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The influence of bodyweight high-intensity interval training on critical velocity and sprinting abilities in well-trained soccer players

NICHOLAS MORTENSEN[1], KRISTEN SNYMAN[2]

Abstract
Introduction. **The need for efficient training programs is critical for high-performance in competitive soccer. High-intensity interval training is an effective exercise modality that can improve both the aerobic and anaerobic energy systems, but its efficacy to enhance performance-related tests in well-trained soccer players is unknown.** Aim of Study. **The purpose of this study was to evaluate a bodyweight high-intensity interval training program and its effects on critical velocity via a 50-meter 3-minute all-out test and maximal sprint speed by a 40-yard dash in well-trained soccer players during the competitive season.** Material and Methods. **The experimental subjects performed a progressive series of high-intensity exercises and conditioning, twice per week for 4 consecutive weeks, in addition to their regular practice and match schedules. A 2 × 2 ANOVA was used for both performance tests, along with the smallest worthwhile change and smallest real difference to measure practical significance compared to the athletes who did not perform the additional training protocol.** Results. **No statistically significant differences were found between time or groups for the 40-yard dash ($p = 0.079$; $p = 0.161$) or 50-m 3-minute all-out tests ($p = 0.052$; $p = 0.351$), however, significant small ($p = 0.024$) and trivial ($p = 0.04$) interactions were found, respectively. For practical significance, considerable differences between the experimental and control groups were found for both performance tests.** Conclusions. **The results can be a practical option for strength and conditioning coaches to improve game-impacting sprinting and critical velocity in well-trained soccer players within a 4-week in-season training period with minimal additional training investments.**

KEYWORDS: soccer, critical velocity, high-intensity interval training, performance, maximal sprint speed.

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Corresponding author: nicholasmort11@gmail.com

[1] *Siena Heights University, Nursing and Health Sciences, Siena, United States*
[2] *Concordia University Chicago, Health & Human Performance, Chicago, United States*

Introduction

Soccer emphasizes cardiovascular and neuromuscular systems throughout matches which requires participants to jog, run, sprint, jump, kick, and slide tackle, both with and without the possession of the ball [2, 23]. As the competition levels increase, the physiological demands and the quality of specific skills and tactics required to be successful on an individual and team basis require more attention [2, 23]. Systematically planned training programs and assessments in soccer require an emphasis on the aerobic and anaerobic energy systems while also addressing the need for frequent changes in speed, direction, power, strength/endurance, and intensities [2, 20]. Athletes expressing the highest levels of these performance traits during matches will typically improve their chances of success during match play [2, 20]. However, during the competitive season, tactical/technical training sessions generally are prioritized, which emphasize specific skill sets needed to execute team gameplay, limiting the opportunities for training specific cardiovascular or neuromuscular needs for performance enhancement leading up to a match [2, 20].

As physiological and psychological demands increase throughout a match, soccer players will likely encounter various levels of fatigue that may negatively impact performance [2, 17]. These fatigue levels could result from muscle acidification, neuromuscular inefficiencies, depleted muscle glycogen stores, or a combination [20]. The high variability of fatigue depends considerably on the athletes' playing position, the severity of acute and chronic stressors, and their ability to recover between intense performance periods, all of which reflect the efficiency of an athlete's physiological systems [17, 20]. The capabilities of these high-performing athletes can be practically evaluated using numerous running field tests such as the 40-yard dash (40-YD) to assess maximal sprint speed (MSS) and the 3-minute all-out test (3AOT) to determine the efficiency of the aerobic and anaerobic systems [15, 17]. Improving fatigue resistance is possible, but these improvements are mainly unknown in well-trained athletes, specifically, soccer players who already have high aerobic capacities and fatigue resistance [2].

