

Beyond Warm-Ups: How Conditioning Activities Shape Mental and Physical Readiness in Young Soccer Players

by

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This study aimed to compare inhibitory control, perceived exertion, subjective mental fatigue, and countermovement jump (CMJ) height in young soccer players following three different conditioning activities: (a) a coordinative task, (b) sprinting, and (c) a combination of coordinative and sprint tasks. Twenty-five under-15 soccer players participated in four randomized and crossover experimental conditions: Coordinative (COORD), Sprint (SPRT), Combined (COMB), and Control with low cognitive demand (CONT). Before and after each warm-up activity, the following variables were measured: perceived exertion, perceived mental fatigue, CMJ height, stroop test response time, and accuracy. Generalised Estimating Equations analysis revealed a main effect of time for perceived exertion ($p < 0.001$), perceived mental fatigue ($p < 0.001$), the CMJ ($p < 0.001$), and response time ($p = 0.012$). After performing the SPRT and COMB warm-ups, players reported higher perceived exertion and reduced CMJ performance when compared to the other experimental conditions ($p < 0.05$). Greater subjective mental fatigue was observed following the COORD and COMB warm-ups than the CONT experimental condition ($p < 0.05$). However, only the COMB condition resulted in increased response time for the inhibitory control when compared to the CONT condition ($p < 0.05$). Caution is warranted when incorporating COMB warm-ups into training sessions that are followed by tasks requiring both physical and cognitive effort.

Keywords: team sports; sports performance; mental load; youth athletes

Introduction

Soccer is a team sport often characterized by the simultaneous execution of high-intensity physical actions and perceptual-cognitive skills (e.g., anticipation, decision-making, and visuomotor skills) in a dynamic and unpredictable environment (Coutinho et al., 2017, 2018). For instance, during an official match, a player may be required to decide whether or not to pass the ball to a teammate, under time pressure and while running at high speed, while also preventing an opponent from intercepting the ball. In this context, preparatory activities are crucial in introducing physical and cognitive demands, which could be specific and similar to official

match and training sessions, although without causing cumulative neuromuscular and mental fatigue (McGowan et al., 2015). Beyond merely activating physiological systems, such activities can directly influence neuromuscular readiness and athletes' perceptual-cognitive processes (Fortes et al., 2018; McGowan et al., 2015; Silva-Neto et al., 2023). Thus, implementing tasks that concurrently challenge physical and cognitive components appears particularly relevant in sports like soccer, which demand rapid perceptual-cognitive skills and high-intensity actions. Also, these activities should resemble competition requirements, facilitating transfer and positive adaptations, such as combining cognitive and motor demands simultaneously.

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Within this context, the concept of Post-Activation Performance Enhancement (PAPE) has emerged as one explanation for improved performance following preparatory activities (Blazevich and Babault, 2019; Dickey et al., 2025). PAPE refers to the acute enhancement of physical performance induced by prior conditioning exercises (Blazevich and Babault, 2019). Sprint and coordinative exercises are frequently employed for this purpose (Brink et al., 2022). Sprinting not only represents a common action leading up to goals in soccer (Faude et al., 2012) but when used as a conditioning activity, it can also stimulate physiological mechanisms that enhance subsequent strength and power output (Blazevich and Babault, 2019). In contrast, coordinative exercises require athletes to perform complex motor patterns that integrate balance, timing, spatial orientation, and precise movement control. These tasks challenge the neuromuscular system to execute varied movements in a coordinated manner, often under time constraints or with continuous transitions between different actions. These tasks are known to activate brain regions associated with motor (Pesce, 2012) and executive functions (e.g., inhibitory control) (Krämer et al., 2013), such as the prefrontal cortex (Jost et al., 2024). Therefore, combining sprint and coordinative tasks in a physical warm-up configuration may stimulate both physical and cognitive components simultaneously, potentially replicating the demands of the actual match scenario more effectively than isolated tasks. Nonetheless, the effects of such combined warm-up activities remain insufficiently explored in scientific literature.

Although PAPE is frequently associated with improvements in acute physical performance, particularly in activities involving strength and sprint, conditioning activities that also include cognitive stimulation may enhance not only neuromuscular activation but also cognitive readiness. Coordinative tasks, for instance, have been shown not to impair physical performance while potentially enhancing executive function-related cognitive processes (Coutinho et al., 2017, 2018), which are critical in soccer (Scharfen and Memmert, 2019). Therefore, activities that stimulate both the neuromuscular system and brain regions involved in executive functions, such as the prefrontal cortex, may contribute to

enhanced physical and cognitive readiness before competition (Jost et al., 2024; Pesce, 2012). In sports like soccer, which are characterized by rapid and pressured decision-making, the inclusion of such exercises appears particularly relevant. Combining physical and cognitive tasks emerges as a promising strategy in the immediate pre-competition phase, potentially facilitating an effective transition from the warm-up to performance and enhancing overall athletic output.

Recent studies have begun to investigate the outcomes of conditioning activities that combine different types of tasks (Fortes et al., 2018; Silva-Neto et al., 2023). Rubio-Morales et al. (2022) suggested that combined warm-ups might increase mental fatigue, though without negatively impacting cognitive performance, such as response time. To our knowledge, this is the only study that has examined the effects of combined tasks on cognitive processes in athletes. On the other hand, Fortes et al. (2018) examined the effects of various warm-up strategies, including combinations of jumping, resistance, and aerobic exercises, on countermovement jump (CMJ) and sprint performance in amateur basketball players. Those authors found improvements in both jump height and sprint performance following combined warm-up strategies (i.e., sprint plus strength activities of short duration). Similarly, Silva-Neto et al. (2023) reported enhanced jump and sprint performance following strength-based conditioning activities. In parallel, Pinheiro et al. (2022) observed impaired jump performance following sprint tasks. Given these mixed findings and the limited research on the cognitive effects of combined warm-ups, further investigation may provide valuable insights for designing more effective preparatory routines.

