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Research article

Comparing Physical Fitness Adaptations Induced by Small-Sided Soccer Games with and Without Ball Touch Limitations: A Randomized Parallel and Controlled Study

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Abstract

While ball touch limitations are frequently implemented in small-sided games (SSGs) to alter physiological and physical responses, existing research has yet to assess their medium-term impact on physical fitness adaptations. This study aimed to compare the effects of SSGs with ball touch limitations (limitedBT) versus free play (freeBT) on adaptations in linear speed, anaerobic power, and aerobic performance. In this randomized parallel controlled trial, 47 youth male soccer players (16.6 ± 0.6 years) were randomly assigned to limitedBT (n = 16), freeBT (n = 16), or a control group (n = 15). Over six weeks, participants in the experimental group attended three additional SSG sessions per week, lasting 12 to 20 minutes, with formats including 4v4, 3v3, 5v5, and 2v2, where the only difference between groups was that the freeBT group had no ball touch limitations, while the limitedBT group did; the control group only participated in regular training. Players were assessed at baseline and post-intervention for linear speed over 10 and 30 meters, anaerobic power performance using the Repeated Sprint Ability Test (RAST), and aerobic performance using the Yo-Yo Intermittent Recovery test (YYIRT). While at the baseline, no differences were found between groups, following the intervention, significant differences between the groups were observed in the YYIRT (p < 0.001; η_p^2 = 0.278), 10-m sprint time (p < 0.001; η_p^2 = 0.367), RAST total time (p < 0.001; η_p^2 = 0.367) and RAST initial-final decline (p<0.001; η_p^2 = 0.274). In the case of YYIRT, the control group showed significantly lower values post-intervention compared to both freeBT (p = 0.048) and limitedBT (p < 0.001). For the 10-meter sprint time, limitedBT demonstrated significantly faster times than both freeBT (p = 0.045) and control (p < 0.001), while freeBT was also significantly faster than control (p = 0.042). Regarding RAST total time, limitedBT recorded significantly better times than both freeBT (p = 0.042) and control (p < 0.001), with freeBT also outperforming control (p = 0.045). Finally, in the RAST initial-final decline, the control group performed significantly worse than both limitedBT (p < 0.001) and freeBT (p = 0.034). In conclusion, this study found that limitedBT effectively enhances anaerobic and short-distance sprint performance, while both limitedBT and freeBT formats similarly improve aerobic capacity, suggesting that incorporating ball touch conditions into training can optimize overall player fitness.

Key words: Football, small-sided games, aerobic capacity, anaerobic, sprint.

Introduction

Small-sided games (SSGs) are modified soccer drills with fewer players, smaller areas, and adjusted rules, designed to replicate key aspects of the full game (Davids et al., 2013). These games provide more frequent opportunities for decision-making, ball control, and positional play, which are essential to the sport's dynamics (Ometto et al., 2018). By adjusting task conditions, SSGs allow coaches to elicit specific player responses while maintaining a high-intensity physiological environment (Hill-Haas et al., 2011). Smaller formats, such as 1v1 to 4v4, often exceed anaerobic thresholds, while larger fields promote higher-intensity running and sprinting (Bujalance-Moreno et al., 2019). SSGs also enhance tactical awareness and spatial understanding, encouraging quicker decision-making, better ball control, and improved technical performance (Fernández-Espínola et al., 2020), making them a valuable tool for developing physical and tactical-technical skills (Ometto et al., 2018).

In SSGs, coaches frequently adjust conditions such as the number of players, field dimensions, and game rules (e.g., ball touch limitations, scoring method) to meet specific training goals (Clemente et al., 2021). These modifications affect the intensity and type of player engagement, prompting acute physiological and physical responses (Bujalance-Moreno et al., 2019). Smaller teams and larger playing areas typically increase the frequency of high-intensity actions, resulting in elevated heart rates (Rampinini et al., 2007; Clemente et al., 2023). This stimulates cardiovascular and anaerobic capacity, as supported by existing evidence (Hammami et al., 2018; Moran et al., 2019; Clemente et al., 2024). Other rules, such as modifying task objectives, have also shown differences in intensity, with games focused on ball possession or multiple goals proving to be more intense than those with a single regular goal (Almeida et al., 2017). Additionally, limiting the number of ball touches has been shown to increase intensity, with fewer touches allowed resulting in greater intensity (Dellal et al., 2011c; Casamichana et al., 2014). While the effects of player numbers and field dimensions are well-documented, there is a research gap concerning the long-term impact of various game rules, as most studies have only examined acute responses, with limited evidence on the adaptations following extended training programs (Clemente et al., 2021).

One example is the ball touch limitation rule. Studies have shown that touch limitations typically increase the physiological intensity of the game (Dellal et al., 2011c; Casamichana et al., 2014), likely by forcing quicker decision-making, more frequent ball movement (Sousa et al., 2019), and greater player displacement, which elevates heart rates and perceived exertion levels. This constraint

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possibly encourages players to become more actively involved in the game, as evidenced by an increased number of passes and technical actions compared to free play scenarios (Clemente and Sarmento, 2020). For example, in one of the first studies (Dellal et al., 2012) comparing one-touch, two-touch, and free play formats, it was observed that high-intensity running significantly increased under the one-touch condition compared to free play in the same 4v4 format. Additionally, when comparing amateur and professional players across formats from 2v2 to 4v4, it was found that the most restrictive touch limitation (one touch) resulted in significantly greater total distance covered, more sprinting, higher ratings of perceived exertion, and increased blood lactate concentrations (Dellal et al., 2011b).

