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Research article

Supervised Offseason Training Programs are able to mitigate the Effects of Detraining in Youth Men Soccer Players Physical Fitness: A Randomized Parallel Controlled Study

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Abstract
This study aimed to analyze the effects of three off-season training programs on the aerobic capacity, countermovement jump (CMJ), and linear sprint performance of young male soccer players. The study employed a randomized multi-arm design, consisting of three experimental groups: i) a high-intensity interval training (HIIT) group; (ii) a plyometric jump training (PJT) group; and (iii) a HIIT+PJT group; and an inactive control group. Fifty-eight under-19 male soccer players (aged 17.6 ±0.6 years) were randomly assigned to participate in a 3-week offseason training program exclusively performing HIIT, PJT, or a combination of both, while the fourth group remained inactive. Players underwent assessments twice, using the Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT), CMJ, and 30-meter linear sprint. Significant interactions between time and groups were found in CMJ ($p<0.001$), YYIRT ($p<0.001$), and 30-m sprint ($p<0.001$). Group*time interaction revealed that the control group was significantly different from HIIT ($p<0.001$), PJT ($p<0.001$), and HIIT+PJT ($p<0.001$) considering the CMJ. Moreover, the control group was significantly different from HIIT ($p=0.037$) in YYIRT. Finally, the control group was significantly different from HIIT ($p=0.024$), PJT ($p<0.001$), and HIIT+PJT ($p=0.021$) considering the 30-m sprint. In conclusion, off-season training programs are effective in significantly reducing declines in CMJ and sprint performance compared to maintaining training cessation. However, in the YYIRT, only HIIT seems to be significantly superior to maintaining inactivity. To mitigate aerobic performance declines, incorporating HIIT sessions twice weekly during the offseason is advisable. To enhance or maintain jump performance, integrating at least one session of PJT weekly is beneficial.

Key words: Football, detraining, physical exercise, physical fitness, aerobic exercise, resistance training.

Introduction

Short-term detraining often occurs during the transition between soccer seasons (Silva et al., 2016). During short-term detraining in soccer players, physiological mechanisms involve decreased aerobic capacity due to reductions in cardiac output and blood volume (Mujika and Padilla, 2000), alongside muscle atrophy from decreased protein synthesis and appropriate training stimulus (Mujika and Padilla, 2001b). This leads to diminished endurance and strength (Mujika and Padilla, 2000). Additionally, impaired neuromuscular coordination results from decreased motor unit recruitment, affecting speed, agility and coordination on the field (Loturco et al., 2023).

The immediate effects of detraining resulting from the season's cessation can lead to reductions ranging from 12.2% (Nakamura et al., 2012) to 22.6% (Thomassen et al., 2010) in aerobic capacity, as observed in tests such as the Yo-Yo Intermittent Recovery test (YYIRT). Additionally, there may be decreases of approximately 5.3% in countermovement jump height (CMJ) (Caldwell and Peters, 2009) and up to 3.3% (Caldwell and Peters, 2009) in linear sprint performance. These reductions are noteworthy because when the season restarts, diminished performance levels may compromise the ability to handle the higher training loads typically encountered during the pre-season, potentially leading to overreaching or an increased risk of injuries (Jeong et al., 2011; Silva et al., 2016).

The offseason can pose particular challenges, especially for individuals lacking specific training guidance, such as youth players. Consequently, offseason training programs hold significant value in mitigating the declines resulting from the cessation of regular training sessions (Clemente et al., 2022). They also offer an opportunity to introduce alternative training methods aimed at sustaining a certain level of physical fitness, although with a reduced training volume compared to the regular season (Clemente et al., 2021b).

For example, research studies have revealed that implementation of offseason training programs can mitigate the decrements in physical fitness, thus being significantly different from remaining inactive (Silva et al., 2016; Clemente et al., 2022). In the case of (Joo, 2018), while players experiencing training cessation showed a drop in YYIRT levels of about -14.8%, those exposed to high-intensity interval training (HIIT) during the off-season actually improved by 3.4%. Similarly, in (Christensen et al., 2011), while players experiencing training cessation declined YYIRT levels by 22.6%, the group exposed to HIIT improved their levels by 6.1%.

However, current literature on offseason training interventions and detraining in soccer is diverse and heterogeneous (Silva et al., 2016; Clemente et al., 2021b). The variation in detraining periods, and the lack of comparison between different training approaches, does not allow for the identification of the most appropriate training programs to mitigate decrements while ensuring that players still have adequate rest. Considering aerobic capacity as the key

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physical fitness variable in soccer, and CMJ and linear sprint as important physical attributes associated with muscle power in soccer's most intense actions (Aquino et al., 2020), it is important to understand how to mitigate their decrements.