Accordingly, comparing the cognitive and physical responses of soccer players to motor conditioning activities with varying coordinative and sprint demands can inform the optimal design and prescription of such tasks for young soccer players. Therefore, the aim of the present study was to compare the effects of sprint-based, coordinative, and combined conditioning activities on inhibitory control, the rate of perceived exertion, perceived mental fatigue, and vertical jump height in under-15 soccer players. It was hypothesized that all experimental conditions

would similarly increase perceived exertion, with sprint-based tasks leading to greater improvements in jump height. In addition, improvements in inhibitory control and increased mental fatigue were expected following the coordinative and combined conditions.

Methods

Participants

A priori sample size estimation was based on data from a pilot study involving seven youth soccer players with similar characteristics to those in the present study. An a priori power analysis was conducted to determine the minimum number of participants required to detect statistically significant differences between conditions with adequate statistical power. The primary outcome of interest was the interaction between conditions (experimental and control conditions) across the dependent variables: perceived exertion, perceived mental fatigue, CMJ height, and Stroop test performance (accuracy and response time). The statistical model used to estimate the required sample size was a repeated-measures MANOVA. The smallest partial eta-squared value (η^2_p) observed in the pilot study was 0.568, which corresponded to an effect size of $f = 0.816$, as recommended by G*Power software (version 3.1.7) (Faul et al., 2007). The analysis was conducted with the following parameters: $\alpha = 0.05$, statistical power ($1 - \beta$) = 0.80, and a two-tailed test. The assumed statistical design was a within-subjects repeated-measures model with a single categorical variable (type of the warm-up task). The analysis indicated that a minimum of 21 participants would be required to detect the observed effect under these conditions.

In total, 25 players completed all phases of the study and were included in the final analysis. Initially, 32 under-15 soccer players (age: 14.63 ± 0.49 years; body mass: 61.91 ± 6.30 kg; body height: 1.72 ± 0.07 m; BMI: 20.92 ± 1.50 kg·(m²)⁻¹) from two different clubs were recruited for the study. However, during the study, several athletes from both clubs were excluded from the analyses for various reasons. In Club 1, two athletes sustained injuries during friendly matches and were unable to continue. One additional player from the same club did not complete the assessments and was excluded. In Club 2, two athletes were excluded due to injuries sustained during training and a

match. Furthermore, two other players were excluded for missing follow-up assessments after completing the first condition. Importantly, no injuries occurred during the execution of the study tasks.

Inclusion criteria were as follows: being registered with the state soccer federation for at least one year, having participated in at least one state or national competition, and not having sustained muscular, ligament, or skeletal injuries within three months prior to data collection, as previous studies indicated a deleterious impact of injuries in sprint (Mendiguchia et al., 2014) and jump (Hart et al., 2019) performance. Athletes were excluded if they experienced discomfort or injury during the assessments or experimental conditions, were unable to perform the proposed coordinative tasks, or failed to complete any of the required stages. Table 1 presents the characteristics of the final sample.

According to McKay et al. (2022), the participants were classified as tier 2 athletes (i.e., Trained/Developmental), typically characterized by participating in ~3 training sessions per week and one competitive match in local-level leagues.

The study was approved by the Institutional Review Board of the Universidade Federal de Minas Gerais, Belo Horizonte, Brazil, under the approval number CAAE: 59836022.0.0000.5149 (approval date: 16 November 2022). The research was conducted following the reading, clarification, and signing of the informed consent form by the participants and by the club responsible for the athletes.

Experimental Approach and Data Collection Procedures

This study employed an experimental design with a counterbalanced crossover format, in which all participants completed all tasks. This design was chosen to optimize the control of confounding variables and improve statistical efficiency (Chen et al., 2023). Over the course of the intervention, athletes completed three preparatory activity conditions and one control intervention. Perceptual, cognitive (executive function), and physical performance assessments were conducted before and after each condition. During the control condition, participants watched a documentary and underwent the same assessments before and after the viewing.

On the first day, athletes performed the Yo-Yo Intermittent Recovery Test Level 1 (Bangsbo et al., 2008) during which both maximum and average heart rates were recorded using a heart rate monitor (Polar Electro Oy, H1, Kempele, Finlandia). After the test, participants were familiarized with the Perceived Mental Fatigue (PMF) scale, the rating of perceived exertion (RPE), and the NASA Task Load Index (NASA-TLX) questionnaire. Mental fatigue was defined for participants as a psychobiological state caused by cognitively demanding activity sustained over a period (Fortes et al., 2019), and exertion was defined as the level of physical strain (Foster et al., 2001) experienced during the tasks. On the following day, participants were familiarized with the three experimental conditions: 1) coordinative, 2) sprint, and 3) combined. After familiarization, participants completed each condition in random assignment. Athletes were instructed not to engage in any vigorous physical activity outside their club routine for at least 24 h before data collection and to sleep at least 7 h the night before testing. Additionally, they were advised to avoid caffeine intake for at least 3 h before each assessment. Prior to beginning the procedures, a briefing was conducted to verify compliance with these recommendations.

