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Investigation of Acute Effects of Concurrent Training Programs on Physiological Parameters, Explosive Strenght and Balance Performance in Soccer Players

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Abstract

In the study, the acute effects of two different concurrent training models including high intensity interval training (HIIT) and high intensity interval functional training (HIFT) plus strength training (S) on physiological indicators (blood lactate and heart rate) and performance (balance and explosive power) parameters were examined in soccer players. A total of 13 moderately active young soccer players (19.92; ±1.44 years) participated in the study. In the study, body composition measurements, heart rate, blood lactate, explosive strength measurement and balance testing were measured. Training models (S+HIIT-S+HIFT) were applied sequentially with a crossover design. The training sessions were conducted with a three-day interval. Mixed model ANOVA was used for repeated measures and Bonferroni Correction was used for pairwise comparisons. Significance level was accepted as $p<0.05$. The observation that both heart rate (HR) and blood lactate concentration (LA) values exhibited similar increases in the concurrent training groups (S+HIIT and S+HIFT) in relation to the training intensity suggests that the intensity was appropriately calibrated in both training programs within the scope of this study. It was observed that the S+HIIT group exhibited a statistically significant and more rapid decrease in the blood lactate value compared to the S+HIFT group. When the explosive force performance (CMJ) was analyzed; S+HIFT explosive force value was found to be lower than the baseline value, while this value was higher in the S+HIIT group compared to the baseline value. In summary, there was a statistically significant difference CMJ in the S+HIIT group, while this difference was not significant in the S+HIFT group. In our study, it was determined that the changes in balance performance before and after training were similar in both groups ($p>0.05$).

Keywords: Concurrent training, explosive strength, balance, heart rate, blood lactate

Özet

Futbolcularda Eş Zamanlı Antrenman Programlarının Fizyolojik Parametreler, Patlayıcı Kuvvet ve Denge Performansı Üzerine Akut Etkisinin İncelenmesi

Araştırmada futbolcularda yüksek şiddetli aralıklı antrenman (HIIT) ve yüksek şiddetli aralıklı fonksiyonel antrenman (HIFT)'a ilave kuvvet antrenmanı (K) içeren iki farklı eş zamanlı antrenman modelinin fizyolojik parametreler (kan laktat ve kalp atım hızı) ile performans (denge ve patlayıcı kuvvet) parametreleri üzerine akut etkisi incelendi. Araştırmaya, toplamda 13 orta düzeyde aktif genç futbolcu katılmıştır (19,92; ±1,44 yıl). Çalışmada vücut kompozisyonu ölçümleri, kalp atım hızı, kan laktat, patlayıcı kuvvet ölçümü ve denge testi uygulandı. Antrenman modelleri (K+HIIT-K+HIFT) crossover tasarım ile sırayla uygulandı. Antrenmanlar üç gün ara ile yapıldı. Uygulamalar sırasında ve sonrasında kalp atım hızı ve kan laktat konsantrasyonundaki değişimlerin farklılığı karışık desen ANOVA ile incelendi. İkili karşılaştırmalarda ise Bonferroni Düzeltmesi kullanıldı. Anlamlılık düzeyi $p<0.05$ olarak kabul edildi. Eş zamanlı antrenman gruplarında (K+HIIT ile K+HIFT) kalp atım hızı (KAH) ve kan laktat konsantrasyonu (LA) değerlerinin antrenman şiddetine bağlı olarak benzer şekilde yükselmesi bu çalışmadaki her iki antrenman programında şiddetin doğru bir şekilde ayarlandığının bir göstergesi olarak karşımıza çıktı. Her iki antrenman modelinin toparlanma süreçleri değerlendirildiğinde K+HIIT grubunun LA değeri, K+HIFT grubuna göre daha hızlı ve istatistiksel olarak anlamlı bir şekilde düşüş gösterdiği tespit edildi. Patlayıcı kuvvet performansı (CMJ) incelendiğinde ise; K+HIFT patlayıcı kuvvet değeri başlangıç değerine göre daha düşük bulunurken bu değer K+HIIT grubunda başlangıç değerine göre daha yüksek bulundu. Özetle bu değerde, K+HIIT grubunda istatistiksel olarak anlamlı farklılık tespit edilirken K+HIFT grubunda ise bu fark anlamlı değildi. Araştırmamızda antrenman öncesi ve sonrası denge performansında meydana gelen değişimlerin K+HIIT ve K+HIFT gruplarında benzer olduğu tespit edildi ($p>0.05$).