The relevance of exploring the impact of ball touch limitations in SSGs for practitioners and coaches is substantial, as it can provide valuable insights into how such conditions influence players' physical development and performance. While existing research has thoroughly examined the physiological and physical demands of ball touch limitations (Dellal et al., 2011c; Casamichana et al., 2014), there is a notable gap in understanding the long-term effects of these limitations on key physical adaptations, such as aerobic and anaerobic performance, as well as speed and power. The increasing body of research on SSGs has largely focused on comparing these formats to other training methods (Clemente et al., 2021) or on variations in field dimensions (Wang et al., 2024). However, these studies often overlook the critical aspect of ball touch restrictions and their specific role in enhancing or altering physical conditioning. For coaches, understanding how prolonged exposure to ball touch limitations influences athletic development is essential, as it can affect the way they design training regimens and adjust exercise intensities for optimal results.

To bridge this gap, experimental studies testing the impact of ball touch limitations on physical adaptations in youth athletes are needed. Such research will provide coaches with evidence-based strategies, allowing them to make more informed decisions when manipulating training conditions to target specific performance outcomes. Ultimately, by investigating the effects of SSGs with limited ball touches (limitedBT) compared to free play (freeBT), this study aims to shed light on how these different training stimuli influence linear speed, anaerobic power, and aerobic performance, contributing to a deeper understanding of their potential long-term effects on youth soccer players' physical fitness. This knowledge can then be used to optimize training designs that better support players' development and competitive readiness.

Methods

Experimental approach to the problem

The study utilized a randomized controlled design, incorporating two experimental intervention groups (limitedBT and freeBT), with a control group engaging only in the regular in-field soccer training. Participants were selected through convenience sampling from two regional soccer teams.

To reduce the potential influence of specific club training routines on the outcomes, players were randomly assigned to one of the three groups, with balanced participant numbers within each team. The randomization process was carried out using opaque envelopes to ensure concealment and prevent any bias during group allocation. Prior to the initial assessment, each participant was assigned a group through a 1:1 randomization ratio. Inside each opaque envelope was a sealed, randomly generated assignment card indicating the participant's group placement. This method ensured that neither the participants nor the researchers involved in the assessment were aware of the group assignments beforehand, maintaining the integrity of the randomization process.

Assessments were carried out by independent evaluators, who had no knowledge of the group assignments or the interventions being implemented. These evaluations took place one week before the intervention and again after the six week. However, due to logistical challenges during training, neither the players nor the researchers administering the protocols were blinded to the group assignments.

Participants

The sample size for the study was determined using G*Power software (version 3.1.9, Universität Düsseldorf, Germany). The calculation was based on an effect size f of 0.788, which was derived from eta squared (0.383) reported in a previous study investigating the impact of SSG on aerobic performance (Wang et al., 2024). Three groups and two measurement points were considered in the analysis. A statistical power of 0.95 and a significance level of 0.05 were set for the ANOVA repeated measures within-between interaction. The resulting recommendation for the total sample size was 12 participants.

The study's inclusion criteria were defined as follows: (i) participation in both evaluation time points (pre- and post-intervention), (ii) at least three years of soccer experience, (iii) attendance of 85% or more of regular training sessions, (iv) no injury or illness occurring during the study, (v) no engagement in supplementary conditioning programs, and (vi) boys outfield players. Goalkeepers were excluded because they typically possess different technical skills compared to outfield players, and their position is tactically distinct, which could potentially affect the overall team performance in the games. Additionally, players were excluded if they were involved in other strength and conditioning programs, as this could influence the adaptations.

Following recruitment across two teams, 53 players expressed interest in participating. However, five players were excluded because they played as goalkeepers, and one participant was excluded due to an injury that prevented attendance at the initial evaluation. Consequently, 47 eligible players were randomly allocated to one of the three groups (see Figure 1).

The study involved 47 male youth soccer players, who had an average age of 16.6 ± 0.6 years, a mean height of 168.1 ± 5.2 cm, a body mass averaging 59.6 ± 7.1 kg, and a body mass index of 20.9 ± 1.8 kg/m². The characteristics of each group are detailed in Table 1. These participants were categorized as being at a trained or

