

Research article

The Effectiveness of Passive Half-Time Interventions on Simulated Second-Half Performance in Elite Youth Soccer Players

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Abstract

The half-time period in soccer provides a potentially important window to implement short-duration interventions aimed at maintaining second-half performance. However, passive rest has been associated with a decline in subsequent physical and technical performance. While re-warm-up strategies are well studied, little is known about the efficacy of technology-based, passive recovery modalities, device-supported interventions that require minimal active movement or physical exertion from the athlete, during half-time intervals. This study examined whether percussive therapy, electrical muscle stimulation, and pneumatic compression can mitigate second-half performance decline in male adolescent soccer players. Forty-three academy-level players (17.5 ± 0.6 years) completed a simulated soccer protocol including the Loughborough Soccer Pass Test (LSPT), repeated 20-meter sprints, and completed Total Quality of Recovery (TQR) assessments before and after half-time. Participants were randomized into one of four intervention groups during the 15-minute half-time interval: Passive Rest (CON), Percussive Therapy (Theragun Pro; TG), EMS (PowerDot; PD), and Pneumatic Compression (RecoveryAir; COMP). Linear mixed-effects models assessed Time $\times$ Condition interactions for performance and recovery outcomes. Passive half-time rest led to significant deterioration in technical skill, sprint performance, and perceived recovery ($p < .05$) for the control group. TG and PD significantly improved technical performance (LSPT scores) compared to the control group ($d = 0.65$ and 0.72 , respectively; $p < .01$). Furthermore, TG and COMP were effective at maintaining 20-meter sprint times ($d = 0.58$ and 0.49 ; $p < .01$), whereas the control group experienced significant slowing. Perceived recovery (TQR) scores significantly declined in the CON group from First Half to Second Half (16.5 ± 2.2 to 11.1 ± 2.3). However, this decline was significantly attenuated in all intervention groups: TG (17.5 ± 1.9 to 14.2 ± 1.9), PD (17.3 ± 1.9 to 15.1 ± 1.9), and COMP (17.6 ± 1.9 to 15.9 ± 2.0). Short-duration passive interventions during half-time can mitigate performance decline in adolescent soccer players. TG and EMS appear most effective for preserving technical skills, while COMP may support perceived recovery. These findings highlight practical strategies for optimizing in-game performance and inform evidence-based half-time protocols.

Key words: Soccer performance, half-time recovery, compression therapy, percussive therapy, EMS therapy, athlete recovery, adolescent, youth academy, simulated match.

Introduction

Soccer is an intermittent team sport characterized by repeated high-intensity locomotor actions interspersed with lower-intensity activity, alongside the continual execution

of technical skills under dynamic match conditions. Half-time represents an enforced cessation of activity that permits partial recovery of cardiorespiratory and metabolic function, during which passive rest can result in simultaneous alterations in thermal state, neuromuscular performance, and athletes' perceptual and cognitive strategies for the subsequent exercise bout (Russell et al., 2015). Performance in elite soccer is characterized by two distinct patterns of decline: a progressive general second-half decline and an immediate post-half-time 'dip' (Mohr et al., 2004; Russell et al., 2015; Franceschi et al., 2025). The general decline is typically observed throughout the second half and is primarily attributed to cumulative fatigue resulting from; (Marqués Jiménez et al., 2017; Mohr et al., 2004). In contrast, the immediate post-half-time dip occurs specifically within the first 5 - 15 minutes of the second half (Mohr et al., 2004). This transient 'slump' in sprint performance and technical execution is uniquely driven by a reduction in muscle and core temperature during the 15-minute passive half-time interval, rather than by long-term energy depletion.

Given the reported deterioration in second-half performance, recent studies have highlighted the importance of halftime strategies in professional soccer (re-warm-up, heat maintenance, nutrition/hydration), particularly for maintaining muscle temperature and performance (Iwahashi et al., 2023; Abreu et al., 2025; Bang and Park, 2022; Abade et al., 2017). The most investigated strategies include implementing a re-warm-up, typically involving 3 - 7 minutes of dynamic, sport-specific exercise to maintain muscle temperature (Abreu et al., 2025; Abade et al., 2017; Lovell et al., 2013a; Bang and Park, 2022); however, the practical implementation of these strategies is limited due to the constraints of space and time. Additionally, hydration and nutritional strategies such as the ingestion of carbohydrates and caffeine to support energy metabolism and central nervous system function help to improve second half performance (Russell et al., 2015). The relative efficacy and logistical challenges of implementing these diverse physical and physiological preparation tools in the high-pressure environment of competition, amid technical and tactical priorities, remain key challenges for coaches and sports scientists.

The half-time period in soccer presents an important, yet time-constrained, opportunity for players to engage in a range of strategies aimed to enhance performance before competition resumes while allowing coaches the opportunity to communicate tactical, motivational, and

personnel changes. Traditional passive rest during this 15-minute break has consistently been shown to negatively impact second-half performance, unless combined with hydration and nutritional strategies; (Russell et al., 2015; Lovell et al., 2013b; Zois et al., 2013). Primarily, a reduction in muscle temperature has been shown to lead to subsequent decrements in physical performance during high-intensity actions such as sprint speed and jump height (Mohr et al., 2004; Russell et al., 2015). These findings warrant further investigation and consideration of passive half-time routines, as well as the exploration of more effective strategies to optimize second-half performance.