Comparing HIIT training methods and resistance training methods easily employable as plyometric jump training (PJT) can be particularly interesting, as both have shown to be very effective in improving and maintaining physical attributes (Kunz et al., 2019; Ramirez-Campillo et al., 2020; Clemente et al., 2021a) while requiring minimal training time. Comparing both, and having a program combining both, can be of particular interest (Ferley et al., 2020). Furthermore, considering the window of opportunity for youth participants, often lacking individualized training and offering a greater margin for trainability, specialized individual offseason training programs could significantly benefit their long-term careers (Kelly and Williams, 2020). This study offers evidence of the potential effects of such programs, providing valuable insights for practitioners aiming to introduce complementary training approaches typically excluded from standard on-field routines.

Due to the fact that no study has compared both methods or compared both isolated against a combined training program, the current research holds innovation in providing evidence about these aspects. Thus, the purpose of this study was to analyze the effects of three offseason training programs on the aerobic capacity, countermovement jump, and linear sprint performances of youth male soccer players.

Methods

Study design and experimental approach

This study conducted a randomized parallel controlled trial, wherein players who voluntarily expressed interest in participating were randomly assigned to one of several groups (HIIT, PJT, HIIT+PJT, control). The study employed blinding for the evaluators but not for the players and the physical trainers who prescribed and accompanied them during the training sessions. Randomization was conducted before the initial player evaluations, and the groups were maintained consistently throughout the intervention, thereby guaranteeing allocation concealment. Importantly, the randomization process was overseen by a team member not directly involved in the research, further safeguarding against potential biases. Sealed envelopes containing an equal number of letters per group were used for randomization. Recruitment involved advertising off-season training programs in clubs and on social media. The intervention lasted three consecutive weeks, with assessments conducted at baseline (one week prior to the intervention) and post-intervention (one week after the intervention). The duration of the intervention was limited to the availability of the offseason period, yet it was aligned with the average duration observed in studies focusing on short-term detraining in soccer (Nakamura et al., 2012). The study commenced one week after the cessation of training with their respective teams.

Participants

The sample size was estimated a priori based on the mean values from the study by (Joo, 2018) for the YYIRT. Using an estimation for repeated measures, an effect size of 0.67, four groups, and 2 measurements, with a power of 0.95 and a significance level of 0.05, the recommended sample size provided by G*power software (version 3.1.9) was 36 participants. The eligibility criteria for this study were: (i) being outfield players; (ii) not performing any other training than that assigned by this experiment; (iii) not being injured in the latest month; (iv) adhering to at least 90% of the training intervention; (v) not missing the two physical fitness assessments.

After the recruitment process, 67 participants were identified. Following the matching process with the eligibility criteria, 58 participants remained for the final analysis (Figure 1). These participants had an average age of 17.6 ± 0.6 years, a body mass of 62.8 ± 2.1 kilograms, a height of 173.6 ± 2.5 centimeters, and an average of 4.7 ± 0.7 years of experience. Descriptive statistics for each group can be found in Table 1. All participants were members of regional-level under-19 teams, indicating a trained/developmental competitive level, with an average of three training sessions per week. They were familiarized with the study design and provided with information on the benefits and risks of participation. Legal guardians signed a consent form after the procedures were explained. Participants were informed that their involvement was voluntary and that there would be no consequences for withdrawing voluntarily. The study adhered to ethical standards outlined in the Declaration of Helsinki and was approved by the Institutional Ethical Review Board at the Chengdu Institute of Physical Education, with reference code 2023#104.

Offseason training programs

Each intervention group participated in two training sessions per week for three consecutive weeks, totaling six sessions throughout the intervention period. These sessions were conducted in small groups throughout the day, to accommodate the participants' availability. There was a 48-hour rest period between each training session.

The HIIT sessions took place on the track field (straight line running), while the PJT sessions were conducted on a concrete floor. For HIIT, training intensity was standardized based on the results of the 30-15 Intermittent Fitness Test, which was administered the week prior to the start of the intervention solely to individualize training intensity for each player. In the case of PJT, players were instructed to perform each repetition at maximal intensity.

Table 1. Descriptive statistics of the participants.

	HIIT (n=15)	PJT (n=14)	HIIT+PJT (n=14)	Control (n=15)
Age (years)	17.5±0.5	17.6±0.6	17.6±0.6	17.7±0.5
Experience (years)	4.5±0.5	4.9±0.7	4.8±0.8	4.8±0.7
Height (cm)	173.8±3.0	173.4±2.5	173.6±2.1	173.6±2.5
Body mass (kg)	62.6±2.1	63.0±2.1	62.8±2.2	63.0±2.1

HIIT: high-intensity interval training group; PJT: plyometric jump training group; and HIIT+PJT group