Experimental Conditions

The coordinative (COORD) task was based on the exercises proposed by Coutinho et al. (2017). Athletes performed seven motor tasks using an agility ladder and a standard soccer ball for a total of 20 min. To ensure understanding, a demonstration video was shown, and an experienced evaluator performed the exercises live. Athletes then practiced all seven tasks in a predetermined sequence. Five tasks were performed without the ball, and two with the ball. According to Coutinho et al. (2017), including ball-handling exercises increases attentional demand and, consequently, the cognitive load of the motor task. Participants completed each drill along the 5-m agility ladder, returned to the starting point, and immediately began the next task without rest. Demonstration videos of the coordinative tasks used in the present study are available for viewing at: <https://figshare.com/s/01f245507868bf05a8f2>.

The sprint task (SPRT) was based on the procedures used by Coutinho et al. (2018). A 20-m

course was set up, in which players completed 40-m shuttle sprints with a 180° change of direction at the end of the course. Participants performed 3 sets of 10 sprints, with a 25-s rest interval between sprints and 2 min and 30 s between sets. The heart rate was monitored throughout the condition. Sprint time was recorded, and the fatigue index was calculated using the following equation: $[(\text{Fastest sprint} - \text{Last sprint}) / \text{Fastest sprint} \times 100]$ (Table 1) (Jiménez-Reyes et al., 2019). Two evaluators monitored each athlete's sprint time using separate stopwatches. Intraclass correlation coefficients (ICCs) were then calculated to determine inter-rater reliability, with the ICC <0.5 considered poor, 0.5–0.75 moderate, 0.75–0.9 good, and >0.9 excellent (Jiménez-Reyes et al., 2019).

The combined (COMB) task consisted of both the coordinative and sprint exercises. Participants first completed the agility ladder drills measuring 5 m, then immediately performed a 40-m sprint with a 180° change of direction after 20 m (totaling 45 m). This resulted in ~30 sprints per participant during the task. After the sprint, athletes returned to the ladder starting point and rested for 25 s before the next repetition. The coordinative portion and total duration of the combined condition matched those of the COORD condition.

In the low cognitive load control condition (CONT), athletes watched a 20-min emotionally neutral documentary. Similar tasks using video exposure had been used to control for mental fatigue in experimental research (Fortes et al., 2019) and had shown no significant changes in physical or cognitive variables. The control session was conducted in a quiet, enclosed room at ambient temperature, free from mobile phone use and external distractions. The same assessment procedures were conducted before and after watching the video.

Measures

Inhibitory control, a key component of executive function, and sustained attention were assessed using the Stroop test (Graf et al., 1995). Response time and the number of correct answers were evaluated before and after the experimental and control conditions. The test was conducted individually and involved naming the colour of 36 words, which could differ from the semantic meaning (e.g., the word “red” displayed in green).

The test consisted of three blocks of 12 stimuli each: control stimuli (coloured rectangles), congruent stimuli (colour and word match), and incongruent stimuli (colour and word mismatch) (Fortes et al., 2019). Response time (ms) for each item was recorded. Total response time for the congruent and incongruent blocks (in seconds) was used for analysis, as well as total test duration. The number of correct responses in each block and across the full test was also analyzed. Participants were encouraged to respond as quickly and accurately as possible. The Stroop test had previously demonstrated high reliability (ICC = 0.90; CI 95%: 0.856–0.931) (Takahashi and Grove, 2020).

Perceived mental fatigue was assessed using a 100-mm visual analogue scale (VAS). Lee et al. (1991) reported strong validity and reliability ($r = 0.81$; ICC = 0.91) for this instrument. Participants marked a vertical line on the scale that best represented their perceived level of mental fatigue before (baseline) and after the conditions. Perceived mental fatigue measures are widely used in soccer and have shown sensitivity in detecting mental fatigue in athletes (Fortes et al., 2019).

The RPE and mental fatigue were also assessed during the study. The RPE was recorded using a 1–10 scale, as described in the study by Foster et al. (2001), both before the sessions (baseline exertion) and 30 min post-condition. The RPE was also used to calculate the total session load (session-RPE, sRPE) by multiplying perceived exertion by warm-up task duration (Foster et al., 2001). This method had shown strong validity ($r = 0.80$) and excellent reliability (ICC = 0.95) for internal training load monitoring (Haddad et al., 2017).

CMJ height was used to assess neuromuscular readiness (Claudino et al., 2017) before and after each condition using a contact mat (S2 Elite Jump 2.11, Elite Jump System Brazil). A previous investigation demonstrated high reliability (measurement error = 1.2 cm; between-subject variability = 1.1 cm) when CMJ height was assessed using a contact mat (Pueo et al., 2017). Since the CMJ is routinely used in the club's testing protocols, no additional familiarization was required. Standard warm-up procedures were performed before baseline testing to avoid bias. Three jumps were recorded per timepoint, with at least 15 s of rest between trials. The mean of the

three jumps was used for analysis. CMJ average height is sensitive to fatigue-induced performance changes (Claudino et al., 2017). Prior studies found the CMJ test reliable in detecting fatigue (CV = 2.6%; ICC = 0.97; CI 95%: 0.92–0.98) (Jiménez-Reyes et al., 2019).

The NASA Task Load Index (NASA-TLX) questionnaire (Hart and Staveland, 1988) was used to assess the perceived mental workload. The global score is based on six domains: (1) mental demand, (2) physical demand, (3) temporal demand, (4) performance satisfaction, (5) effort, and (6) frustration. Global mental workload was calculated by weighting domain scores, prioritizing mental and physical demand, and summing the weighted values. Validity had been confirmed in previous studies (concurrent $r = 0.751$, $p < 0.001$; convergent $r = 1.00$, $p < 0.001$) (Rubio et al., 2004), with intraclass correlation coefficients ranging from 0.71 to 0.81, indicating good reliability (Devos et al., 2020).