Modalities such as percussive therapy, electrical muscle stimulation, and pneumatic compression are most commonly implemented following training or match play as part of post-exercise recovery routines (Calleja-González et al., 2021). However, given their passive nature and minimal physical demands, these interventions may also have potential application during the half-time period as strategies to attenuate the usual second-half performance decline. Recent research on the effects of percussive therapy has shown that it increases blood flow and alleviates pain (Sams et al., 2025; Sams et al., 2023). Electrical muscle stimulation increases blood flow and reduces inflammation (Sañudo et al., 2020; Babault et al., 2011). Pneumatic compression can also increase blood flow and decrease muscle stiffness (Artés et al., 2024; Nuell et al., 2025). To the authors' knowledge, no research exists on the use of these modalities during soccer half-time. Understanding the effectiveness of these modalities during the half-time period may offer valuable insights into reducing performance deterioration.

Given the growing emphasis on optimizing performance in academy-level soccer players and the limited research on half-time recovery, this study investigates the impact of different half-time recovery modalities on the second-half performance of adolescent male soccer players. By exploring how athletes use tools such as percussive therapy, electrical muscle stimulation, and pneumatic compression during this critical recovery window, this research seeks to provide practical insights to enhance performance outcomes and inform evidence-based recommendations for adolescent-level competition.

Methods

Participants

Forty-three ($n = 43$) male participants were recruited via sampling from Northampton Town Football Club Academy teams, with club approval obtained prior to the start of the study (Table 1). Participants were informed that study involvement would not affect team selection. Prior to testing, all players (and parent/guardians, if applicable) received an information sheet, consent form, and PAR-Q.

Ethical approval was granted by the Sport and Exercise Ethics Committee at the University of Northampton, and the study was conducted in accordance with the Declaration of Helsinki, except for the registration of the study in a public database.

Participants were excluded where any existing or recent (within the last 2-months) lower limb injury had been sustained, or any pre-existing contraindications to any of the interventions (as detailed by the manufacturer) were reported.

Study design

A single-blind, independent-subject design, randomized controlled trial was conducted. Participants were blinded to performance outcomes until testing concluded. Twenty-four hours prior to the test conditions, all participants completed a familiarization session. To establish test-retest reliability, two attempts at the Loughborough Soccer Pass Test (LSPT) were completed, reporting good reliability ($ICC = 0.87$) against the error scores attained, three 20-meter sprints, and self-administered interventions (Le Moal et al., 2014). Prior research supports the need for at least one familiarization session to ensure valid LSPT results (Yaşlı et al., 2026).

Participants were then randomly assigned (via computerized random number generation) to one of four half-time intervention groups: (1) Control group of passive rest (CON), (2) Percussive Therapy (Theragun PRO 4th Generation, Therabody Inc, California, US; TG), (3) Electrical Muscle Stimulation (PowerDot, Therabody Inc, California, USA; PD), (4) Pneumatic Compression (RecoveryAir PRO, model 737R, Therabody Inc, California, USA; COMP). Participants were blinded to all other conditions and only familiarised to the intervention of their allocation.

Simulated soccer match

The simulation included a warm-up, the Loughborough Soccer Pass Test (LSPT) (Figure 1), and repeated sprints to replicate the physiological demands of a soccer match (Bradley et al., 2010). Fifteen 20-meter sprints were used to approximate typical match sprint distances, 200 - 800m (Osgnach et al., 2010).

Warm-Up: Participants completed a 5-minute RAMP protocol targeting sprint- and kick-related muscles (e.g., quadriceps, hamstrings, glutes) (Pandy et al., 2021; Baczkowski et al., 2006).

Loughborough Soccer Pass Test (LSPT): The LSPT is reported as a valid and reliable test used to screen interactive stimuli associated with footballing ability by challenging skills such as passing, dribbling, ball control, and decision-making (Le Moal et al., 2014). The LSPT was performed twice, once at the beginning of each simulated half. Figure 2 displays the setup. LSPT total-performance was the primary outcome of interest.

Table 1. Demographics by group.

Outcome	Condition			
	CON (n = 14)	TG (n = 10)	PD (n = 11)	COMP (n = 8)
Age (yrs)	17.4 ± 0.5	17.5 ± 0.06	17.5 ± 0.6	17.7 ± 0.7
Weight (kg)	66.8 ± 2.9	65.3 ± 3.5	66.3 ± 3.2	67.1 ± 2.7
Height (cm)	179.2 ± 3.91	176.3 ± 5.14	178.1 ± 4.22	179.6 ± 3.07

CON = Control; TG = Theragun Pro Gen 4; PD = PowerDot 2.0; COMP = Therabody Recovery Air 1st generation