High-Intensity Interval Training (HIIT) is an exercise modality centered on altering sets and recovery periods that vary between high and low intensities/volumes for specific times [7]. HIIT programs have improved aerobic and anaerobic capabilities in various populations, with additional neuromuscular benefits when incorporating resistance training [7, 17, 27]. In a landmark study by Tabata et al. [28], 2 groups ($n = 14$) were evenly divided to perform an aerobic (70% of $\dot{V}O_{2max}$, 60 minutes per day) or anaerobic (7 to 8 sets of 20 seconds of work at 170% of $\dot{V}O_{2max}$, followed by 10 seconds of rest) cycling program 5 days per week for 6 consecutive weeks. The aerobic group significantly ($p < 0.01$) improved their $\dot{V}O_{2max}$ (53 ± 5 to 58 ± 3 ml·kg^{-1}·min^{-1}), but did not significantly ($p > 0.10$) improve anaerobic capacity, while the anaerobic group significantly improved ($p < 0.01$) both $\dot{V}O_{2max}$ and anaerobic capacity by 7 ± 1 ml·kg^{-1}·min^{-1} and 28%, respectively, when compared to pre-training values [28]. Furthermore, HIIT can improve aerobic and anaerobic conditioning in athletes, usually in less time than traditional cardiovascular training [7, 17, 18, 23, 27]. For instance, McRae et al. [18] evaluated aerobic running (~85% maximal heart rate for 30 minutes; $n = 7$) and a HIIT (20 seconds of as many repetitions as possible of whole-body exercises, followed by 10 seconds of rest for 8 rounds) program against non-exercise controls, 4 days per week for 4 weeks. Collectively, all subjects significantly ($p < 0.05$) improved their $\dot{V}O_{2peak}$ (aerobic: 45 ± 5.0 to 48 ± 3.0 ml·kg^{-1}·min^{-1}; HIIT: 43 ± 7.6 to 46 ± 7.8 ml·kg^{-1}·min^{-1}), but only the HIIT group saw significant ($p < 0.05$) improvements in leg extension, chest press, sit up, push-up, and back extension capabilities [18]. The performance upgrades with the HIIT group were due to the subjects invoking an average of 80% or more of their HRmax per session while creating additional local and systemic muscular endurance adaptations via metabolic stress [18, 22]. HIIT programs provide opportunities to train at different intensities and volumes, reflecting an athlete's current physical and psychological abilities to work in high-stress environments while invoking numerous positive adaptations [7, 8, 17].

HIIT programs have also demonstrated numerous improvements among soccer players, such as improving fatigue resistance, recovery capabilities, and aerobic power, all of which can positively impact performance during match-play [2, 7, 23, 27]. For example, Rowan et al. [23] divided $\dot{V}O_{2max}$ matched collegiate soccer players into a HIIT and aerobic training group where they performed their conditioning sessions twice per week over 5weeks during the season. The HIIT group performed 5 repetitions of 30-second sprints as fast as possible, with 3.5 to 4.5 minutes of active recovery, and the aerobic-only group performed a 40-minute run at 80% of their $\dot{V}O_{2max}$ [23]. Both HIIT and aerobic groups significantly improved mean $\dot{V}O_{2max}$ (50.68 to 53.04 ml·kg^{-1}·min^{-1}, 4.73% increase; 50.64 to 52.31 ml·kg^{-1}·min^{-1}, 3.42% increase, $p = 0.002$) and average distance covered during the Yo-Yo Intermittent Recovery test (1857 ± 423 to 2131 ± 436 m, $p = 0.001$; 1473 ± 494 to 1613 ± 510 m, $p = 0.042$) with no significant differences between groups [23]. The application of HIIT created just as substantial aerobic and anaerobic performance values as traditional endurance training, but with considerably less time [23]. Moreover, a meta-analysis by Kunz et al. [16] further supports the use of HIIT in soccer and found that small-sided games (intense ball-handling games performed on smaller fields) and running-based HIIT programs produced similar positive performance outcomes in young soccer players, including moderate-to-large positive effects on $\dot{V}O_{2max}$, $\dot{V}O_{2peak}$, running economy, and change-of-direction performance. Despite the documented effectiveness of HIIT in soccer athletes, the use of bodyweight high-intensity interval training (BW HIIT) programs in well-trained soccer players has not been established, and it is unknown if these athletes would benefit from this type of training, especially in the middle of the season, to improve or better prepare for the most crucial times of competition.

Aim of Study

The purpose of the research study was to determine the potential impact a bodyweight high-intensity interval training (BW HIIT) program has on a well-trained soccer player's critical velocity (CV) via a 50-meter 3AOT and MSS by a 40-YD [2, 19]. The study's results can provide options to improve athletic performance during the competitive season without using equipment.