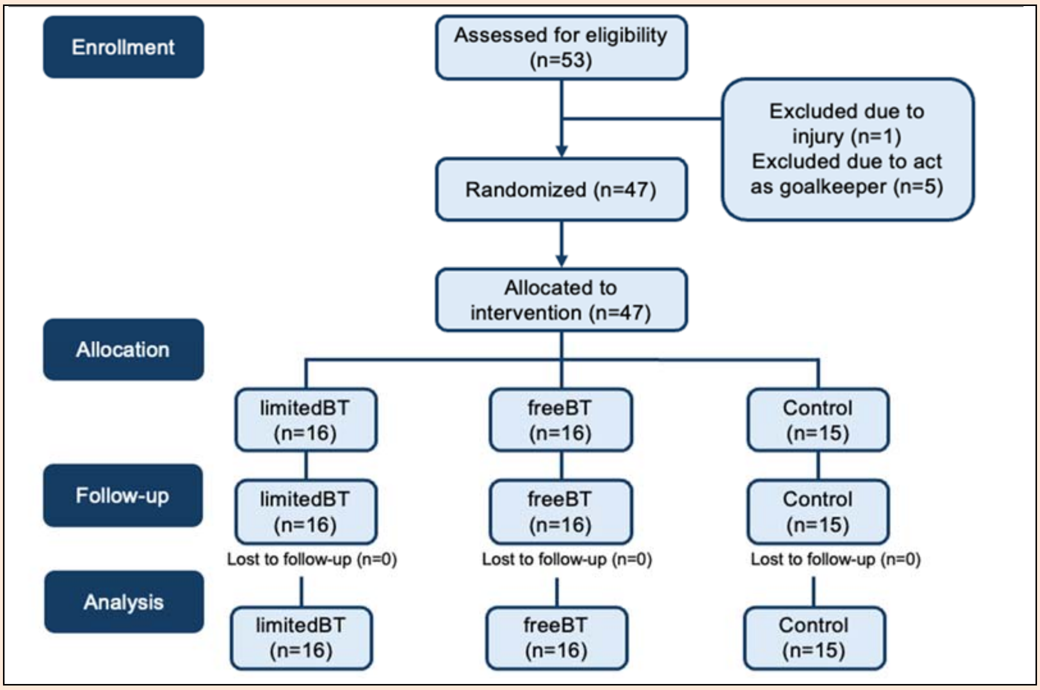

Figure 1. Participants flowchart. limitedBT: ball touches limitation; freeBT: free play.

Table 1. Characteristics of the participants.

	Age (years)	Height (cm)	Body mass (kg)	Body mass index (kg/m^2)
freeBT (n = 16)	16.6 ± 0.8	165.6 ± 4.4	56.4 ± 6.1	20.5 ± 1.8
limitedBT (n = 16)	16.6 ± 0.6	169.8 ± 4.7	61.5 ± 5.9	21.4 ± 1.9
Control (n = 15)	16.6 ± 0.5	169.0 ± 5.8	59.7 ± 7.5	20.8 ± 1.7

limitedBT: ball touches limitation; freeBT: free play.

developmental level (McKay et al., 2022). Competing at the regional level, these players attended training sessions three four per week, with a primary focus on preparing for competition. Each session, lasting between 90 and 115 minutes, was designed to enhance competitive readiness and specialized skills. The structure included a general warm-up, followed by targeted physical conditioning, technical and tactical drills, positioning exercises, and ended with a formal game and a cool-down period. The adherence rates to the intervention sessions, which incorporated SSG, were 93.2% for the limitedBT group and 94.3% for the freeBT group.

The Ethics Committee of the ChengDu Sport University granted initial approval for the study protocol (approval code 2025/5). Informed consent was obtained from all participants as well as their legal guardians. The study adhered to the ethical guidelines set forth in the Declaration of Helsinki regarding research involving human participants.

Small-sided games programs

The research incorporated SSG interventions over 6 weeks as an additional program to complement regular soccer training sessions held in field. While soccer coaches exclusively managed the standard sessions, the researchers were responsible for implementing the experimental interventions. Over a span of six weeks, participants in the experimental groups attended three extra SSG sessions each week, whereas the control group only participated in the usual in-field training (Table 2). The first session occurred 48 hours after the match, with the second session following 24 hours later, and a third session scheduled 48 hours before the next match. These sessions, conducted prior to regular training, began with a standardized warm-up comprising 7 minutes of jogging, 7 minutes of dynamic stretching targeting lower limbs, and 5 minutes of muscular potentiation exercises. Table 1 provides details of the training plans utilized during the intervention period.

During the training period, the sessions ranged from 12 to 20 minutes. Sessions with smaller formats were more intermittent, involving less time and more sets, while the opposite approach was also used. Additionally, there was a gradual increase in volume: the first two weeks featured shorter sessions (12 to 15 minutes), followed by a progression to 15 to 20 minutes, with the same formats but more sets. In the final week, a slight decrease in volume was implemented.

The freeBT group was allowed to play without any restrictions on the number of ball touches. In contrast, the limitedBT group was limited to a specific number of touches, with the first touch counting as the reception. For instance, with a one-touch restriction, the reception had to occur in the pass itself, while a two-touch restriction allowed players to receive the ball, potentially orienting for progression, before making the pass. The rules closely mirrored those of a formal game, except that no offside rule was implemented, and the ball was repositioned by foot instead of by hand when it went out of bounds. To foster a competitive environment, teams faced various opponents during each repetition, with the results contributing to their

Table 2. Detailed SSGs training program.

Week	Session	Format	Pitch	Target	Ball touch limitations (n)	Sets (n)	Duration per set (min)	Rest between sets (min)
1	1	4 vs 4	35x35m	Small goal	limitedBT: 2 freeBT: none	3	5	2
1	2	3 v 3	30x20m	Small goal	limitedBT: 3 freeBT: none	4	3	2
1	3	5 v 5	40x30m	Goalkeeper	limitedBT: 2 freeBT: none	3	5	2
2	4	4 vs 4	35x35m	Small goal	limitedBT: 2 freeBT: none	3	5	2
2	5	3 v 3	30x20m	Small goal	limitedBT: 3 freeBT: none	4	3	2
2	6	5 v 5	40x30m	Goalkeeper	limitedBT: 2 freeBT: none	3	5	2
3	7	4 vs 4	35x35m	Small goal	limitedBT: 1 freeBT: none	4	5	2
3	8	3 v 3	30x20m	Small goal	limitedBT: 2 freeBT: none	5	3	2
3	9	5 v 5	40x30m	Goalkeeper	limitedBT: 1 freeBT: none	4	5	2
4	10	4 vs 4	35x35m	Small goal	limitedBT: 1 freeBT: none	4	5	2
4	11	3 v 3	30x20m	Small goal	limitedBT: 2 freeBT: none	5	3	2
4	12	5 v 5	40x30m	Goalkeeper	limitedBT: 1 freeBT: none	4	5	2
5	13	3 v 3	30x20m	Small goal	limitedBT: 2 freeBT: none	5	3	2
5	14	2v2	25x15m	Small goal	limitedBT: 2 freeBT: none	6	2	2
5	15	4 v 4	40x30m	Goalkeeper	limitedBT: 1 freeBT: none	4	5	2
6	16	3 v 3	30x20m	Small goal	limitedBT: 2 freeBT: none	5	3	2
6	17	2v2	25x15m	Small goal	limitedBT: 2 freeBT: none	6	2	2
6	18	4 v 4	40x30m	Goalkeeper	limitedBT: 1 freeBT: none	4	5	2