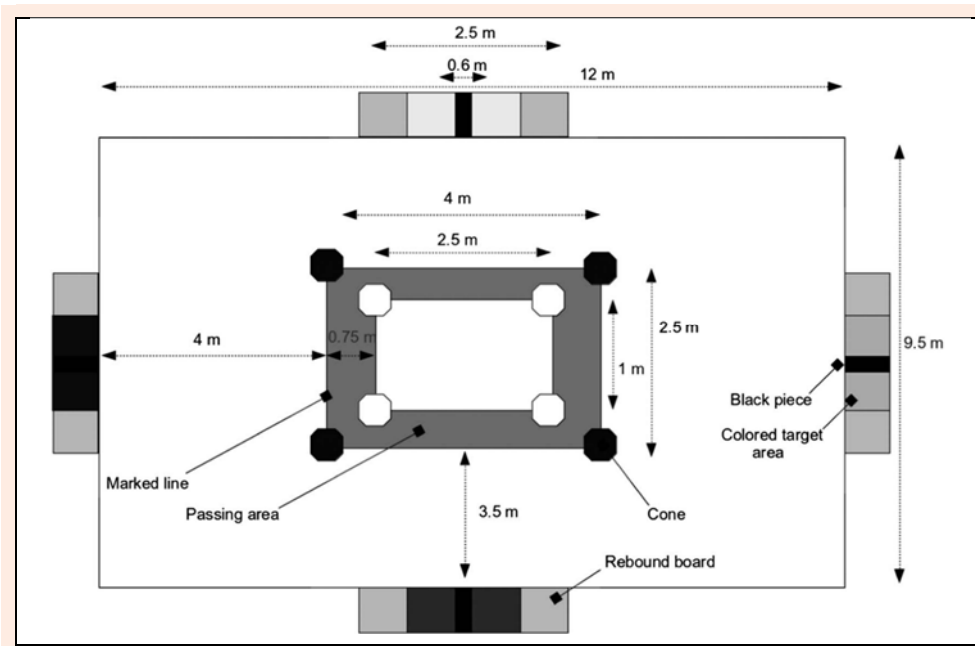


Figure 1. LSPT Design / Layout (Impellizzeri et al., 2008). The area measured was 12 x 9.5m with benches placed on each border. Each bench features a coloured target measuring 30 x 60cm, which participants were instructed to aim for. A 10cm strip was marked in the centre of the coloured target signifying a perfect pass, rewarded with 1-second taken from their penalty score. Inside the area is a passing zone measuring 0.75m in width surrounding a central dribbling zone measuring 2.5 x 1m. Participants were required to perform sixteen-passes in a clockwise direction as fast and accurate as possible.

A meaningful attenuation of decline was defined statistically as a small-to-medium standardized effect size (Cohen's $d = 0.20 - 0.50$) and practically as any reduction in performance decay that maintains a player's passing accuracy and sprint capability closer to their baseline (first-half) standard, which could influence critical in-game transitional moments during the opening stages of the second half.

Three performance metrics were recorded: 1) LSPT-time (duration to complete 16 passes, excluding

penalties), 2) LSPT penalty-time (cumulative time from errors), and 3) LSPT total-performance (sum of LSPT-time and penalty-time) (Impellizzeri et al., 2008). LSPT total-performance was the primary outcome of interest. Penalties were assigned as follows: 5 seconds for missing the bench or passing to the wrong target, 3 seconds for missing the target or handling the ball, and 2 seconds for passing outside the designated area or contacting a cone (Le Moal et al., 2014).

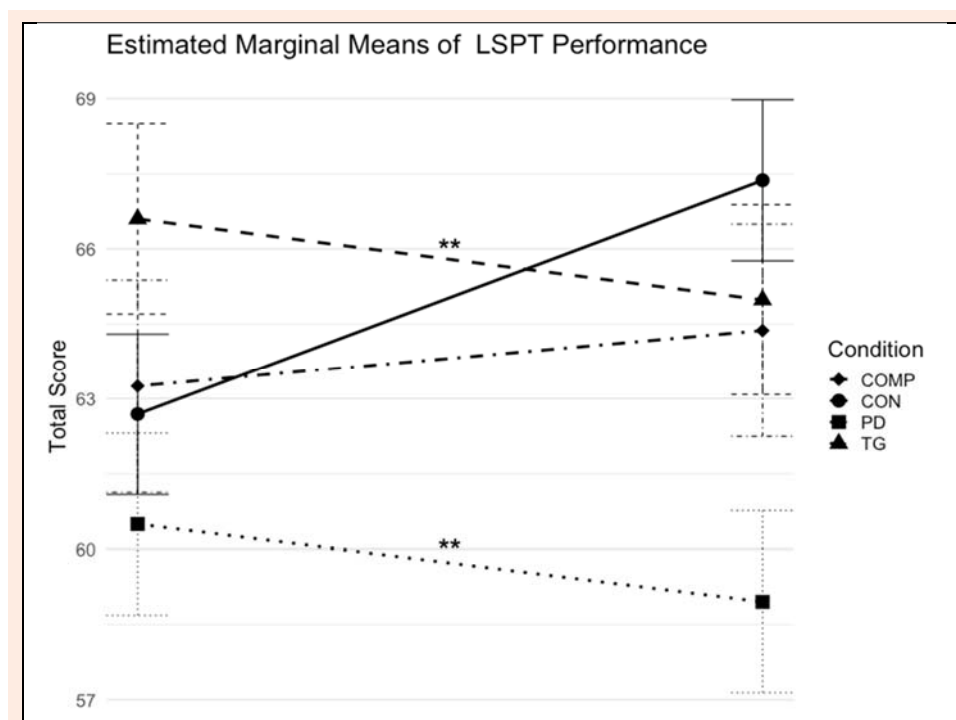


Figure 2. LSPT performance estimated marginal means.

Sprint Performance and Heart Rate: To simulate typical match play demands (Ingebrigtsen et al., 2015). Participants completed fifteen 20-meter sprints, measured using Brower TCi timing gates, with 30 seconds of rest between each sprint. Sprints began from a standing start 30 cm behind the gate. Heart rate (HR) was continuously monitored using a Polar T31 chest strap and recorded after each sprint. Mean sprint time (s) and HR (bpm) were calculated for pre- and post-intervention sessions. Sprints were performed immediately following the LSPT.

