatigue (Lum & Barbosa, 2019). Similarly, during periods of fixture congestion, implementing IST may help athletes maintain performance while continuing strength training routines (Lum & Barbosa, 2019). However, it is important to note that the chronic adaptations to IST may differ from those of DST, particularly regarding hypertrophy and dynamic strength gains, which may limit its long-term applicability as a standalone training method (Byrne & Eston, 2002; Kadlec et al., 2024; Lum et al., 2023). Nevertheless, these practical recommendations should be interpreted cautiously, as the present study isolated the strength training stimulus and did not include the technical-tactical training loads typically encountered during a competitive microcycle. Future studies should therefore investigate these training modalities under more ecologically valid conditions.

Despite the relevance of the findings presented in this study, several limitations should be acknowledged. First, the sample comprised only youth male soccer players, limiting the generalizability of the findings to other populations or age groups. Second, although both protocols were prescribed at high relative intensities and elicited similar ratings of perceived exertion, internal load was not directly equated between conditions. Metrics such as total mechanical work, impulse, or time under tension were not quantified, which limits our ability to fully disentangle the effects of contraction mode from those of overall session demand. In addition, although participants were instructed to perform the eccentric and concentric phases using an approximately 2-second cadence, movement tempo was guided verbally rather than objectively monitored. Consequently, slight variations in time under tension may have occurred, limiting the direct comparability with

the strictly timed 4-second isometric contractions. Third, only the acute and short-term responses to a single training session were examined; therefore, no conclusions can be drawn regarding the long-term adaptations associated with repeated exposure to either training modality. Moreover, dietary intake and sleep quality were not controlled, and both factors may have influenced recovery kinetics and subsequent neuromuscular performance. Finally, although the selected outcome measures are widely accepted and commonly used in applied sport science, they provide only indirect information regarding the physiological mechanisms underlying fatigue. The inclusion of physiological assessments, such as electromyography (Sun et al., 2022), muscle damage biomarkers (e.g., serum creatine kinase activity) (Baird et al., 2012), or assessments such as low-frequency fatigue (Maia et al., 2025), would have enabled a more comprehensive characterization of the neuromuscular responses to both training modalities. Future research should therefore examine the chronic adaptations to isometric and dynamic strength training while integrating mechanistic assessments to better elucidate the physiological basis of the observed responses. Furthermore, investigating the strategic implementation of these training modalities across different phases of the competitive microcycle may help practitioners optimize performance development while minimizing residual fatigue.

Conclusions

This study demonstrated that IST induced less neuromuscular impairment and perceived fatigue compared to DST in youth soccer players. The reduced demand of IST seems to facilitate recovery while allowing the maintenance of strength training practices. These findings suggest that IST may be a promising modality for periods requiring rapid recovery, offering a practical alternative or complement to DST in athletic training. We suggest that coaches and practitioners incorporate IST strategically to optimize recovery and performance, especially in highly demanding training or competitive periods.

Ethics approval

Approved by the university of Maia Ethics Comitee (code 240/2024).

Protocol Registration: ClinicalTrials.gov under the code NCT06692608.

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