freeBT: small-sided games in free play; limitedBT: small-sided games with limited ball touches.

cumulative points. Coaches ensured balanced teams by considering players' skills, physical characteristics, and positions, maintaining consistent team rosters throughout the study. During game sessions, coaches refrained from providing tactical or technical instructions or verbal encouragement. Balls were strategically placed near the field to enable quicker repositioning.

Physical fitness evaluations

Evaluations were carried out twice: initially in the week preceding the intervention and again in the week following its completion. To ensure consistency, both assessments occurred on the same weekdays, 48 hours after the final match. These sessions were conducted in-field, with a temperature of 20.3 ± 1.4°C and 54.2 ± 3.1% relative humidity, during the afternoon. The evaluation process began with the collection of demographic data and anthropometric measurements. Participants then engaged in a standardized warm-up, which included 7 minutes of jogging, 7 minutes of dynamic stretching for lower limbs, and 5 minutes of muscular potentiation. After completing the warm-up, participants underwent the tests in a specific sequence: starting with anthropometric measurements, followed by linear speed assessments, then the RAST test, and concluding with the Yo-Yo Intermittent Recovery Test Level 1. Five minutes of rest was provided between tests.

Linear speed tests

The 30-meter sprint test, designed to assess sprint performance at both the 10-meter and 30-meter marks, was conducted on synthetic turf. Participants began the sprint from a split stance with their dominant leg forward, starting 30 cm behind the first set of photocells. Consistency in the starting posture, with the same leading leg for all trials, was required.

The sprint commenced upon the signal of a countdown, and participants were instructed to only begin decelerating once they crossed the second set of photocells. To ensure accurate timing, the photocells were set at the participant's hip height and placed at key points: the start line, 10 meters, and 30 meters (the finish line). Sprint times were recorded using three pairs of photocells (SmartSpeed, Fusion Sport, Queensland, Australia).

Each participant completed two sprints, with a 3-minute rest between attempts. The variability between trials, expressed as a coefficient of variation, averaged 2.2%. For analysis, the faster sprint time at both 10- and 30-m (recorded in seconds) were used.

Repeated Sprint Ability Test (RAST)

The RAST test involved five 30-meter linear sprints on synthetic turf, with 30 seconds of rest between each sprint. This test has been previously validated for its reliability with youth soccer players (Castagna et al., 2018). Players were instructed to exert maximum effort during each sprint, with verbal encouragement provided throughout. Two pairs of photocells were positioned at both the start and finish lines (SmartSpeed, Fusion Sport, Queensland, Australia). For consistency, players began each sprint from the same position as used in the linear sprint test. Sprint times were recorded in seconds for each trial. The total sprint time, calculated as the sum of the five sprints (in seconds), along with the percentage difference from the first to the last sprint (%first-last), were documented for further analysis.

The Yo-Yo Intermittent Recovery Test – Level 1

To assess the players' aerobic capacity, the YYIRT was utilized. This test is considered a reliable tool for measuring both aerobic fitness and game-specific endurance (Krustrup et al., 2003). It consists of repeated 20-meter shuttle runs, with each successive level increasing in intensity. Starting with a pace of 8 km/h, participants ran back and forth between two markers 20 meters apart, with a 10-second recovery period after each shuttle. The test was paced by audio beeps, which initially occurred at an 8 km/h pace and progressively decreased the time between beeps, thereby requiring participants to run faster as the test advanced. Each new level increased the speed by 0.5 km/h, continuing until the participant could no longer meet the pace or missed two consecutive shuttles. The test ended when either of these conditions occurred, and the distance covered (in meters) was recorded as the final result.

Statistical procedures

Prior to conducting inferential analyses, the normality of the sample distribution was assessed using the Kolmogorov-Smirnov test ($p > 0.05$), indicating a normal distribution. To check for homogeneity of variance, Levene's test was applied ($p > 0.05$). A mixed ANOVA was performed with time (baseline and post-intervention) and group (freeBT, limitedBT, and control) as the factors. Effect sizes were evaluated using partial eta squared η_p^2 (Richardson, 2011): small (>0.01), moderate (>0.06), and large (>0.14). Post-hoc comparisons were carried out using the Bonferroni test. The magnitude of differences in pairwise comparisons was determined using Cohen's d, with effect size categories as follows (Hopkins et al., 2009): trivial (0.0 - 0.2), small (0.2 - 0.6), moderate (0.6 - 1.2), and large (1.2 - 2.0). Statistical analyses were conducted with JASP software (version 0.18.3, University of Amsterdam, The Netherlands), and significance was set at $p < 0.05$.