Total Quality of Recovery (TQR)

TQR, a non-invasive measure of perceived recovery, was recorded before each half of simulated play. Scores range from 6 to 20, with 6 representing poor (very, very low) recovery and 20 indicating maximal (very, very good) recovery, like Borg's RPE scale for which participants were asked "how would you rate your overall recovery?". TQR was collected after first-half testing (pre-intervention) and after second-half testing (post-intervention), based on prior associations with muscle damage biomarkers (Osiecki et al., 2015).

Interventions

Control Group (CON): Participants rested passively for 15 minutes without doing any stretching or reactivation.

Theragun Percussive Therapy Group (TG) (Skinner et al., 2023; Sams et al., 2023; Sams et al., 2025): Remaining within close view of the researcher participants self-applied TG with dampener head at a frequency of 2400 rpm (40Hz), force level 1 - 2 (7 - 16lbs). Application speed was paced metronomically at one length of the muscle (origin to insertion) every 2-seconds. The 8-minute treatment involved applying the Theragun for one minute to each muscle group (calves, quadriceps, hamstrings, and gluteals) on each lower limb. Participants then performed a 7-minute seated rest, to match the 15-minute half-time parameter.

Electrical Muscle Stimulation Power Dot Group (PD) (Sañudo et al., 2020; Babault et al., 2011): Electrode placement was surface-marked by the researcher on the hamstrings and quadriceps prior to the start of the study, following the standardized protocol detailed in the supplementary material. In the PD mobile application, participants selected the "Light Recovery Mode" and increased the stimulation intensity to a level of tolerable comfort at which visible muscular twitching was present. This mode has a continuous 1Hz frequency, pulse width of 208µs, and a biphasic rectangular alternating current waveform with zero mean (under load). The mean stimulation intensity applied was $37.6 \pm 2.7\%$ for the quadriceps and $42.5 \pm 1.2\%$ for the hamstrings, this corresponds to a stimulation amplitude of $48.9 \pm 3.5\text{mA}$ for the quadriceps and $55.3 \pm 1.6\text{mA}$ for the hamstrings. The 10-minute intervention consisted of continuous stimulation of each muscle group, followed by a 5-minute seated rest period during which electrodes were removed.

Therabody Pneumatic Compression Boot group (COMP) (Nuell et al., 2025; Artés et al., 2024): Participants selected the "Recover" mode with compression set at 100mmHg for 10 minutes with hold periods of 10-seconds release periods of 5-seconds and the gradient set at 100 in the most distal chamber, decreasing to 99, 98, 97 within

each chamber proximally. Inflation commenced at the most distal section (foot) before sequentially inflating proximally up to the upper thigh. This was followed by 5 minutes of seated rest, to match the 15-minute half-time parameter.

Upon completion of their assigned interventions, participants immediately returned to the testing location for completion of the second half performance. This was repeated identically as described above.

Statistical analysis

Analyses were conducted in RStudio (v2024.09.0+375) using linear mixed-effects models (LMMs) via the lmerTest package. Outcome variables included sprint time, HR, LSPT metrics, and TQR. Fixed effects were Time (first vs. second half), Condition (CON, TG, PD, COMP), and their interaction. A random intercept for 'Participant' was included to account for the nested structure of the repeated measures (First Half vs. Second Half) and to control for the inherent inter-individual variability in baseline technical skill and physical capacity.

The primary focus was the Time $\times$ Condition interaction to assess intervention effects on second-half performance. Significance was set at $p = .05$. To control for the increased risk of Type I errors associated with multiple outcome measures and post-hoc comparisons, a Bonferroni-Holm adjustment was applied to all p-values. This ensures that the cumulative alpha level across the study remains at 0.05, providing a conservative and rigorous threshold for claiming statistical significance. Post hoc comparisons used estimated marginal means (EMMs), with Cohen's d calculated for effect size. Standardized mean differences (Cohen's d) were calculated to quantify the magnitude of the intervention effects. To ensure a conservative and stable estimate, d was standardized using the pooled baseline (First Half) standard deviation rather than model-based residuals. Confidence intervals (95% CI) were calculated for both the raw interaction estimates and the standardized effect sizes to illustrate the precision of the observed effects and their practical relevance to elite soccer performance. Both performance improvements and reduced declines were considered beneficial. Data visualizations were created using ggplot2, and descriptive statistics (means $\pm$ SD) are reported for all outcomes.

Results

To ensure the study was adequately powered to detect meaningful changes in performance, an a priori power analysis for a 4 (Condition) $\times$ 2 (Time) interaction was conducted. Based on an alpha of 0.05 and a power of 0.80, a minimum sample of $n = 36$ was required to detect a medium effect size ($f = 0.25$). Our final enrollment of $n = 43$ participants satisfies this requirement and provides sufficient degrees of freedom to rigorously estimate individual-level variance in our Linear Mixed-Effects Models (LMMs). This sample size, combined with the use of LMMs, ensures sensitivity to detecting nuances in halftime intervention efficacy.

Loughborough Soccer Pass Test (LSPT)

The mean percent change was calculated for all groups, and

a decrease in the overall LSPT score indicated better performance. The overall LSPT score increased for CON (7.47%) and COMP (1.77%), indicating deterioration. The overall LSPT score decreased for TG (-2.43%) and PD (-2.55%), indicating improved performance.

There was a significant main effect of Time, $b = 4.68$, $SE = 1.49$, $t(39) = 3.14$, $p = 0.003$, indicating a deterioration in performance from first to second half in the CON group. There were no main effects of conditions; all groups saw similar performance in the first half as the CON group. There was a Time $\times$ Condition interaction were found for PD group ($b = -6.22$, $SE = 2.25$, $t(39) = -2.77$, $p = 0.009$, $d = 0.39$) and (TG group: $b = -6.30$, $SE = 2.31$, $t(39) = -2.73$, $p = 0.010$, $d = 0.41$), these groups had less deterioration in performance than the control group in the second half. See figure 2.