Statistical Analysis

Descriptive statistics (mean \pm standard deviation) were calculated for all variables. To assess the effect of each task on the dependent variables, Generalized Estimating Equations (GEEs) were applied. For the outcomes of perceived exertion, mental fatigue, the CMJ, and inhibitory control (accuracy and response time), the pre-test value was included as a covariate to control for baseline differences, as recommended by Jiang et al. (2015). Those authors showed that including covariates in GEE models improved statistical power and effect estimation, particularly when strong pre-post correlations existed (Jiang et al., 2015).

Thus, comparisons across conditions were based on post-experiment values, adjusted for baseline. Bonferroni post-hoc tests were conducted when necessary, and effect sizes were expressed as standardized Beta coefficients (β). Following recommendations from Pek and Flora (2018), standardized effect sizes were interpreted based on their relative magnitude and practical significance, acknowledging the absence of universally accepted benchmarks for interpreting standardized beta coefficients in GEE models. In this context, higher absolute β values reflect a stronger influence of the predictor variable on the population-averaged response. The GEE was

chosen over traditional ANOVA models due to its robustness in the presence of assumption violations and its flexibility in handling different probability distributions for the dependent variable, as detailed in a recent work (De Melo et al., 2022). The model fit was assessed using the Quasi-Likelihood under Independence Model Criterion (QIC), with the lowest QIC indicating the best model (McCullagh and Nelder, 1989). GEE was also used to analyze additional variables, along with the maximum and the average heart rate (HR_{\max} , HR_{mean}), mental workload, and the sRPE, without covariates, as these were measured during (HR) or after (mental workload and sRPE) task execution. All analyses were conducted using IBM® SPSS Statistics version 19. The significance level was set at $p \leq 0.05$. All result figures were generated using R (version 4.5.1) and R Studio (version 2025.05.1+513).

Results

Inhibitory Control

To analyze accuracy and response time across the congruent (Figures 2A and 2C, respectively), incongruent (Figures 2B and 2D, respectively), and total stages of the Stroop test, a GEE model with an identity link function and an unstructured covariance matrix was used. Table 2 presents the QIC values for the gamma and normal distributions. The model with the lowest QIC value was selected. Regarding the number of correct responses, the GEE model did not identify a significant effect of the covariate [$Wald_{(1, 21)} = 2.494$; $p = 0.114$]. Furthermore, no significant differences were found between conditions in correct responses [$Wald_{(3, 21)} = 3.378$; $p = 0.337$] or for the congruent [$Wald_{(3, 21)} = 0.758$; $p = 0.859$] or incongruent [$Wald_{(3, 21)} = 3.019$; $p = 0.389$] stages.

The GEE revealed a significant effect of the covariate [$Wald_{(1, 21)} = 108.097$; $p < 0.001$] for the response time, as well as a significant condition effect [$Wald_{(3, 21)} = 11.033$; $p = 0.012$]. Bonferroni post-hoc analysis indicated that the COMB task resulted in significantly impaired response time when compared to the CONT task ($p = 0.007$; $\beta = 3.731$) (Figure 4C). When the congruent stage was analyzed, a task effect was also observed for the response time [$Wald_{(3, 21)} = 32.904$; $p < 0.001$]. Post-hoc analysis revealed faster response times after the COORD task than SPRT ($p < 0.001$; $\beta = 1.98$), COMB ($p = 0.006$; $\beta = 1.29$), and CONT ($p < 0.001$;

$\beta = 1.89$) tasks. In the incongruent stage, impaired response times were observed after COORD ($p < 0.001$; $\beta = 1.68$) and COMB ($p < 0.001$; $\beta = 1.18$) tasks when compared to the CONT condition. Considering the SPRT condition, response time was also worse after COORD ($p < 0.001$; $\beta = 1.72$) and COMB ($p < 0.001$; $\beta = 1.22$) tasks. Finally, the COMB condition led to more impaired response times compared to COORD ($p = 0.048$; $\beta = 0.50$).

Countermovement Jump

The best-fitting model for CMJ height used an identity link function, an unstructured covariance matrix, and a gamma distribution (QIC = 9.527), outperforming the normal distribution model (QIC = 161.226). The covariate was significant [$Wald_{(1, 21)} = 1090.065$; $p < 0.001$], and the condition had a significant effect on CMJ height [$Wald_{(3, 21)} = 107.666$; $p < 0.001$]. Bonferroni post-hoc tests showed reduced CMJ height after the SPRT condition when compared to COORD ($p < 0.001$; $\beta = -2.445$) and CONT ($p < 0.001$; $\beta = -2.175$) conditions. Similarly, CMJ height after the COMB condition was lower than after COORD ($p < 0.001$; $\beta = -2.464$) and CONT ($p < 0.001$; $\beta = -2.194$) conditions (Figure 3).

Perceived Mental Fatigue

For perceived mental fatigue, the best-fitting GEE model used an identity link function, an unstructured covariance matrix, and a gamma distribution (QIC = 29.574). This model was superior to the one using a normal distribution (QIC = 21054.491). The covariate had a significant effect [$Wald_{(1, 21)} = 138.608$; $p < 0.001$], and a significant condition effect was also observed [$Wald_{(3, 21)} = 130.111$; $p < 0.001$]. Bonferroni post-hoc analysis revealed greater perceived mental fatigue after the COMB condition than SPRT ($p = 0.007$; $\beta = 23.440$) and CONT ($p < 0.001$; $\beta = 39.452$) conditions (Figure 4B). Perceived mental fatigue was also higher after the COORD condition when compared to the CONT ($p < 0.001$; $\beta = 26.694$), but not to the SPRT condition ($p = 0.144$).