Results

Significant interactions between the two evaluation moments and the three groups were found in the YYIRT (F = 35.159; p < 0.001; η_p^2 = 0.615), 10-m sprint time (F = 45.461; p < 0.001; η_p^2 = 0.674), RAST total time (F = 2552.210; p < 0.001; η_p^2 = 0.991) and RAST initial-final decline (F = 22.103; p < 0.001; η_p^2 = 0.501). However, no significant interactions were observed in the 30-m sprint time (F = 0.176; p = 0.839; η_p^2 = 0.008). Table 3 shows the mean and standard deviations of pre- and post-measurements, along with inferential statistics comparing the groups. No significant differences were found between the groups at pre-intervention moments for any of the outcomes ($p < 0.05$). Following the intervention, significant differences between the groups were observed in the YYIRT (F = 8.456; p < 0.001; η_p^2 = 0.278), 10-m sprint time (F = 12.728; p < 0.001; η_p^2 = 0.367), RAST total time (F = 12.747; p < 0.001; η_p^2 = 0.367) and RAST initial-final decline (F = 8.310; p < 0.001; η_p^2 = 0.274).

In the case of YYIRT, the control group showed significantly lower values post-intervention compared to both freeBT (p = 0.048) and limitedBT (p < 0.001). For the 10-meter sprint time, limitedBT demonstrated significantly faster times than both freeBT (p = 0.045) and control (p < 0.001), while freeBT was also significantly faster than control (p = 0.042). Regarding RAST total time, limitedBT recorded significantly better times than both freeBT (p = 0.042) and control (p < 0.001), with freeBT also outperforming control (p = 0.045). Finally, in the RAST initial-final decline, the control group performed significantly worse than both limitedBT (p < 0.001) and freeBT (p = 0.034).

Figure 2 shows the within-group variations for the YYIRT, 10-m, and 30-m linear sprint times across the groups. It was observed that the YYIRT was significantly improved in both the freeBT (p < 0.001) and limitedBT (p < 0.001) groups. Similarly, the 10-m sprint time was significantly improved in both experimental groups (p < 0.001).

Figure 3 shows the within-group variations for the RAST total time and initial-final decline across the groups. It was observed that the RAST total time was significantly improved in both the freeBT (p < 0.001) and limitedBT (p < 0.001) groups. Similarly, the RAST initial-final decline was significantly improved in both experimental groups (p < 0.001).

Discussion

This experimental study is the first to examine the physical fitness adaptations resulting from players participating in SSG with and without ball touch limitations. Our findings indicate that limiting ball touches can be particularly effective in promoting greater improvements in anaerobic power in comparison to freeBT. Additionally, it led to more significant enhancements in short linear speed, such as the 10-meter sprint, compared to free play. Conversely, both experimental groups showed similar improvements in aerobic capacity, which were significantly superior to those observed in the control group. Lastly, no significant benefits were observed in either experimental group when compared to the control group in the 30-meter linear sprint.