For subscale speed, there was a Main effect of Time, $b = 1.97$, $SE = 0.67$, $t(39) = 2.93$, $p = 0.006$, with CON deteriorating. Time $\times$ Condition interaction for PD approached significance ($b = -1.96$, $SE = 1.01$, $t(39) = -1.94$, $p = 0.060$, $d = 0.10$), showing less deterioration. For subscale penalties, there was a Main effect of Time, $b = 2.71$, $SE = 1.10$, $t(39) = 2.46$, $p = 0.018$ (increase in CON). Main effect of Condition for TG, $b = 5.61$, $SE = 2.06$, $t(55) = 2.73$, $p = 0.009$ (higher baseline penalties). Time $\times$ Condition interactions indicated smaller increases for PD ($b = -4.26$, $SE = 1.66$, $t(39) = -2.56$, $p = 0.014$, $d = 0.53$) and TG ($b = -6.31$, $SE = 1.71$, $t(39) = -3.70$, $p < 0.001$, $d = 1.23$).

Heart rate during sprint performances

Heart rate: Mean percent change was calculated for all groups: CON (+3.09%), TG (+1.25%), PD (+1.96%), and COMP (+3.59%). A main effect of time, $b = 5.21$, $SE = 0.92$, $t(39) = 5.66$, $p < .001$, indicated increased heart rate in CON. A significant main effect of Condition $b = -8.89$,

$SE = 4.42$, $t(64.27) = -2.01$, $p = .048$, a lower heart rate in compression than control group. A significant Time $\times$ Condition interaction, $b = -3.11$, $SE = 1.43$, $t(39) = -2.18$, $p = .035$ $d = -1.34$. The TG group experienced a significantly smaller increase in heart rate than the control. No Time $\times$ Condition interaction occurred for PD and COMP (see Figure 3).

20-meter run: Mean percent change was calculated for all groups: CON (+2.34%) and PD (+1.64%), and COMP (+0.08%) and TG (-0.818%). There was a main effect of Time, $b = 0.066$, $SE = 0.017$, $t(39) = 3.97$, $p < .001$, time increased from first to second half in the CON. Within the key test of interest, Time $\times$ Condition, TG ($b = -0.091$, $SE = 0.026$, $t(39) = -3.58$, $p = .001$, $d = 0.56$) and COMP ($b = -0.064$, $SE = 0.028$, $t(39) = -2.30$, $p = .027$, $d = 0.07$) both had smaller increases in time in the 2nd half when compared to control. PD performance did not change significantly over time compared to control (see Figure 3).

Total Quality of Recovery (TQR)

Mean percent change was calculated for all groups, and higher TQR indicated a better perceived recovery. The TQR decreased in all groups: CON (32.5%), TG (18.9%), PD (12.6%), and COMP (9.93%). A significant main effect of Time, $b = -5.36$, $SE = 0.39$ $t(39) = -13.79$, $p < .001$, indicating that TQR scores decreased significantly from the first to the second half the CON group. No main effects of conditioning, indicating all group were similar in the first half. Time $\times$ Condition interactions were observed in all intervention groups, COMP: $b = 3.61$, $SE = 0.64$, $t(39) = 5.60$, $p < .001$ $d = 1.70$, PD: $b = 3.18$, $SE = 0.59$, $d = 2.12$, $t(39) = 5.42$, $p < .001$, and TG: $b = 2.06$, $SE = 0.60$, $t(39) = 3.42$, $p = 0.0015$, $d = 3.21$. The decrease in TQR was less pronounced in all interaction groups compared to the control (see Figure 4). All outcomes measures were presented in Table 2 and 3.