Material and Methods

Subjects

Twenty highly aerobically trained soccer players (mean age = 24 ± 6 years) representing Livonia City Football Club, a semi-professional team representing the Midwest Premier League in the United States, were included in this study. All participating subjects had at least 4 years of competitive experience at the high school or college levels and were either current members of a collegiate soccer program working with the team during their off-season training or graduated from a collegiate program and were working with the team solely. Subjects were not divided into position-specific groups due to individuals playing multiple positions based on team needs and strategies; however, subjects who play goalie were excluded since goalkeepers traditionally have the lowest aerobic capacities compared to other positions due to their unique position-specific needs [2, 13]. Subjects were instructed to avoid caffeine/stimulant consumption at least 12 hours before testing, along with limiting a large consumption of food/mixed macronutrient meals at least 90 minutes beforehand to minimize ergogenic or ergolytic interferences [8, 14]. After obtaining informed consent, subjects were randomized into experimental and control groups and then participated in baseline performance testing for the 40-YD and 3OAT.

Test selection

Soccer players perform a series of low-, medium-, and high-intensity actions and movements throughout a soccer match, and the amount/capacity of high-speed running, along with the ability to recover between bouts, is a significant distinguishing factor between high and low competition levels [2, 21, 22] Therefore, consistently evaluating high-intensity exercise outcomes is necessary for soccer as a general and position-specific measurement of athletic performance [2, 17, 21, 22]. A high aerobic capacity, marked by relative $\dot{V}O_{2max}$, is associated with greater performance outcomes across many sports and activities [2, 12, 17]. Yet, due to the varying demands and actions within the sport of soccer, additional performance measurements, such as lactate threshold (LT), maximal lactate steady state (MLSS), MSS, and CV, are also evaluated to provide a more accurate performance assessment both in laboratories and the field [2, 15, 18, 20]. Even though laboratory tests typically provide more data sets in controlled settings, field tests are more likely to stimulate performance demands encountered during matches since they occur in similar environments encountered during practices and matches [2, 15, 17, 20].

Speed tests evaluate an individual's ATP-PCr and anaerobic glycolytic energy systems and typically last 20 seconds or less to determine acceleration and MSS capabilities [17]. The 40-YD is a popular performance test assessing linear speed, with high correlation values ($r = 0.89$-0.97) and reliabilities ($ICC = 0.985$; $p < 0.001$) when assessing multiple attempts and can also be manipulated based on individual or sport-specific needs [17]. It is a practical field-based test evaluating an individuals ability to accelerate (0-20 yards) linearly and achieve/maintain MSS (20-40 yards), both of which are primary attributes expressed repeatedly during soccer competitions for most playing positions [2, 17, 20, 22].

CV describes the efficiency between the energy systems and the capability to operate at various intensities/distances and recovery intervals while providing activity-specific assessments and performance predictions, especially at high-intensity capacities, making it a valuable tool in assessing most soccer positions [2, 15, 21]. The 3AOT is a valid and reliable performance test when evaluating CV [1, 17, 20]. For example, research by Alves de Aguiar et al. [1] had 7 male runners complete time trials of 800, 1600, and 2400 meters (m), along with two 3AOTs for CV comparisons. Both 3AOTs displayed excellent reliability scores for CV (trail 1: 3.90 ± 0.41 m/s^{-1}, trail 2: 3.89 ± 0.48 m/s^{-1}, ICC = 0.95, coefficient of variation = 2.97%) and D' (trial 1: 176 ± 42 m, trial 2: 183 ± 35 m, ICC = 0.93, coefficient of variation = = 5.12%) in comparison to prediction models of the 3 time trials [1]. In addition, Saari et al. [24] demonstrated that shuttle run 3AOT (2.94 ± 0.39 m/s^{-1}) displayed similar ($p = 0.71$, coefficient of variation = 7.7%) CV outcomes compared to continuous (3.00 ± 0.36 m/s^{-1}) 3AOT in 12 active subjects, further validating either method for CV predictions. Both the 40-YD and 3AOT are excellent field options to evaluate numerous sprinting and CV characteristics that soccer players frequently emphasize during training and matches [1, 15, 17, 20, 22, 24].

Testing protocols

The 40-YD and the 3AOT pre- and post-performance assessments were conducted 1 hour before a regularly scheduled evening practice at an outdoor soccer practice facility. A tape measure and cones outlined the 40-YD, marking both the start and finish lines. When ready and after individual warm-ups, subjects approached the starting line going into a split stance, placing one foot of their choosing as close to the start line as possible, with the option of placing one or both hands on the ground representing a 3 or 4-point stance. Timing began as soon as the subject initiated movement and stopped once they crossed the finish line. Subjects rested for approximately minutes and then performed a second trial, with their best running time achieved between both attempts counted as their official score.