Anahtar Kelimeler: Eş zamanlı antrenman, patlayıcı kuvvet, denge, kalp atım hızı, kan laktat

INTRODUCTION

Sportive performance can be affected by many physical, physiological, psychological variables and external factors. The combination of strength and endurance training, called concurrent training, is used to develop specific motor abilities according to the needs of the sport. Concurrent training plays a significant role in the advancement of several sports disciplines, leading to modifications in body composition, heightened physiological load outputs, preservation of health, and impacts related to age, gender, and bodily functions (48, 34). In soccer, which requires the development of concurrent training, it is considered a basic prerequisite to have an improved physical fitness and to achieve high performance during the match. While the majority of existing studies claim that endurance capacity is an important characteristic to achieve a high level of performance in soccer players (23), some studies emphasize the importance of sprinting, jumping and agility abilities that require short-term explosive power (20, 53).

The concurrent training model may be met with many designs. In this study, HIIT (high-intensity interval training) (50, 9, 55, 19, 45, 21) and HIFT (high-intensity functional training) programs (5), which have been frequently used in concurrent training models in recent years, were included. It is recommended to apply different protocols of concurrent training according to sports branches. In the selection of these protocols, the purpose of the training should be taken into consideration, as well as the condition of the athletes (55).

Several studies have documented the positive effects of concurrent training on performance development (4, 50, 8, 27, 51, 40, 6, 44). However, it is important to note that other studies have reported negative effects, indicating the need for further investigation (14, 36, 41, 54, 2).

Concurrent training is known as a complex training model that is influenced by several factors such as exercise mode and intensity, muscle groups trained (upper and lower body), participant characteristics (elite athletes, sedentary, moderately trained athletes, young, old). It is also claimed that the interaction of these factors among themselves can influence the results and level of training adaptations (19).

Studies examining the acute effects of concurrent training on performance (explosive strength and balance) and physiological load outcomes (blood lactate and heart rate) were found to be insufficient in the literature. Moreover, the Strength training (S) S+HIFT model was tested for the first time in this study as a different concurrent training model. Existing studies also emphasize the need for more comprehensive research on this issue. Therefore, the present study was designed to examine the acute effects of two different concurrent training programs on both performance and physiological parameters. It is thought that the findings and results to be obtained from the study will shed light on the literature in terms of eliminating the uncertainties about concurrent training and the debates about its effects. Furthermore, it is widely believed that the outcomes of this study will yield significant insights applicable to coaching, athletes, and the field of sports sciences.

METHOD

Participants

The sample size for this study was determined using a power analysis conducted in the G*power software, with a significance level of 0.05, a power of 0.80, and an effect size of 0.80. Following the assessment, the overall sample size was established to consist of 12 people. The study was conducted using a sample of 13 male athletes aged 18-25 who voluntarily participated. These individuals were in good health, had a minimum of 2 years of training experience, and were actively involved in the university football league. Table 1 provides an overview of the physical attributes of the participants. The research procedure was carried out in adherence to the principles outlined in the Declaration of Helsinki and after the approval of the Fenerbahce University Non-Interventional Clinical Research Ethics Committee (Decision Number: 50.2023fbu). Prior to commencing the study, the participants were provided with comprehensive information regarding the study. The subjects provided consent for voluntary participation in the study.

Table 1. Physical characteristics of the participants

Parameters (n=13)	Mean	Std. Deviation	Minimum	Maximum
Age (years)	19.92	1.44	18	22
Training experience (years)	9.69	3.37	4	17
Body height (cm)	180.15	7.24	165	191
Body weight (kg)	72.93	10.14	58.9	89.9
Skeletal Muscle Weight (kg)	36.80	5.38	29.6	46.3
Body Fat Weight (kg)	9.09	3.61	1.90	14.6
Body Fat Percentage (%)	10.73	4.58	3	18.7
BMI (kg/m^2)	22.30	2.42	19	26.3
Maximal Bench press (kg)	63.46	11.61	50	85
Maximal Squat press (kg)	92.69	19.53	70	145

95% CI= 95% confidence interval lower and upper limits of the mean; BMI= Body mass index

Experimental design

In the present study, two different concurrent training models, namely S+HIIT and S+HIFT, were implemented. The training models were executed with a randomized crossover method.

The primary objective of this design is to mitigate the influence of individual and physical attributes of the participants on the outcomes of measurements, while also reducing the variability that may arise among participants (28). Each participant completed both the initial and subsequent training patterns in a randomized sequence at various time intervals.