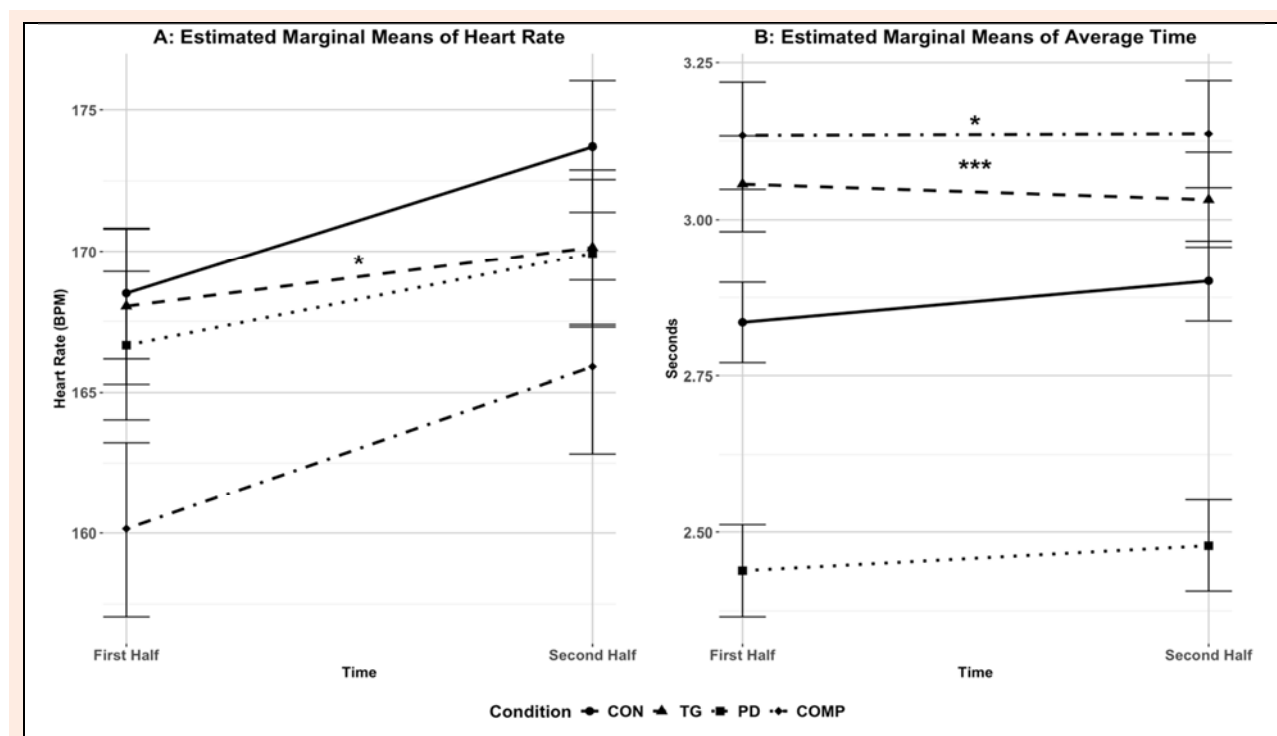


Figure 3. Heart rate estimated marginal means (A) and sprint performance (B).

Table 2. Mean and standard deviation ($\pm$) of all outcomes measures.

Group	20m Sprint				LSPT				TQR			
	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	Pre-Test	Post-Test
	HR (BPM)	HR (BPM)	Time (s)	Time (s)	Time (s)	Time (s)	Pen (NP)	Pen (NP)	Total (NP+s)	Total (NP+s)	(Score)	(Score)
Control	169 $\pm$ 11	174 $\pm$ 10	2.84 $\pm$.38	2.90 $\pm$.38	37.4 $\pm$ 3.1	39.4 $\pm$ 3.1	25.3 $\pm$ 6.5	28.0 $\pm$ 4.6	62.7 $\pm$ 8.4	67.4 $\pm$ 6.	16.50 $\pm$ 2.2	11.1 $\pm$ 2.34
TG	168 $\pm$ 8	170 $\pm$ 8	3.06 $\pm$.14	3.03 $\pm$.13	35.7 $\pm$ 3.5	37.7 $\pm$ 2.5	30.9 $\pm$ 5.2	27.3 $\pm$ 5.5	66.6 $\pm$ 5.8	65.0 $\pm$ 5.2	17.5 $\pm$ 2.1	14.2 $\pm$ 2.0
PD	167 $\pm$ 9	170 $\pm$ 8	2.44 $\pm$.10	2.48 $\pm$.10	36.4 $\pm$ 1.1	36.4 $\pm$ 1.4	24.1 $\pm$ 5.1	22.6 $\pm$ 3.2	60.5 $\pm$ 5.2	59.0 $\pm$ 3.2	17.3 $\pm$ 1.7	15.1 $\pm$ 2.2
COMP	160 $\pm$ 5	166 $\pm$ 5	3.13 $\pm$.12	3.14 $\pm$.12	38.0 $\pm$ 2.1	39.3 $\pm$ 3.7	25.3 $\pm$ 3.7	25.1 $\pm$ 4.3	63.3 $\pm$ 5.4	64.4 $\pm$ 6.7	17.6 $\pm$.9	15.9 $\pm$.8

CON = Control; TG = Theragun Pro Gen 4; PD = PowerDot 2.0; COMP = Therabody Recovery Air 1st generation; LSPT = Loughborough Soccer Pass Test; BPM = Beats per minute; s = seconds; NP = number of penalties; NP+ s = number of penalties + seconds.

Table 3. Estimated marginal means and confidence intervals for all outcome measures.

Outcome Measure		Group	First Half (EMM [95% CI])	Second Half (EMM [95% CI])
Technical Skill	LSPT Total Performance (s) (Total Score)	CON	62.69 [59.47, 65.91]	67.37 [64.16, 70.59]
		TG	66.60 [62.80, 70.40]	64.98 [61.18, 68.79]
		PD	60.50 [56.87, 64.12]	58.95 [55.33, 62.58]
		COMP	63.25 [59.00, 67.50]	64.37 [60.12, 68.62]
	LSPT Completion Time (s) (Subscale: Speed)	CON	37.40 [35.95, 38.85]	39.37 [37.92, 40.82]
		TG	35.70 [33.98, 37.42]	37.68 [35.97, 39.40]
		PD	36.40 [34.77, 38.04]	36.41 [34.77, 38.04]
		COMP	38.00 [36.08, 39.92]	39.25 [37.33, 41.17]
	LSPT Penalties (s) (Subscale: Accuracy)	CON	25.29 [22.62, 27.95]	28.00 [25.34, 30.66]
		TG	30.90 [27.75, 34.05]	27.30 [24.15, 30.45]
		PD	24.09 [21.09, 27.09]	22.55 [19.54, 25.55]
		COMP	25.25 [21.73, 28.77]	25.13 [21.60, 28.65]
Physical Performance	20-m Sprint Time (s)	CON	2.84 [2.71, 2.96]	2.90 [2.77, 3.03]
		TG	3.06 [2.90, 3.21]	3.03 [2.88, 3.19]
		PD	2.44 [2.29, 2.59]	2.48 [2.33, 2.63]
		COMP	3.13 [2.96, 3.31]	3.14 [2.96, 3.31]
	Heart Rate (BPM)	CON	168.50 [163.81, 173.19]	173.71 [169.02, 178.40]
		TG	168.04 [162.49, 173.59]	170.14 [164.59, 175.69]
		PD	166.65 [161.36, 171.95]	169.93 [164.64, 175.22]
		COMP	160.15 [153.94, 166.35]	165.90 [159.69, 172.10]
Perceptual Recovery	TQR Score (6 - 20 scale)	CON	16.50 [15.46, 17.54]	11.14 [10.10, 12.19]
		TG	17.50 [16.27, 18.73]	14.20 [12.97, 15.43]
		PD	17.27 [16.10, 18.45]	15.09 [13.91, 16.27]
		COMP	17.63 [16.24, 19.01]	15.88 [14.49, 17.26]