After all subjects performed both 40-YD trials and completed a 5-minute recovery period, they performed one test of the 3AOT. The primary investigator outlined end lines 50-m apart, with cones marking each 10-m increment. After the subjects recovered and understood expectations/completed a walk-through, they approached the starting line similarly to the 40-YD trials. Subjects ran as fast as possible to the other end line, touching the line with one foot, and then returned to the starting line, repeating this process for 3 minutes. Timing started when the subject initiated movement and tracked how many yards were covered during the trial. Once 3 minutes had elapsed, the primary investigator marked where the subjects finished and noted the total distance covered during the test. Once all data sets were collected and recorded on paper, each subject's assigned number, position, and scores for each test were recorded on an electronic spreadsheet and used for scoring comparisons during the post-tests.

After completing the tests, all athletes continued their regularly scheduled training, practice, and match schedules during the competitive season, which typically contained 2 to 3 practices and 1 to 2 matches per week. The athletes were not required to perform any additional training sessions together outside of their practices, and if they were performed, they were completed on an individual basis and not tracked/ recorded for this study. The subjects were assigned to either the experimental (n = 10) or control (n = 10) groups based on their ability to commit to the exercise program and desire to participate in additional training sessions. The experimental group began their additional workouts one week after completing the first round of testing and performed 2 BW HIIT workouts weekly (8 total) for 4 consecutive weeks (Appendix A). Subjects used a Rating of Perceived Exertion (RPE) scale of 6 (no exertion at all) to 20 (maximal exertion) to execute their runs and recovery periods appropriately and according to the directions outlined (Appendix A), noting all sensations and feelings of physical stress and fatigue [9]. Subjects were instructed on how to rate their level of exertion using the RPE scale (both verbally and within the informed consent), why the scale/level of effort matters during each set/ repetition, and how to record their effort levels using the sheets provided to meet their goals (Appendix B). In addition to RPE, subjects also recorded the number of repetitions performed during each bout of exercise using a data tracking sheet to ensure high levels of effort were maintained throughout the program, along with aiming for a 10 percent increase in total repetitions during weeks 3 and 4 of training.

The primary investigator provided verbal encouragement to the subjects to help ensure proper form and execution of each exercise round as hard as possible. After individual warm-ups, the exercise program took approximately 20 minutes for each session, considering the 1-minute rest periods between each exercise protocol. When the exercise program finished, subjects joined their team for the rest of their scheduled practice or could do what they wanted if the program took place on a non-practice day. All subjects in the experimental group were expected to complete 8 exercise sessions during the 4 weeks, with attendance/compliance measured electronically by the primary investigator before beginning each session. If subjects did not make a session, they arranged a make-up day within the same week with the primary investigator. If 2 of the 8 regularly scheduled exercise sessions were missed, the subjects were dropped from the experiment and not included in the final data collection. Once the experimental group completed 8 exercise sessions over 4 weeks, all subjects retested their 40-YD and 3AOT for comparison to their initial values.

Data analysis

The data from each group's performance for both pre- and post-tests are outlined in Table 1. Two, 2 × 2 mixed factor ANOVAs [(time: pre, post) × (group: exp, control)] were conducted to investigate the exercise training program's impact on 40-YD and 3OAT scores between each group, respectively. Tukey HSD post hoc tests were administered to probe any significant main effects. An alpha level of 0.05 was used for all inferential analyses. For effect size, partial eta squared was set to <0.25, 0.25-

-0.50, 0.50-1.0, and >1.0 as trivial, small, moderate, and large effect size, respectively [26]. Practical significance was measured using the smallest worthwhile change (0.2 × between-subject SD) and smallest real difference (1.96 × √2 × standard error of measurement) determine performance differences and potential effectiveness of the training program on both field tests [2].

Table 1. Descriptive statistics for the experimental and control groups

Test	Timing group	M (SD)	Range
40-YD (sec)	EXP pre	5.07 (0.17)	4.68-5.28
	EXP post	4.99 (0.16)	4.65-5.21
	CON pre	4.90 (0.22)	4.5-5.25
	CON post	4.91 (0.23)	4.46-5.22
3AOT (yd)	EXP pre	753 (39.24)	680-830
	EXP post	775.3 (38.36)	734-848
	CON pre	750.6 (28.59)	710-790
	CON post	749.9 (30.47)	700-796

Note: EXP – experimental group, CON – control group, 40-YD – 40-yard dash, 3AOT – 3-minute all-out test, pre – pre-test, post – post-test