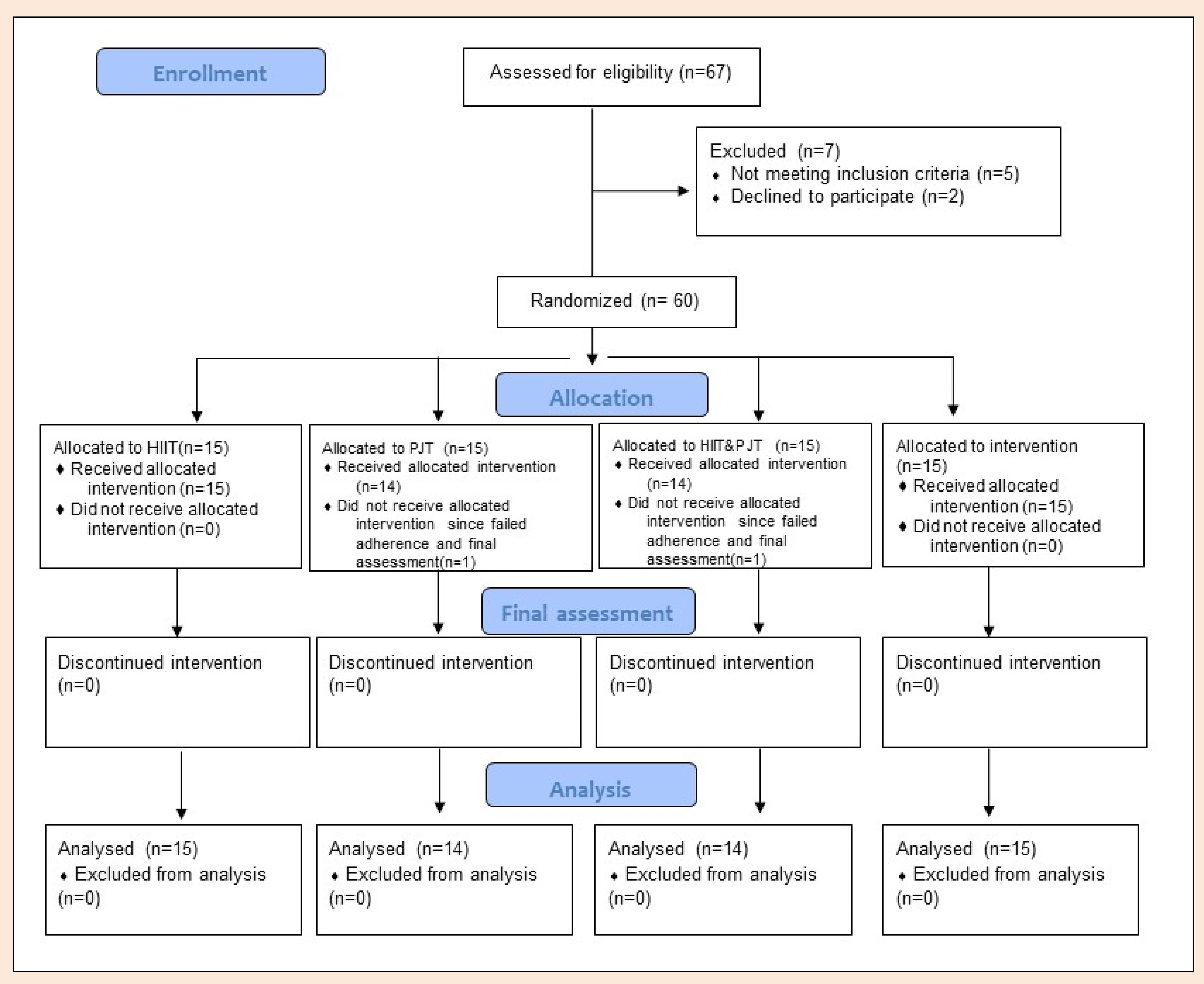

Figure 1. Participant flow diagram.

Prior to each training session, all intervention groups (i.e., HIIT, PJT, and HIIT+PJT) completed a 7-minute warm-up protocol consisting of 4 minutes of jogging and 3 minutes of dynamic stretching focusing on the lower limbs. Following the warm-up, participants performed the training exercises as described in Table 2. These sessions were supervised and guided by two personal physical trainers with expertise in fitness training and backgrounds in sports sciences and physical education.

The control group maintained their regular routines during the training cessation period. None of the participants engaged in any supplementary training.

Physical fitness assessments

The physical fitness assessments were conducted on the same day, twice during the study (pre- and post-intervention). These assessments took place on the track field in the afternoon and followed a specific order: warm-up (the same as reported in training intervention), CMJ, 30-meter linear sprint, and YYIRT. Between tests, players were provided with a 3-minute rest period.

Countermovement jump: The classical countermovement jump was implemented. The athlete began in a standing position, then initiated a rapid downward movement by flexing the hips, knees, and ankles. After that, they quickly transitioned for vertical jumping, always with knees extended and hands on the hips, before landing back on the floor. Flight time was assessed using the validated MyJump 2 mobile application, which has demonstrated reliability in previous studies when compared to gold standard methods such as the Optojump photoelectric cell system (Bogataj et al., 2020). Notably, significant correlations were observed between the MyJump 2 app and OptoJump for both squat jumps ($r = 0.97$, $p = 0.001$) and countermovement jumps ($r = 0.97$, $p = 0.001$) in the total sample (Bogataj et al., 2020). The height of the jump in centimeters was retrieved as the main outcome. The players had one attempt of familiarization, followed by two trials interspaced by a 3-minute rest. The best jump height was used as the main outcome for the data analysis. The average within-player coefficient of variation between trials was 2.3%.