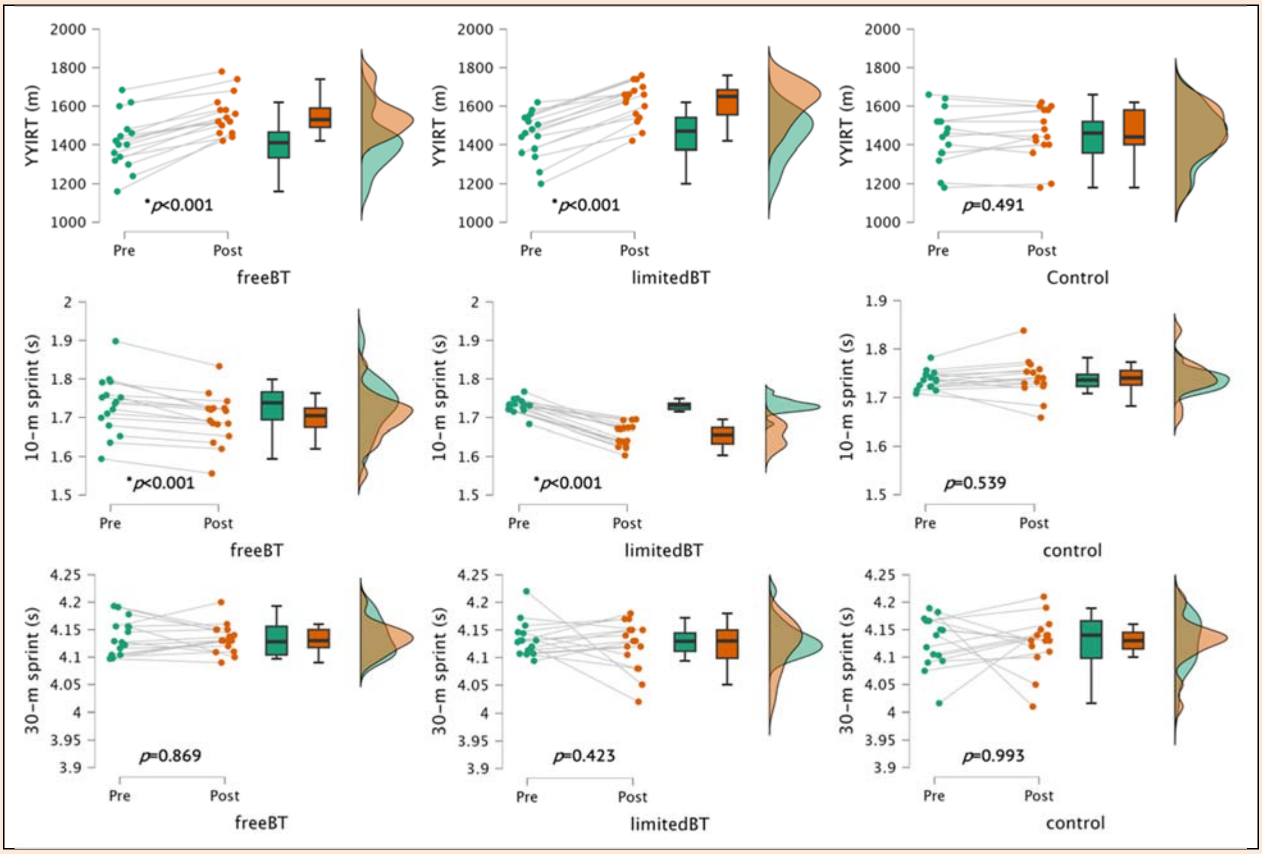

Figure 2. Intra-individual variations (pre- and post-intervention) for the Yo-Yo Intermittent Recovery Test Level 1 (YYIRT), 10-m, and 30-m linear sprint times, considering the groups of free ball touches (freeBT), limited ball touches (limitedBT), and control. *: Significant difference within the group at p < 0.05.

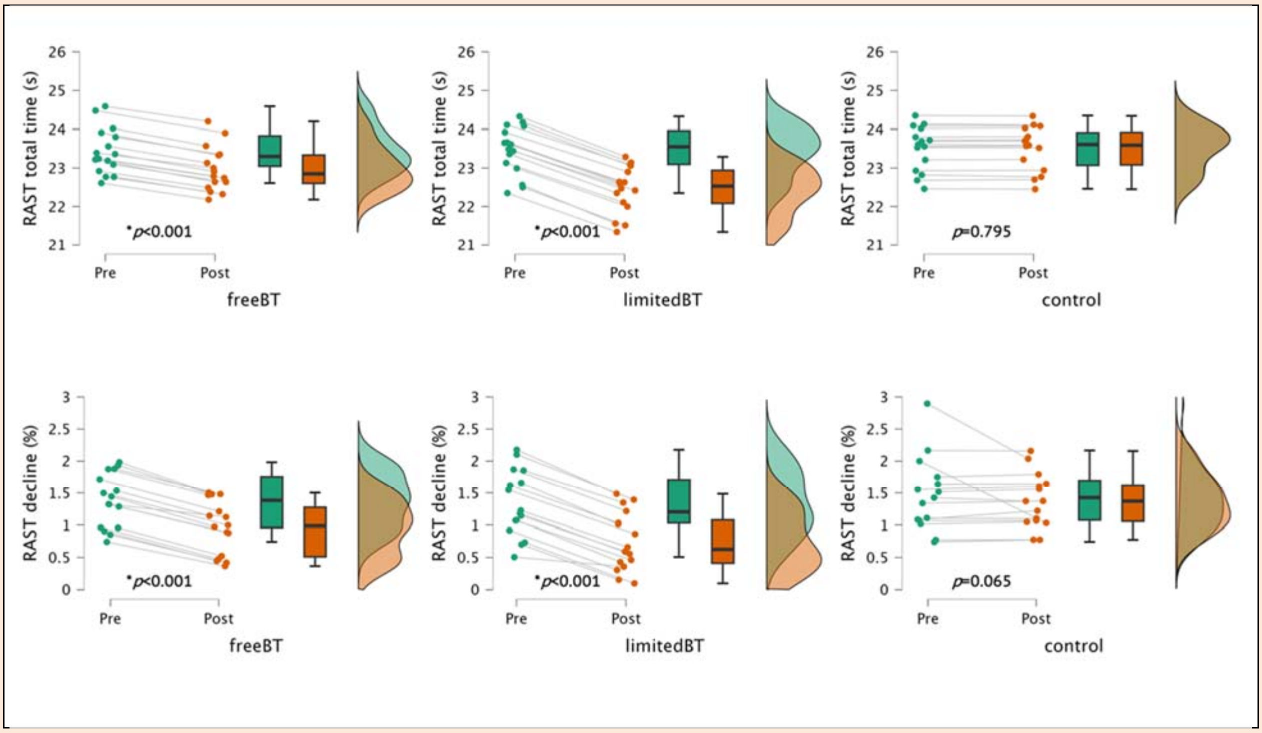

Figure 3. Intra-individual variations (pre- and post-intervention) for the Repeated Sprint Ability Test (RAST) total time and initial-final decline considering the groups of free ball touches (freeBT), limited ball touches (limitedBT), and control. *: Significant difference within the group at p < 0.05.