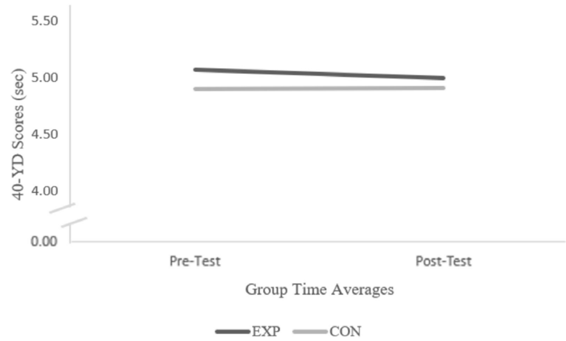

Figure 1. Interaction effects of avarage 40-yard dash (40-YD) pre-test and post-test times between the experimental (EXP) and control (CON) groups

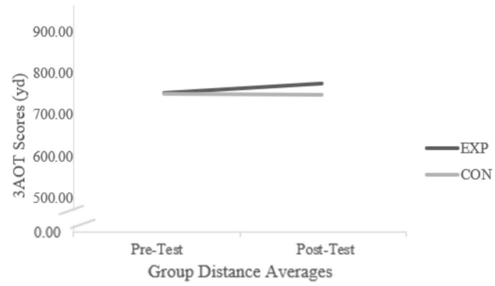

Figure 2. Interaction effects of avarage 3-minutes all-out test (3AOT) pre-test and post-test distances (yd) between the experimental (EXP) and control (CON) groups

Results

There was not a significant main effect for time [$F(1, 18) = 3.47$, $p = 0.079$, $\eta_p^2 = 0.162$] or groups [$F(1, 18) = 2.14$, $p = 0.161$, $\eta_p^2 = 0.11$] involving 40-YD dash performance (Figure 1). There was a significant interaction between groups and time [$F(1, 18) = 6.12$, $p = 0.024$, $\eta_p^2 = 0.25$], however, Tukey's HSD post hoc tests assessed the differences between each pre and post-test scores of the experimental and control groups, confirming no significant differences ($p > 0.05$) were achieved in 40-YD performances. Another 2 × 2 mixed factor ANOVA [(time:pre,post) × (group:exp,control)] was conducted to investigate the exercise training program's impact on 3AOT scores between each group (Figure 2). There was not a significant main effect for time [$F(1, 18) = 4.32$, $p = 0.052$, $\eta_p^2 = 0.19$] or group [$F(1, 18) = 0.92$, $p = 0.351$, $\eta_p^2 = 0.05$] regarding 3AOT scores. There was a significant interaction between time and group [$F(1, 18) = 4.90$, $p = 0.04$, $\eta_p^2 = 0.21$], however, Tukey's HSD post hoc tests assessed the differences between each pre and post-test scores of the experimental and control groups, confirming no significant differences ($p > 0.05$) were achieved in 3AOT performances.

The smallest worthwhile change and smallest real difference were also used to measure practical significance for the 40-YD and 3AOT pre- and post--test performances. Eight out of 10 subjects from the experimental group achieved the smallest worthwhile change of at least 0.03 seconds for the 40-YD, while the control group had only subjects achieve at least a 0.04 second improvement. The experimental group also produced the smallest real difference of 0.11 second improvement, while the control group reached only 0.01 seconds between the pre- and post- 40-YD performances. For the 3AOT, the experimental and control groups had 6 out of 10 subjects obtain the smallest worthwhile change of 7.85 and 4.52 yards between the pre- and post-tests, respectively. The experimental group also displayed the smallest real difference of 30.91 yards, while the control group collectively achieved 0.98 yards between initial and final tests.

Discussion

The main findings failed to demonstrate significant differences between the experimental and control groups for BW HIIT on the 40-YD and 3AOTs. However, the significant interaction effects for the 40-YD and

3AOTs, along with the smallest worthwhile changes and smallest real differences, showcase that the experiment provided performance-impacting improvements in the experimental group's sprinting and CV abilities after 4 weeks. These findings provide the foundations for future research to determine the usefulness of the BW HIIT training program and its impact on sprinting and CV abilities across a longer training period [2].