Discussion

This study aimed to examine whether a range of half-time passive interventions could mitigate reduction in simulated soccer match performance in elite academy-level male soccer players. The results of the present study confirmed previous work in that passive half-time rest resulted in deterioration in technical performance, sprint performance whilst increasing cardiovascular response, and perceived recovery. The main finding was that all three applied interventions attenuated decline in at least one performance or perceptual outcome. This supports the premise that half-time represents a modifiable window for performance preservation rather than a period of performance loss as seen in previous literature; (Lovell et al., 2013a; Mohr et al., 2004; Russell et al., 2015).

Consistent with prior work, we observed second-half decrements following passive half-time rest (Abade et al., 2017; Mohr et al., 2004; Russell et al., 2015). Previous

match-play studies demonstrate that muscle temperature falls during half-time and that this drop is associated with slower sprint capacity at the start of the second half when players remain inactive compared with brief re-warm-up (Mohr et al., 2004; Lovell et al., 2013a). Experimental simulation work indicates that a brief 7-min shuttle jog during half-time attenuates the typical slowing in 20-m sprints versus seated rest, reinforcing that small, feasible interventions can help under tight time constraints (Bang and Park, 2022). The present study extends half-time research by showing that passive half-time interventions, rather than physical re-warm-up alone, can attenuate second-half performance decline.

TG exhibited the most consistent performance of protective interventions across measured outcomes. When compared with CON, the TG group showed reduced deterioration in overall LSPT performance (time + penalties), smaller worsening of 20-m sprint time, a smaller rise in heart rate, and a smaller drop in TQR. Practitioners should

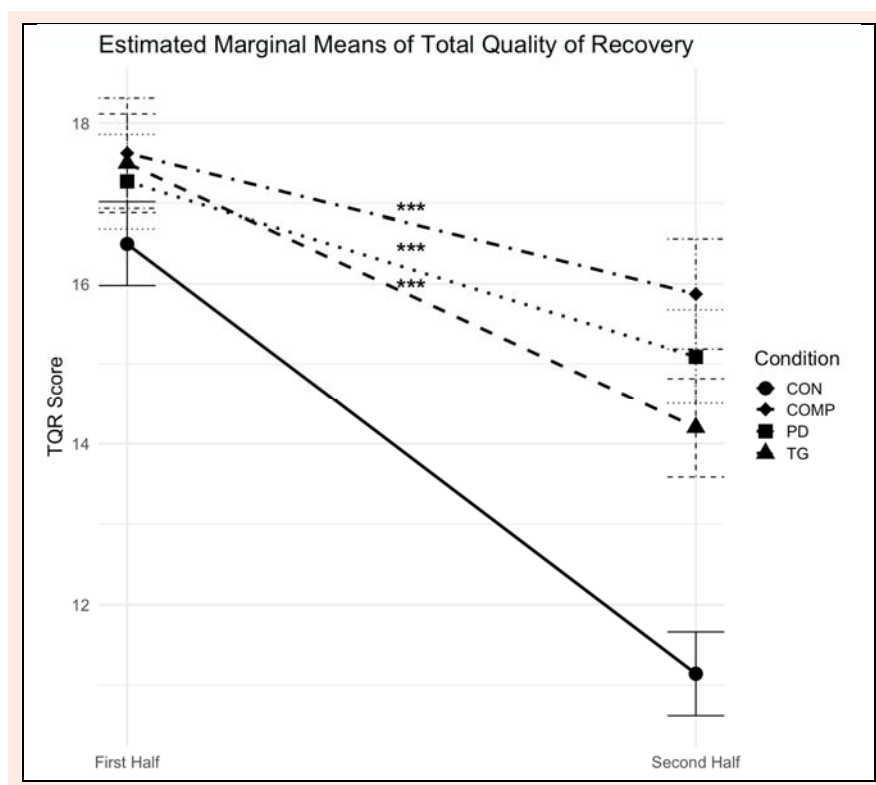


Figure 4. Estimated marginal means total quality of recovery.

interpret halftime TQR scores as vital measures of an athlete's cognitive readiness and subjective willingness to compete, noting that this perceptual state can occasionally decouple from objective physical and technical performance outputs. Previous work indicates that PT can acutely influence local tissue compliance and perceived muscle readiness without impairing force production, which may support repeated high-intensity and technical actions under fatigue (Sams et al., 2023). The authors interpret these as preservation rather than enhancement effects, attenuating decline relative to passive rest, aligned with the half-time literature's emphasis on maintaining outputs across the transition into the second half (Russell et al., 2015).