Rating of Perceived Exertion

For the rating of perceived exertion, the GEE model with an identity link, unstructured covariance, and a gamma distribution (QIC = 18.346) showed a better fit than the normal distribution model (QIC = 159.854). The covariate had a significant effect [$Wald_{(1, 21)} = 13.446$; $p < 0.001$],

and the model revealed a significant condition effect [Wald_(3, 21) = 406.757; $p < 0.001$]. Bonferroni post-hoc tests showed that perceived exertion was higher after the SPRT condition when compared to COORD ($p < 0.001$; $\beta = 3.870$), COMB ($p < 0.001$; $\beta = 1.227$), and CONT ($p < 0.001$; $\beta = 6.321$) conditions. The COMB task also induced higher perceived exertion than COORD ($p < 0.001$; $\beta = 2.644$) and CONT ($p < 0.001$; $\beta = 5.095$) tasks. The COORD condition also induced greater perceived exertion than the CONT condition ($p < 0.001$; $\beta = 2.451$) (Figure 4A).

The sRPE (Figure 5C) was analyzed using a GEE model with a gamma distribution (QIC = 8.801), which was superior to the normal model (QIC = 43419.483). A significant condition effect was observed [Wald_(2, 21) = 127.590; $p < 0.001$]. Post-hoc tests indicated that the sRPE was higher for the SPRT than COORD ($p < 0.001$; $\beta = 77.717$) and COMB ($p < 0.001$; $\beta = 28.117$) conditions. Additionally, the sRPE was higher for the COMB when compared to the COORD condition ($p < 0.001$; $\beta = 49.600$).

Heart Rate and the Session-RPE

The heart rate, both maximum and mean, was analyzed using GEE models with an identity link, an unstructured covariance matrix, and a

gamma distribution (HR_{max} QIC = 6.211; HR_{mean} QIC = 6.175), which outperformed models with normal distributions (HR_{max} QIC = 6347.680; HR_{mean} QIC = 9544.320). A significant effect of the condition on the HR_{max} was found [Wald_(2, 21) = 10.980; $p = 0.004$] (Figure 5A). Bonferroni post-hoc tests revealed that the HR_{max} was higher for COMB ($p = 0.012$; $\beta = 8.600$) and SPRT ($p = 0.003$; $\beta = 9.120$) conditions when compared to the COORD condition. Similar results were observed for the HR_{mean} [Wald_(2, 21) = 12.447; $p = 0.002$], with higher values in COMB ($p = 0.022$; $\beta = 7.440$) and SPRT ($p = 0.001$; $\beta = 10.440$) conditions when compared to the COORD condition (Figure 5B).

Mental Workload

Mental workload (Figure 5D) was analyzed using a GEE model with a normal distribution (QIC = 8.88), which provided a better fit than the gamma model (QIC = 13.42). A significant condition effect was found [Wald (3, 21) = 578.254; $p < 0.001$], with the lowest mental workload values observed for the CONT when compared to SPRT ($p < 0.001$; $\beta = 0.50$), COORD ($p < 0.001$; $\beta = 0.52$), and COMB ($p < 0.001$; $\beta = 0.53$) conditions. No significant differences were found among the three experimental conditions.

Table 1. Baseline data and characteristics of the study participants.

Variables	Participants (n = 25)
Age (years)	14.63 ± 0.49
Training frequency (days-week ⁻¹)	5.00 ± 0.00
Body Mass (kg)	61.91 ± 6.30
Body Height (cm)	1.72 ± 0.07
BMI (kg·m ⁻²)	20.92 ± 1.50
Sitting height (m)	130.33 ± 5.18
SMR (%)	75.89 ± 2.40
Fastest sprint (s)	6.88 ± 1.37
Fatigue index (%)	16.02 ± 16.27
SPRT task duration (s)	1215.00 ± 79.00
CMJ Height (cm)	37.45 ± 3.40
Yo-Yo-Test Distance (m)	1400.00 ± 386.10
HR _{max} Yo-Yo-test (bpm)	202.00 ± 8.00
HR _{med} Yo-Yo-test (bpm)	164.00 ± 12.00

SMR: Somatic Maturation Relationship; SPRT: Sprint; CMJ: Countermovement Jump; HR: Heart Rate

Table 2. QIC values obtained when the models were performed using normal and gamma probability distributions.

Dependent Variables	QIC Values	
	Normal	Gamma
Number of correct answers in the congruent stage	25.57	0.76*
Number of correct answers in the incongruent stage	82.64	11.36*
Total number of correct answers	218.67	9.76*
Response time in the congruent stage	448.52	39.74*
Response time in the incongruent stage	899.04	1.89*
Total response time	2103.53	9.99*

Notes: (*) The model with the probability distribution that presented the best fit to the variable