Various factors influence athletic performance, including genetics, environment, injury status/ history, and physical preparation [8]. While some of these aspects cannot be manipulated, power, technique, and aerobic/ anaerobic capabilities are all traits that continue to be emphasized to maximize an individual's performance in soccer [2, 20, 22]. The higher performing an individual or team is compared to their opponent, the greater the likelihood of positively influencing key outcomes, plays, and winning matches [2, 20, 22]. For instance, in an analysis of professional soccer players, the top division performed 25 to 33% longer sprints ($p < 0.001$) during match play compared to the third division despite similar distances covered between playing positions, showcasing higher workload capabilities of top performing players [12]. In addition, elite players displayed 41% higher distances covered in progressive running tests (965 $\pm$ 251 vs 685 $\pm$ 217 m; $p < 0.05$) in comparison to the sub-elite players, further demonstrating their abilities to perform under severe-intensity conditions [12]. In another analysis during the 2016-2017 season, the top 4 finishing teams in the elite Italian professional circuit demonstrated lower percentages of running (65.98 $\pm$ 1.51 vs 66.84 $\pm$ $\pm$ 2.18; $p < 0.001$) and higher percentages of jogging (25.61 $\pm$ 1.71 vs 25.30 + 1.97; $p = 0.037$) and sprinting (8.41 $\pm$ 1.04 vs 7.86 $\pm$ 0.82; $p < 0.001$) in comparison to the rest of the teams in the league [28]. The total goals scored ($r = 0.906$; $p < 0.001$) and final position ranking ($r = 0.850$; $p < 0.01$) were also strongly correlated, indicating that the best teams displayed high levels of jogging and sprinting during match-play, which positively influenced outcomes throughout the season [28]. Improving athletic performance, however, becomes increasingly difficult as individuals become more trained and get closer to reaching their maximal potential, which is a considerable factor in these well--trained subjects [25].

There are notable shortcomings that may have contributed to the lack of statistical significance in addition to the ones identified before the experiment was conducted. The most significant limitation that occurred was the sample size. For the a priori levels to be set to 0.05, a minimum sample size of 52 subjects from both the experimental and control groups would be required to avoid a type II error [3, 5, 6]. However, the small sample size of 20 total subjects underpowered the results, which is a significant factor in failing to reject the null hypothesis [3, 5, 6]. Due to the small sample size, the collective improvements of the subjects needed to drastically improve beyond their pre-test values to obtain statistical significance [3]. Since there were at least 50 subjects to choose from between both teams, the primary investigator aimed to have at least 20 subjects for the experimental group and 20 for the control group to empower the sample size and better understand the results obtained. Unfortunately, the lack of subjects completing the study was attributed to injuries sustained during the 6-week timeframe, the inability to commit to the additional conditioning sessions, or current collegiate players transitioning from the club to their university teams. Despite the primary investigator's desire to investigate if significant performance improvements can improve within the season, these factors reduced subject participation and limited the results.

In addition to the small sample size, the training stimuli/ volume may not have been enough or too much to improve sprinting or CV abilities significantly due to the offsetting demands of regular practices/conditioning sessions and normal competition schedules, all of which may impact recovery capabilities and positive adaptations [2, 10]. The modalities of backward sprinting, HIIT, and high-speed interval running have previously been documented to significantly improve athletic performance variables in soccer players by enhancing sprinting capabilities, muscular endurance, and fatigue resistance, respectively [5, 10, 17, 22, 23, 30]. The in-season training period may have limited performance adaptations due to the physical preparation that took place in previous training periods and current demands of the competitive season, further necessitating additional testing of the BW HIIT intervention during other cycles of the season, such as the off-season or pre--season [5, 9, 22, 23]. Previous studies that used similar training methods took place during the off-season training periods, which provides a greater opportunity for extensive adaptations to occur [10, 23, 30]. The exercise sessions in these previous studies were also the primary training modality, with subjects performing 2 to 5 weekly bouts lasting between 5 to 10 weeks [10, 20, 30]. The current study had subjects perform the training program twice per week for 4 weeks in addition to practices 2 to 3 times per week and regular competitions, speculating that competing demands and fatigue could have been primary factors in not achieving significant performance improvements, along with the program's duration [9, 10, 17, 21, 22, 23, 30].

The age and skill levels of the subjects may have also played a vital role in the lack of statistically significant performance improvements. For instance, the typical high school age range is between 14 to 18 years of age, and the subjects recruited for the current study ranged between 18 to 30 years [9]. Peak performance for world-class track and field sprinting times usually peaks between 25 to 27 years, with longer distance events observing higher peak performance ages [9]. Since physical maturation has likely not peaked in the adolescent or high-school athletes observed in previous studies [11, 30], their potential training adaptations may be more extensive than subjects within the next age group decade [9, 25]. The subjects of the current research study were all current or former colligate athletes, indicating they had more training years and are likely closer to their genetic ceiling for performance capabilities compared to the younger counterparts in the other studies [9, 10, 11, 25, 30]. In addition, all subjects of the current research study were part of a semi-professional team, demonstrating their high skill and performance levels before the experiment [2, 11, 25]. Despite the lesser likelihood of achieving substantial performance improvements in the current study's subjects versus other sub-elite populations, the need to research performance improvements in these athletes remains high for influencing outcomes for competitions [2, 25].