Table 3. Mean and standard deviations of pre- and post-measurements, along with inferential statistics comparing the groups.

		freeBT (n = 16)	LimitedBT (n = 16)	Control (n = 15)	Between-group ANOVA	Pairwise comparisons
YYIRT	Pre	1415.5 ± 137.3	1452.0 ± 117.6	1444.5 ± 143.3	F = 0.335; p = 0.717; η_p^2 = 0.015	freeBT ≈ limitedBT (p > 0.999; ES = 0.286) freeBT ≈ control (p > 0.999; ES = 0.207) limitedBT ≈ control (p > 0.999; ES = 0.057)
	Post	1557.5 ± 104.0	1622.5 ± 99.8	1454.7 ± 137.0	*F = 8.456; p < 0.001; η_p^2 = 0.278	freeBT ≈ limitedBT (p = 0.344; ES = 0.638) *freeBT > control (p = 0.048; ES = 0.853) *limitedBT > control (p < 0.001; ES = 1.417)
10-m sprint (s)	Pre	1.731 ± 0.073	1.730 ± 0.02	1.736 ± 0.02	F = 0.073; p = 0.930; η_p^2 = 0.003	freeBT ≈ limitedBT (p > 0.999; ES = 0.022) freeBT ≈ control (p > 0.999; ES = 0.108) limitedBT ≈ control (p > 0.999; ES = 0.300)
	Post	1.697 ± 0.06	1.654 ± 0.03	1.740 ± 0.04	*F = 12.728; p < 0.001; η_p^2 = 0.367	*freeBT > limitedBT (p = 0.042; ES = 0.956) *freeBT < control (p = 0.045; ES = 0.860) *limitedBT < control (p < 0.001; ES = 2.457)
30-m sprint (s)	Pre	4.136 ± 0.032	4.133 ± 0.03	4.128 ± 0.05	F = 0.195; p = 0.824; η_p^2 = 0.009	freeBT ≈ limitedBT (p > 0.999; ES = 0.097) freeBT ≈ control (p > 0.999; ES = 0.195) limitedBT ≈ control (p > 0.999; ES = 0.125)
	Post	4.134 ± 0.03	4.122 ± 0.04	4.127 ± 0.05	F = 0.335; p = 0.717; η_p^2 = 0.015	freeBT ≈ limitedBT (p > 0.999; ES = 0.343) freeBT ≈ control (p > 0.999; ES = 0.175) limitedBT ≈ control (p > 0.999; ES = 0.111)
RAST total time (s)	Pre	23.43 ± 0.59	23.46 ± 0.62	23.51 ± 0.57	F = 0.062; p = 0.940; η_p^2 = 0.003	freeBT ≈ limitedBT (p > 0.999; ES = 0.050) freeBT ≈ control (p > 0.999; ES = 0.138) limitedBT ≈ control (p > 0.999; ES = 0.084)
	Post	22.97 ± 0.58	22.44 ± 0.61	23.50 ± 0.57	*F = 12.747; p < 0.001; η_p^2 = 0.367	*freeBT > limitedBT (p = 0.042; ES = 0.891) *freeBT < control (p = 0.045; ES = 0.922) *limitedBT < control (p < 0.001; ES = 1.797)
RAST initial-final decline (%)	Pre	1.388 ± 0.42	1.336 ± 0.51	1.472 ± 0.57	F = 0.286; p = 0.753; η_p^2 = 0.013	freeBT ≈ limitedBT (p > 0.999; ES = 0.112) freeBT ≈ control (p > 0.999; ES = 0.170) limitedBT ≈ control (p > 0.999; ES = 0.252)
	Post	0.961 ± 0.41	0.748 ± 0.45	1.371 ± 0.42	*F = 8.310; p < 0.001; η_p^2 = 0.274	*freeBT ≈ limitedBT (p = 0.505; ES = 0.495) *freeBT < control (p = 0.034; ES = 0.988) *limitedBT < control (p < 0.001; ES = 1.432)

freeBT: small-sided games in free play; limitedBT: small-sided games with limited ball touches; YYIR: Yo-Yo Intermittent recovery test level 1; RAST: repeated ability sprint test; ≈: similar and not significantly different; *: significantly different; ES: effect size resulting from cohen's d

This study distinguishes itself from previous research by focusing on the effects of SSGs with ball touch limitations on aerobic capacity, anaerobic power and sprint performance, a topic that, to our knowledge, has not been explored before. It provides new insights into how this specific condition can influence player conditioning. While earlier studies have examined acute physiological and physical responses, such as heart rate, and distances covered in SSGs with ball touch limitations (Dellal et al., 2011c; Casamichana et al., 2014), none have explicitly explored the medium-term adaptations of this condition on physical fitness.

Our results showed that anaerobic performance, assessed through total sprint time and the difference between the first and last sprint, was significantly improved in both the limitedBT and FreeBT groups compared to the control group. However, the LimitedBT group exhibited significantly greater benefits in the level of adaptation compared to the FreeBT group. Previous descriptive studies comparing limited ball touch conditions with free play in terms of acute physiological responses typically show that limiting ball touches significantly increases heart rate responses, ratings of perceived exertion, and blood lactate levels within the same play formats (Dellal et al., 2011b; Lauria et al., 2024).

In the limitedBT condition, players are likely subjected to more frequent and intense efforts due to the reduced time available for ball control (Dellal et al., 2011c), which increases the demand for rapid movements to create opportunities to receive the ball and maintain possession. This repeated exposure to high-intensity efforts likely enhances the efficiency of the anaerobic energy systems, particularly the phosphocreatine and glycolytic pathways (Buchheit and Laursen, 2013). These adaptations possibly contribute to improved anaerobic capacity and reduced fatigue across multiple high-intensity efforts, as seen in the RAST test. This is evidenced by significant improvements in total sprint time and a reduction in performance decrement. The greater benefits observed in the limitedBT group compared to the freeBT group suggest that the imposed limitations create a more effective training stimulus for targeting and enhancing anaerobic performance capacities.