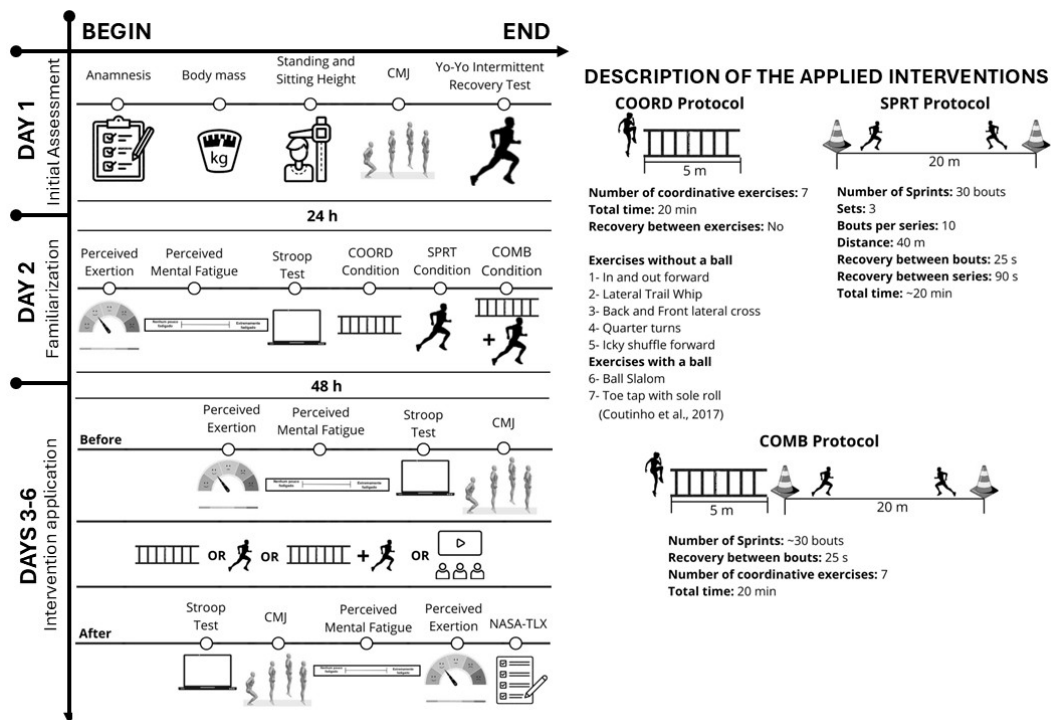


Figure 1. Schematic diagram of the experimental design, data collection procedures, and description of the interventions used in the present study.

CMJ: Countermovement Jump; NASA-TLX: National Aeronautic Scale Assessment-Task Load Scale. The recovery interval between days 3 and 6 was 24 h

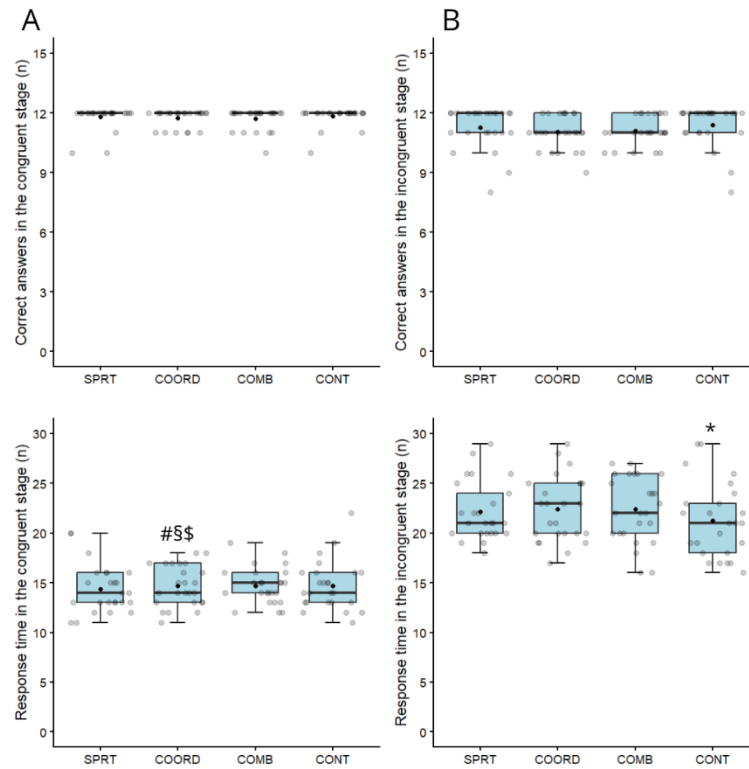


Figure 2. Boxplot and individual values for number of correct responses and response time in the congruent and incongruent conditions of the Stroop test across experimental conditions.

(\$) Statistically significant difference when compared to the SPRT condition; (*) Statistically significant difference when compared to the COORD condition; (#) Statistically significant difference when compared to the COMB condition; (§) Statistically significant difference when compared to the CONT condition

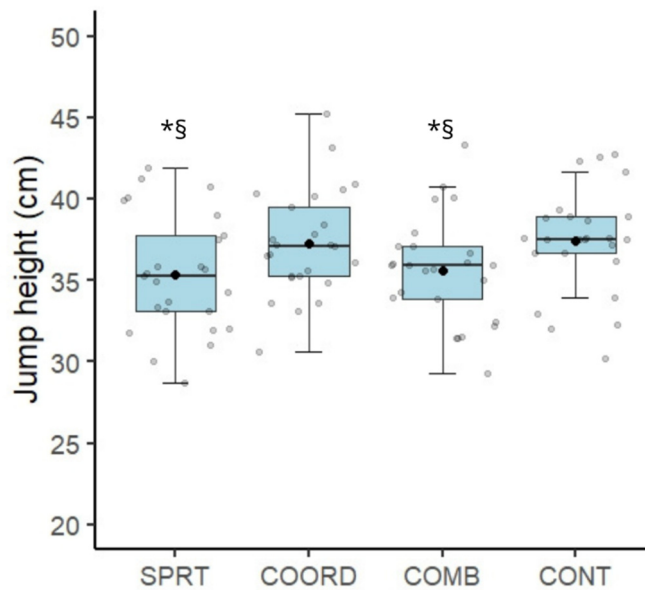


Figure 3. Boxplot and individual values for countermovement jump height across experimental conditions. (\$) Statistically significant difference when compared to the SPRT condition; (*) Statistically significant difference when compared to the COORD condition; (#) Statistically significant difference when compared to the COMB condition; (§) Statistically significant difference when compared to the CONT condition