30-m linear sprint test: The 30-meter linear sprint test was conducted on a track field to assess sprinting performance. Participants began the sprint from a split stance, with their preferred leg forward. Positioned 30 cm before the initial pair of photocells, they were instructed to maintain a consistent starting posture with the same leading leg throughout.

Table 2. Training programs implemented during the offseason.

	HIIT	PJT	HIIT+PJT
Week 1	Session 1: 4 sets, 2 repetitions, 45 seconds work (90%VIFT) inter-spaced by 45 seconds rest between repetitions and 3 minutes between sets Session 2: 4 sets, 2 repetitions, 60 seconds work (85%VIFT) inter-spaced by 60 seconds rest between repetitions and 3 minutes between sets	Session 1: 4 × HCMJ two leg; 4 × HCMJ dominant leg; 4 × HCMJ non dominant leg; 4 × HRCMJ (3 bounce); 4 × HRCMJ (3 bounce) dominant leg; 4 × HRCMJ (3 bounce) non dominant leg (3 minute rest between exercises) Session 2: 4× VCMJ; 4× VCMJ; 4× VCMJ; 4× drop jumps (30 cm); 4× drop dominant leg jumps (15 cm); 4× drop non dominant leg jumps (15 cm) (3 minute rest between exercises)	Session 1: 4 × HCMJ two leg; 4 × HCMJ dominant leg; 4 × HCMJ non dominant leg; 4× VCMJ; 4× VCMJ; 4× VCMJ; 4× drop jumps (30 cm) (3 minute rest between exercises) Session 2: 4 sets, 2 repetitions, 45 seconds work (90%VIFT) inter-spaced by 45 seconds rest between repetitions and 3 minutes between sets
Week 2	Session 3: 4 sets, 2 repetitions, 45 seconds work (90%VIFT) inter-spaced by 45 seconds rest be-tween repetitions and 3 minutes between sets Session 4: 4 sets, 2 repetitions, 60 seconds work (85%VIFT) inter-spaced by 60 seconds rest between repetitions and 3 minutes between sets	Session 3: 4 × HCMJ two leg; 4 × HCMJ dominant leg; 4 × HCMJ non dominant leg; 4 × HRCMJ (3 bounce); 4 × HRCMJ (3 bounce) dominant leg; 4 × HRCMJ (3 bounce) non dominant leg (3 minute rest between exercises) Session 4: 4× VCMJ; 4× VCMJ; 4× VCMJ; 4× drop jumps (30 cm); 4× drop dominant leg jumps (15 cm); 4× drop non dominant leg jumps (15 cm) (3 minute rest between exercises)	Session 3: 4 × HCMJ two leg; 4 × HCMJ dominant leg; 4 × HCMJ non dominant leg; 4× VCMJ; 4× VCMJ; 4× VCMJ; 4× drop jumps (30 cm) (3 minute rest between exercises) Session 4: 4 sets, 2 repetitions, 60 seconds work (85%VIFT) inter-spaced by 60 seconds rest between repetitions and 3 minutes between sets
Week 3	Session 5: 4 sets, 2 repetitions, 45 seconds work (90%VIFT) inter-spaced by 45 seconds rest between repetitions and 3 minutes between sets Session 6: 4 sets, 2 repetitions, 60 seconds work (85%VIFT) inter-spaced by 60 seconds rest between repetitions and 3 minutes between sets	Session 5: 4 × HCMJ two leg; 4 × HCMJ dominant leg; 4 × HCMJ non dominant leg; 4 × HRCMJ (3 bounce); 4 × HRCMJ (3 bounce) dominant leg; 4 × HRCMJ (3 bounce) non dominant leg (3 minute rest between exercises) Session 6: 4× VCMJ; 4× VCMJ; 4× VCMJ; 4× drop jumps (30 cm); 4× drop dominant leg jumps (15 cm); 4× drop non dominant leg jumps (15 cm) (3 minute rest between exercises)	Session 1: 4 × HCMJ two leg; 4 × HCMJ dominant leg; 4 × HCMJ non dominant leg; 4× VCMJ; 4× VCMJ; 4× VCMJ; 4× drop jumps (30 cm) (3 minute rest between exercises) Session 2: 4 sets, 2 repetitions, 45 seconds work (90%VIFT) inter-spaced by 45 seconds rest between repetitions and 3 minutes between sets

HIIT: high-intensity interval training group; PJT: plyometric jump training group; and HIIT+PJT group; HCMJ: horizontal countermovement jumps; VCMJ: vertical countermovement jumps; VIFT: final velocity at 30-15 Intermittent Fitness test

At the beginning indicated by a countdown, participants were instructed to decelerate only after passing the final pair of photocells. The height of the photocells was adjusted to align with the hip height of each participant. Sprint times were recorded using two pairs of photocells (SmartSpeed, Fusion Sport, Queensland, Australia). Each participant completed two trials of the 30-meter sprint, separated by a 3-minute rest period. The within-participant variability between trials, presented as a coefficient of variation, averaged 1.9%. The faster time of the two sprints (measured in seconds) was utilized for subsequent data analysis.