A final primary limitation is that the novel exercise program used by the experimental group is based on training programs derived from previous studies [5, 18, 27, 30], and while each program found significant performance improvements, the training protocols utilized by the experimental group in this study used only parts of these programs for additional conditioning purposes. Even though the subjects were part of a semi-professional team, the team's programs lacked specific periodized training modalities and exercise tools that other clubs may have regular access to, providing them with potential performance training disadvantages, which is why the goal was to determine if these attributes can improve within minimal investments in time and equipment. Regardless of a team's circumstances, there are specific periods when training programs are designed to achieve peak performance levels during the competitive season, usually in preparation for the most important competitions, further highlighting the study's importance [10].

Current academic studies and publications rely heavily on finding innovative research that produces statistically significant results, which prompts researchers to make determinations based on absolute terms and may create biases or manipulation of data/analyses without a true effect [3, 6, 29]. The findings in sports science research can vary greatly due to numerous dependent/independent variables and sample sizes, which all play a role in determining significance [3, 6]. If findings are excluded by not achieving these standards, the progress of understanding and progressing human performance may be limited [3, 6]. Relying solely on published statistically significant data could also impact follow-up or meta-analysis research, and it may not consider the entirety of findings regarding specific athletic performance tests and training modalities [3]. Therefore, the data in sport science research should be presented clearly for readers to translate the findings instead of relying on the author's interpretations, which can be accomplished through alternative statistical methods that highlight practical significance, feasibility, and create opportunities for future research/applications, especially when statistical significance is not found [3, 4, 6]. For instance, top level professional starting soccer players that play the majority of the match displayed greater total distance covered and high-intensity running vs nonstarters, and starters also displayed higher instances of countermovement jump height and peak power [9]. Despite not achieving statistical significance, exercise training strategies will likely need to differentiate between starters and nonstarters to best prepare for competition and performance capabilities [9]. Furthermore, the top 100 sprinters in the world from 2002 to 2016 achieved mean annual improvements between 0.1-0.2% [9]. The top ten athletes in all track and field categories except throwers also had small, yet the greatest improvements as they reached their peak age compared to athletes ranked 11 to 100 (1.8 + 1.1 to 1 + 0.9%) during this timeframe, further emphasizing the need for athletic performance to improve in elite athletics, even marginally, to create significant impacts in competition [3, 9].

Other soccer performance variables/assessments could also test the program's efficacy, such as vertical or horizontal jumps for lower body power and other aerobic capacity tests such as the Yo-Yo Intermittent Recovery test [4, 23]. In addition, testing different age groups/genders and applying the protocols to other field sports can all offer greater insight into understanding the usefulness of the exercise program and addresses the gaps found [3, 4, 7, 23, 29]. If similar results are obtained in the replication studies, or additional variables/relationships are identified, it increases the confidence of the original analysis while also providing converging evaluations [3, 6]. When key variables, specific problems, and potential outcomes are identified, additional follow-up research designs are needed to determine further if a cause-and-effect relationship can be established, along with highlighting the exercise program's efficacy and practicality in practice for athletes and coaches [3, 4, 6, 29].

The data from the present study provides an exploratory hypothesis in that the training program did produce performance-related, practical improvements in both the 40-YD and 3AOT, but these results were not similarly supported by traditional inferential analyses [3, 4, 6]. Future trials with large sample sizes or longer durations for training would likely reveal additional, useful information regarding the practicality of including a program such as this into a competitive season schedule [3, 4, 6].

Conclusions

In soccer, the athleticism required for competitive success is dependent on the level of competition, playing position, and tactics, which is why administering and analyzing performance tests are crucial for understanding individual and team capabilities/goals. The variety of exercise programs available can improve many traits required, but executing a training program during the competitive season that complements the demands of practices and games is less clear. This study aimed to understand if sprinting and CV abilities can improve within well-trained soccer players during the competitive season. Despite the lack of statistical significance, the training program produced practically significant results for both performance attributes after a 4-week mesocycle, which coaches can use to prepare their athletes for the most important competitions. The results provide the framework for future investigations and replication studies to determine the impact of a BW HIIT on well-trained soccer players and potentially other field sports.