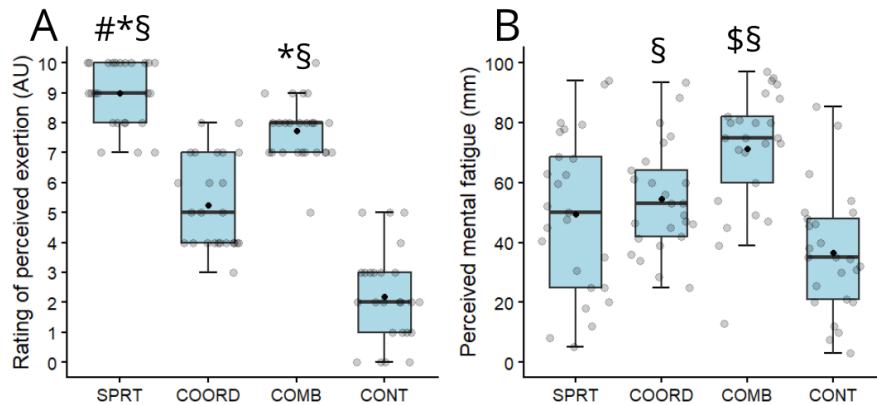


Figure 4. Boxplot and individual values for perceived exertion and perceived mental fatigue across experimental conditions.

(§) Statistically significant difference when compared to the SPRT condition; (*) Statistically significant difference when compared to the COORD condition; (#) Statistically significant difference when compared to the COMB condition; (§) Statistically significant difference when compared to the CONT condition

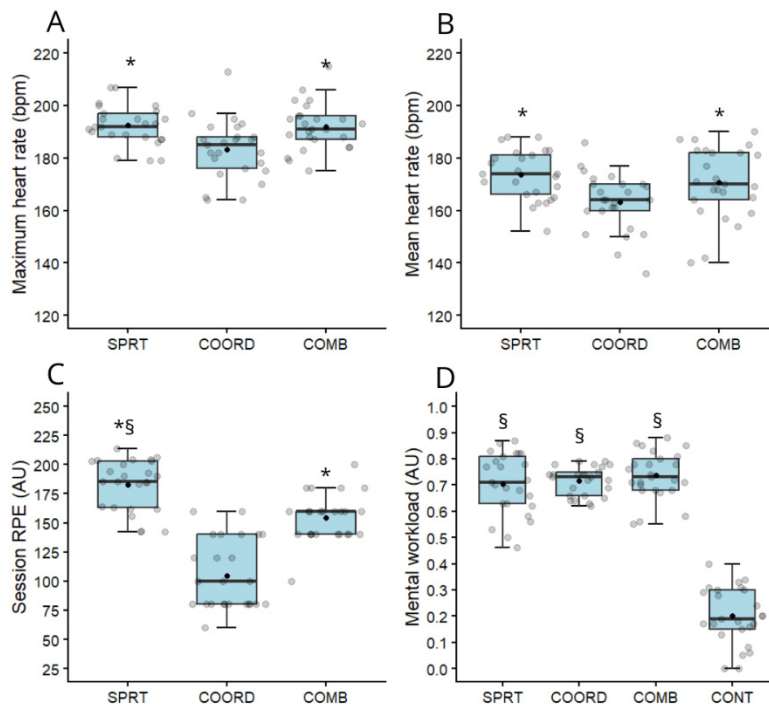


Figure 5. Boxplot and individual values for perceived exertion and perceived mental fatigue across experimental conditions.

(§) Statistically significant difference when compared to the SPRT condition; (*) Statistically significant difference when compared to the COORD condition; (#) Statistically significant difference when compared to the COMB condition; (§) Statistically significant difference when compared to the CONT condition

Discussion

The aim of the present study was to compare the effects of sprint-based, coordinative, and combined conditioning activities on inhibitory control, perceived exertion, perceived mental fatigue, and CMJ height in under-15 soccer players. The main finding indicates that after the combined (COMB) task, athletes showed impaired response times when compared to the control (CONT) condition. Furthermore, greater perceived mental fatigue and session-RPE were observed after the COMB and COORD tasks when compared to the cognitively undemanding task (CONT). However, no significant differences were observed between COORD and CONT conditions for the inhibitory control, suggesting that the negative effects on cognitive performance emerged only when physical effort was added to the coordinative task. These findings partially support our initial hypothesis. While the expectation of increased perceived mental fatigue following the COORD and COMB tasks was confirmed, the anticipated improvements in inhibitory control were not observed. On the contrary, the COMB condition led to a decline in response time, suggesting that the concurrent cognitive and physical demands may have exceeded the athletes' capacity.