Yo-Yo Intermittent recovery test: The Yo-Yo Intermittent Recovery Test Level 1 (YYIRT) was implemented to assess participants' aerobic performance. The test was conducted on the track field. The test involved repeated 20-meter shuttle runs performed at increasing speeds dictated by audio signals. Participants were required to run back and forth between two lines set 20 meters apart, with a brief active recovery period between shuttles. The speed started at 10 km/h and gradually increased throughout the test (Krustrup et al., 2003).

Participants were instructed to maintain the pace dictated by the audio signals for as long as possible, ensuring they reached the end line before the next signal. If a participant failed to reach the line before the signal, they were given a warning. After two consecutive failures to reach the line in time, the test was terminated, and the total distance covered (in meters) was recorded as the test score.

Statistical analysis

Descriptive statistics were reported as the mean and standard deviation. Normality was assessed using the Kolmogorov-Smirnov test ($p > 0.05$), and homogeneity was evaluated using Levene's test ($p > 0.05$). Once both normality and homogeneity assumptions were confirmed, a mixed ANOVA test (time*group) was conducted to compare outcomes before and after the intervention, taking into account the different groups. Partial eta squared was calculated as the effect size. Pairwise comparisons were conducted using the Bonferroni test, while Cohen's standardized effect size was employed to analyze the magnitude of the differences between groups. Effect size magnitudes were interpreted as follows (Cohen, 1988): small (d: 0.2 to 0.5), medium (d = 0.5 to 0.8), and large ($d \geq 0.8$). Statistical analyses were performed using SPSS (version 28.0.0.0, IBM, USA), with significance set at $p < 0.05$.

Results

Baseline comparisons revealed no significant differences between groups on CMJ (F=0.979; p=0.410; η^2=0.052), YYIRT (F=0.087; p=0.967; η^2=0.005) and 30-m sprint time (F=0.140; p=0.935; η^2=0.008). Descriptive statistics of physical fitness outcomes pre and post-intervention can be observed in Table 3.

There was not a significant main effect of time on CMJ (F=0.457; p=0.502; η_p^2=0.008) excluding the interaction with groups. However, significant interactions between time and groups were found in CMJ (F=18.968; p<0.001; η_p^2=0.513). Group*time interaction revealed that the control group was significantly different from HIIT (mean difference: –2.133cm; p<0.001), PJT (mean difference: –2.390 cm; p<0.001), and HIIT+PJT (mean difference: –2.533cm; p<0.001). Considering the within-group differences, HIIT and HIIT+PJT did not significantly vary from pre to post (p>0.999 and p>0.080, respectively), while PJT significantly improved (mean difference: +0.786cm; p=0.002) and control group significantly declined his performance (mean difference: −1.533cm; p<0.001). Figure 2 shows the individual percentage of difference (post-pre) for the three main outcomes.

There was a significant main effect of time on YYIRT (F=56.727; p<0.001; η_p^2=0.512) excluding the interaction with groups. However, significant interactions between time and groups were found in YYIRT (F=17.570; p<0.001; η_p^2=0.494). Group*time interaction revealed that control group was significantly different from HIIT (mean difference: –270.67m; p=0.037), although no other significant differences were found (p>0.05). Considering the within group differences, HIIT did not significantly varied from pre to post (p=0.474), while PJT significantly declined (mean difference: −110.0m; p<0.001), as well as PJT+HIIT (mean difference: −64.3m; p=0.020) and control group (mean difference: –241.3m; p<0.001).

There was a significant main effect of time on 30-m sprint (F=173.052; p<0.001; η_p^2=0.762) excluding the interaction with groups. However, significant interactions between time and groups were found in 30-m sprint (F=19.012; p<0.001; η_p^2=0.514). Group*time interaction revealed that control group was significantly different from HIIT (mean difference: 0.031s; p=0.024), PJT (mean difference: 0.045s; p<0.001) and HIIT+PJT (mean difference: 0.033s; p=0.021). Considering the within group differences, HIIT significantly declined from pre to post (mean difference: 0.023s; p<0.001), as well as PJT (mean difference: 0.014s; p=0.002), PJT+HIIT (mean difference: 0.019s; p<0.001) and control group (mean difference: 0.054s; p<0.001).