Conflict of Interest

The authors declare no conlifct of interest.

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Appendix A

Exercise Program

	Backward Running (RPE)	Tabata Split Jumps (Reps each set)	Tabata Alternate 1-Leg Plyometrics + Modified Burpees (Reps each set)	Sprint + Walk (RPE)
Week 1	15 yards 2 sets @ Mod 6 sets @ Sev*	20 sec AMRAP 10 sec of rest 8 rounds*	20 sec AMRAP 10 sec of rest 8 rounds*	10 sec @ Sev 20 sec @ Low For 6 mins
Week 2	15 yards 2 sets @ Mod 8 sets @ Sev*	20 sec AMRAP 10 sec of rest 8 rounds*	20 sec AMRAP 10 sec of rest 8 rounds*	10 sec @ Sev 20 sec @ Low For 6 mins
Week 3	20 yards 2 sets @ Mod 6 sets @ Sev*	20 sec AMRAP 10 sec of rest 8 rounds*	20 sec AMRAP 10 sec of rest 8 rounds*	10 sec @ Sev 20 sec @ Low For 7 mins
Week 4	20 yards 2 sets @ Mod 8 sets @ Sev*	20 sec AMRAP 10 sec of rest 8 rounds*	20 sec AMRAP 10 sec of rest 8 rounds*	10 sec @ Sev 20 sec @ Low For 8 mins
Goals	Increase volume or distance each week while maintaining RPE intensities	Improve total repetitions per 8 rounds by 10% during weeks 3 + 4	Improve total repetitions per 8 rounds by 10% during weeks 3 + 4	Maintain RPE intensity levels throughout

Note: Low – low intensity (RPE ≤ 8), Mod – moderate intensity (RPE 12-14), Sev – severe intensity (RPE 18+), AMRAP – as many repetitions as possible
* Subjects rest 1 minute after all sets/rounds are completed for each category before moving on to the next series

Description of Each Exercise Series

Backward Running: After the subject's warm-up using their own methods, they will perform sets at moderate intensities (RPE 12-14) and 6-8 sets at severe intensities (RPE 18+) within the distance outlined each week. Sets will be performed with one subject at a time, and once a set is completed, the subject walks back to the starting line as a form of active recovery. During the active recovery time, the following subject up begins their backward running protocol. This process is repeated until all sets for the day are completed for each subject. RPE is recorded at the end of the end of all sets to ensure appropriate intensities are utilized.

Split Jumps: Starting in the split stance with one foot completely flat/forward and the other foot behind the torso on their toes, individuals then dip their body down by bending their legs. Subjects immediately jump upward and reposition their legs to land softly in opposite directions, and the sequence is repeated until their time is reached. Subjects record their repetitions for each set for tracking purposes.

1-Leg Plyometrics + Modified Burpees: Subjects alternate between both exercises during each round, performing a total of 4 sets of 1-leg plyometrics (2 each leg) and 4 sets of modified burpees. The focus of the 1-leg plyometrics is to perform as many jumps either side-to-side or front-to-back on one leg as possible during the round, focusing on both explosive power and speed. For the modified burpees, the subjects stand upright, then bend over and squat down while placing their hands on the ground slightly wider than shoulder width apart. While bracing the upper body, subjects kick both of their legs up simultaneously until their legs are fully extended, and they land on their toes. Subjects then reverse the process by bringing both legs inward and then jumping upwards as high as possible while extending their body, followed by a quiet landing where the lower body absorbs the impact. Repetitions are recorded for each set for tracking purposes.

Sprint + Walk: The final session consists of all subjects performing the protocol at the same time. Subjects line up at the starting line and then sprint as fast as possible for 10 seconds, followed by 20 seconds of walking as a form of active recovery. The process is repeated for 6 total minutes or 12 total repetitions. Auditory timing cues will be announced by the principal investigator, and subjects will sprint/walk back-and-forth within a 50-meter start and end line. RPE is recorded at the end of all sets to ensure appropriate intensities are utilized.

Appendix B

Tracking Sheet for Each Participating Subject in the BW HIIT Program

Assigned number: ____________

	Backward Running (Total RPE)	Tabata Split Jumps (Reps each set)	Tabata Plyos/Burpees (Reps each set)	Walk + Sprint (Total RPE)
Session 1				
Session 2				
Session 3				
Session 4				
Session 5				
Session 6				
Session 7				
Session 8				