This design enabled the achievement of a comparable degree of accuracy to that of a crossover design, but with a reduced number of participants. This study aimed to assess the performance metrics, specifically balance and explosive strength, as well as physiological outcomes, such as Heart Rate (HR) and Blood Lactate (LA), before and after implementing the training program.

The laboratory and sports facility were visited by participants on four occasions throughout the duration of the study. During the initial visit, the assessment of body composition and the implementation of adaption activities were conducted. Measurements were conducted on balance and jumping apparatuses as part of the trial. Then, the participants underwent maximal strength measures to ascertain the level of intensity required for the training program. Consecutively, the last two sessions incorporated a sequence of training sessions that employed the crossover concept. The training sessions were conducted with a three-day interval. The measurement sessions were conducted within the same time frame (10:00-14:00) and in comparable ambient circumstances (20-25 °C, 35-40% relative humidity). The participants were provided with instructions to refrain from participating in intense physical activities, to guarantee sufficient sleep, and to abstain from consuming substances such as narcotics, alcohol, cigarettes, and caffeine during the 24-hour period prior to the commencement of the tests.

Data Collection

Body composition: The height of the participants was assessed using an anthropometric equipment (Holtain, UK) while they were minimally clothed and barefoot. The height was assessed using a stadiometer (Holtain Ltd., UK) that was securely attached to the wall. The measurements were recorded in centimeters with a precision of ±0.1 millimeters, as stated by Tamer (2000). The researchers utilized bioelectrical impedance measurements (BIA) using the In Body 370S device to assess the body weight and body fat percentage of the participants (1). Body mass index (BMI) was calculated by dividing the participants' body weight (kg) by the square of their height (m2) (Weight (kg)/Height (m2) (56).

Heart Rate (HR) Measurement: The participants' HR measurements were recorded at 5 and 10 minutes (39, 25) of the active recovery period before and after training. Measurements were taken on the left arm with a Basic Comfort Plus brand electronic blood pressure monitor (24).

Blood Lactate (LA) Analysis: Blood lactate measurements of the participants before training and at 5 and 10 minutes of the active recovery period after training (39, 25) were taken with the Edge brand (Brussel / Belgium) lactate kits and device. With blood lactate measurement; blood was taken from the fingertip and the blood lactate value in the blood was measured. Participants were asked to wash their hands before starting the test. Before starting the measurement, the finger to be applied was disinfected with alcohol and wiped dry with cotton wool. Care was taken to ensure that all participants were drawn from the same hand before starting blood collection. First of all, the finger was grasped well, the puncture was made with the puncture tool and the first blood was wiped with cotton wool. The second drop of blood was applied to the application site of the test apparatus. The result in millimoles (mmol) of blood lactate concentration was recorded on a data information sheet prepared for each individual.

Explosive Strength Measurement: A jump test was conducted to assess explosive strength and anaerobic power. During the jump test, participants' baseline information was collected and a trial measurement was then recorded. Every individual engaged in the experiment conducted the test on three separate occasions, and the measurement with the greatest numerical outcome was documented. The CMJ jump method was conducted using the Smart Jump machine to accomplish the jump test. In the CMJ method, participants were instructed to do a jump while maintaining a non-upright stance, with their feet positioned shoulder-width apart and their hands resting on their waist (42, 18). A total of four measurements were conducted to assess explosive force, both before and after two acute training sessions using different combinations of strength training (S) and HIIT or HIFT.

Balance Testing: The measurement of balance was conducted using the SensBalance instrument, specifically the SensBalance Miniboard manufactured by Sensamove® in Utrecht, The Netherlands. The device involved the use of a moving platform. The present investigation involved the collection of static balancing measures from the subjects.

A measurement of balance was conducted over a duration of 60 seconds, as reported by Liviu et al. (29) and Canli et al. (10). The subject was instructed to maintain balance on the balancing beam for a duration of 60 seconds without experiencing any instances of falling. Following a duration of 60 seconds, the performance of each participant in terms of balance was documented on the data sheet. A total of four balance assessments were conducted both prior to and following two training sessions, namely S+HIIT and S+HIFT.

Rated Perceived Exertion (RPE): The study employed the Borg (6-20) scale to assess the RPE during acute training. The participants were provided with information regarding the Borg Scale at their initial visit.

In the study conducted by Yasli et al. (57), individuals were instructed to determine their RPE within a time frame of one minute after acute training. This was done with the aim of assessing the RPE reactions in conjunction with other physiological responses such as heart rate and blood lactate levels. The objective was to enhance the comprehension of training intensity by a comprehensive analysis of these variables.