Table 3. Descriptive statistics (mean and standard-deviation) of the physical fitness measures pre and post-intervention.

	HIIT pre (n=15)	HIIT post (n=15)	PJT pre (n=14)	PJT post (n=14)	HIIT+PJT pre (n=14)	HIIT+PJT post (n=14)	Control pre (n=15)	Control post (n=15)
CMJ (cm)	32.6±1.6	32.6±1.6	32.1±1.3	32.9±0.9	32.6±1.1	33.0±1.3	32.0±0.8	30.5±1.1
YYIRT (m)	2482.7±242.6	2501.3±220.2	2434.3±326.8	2324.3±288.6	2482.9±233.0	2230.7±315.7	2472.0±353.7	2230.7±315.7
30-m sprint (s)	4.14±0.03	4.16±0.03	4.14±0.03	4.15±0.02	4.14±0.04	4.16±0.04	4.14±0.03	4.20±0.02

CMJ: countermovement jump; YYIRT: Yo-Yo Intermittent recovery test level 1; HIIT: high-intensity interval training; PJT: plyometric jump training

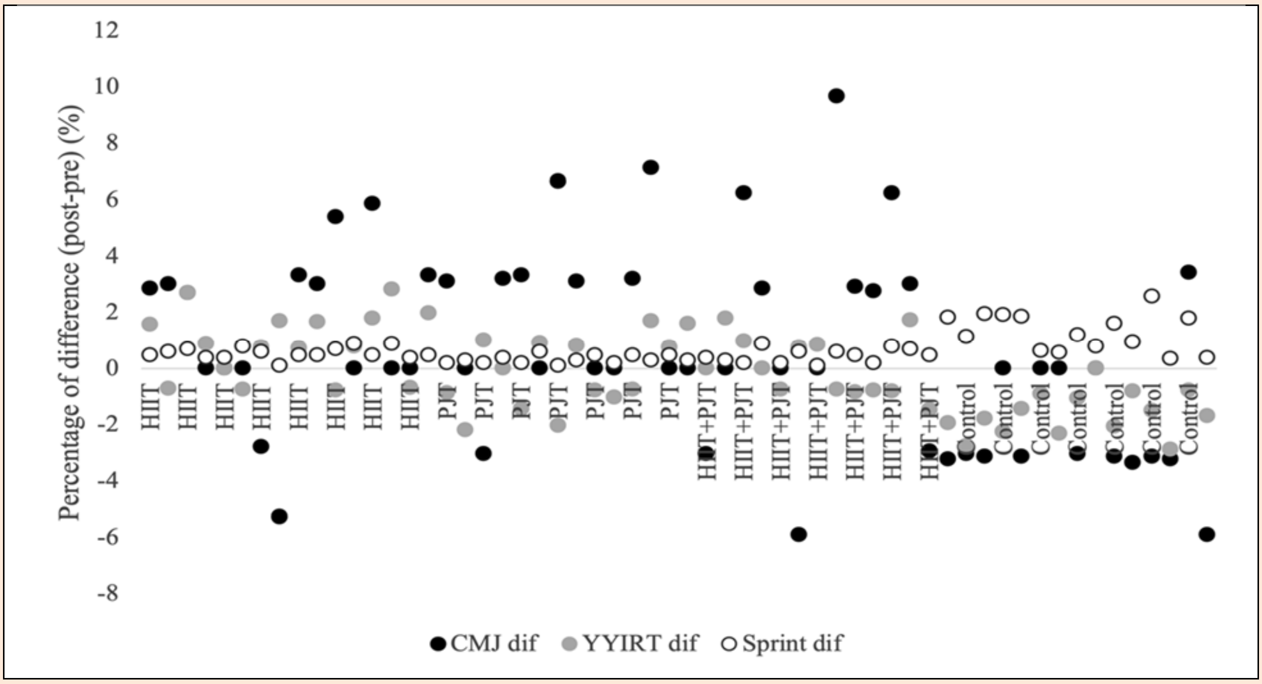

Figure 2. Individual percentage of difference (post-pre) for the countermovement jump (CMJ), Yo-Yo intermittent recovery test level 1 (YYIRT) and 30-m sprint time (Sprint) considering the groups of high-intensity interval training (HIIT), plyometric jump training (PJT), HIIT+PJT and control.

Discussion

This study revealed the efficacy of offseason training programs (HIIT, PJT, and HIIT+PJT) compared to maintaining inactivity during training cessation concerning their impact on physical fitness. However, in the case of the YYIRT, only the HIIT group demonstrated significant differences from the control group. Furthermore, within-group analysis indicated that despite undergoing training, all groups experienced significant declines in linear sprint performance. Additionally, regarding aerobic performance in the YYIRT, only the HIIT group were able to maintain their levels, while the PJT, HIIT+PJT, and control groups experienced significant declines. Lastly, concerning CMJ, participants in the PJT group significantly improved their jumping height, while those in the HIIT and HIIT+PJT groups maintained their performances. Significant decrements were observed in the control group.