In addition to the differences previously identified between limitedBT and freeBT, it was also observed that the limitedBT condition yielded significantly greater benefits in 10-meter linear sprint performance. Both the limitedBT and freeBT groups outperformed the control group. A previous descriptive study comparing various SSG formats (2v2 to 4v4) with and without ball touch limitations found that limiting ball touches increased the total distance covered in sprints and high-intensity runs (Dellal et al., 2011a). The increased or more intense running demands may have provided a greater stimulus, potentially contributing to the improvements in 10-meter sprint performance.

Limiting ball touches likely conducted to more frequent high-intensity running efforts, as players are required to engage in quicker, more explosive movements (e.g., accelerations) to create opportunities to receive and maintain possession of the ball (Castillo et al., 2020). These demands likely stimulated repeated recruitment of fast-twitch muscle fibers (Rebelo et al., 2016), which are crucial for explosive movements like acceleration and sprint. Over time, this repeated activation can increase the muscle's ability to generate force quickly, and enhance neuromuscular coordination.

On the other hand, both the limitedBT and freeBT conditions did not led to significant improvements in 30-meter sprint performance compared to the control group. It is possible that the play formats and field sizes used did not provide adequate space for players to cover longer distances or reach near-maximal sprint speeds over medium distances like 30 meters (Castagna et al., 2017). Instead, the focus may have shifted toward repeated accelerations, which are more common in the small spaces typical of the SSGs employed in this study (Clemente, 2020).

Regarding the impact on aerobic performance, both experimental groups were similarly effective, outperforming the control group, with no significant differences between the LimitedBT and FreeBT conditions. Although ball touch limitations generally increase heart rate responses and blood lactate levels (Lauria et al., 2024), the overall values in small formats like those used (e.g., 2v2 to 4v4) can sometimes reach close to 90% of maximal heart rate even during free play (Dellal et al., 2011a, 2011b; 2011c).

This sustained high-intensity activity likely enhances cardiovascular efficiency, stimulating aerobic power development through mitochondrial adaptations (Delextrat and Martinez, 2014). Increased mitochondrial density and improved mitochondrial efficiency enable better oxygen uptake and utilization, enhancing the muscle's capacity to produce energy aerobically. Additionally, the improved lactate threshold associated with such training allows athletes to sustain higher intensities before lactate begins to accumulate, delaying fatigue. The increased heart rate and blood lactate levels associated with limited ball touches (Lauria et al., 2024) further amplify the cardiovascular demand, though this additional stimulus may not significantly differ in its impact on aerobic capacity when compared to free play. Consequently, both conditions effectively promote aerobic adaptations, leading to similar improvements in aerobic performance across the experimental groups. This suggests that the intensity of the SSGs and the format associated, rather than the presence of ball touch limitations, is possibly the primary driver of aerobic capacity enhancements.

Despite the innovative nature of our study and the interesting results observed, some limitations warrant consideration. Conducting the research with youth players may have influenced the level of adaptation, suggesting that different timelines or magnitudes of adaptation might be observed at higher competitive levels. Convenience sampling in this sports training intervention study introduces key limitations that affect the generalizability of the findings. The lack of diversity in the sample limits the ability to apply the results to different athlete groups or settings, reducing the external validity of the study and making it difficult to generalize the effectiveness of the intervention across various populations. Future research should include larger and more diverse populations, such as professional players and females, to address this limitation. Expanding the sample to include these groups would enhance the generalizability of the findings, as professional players may exhibit different skill levels. Including females is also crucial, as many studies in this field have been predominantly male-focused, and gender differences in performance, physiology, and response to training or interventions might yield valuable insights. The study's short-term focus highlights the need for longitudinal research to assess long-term effects and identify potential performance plateaus. Additionally, the study did not monitor physical efforts during sessions, which limits the exploration of the mechanisms driving the adaptations. Variations in field sizes and game formats should also be examined further to understand the lack of improvement in 30-meter sprint performance.

Despite the limitations, the findings of this study offer valuable practical implications for soccer training. Incorporating SSGs with ball touch limitations can effectively enhance players' anaerobic power and short-distance sprint performance, both of which are crucial for high-intensity actions during matches. Coaches can utilize these conditions to create match-like conditions that demand quick decision-making and rapid movements. For instance, in a ball possession game, players can impose limitations on the number of touches allowed to increase the speed at which the ball must be passed, as well as enhance the dynamics required to break free from pressure. Moreover, the similar improvements in aerobic capacity observed in both limited and free play formats indicate that SSGs are effective for cardiovascular conditioning, regardless of ball touch restrictions. Therefore, integrating SSGs with varying conditions into regular training sessions can provide a balanced stimulus, enhancing both anaerobic and aerobic fitness and optimizing overall player performance. However, caution is needed, as the current research does not determine how the magnitude of improvements may be sustained in the long term, or whether a plateau may occur after the initial gains. Therefore, repeated assessments and adjustments to training periodization are necessary as the season progresses.

Conclusion

While both experimental groups showed similar improvements in aerobic capacity, the limited ball touch condition proved to be a more effective training stimulus for anaerobic adaptations and short-distance sprints. These findings suggest that incorporating ball touch limitations (ranging from one to three touches) during SSGs into training sessions can optimize player performance by enhancing both anaerobic and aerobic fitness. However, further research with larger and more diverse samples, as well as a focus on long-term adaptations and underlying training mechanisms, is needed to fully understand the potential of SSGs across different contexts and competitive levels.

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Key points

- The limitedBT group showed faster 10m sprint times and better anaerobic power (RAST) compared to freeBT and control groups.
- LimitedBT and freeBT equally improved aerobic performance (YYIRT), exhibiting their effectiveness for overall fitness.

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