Findings from this study showed that sprint and coordinative activities alone did not impair performance in subsequent cognitive tasks. However, evidence suggests that combining tasks that demand both physical and cognitive effort may lead to competition for mental resources, thereby impairing executive functioning, as measured by the Stroop test (Herold et al., 2018; Shenhav et al., 2013). In the current study, although both COORD and COMB conditions increased perceived mental fatigue, only the COMB condition impaired the efficiency of executive functions. This suggests an intrinsic relationship between energy availability and mental processing. The COMB condition likely imposed substantial energetic demands on the brain, increasing strain on neural systems responsible for resource allocation and resulting in the cognitive overload (Pesce, 2012). In other words, performing a conditioning activity that combines physical and cognitive demands can impair performance in executive function tasks, especially when physical exertion is sufficient to induce neuromuscular fatigue. While performance decrements were

observed in computerized tests, it is important to note that such assessments do not fully reflect the cognitive demands encountered during soccer training sessions, where attention and inhibitory control are only two among many cognitive functions involved (Haugan et al., 2025; Moreira et al., 2025). Therefore, these findings should be interpreted with caution, as the observed impairments may not occur in dynamic and unpredictable settings such as real-world soccer play.

Although increased ratings of perceived exertion and mental fatigue were reported following the COORD condition compared to the CONT condition, cognitive performance was not impaired in this comparison. Similar findings were reported by Coutinho et al. (2017) who applied a coordinative task condition and observed increased perceptual responses (e.g., exertion and mental fatigue) in soccer players. These findings may be explained by the nature of coordinative activities, which, while cognitively demanding, may allow for efficient allocation of energy resources (Pesce, 2012). Pesce (2012) also argues that such motor tasks may optimize energetic resource management, thereby preserving the efficiency of executive function. Van Cutsem and Marcora (2021) further highlight the use of subjective measures (e.g., VAS) to assess mental fatigue and caution that this condition can be influenced by both cognitive demands and emotional factors. Thus, the interpretation of perceived mental fatigue should consider its subjective nature and interindividual variability.

Conversely, greater perceived exertion and reduced CMJ performance were observed following the COMB and SPRT conditions compared to the CONT condition, confirming the study's initial hypothesis. Higher values of the sRPE, HR_{max}, and HR_{mean} were also associated with the SPRT and COMB conditions. Previous studies have shown that sprint tasks place substantial eccentric demands on the involved muscles (Buchheit and Laursen, 2013). Activities requiring high eccentric contraction, such as sprints, are associated with Z-line disruption in the sarcomeres, inflammation, and muscle soreness, which may impair vertical jump performance (Brandão et al., 2020; Woolley et al., 2014). These factors can disrupt the stretch-shortening cycle, a

key component of CMJ performance, thus

reducing force and power output (Silva-Neto et al., 2023). Additionally, activities involving high-intensity efforts may result in local structural changes in the sarcolemma and accumulation of metabolites, particularly H⁺ ions (Brandão et al., 2020; Woolley et al., 2014), which further contribute to the decrease in jump performance in the COMB and SPRT conditions.

Although this study demonstrated the impact of different conditioning tasks on physical and cognitive outcomes in youth athletes, some limitations must be acknowledged. Objective measures were employed to assess how sprint, coordinative, and combined tasks affected performance, an approach previously recommended in the literature (Fortes et al., 2019). However, other markers, such as biochemical indicators of physical and cognitive stress, could provide further insight into the physiological mechanisms underpinning these responses (Lambourne and Tomporowski, 2010). Furthermore, the lack of control over the players' training routines may have compromised the results. For instance, players might have entered the experimental conditions with varying levels of fatigue due to their prior training activities. We acknowledge that imposing restrictions on the players' regular routines would have resulted in an impractical study design with competitive athletes; therefore, this limitation was consciously accepted. Finally, although the current sample size was statistically determined, it may still be considered small. Further studies with larger samples are needed to improve the generalizability of these findings.

To our knowledge, this is the first study to investigate the effects of specific conditioning activities on the physical and cognitive performance of youth soccer players (under-15). Future research should examine whether these effects are replicable with different motor task combinations and how these activities, typically performed at the start of a session, influence subsequent technical-tactical performance (e.g., in small-sided games). Such investigations are crucial for aligning conditioning work with the overarching pedagogical objectives of training.

The present study offers relevant practical implications for soccer training. Combined conditioning activities resulted in reductions in both physical and cognitive performance.

However, it is important to acknowledge that all

preparatory exercises inherently impose some degree of physiological and cognitive loads. Therefore, rather than avoiding such tasks, coaches and strength and conditioning professionals should focus on regulating the magnitude and timing of the induced fatigue to ensure it facilitates, rather than impairs, subsequent performance as well as long-term adaptations. Furthermore, combined tasks integrating coordinative and sprint exercises were found to increase mental fatigue and reduce cognitive efficiency in tasks involving executive functions, suggesting their potential application in training programs designed to enhance athletes' tolerance to mental fatigue and resilience to the cognitive load.

Conclusions

The current findings suggest that activities combining sprint and coordinative motor tasks can increase response time in the Stroop test and elevate perceived mental fatigue. Furthermore, combining coordinative tasks with sprint efforts enhances the physical and physiological loads of the exercise, which may, depending on the context and timing, influence subsequent performance. Isolated coordinative tasks may increase mental fatigue, but do not impair executive function efficiency, such as inhibitory control. Therefore, coaches and strength and conditioning professionals should carefully consider the intended purpose of each session when applying combined tasks. While such activities may increase fatigue and temporarily reduce performance, they can also serve as valuable stimuli to foster adaptation and enhance resilience to cognitive and physical demands when appropriately dosed and scheduled within the training process.

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