Short-term detraining (less than 4 weeks) significantly impacts aerobic capacity and the factors contributing to performance in this domain (Mujika and Padilla, 2000). For instance, maximal oxygen uptake can decrease by 4 to 14%, depending on the initial trained level, while blood volume may drop by 5 to 12%, and stroke volume by 10 to 17%, especially among highly trained individuals (Mujika and Padilla, 2000). These reductions can collectively lead to diminished performance in aerobic capacity assessments such as the YYIRT. Short-term detraining in soccer players triggers a cascade of physiological adaptations that compromise aerobic capacity. Cardiovascular changes, including reduced stroke volume and cardiac output, limit oxygen delivery to working muscles (Mujika and Padilla, 2000). Concurrently, peripheral adaptations such as decreased mitochondrial density and capillary density impair oxidative metabolism and nutrient delivery within skeletal muscle (Hellsten and Gliemann, 2024). These alterations, combined with neuromuscular shifts favoring less oxidative muscle fibers, contribute to a decline in aerobic performance (Hellsten and Gliemann, 2024).

Our study demonstrates that despite players being divided into three different training groups, in addition to a control group, only those engaged in HIIT training (twice a week) were able to sustain their levels significantly better than the control. These findings are consistent with (Joo, 2018), who found that HIIT training maintained YYIRT performance, with a 3.4% improvement compared to a control group decrease of 14.8%. Similarly, our results corroborate those of (Christensen et al., 2011), indicating a 6.1% improvement in the HIIT group and a 22.6% decrease in those who ceased training.

The different effects of HIIT and PJT on aerobic capacity during detraining period can be elucidated through their different physiological mechanisms. HIIT triggers the increase of mitochondrial biogenesis, enhancing oxygen uptake, and optimizing muscle fiber recruitment (MacInnis and Gibala, 2017). These adaptations result in heightened oxidative capacity and cardiovascular efficiency, facilitating superior utilization of oxygen during exercise (Gibala, 2021). Conversely, PJT primarily targets anaerobic energy pathways and fast-twitch muscle fibers (Davies et al., 2015), limiting its ability to sustainably stimulate aerobic adaptations. Its emphasis on explosive movements and intermittent rest intervals may not provide the consistent cardiovascular stress necessary for maintaining or enhancing aerobic performance during detraining periods. Thus, while HIIT fosters comprehensive muscular and cardiovascular adaptations conducive to aerobic fitness, plyometric jump training's focus on power and explosiveness renders it less effective in preventing declines in aerobic capacity during periods of reduced training (Melchiorri et al., 2014).

Interestingly, our study also revealed that PJT and HIIT+PJT (one session per week each) failed to counteract the effects of the offseason. This aligns with (Nakamura et al., 2012) who employed moderate running and plyometric training in soccer players, showing a 15.3% decrease in aerobic performance with inactivity and a 12.2% decrease in those who remained inactive. This indicates that when athletes experience decreased aerobic training stimuli during periods of reduced activity, whether partially or completely, their training-induced adaptations may diminish rapidly (Mujika and Padilla, 2001a). The abrupt reduction in training volume (O'Connor and Malone, 2019) and the limited frequency of HIIT+PJT, with only one session of HIIT per week, may account for the inability to prevent declines in aerobic performance. It is conceivable that two sessions of HIIT per week are necessary to maintain aerobic performance during the off-season training period.

When the aerobic metabolism and the cardiorespiratory system lack adequate stimulation, they fail to counteract the decline in stroke volume and maximal cardiac output that typically accompanies reduced offseason training (Mujika and Padilla, 2001b). Furthermore, cardiac dimensions tend to reduce, blood pressure tends to increase, and ventilatory efficiency often suffers after periods of training cessation (Mujika and Padilla, 2000). Consequently, there is a significant decline in overall cardiorespiratory fitness, resulting in a swift deterioration of aerobic performance among trained athletes.

Considering the impact of offseason training programs on the CMJ, a significant benefit of PJT in improving jump height was observed, while participants enrolled in HIIT and HIIT combined with PJT maintained their levels. Only the control group, which remained inactive, experienced significant declines in this measure. Interestingly, previous studies on training cessation in soccer have shown that even players attending training sessions can experience declines between 2.1% (Requena et al., 2017) and 5.6% (Koundourakis et al., 2014) in this measure, while inactivity can lead to declines of 5.3% (Caldwell and Peters, 2009). However, contrary to previous studies (Caldwell and Peters, 2009; Koundourakis et al., 2014; Requena et al., 2017), our PJT was specifically designed to focus on stimulating the stretching-shortening cycle, which shown to be favorable for participants performing the sessions twice a week, aligning with other studies conducted on PJT in soccer players (Ramirez-Campillo et al., 2020).