The EMS condition showed reduced deterioration in overall LSPT performance and penalties (e.g., passing to the wrong target) and a smaller reduction in TQR, but no clear advantage in short sprint performance relative to CON. This pattern is consistent with the broader EMS literature in which low-frequency EMS can facilitate blood flow enhancement and metabolite clearance even when effects on sprinting are inconsistent across protocols and populations (Babault et al., 2011; Sañudo et al., 2020; Shu et al., 2025). Low-frequency EMS provides continuous afferent feedback that maintains the somatosensory awareness and submaximal motor unit excitability necessary to acutely preserve fine motor control and passing precision. However, this low-intensity stimulation may not induce the high-frequency motor unit synchronization or metabolic heat required to prime explosive, maximal sprint capacity. Because localized circulatory and metabolic markers were not directly quantified in the present study, these mechanisms remain candidate hypotheses to explain the divergent physical and technical outcomes.

COMP did not meaningfully alter LSPT outcomes

but did attenuate deterioration in average 20-m sprint performance and produced the smallest decline in TQR among interventions. Single sessions of COMP lasting 30 minutes commonly show perceptual benefits, even when immediate performance effects are mixed (Ferrer-Ramos et al., 2024). A recent randomized crossover study reported higher TQR ratings after pneumatic compression versus sham, despite no difference in subsequent cycling power output (Ferrer-Ramos et al., 2024). The present findings, together with previous literature, suggest that single-session pneumatic compression primarily influences perceptual recovery, alongside modest changes in blood flow and circulation (Chase et al., 2020; Stedje and Armstrong, 2021).

Collectively, the findings of the present study indicate that half-time passive interventions can exert perceptual, physical, and technical performance outcome-specific effects rather than uniformly enhancing every domain. Interventions that preserved technical performance (TG, EMS) also attenuated decrements in perceived recovery, whereas sprint preservation appeared with percussive therapy and pneumatic compression in the present study. Importantly, none of the modalities impaired second-half outcomes, supporting feasibility and safety for applied half-time use.

A practical consideration in half-time implementation is the need to prioritize coach-led tactical and technical communication alongside established hydration and nutritional strategies. The interventions examined in the present study were passive, required little additional physical exertion, and were self-administered within the existing half-time duration. Consequently, these interventions can be deployed concurrently during the half-time period alongside coaching instruction, minimizing interference with tactical delivery or increasing physical load. This may be relevant

in professional environments where half-time routines are tightly structured, and interventions that compete with coaching priorities are unlikely to be adopted. The present findings indicate that passive half-time interventions may function as adjuncts within existing half-time processes rather than displacing technical, tactical, or nutritional practices. These strategies are intended to complement, not replace, efficacious half-time practices such as short re-warm-ups or heat maintenance, which have demonstrated benefits for second-half outputs (Abade et al., 2017, Bang and Park, 2022).

Based on these findings, we propose an outcome-driven decision framework for practitioners: if the primary halftime priority is preserving technical passing precision and composure, percussive therapy (TG) or electrical muscle stimulation (PD) should be deployed; conversely, if maintaining explosive sprint capacity or maximizing acute perceptual recovery is paramount, percussive therapy or pneumatic compression (COMP) should be selected. However, as these technologies were evaluated strictly as isolated, standalone interventions, coaches must apply them with caution. Despite the significant findings, several limitations must be acknowledged. First, while the total sample size ($n = 43$) was sufficient for the primary analysis, the per-group sample size is relatively small, which may limit the generalizability of the findings to larger, more diverse populations of soccer players. Second, the nature of the physical interventions precluded the blinding of participants to their assigned conditions; therefore, the potential for expectancy effects cannot be entirely ruled out. The absence of a sham-control condition means we cannot definitively isolate the physiological effects from the psychological perception of having received an intervention. However, in the context of elite academy soccer, using a true 'sham' is often impractical and may compromise the ecological validity of the halftime environment. The study utilised a simulated soccer protocol rather than competitive match play, which may limit ecological validity given the absence of tactical, opponent, psychological, and contextual influences inherent to competition. In addition, no direct physiological or mechanistic measures were collected; therefore, interpretations are limited to observed performance and perceptual outcomes rather than to underlying biological responses to the interventions. Additionally, because tissue temperature was not directly tracked in the present study, temperature changes remain a candidate physiological mechanism rather than a definitive driver of our observed outcomes.

Conclusion

Passive half-time interventions can attenuate the expected decline in second-half physical and technical performance in elite academy soccer players. Passive halftime interventions offer a practical means of attenuating performance decline in elite academy soccer, though the benefits are modality-specific. Percussive therapy and EMS were most effective in preserving technical performance, whereas pneumatic compression supported sprint performance stability and perceived recovery. Notably, none of the modalities significantly enhanced heart rate recovery, and

improvements in sprint performance were localized primarily to the percussive therapy group. These portable modalities offer a pragmatic solution for practitioners to maintain player readiness in congested locker room environments where space for active re-warm-ups is limited and tactical briefings remain the priority. Practitioners should, therefore, select halftime interventions based on the specific physiological or technical priorities of the player and the preceding match demands, rather than viewing these tools as universally effective across all performance domains. These findings provide applied options for half-time performance preservation in academy-level soccer and can complement existing re-warm-up protocols.

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Key points

- Passive half-time rest led to clear declines in second-half sprinting, technical performance, and perceived recovery in elite youth soccer players.
- Simple passive interventions used during half-time reduced these declines, with different modalities supporting technical skill, sprint performance, or perceived recovery.
- Passive recovery tools can be used during half-time without interfering with coaching, hydration, or tactical communication.

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