However, participants in HIIT or even HIIT combined with one session of PJT did not show improvement in the variable, although they did not experience declines in their levels either. Possibly, PJT once a week is sufficient to maintain the muscular stimulus, particularly neural mechanisms and muscular force outputs (Behrens et al., 2013), to ensure the maintenance of performance in CMJ. Conversely, being inactive leads to a significant decline in CMJ performance, possibly due to reductions in muscle strength, power output, and neuromuscular coordination (Silva et al., 2016).

Finally, our study revealed that despite players being enrolled in training sessions, they all experienced significant declines in sprint performance, with the control group exhibiting a significantly worse outcome than the experimental groups post-intervention. A previous study (Joo, 2018) comparing offseason training programs against control groups have consistently shown declines in linear sprint performance, with both the inactive group and the HIIT group experiencing declines of 2.4%. Additionally, (Requena et al., 2017), in a mixed-based offseason training program, reported decrements of 2.4%, and (Nakamura et al., 2012), using a combination of moderate running and plyometric training, observed decrements of 3.3% in sprint performance.

Sprinting is a complex skill that requires a high level of muscular output, power, technique, and skill (Suchomel et al., 2016). Previous reports have suggested that sprinting is a specific skill that demands specialized training, particularly training at maximal or near-maximal levels (Haugen et al., 2014). Failure to achieve these levels can result in inadequate stimulus, thereby promoting declines in performance (Clemente et al., 2021b). Considering that our HIIT training is conducted at sub-maximal running speeds, and plyometric training, while activating muscular output, does not specifically target the application of force in sprinting, it is reasonable to observe declines in performance across all groups at the end of the offseason.

Our study is not without limitations. Some limitations stem from representativeness, as the study only included male soccer players and did not encompass professionals or younger athletes. Moreover, for a more in-depth analysis, it would be beneficial to collect additional variables, particularly considering biomechanical aspects related to muscle force or physiological mechanisms related to cardiac output or stroke volume, in order to better understand the underlying mechanisms that may explain declines in physical fitness and performance. Moreover, it would be valuable to explore other alternative training approaches, such as muscle power training or sprint training, to assess their effects on specific physical performances. In future research, several factors warrant consideration, particularly regarding the duration of training interventions and their impact across various age groups. Additionally, it may be beneficial to incorporate a broader range of training approaches to identify the most suitable methods for addressing the primary attributes of players.

Despite these limitations, the current study is innovative as it compares two different training approaches (HIIT and PJT) and includes a combined version of them to explore which one may be more favorable in mitigating declines in physical fitness performance. As practical implications, it is recommended that players adhere to offseason training programs, viewing them as a means to improve specific qualities or simply to avoid abrupt declines, thus enabling better adaptation to the training loads during the pre-season.

It is suggested that HIIT training be conducted twice a week to mitigate significant declines in aerobic performance while maintaining at least one plyometric training session per week could help preserve lower-limb power and lessen declines in sprint performance.

While caution is warranted in implementing offseason training programs, with individualization being a crucial aspect to consider, our study suggests that short HIIT sessions, comprising 4 sets of 2 repetitions lasting between 45 and 60 seconds each, along with plyometric training incorporating both bilateral and unilateral exercises at maximum intensity, could be effective in mitigating the impact of detraining on the primary physical fitness variables of players. Both training approaches have the advantage of being feasible to implement without requiring extensive resources, as they are adaptable to various facilities and equipment.

Conclusion

This study revealed that HIIT effectively maintains aerobic performance during offseason periods in under-19 soccer players, whereas PJT specifically improves CMJ outcomes. Despite active training, all intervention groups, similar to the control, suffered declines in sprint performance. While all groups experienced declining sprint performance, the control group showed significantly worse declines. Moreover, regarding aerobic performance in the YYIRT, the HIIT group was able to maintain their levels, whereas the PJT, HIIT+PJT, and control groups experienced significant declines. Concerning CMJ, participants in the PJT group significantly increased their jumping height, while those in the HIIT and HIIT+PJT groups maintained their performances. In terms of practical implications, players are encouraged to adhere to off-season training programs, viewing them as opportunities to enhance specific qualities or mitigate abrupt declines, thus facilitating better adaptation to preseason training loads. To mitigate aerobic performance declines, incorporating HIIT sessions twice weekly during the offseason is advisable. To enhance or maintain jump performance, integrating at least one session of PJT weekly is beneficial.

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Key points

- Offseason training programs incorporating high-intensity interval training (HIIT), plyometric jump training (PJT), or a combination of both have proven effective in mitigating the decline observed in soccer training cessation when compared to inactive control groups.
- Maintenance of aerobic performance was achievable only through twice-weekly sessions of HIIT.
- Sprint performance experienced significant declines irrespective of enrollment in these training programs, although the control group exhibited significantly greater impacts.
- Enhancement of countermovement jump ability can be achieved with two sessions of PJT, or maintained with two sessions of HIIT, or a combination of one session of HIIT and one of PJT.

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