Maximal Strength Measurement (One-repetition maximum): The athletes underwent maximal strength assessments in order to ascertain the level of training intensity. The participants were instructed to abstain from engaging in any strenuous physical activity within a 48-hour timeframe preceding the maximal strength training session. The second laboratory visit involved the collection of maximal strength measurements from the participants. Based on the maximal strength measures conducted three days before to the test, training intensities were computed for each participant. Maximal strength refers to the maximum weight an individual can lift during a single repetition. Prior to doing the maximal strength assessment, the participants were provided with detailed information regarding the test protocol. A two-minute warm-up was conducted prior to the administration of the test. One to two sets of warm-up exercises were conducted using a light load, consisting of 6-10 repetitions. Following the warm-up phase, a singular repetition trial was conducted, where in each participant's performance was evaluated at a level of 90%. If the trial was successful, the weight was increased depending on the completion rate. Participants who failed the trial had their weight reduced. A five-minute interval was provided between each trial. The maximum load that can be lifted with good technique is sometimes referred to as the one-repetition maximum. Typically, the determination of one-repetition maximum is achieved within a range of 3 to 5 repetitions. The assessment of maximal strength was conducted for the full squat and bench press. Consequently, a singular measurement of maximum force was acquired for both the upper and lower extremities (32).

Training Protocol

Strength training for both groups includes the full squat (1RM:SxT), bench press (1RM:SxT), CMJ (SxT), and sprint (SxD). Rest time between strength training sessions was 2-3 minutes. After 15 minutes recovery time was given after strength training, endurance training was started. The endurance training of the S+HIIT group included a 20-second run and 10-second rest (personalized distance). S+HIFT group included opposite skips, air squat jumps, lateral squats, lunges, jumping jacks, burpees, mountain climbers, and glute bridge movements. Each movement was performed as 20s load-10s rest. Eight movements were planned as 4 sets. 1 minute rest was given between sets. Thus, the duration of HIIT and HIFT training was kept equal (20 min). The average training duration was 90 minutes.

Data Analysis: The data were subjected to analysis using the statistical software SPSS 24 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were employed to provide an overview of the participants' overall characteristics. The means and standard deviations of the test values were computed. The Shapiro-Wilk test was employed to assess the normality of the data, while Levene's test was utilized to examine the homogeneity of variance. The results indicated that the data exhibited normal distribution. The paired sample t-test was employed to assess the pre- and post-intervention differences within two different interventions. Mixed model ANOVA was used for repeated measures and Bonferroni Correction was used for pairwise comparisons. Significance level was accepted as $p<0.05$.

Ethical approval and institutional permission

The research procedure was carried out in adherence to the principles outlined in the Declaration of Helsinki and after the approval of the Fenerbahce University Non-Interventional Clinical Research Ethics Committee (Decision Number: 50.2023fbu).

FINDINGS

The present investigation observed a significant time interaction effect between the two training models, namely S+HIIT and S+HIFT, in relation to blood lactate values (Table 2). However, it is important to note that there was no statistically significant differences seen between the two training models in terms of blood lactate values during the initial measurements, as depicted in Figure 3. In a similar vein, it was observed that the concentration of blood lactate increased at the 5-minute mark following both types of training models, but subsequently dropped at the 10-minute mark post-training. Following the S+HIIT, there was a notable increase in blood lactate at the 5-minute mark compared to the first baseline measurement (p<0.001). Conversely, by the 10-minute mark, there was a substantial decrease in blood lactate levels (p<0.05). Following the S+HIFT intervention, it was seen that the blood lactate concentration at the 5-minute mark exhibited a statistically significant increase when compared to the baseline measurement. However, no significant difference in the decrease of blood lactate was observed at the 10-minute mark (p>0.05).

Table 2. Dependent variables across all time points and training models

		Time (min)				
Dependent variable	**Training Models**	**Pre-0**	**Post-5**	**Post-10**	**F**	**p**
Blood Lactate (mmol/L) mean(±SD)	S+HIIT	1.62±1.14	5.82±3.17¶Ϫ	2.90±2.29	17.387*	.001§
	S+HIFT	1.69±1.21	4.93±3.70ϕ	3.41±3.63		
Heart Rate (bpm) mean (±SD)	S+HIIT	68.85±11.31	97.85±19.87¶Ϫ	83.62±14.94	40.596*	.001§
	S+HIFT	70.85.13.64	91.62±13.53¶¥	74.62±12.97		

§ Significant interaction effect p<0.001
ϕ A Significant difference from baseline measures from the same condition p<0.05
¶ A Significant difference from baseline measures from the same condition p<0.001
Ϫ A Significant difference from 10 minutes measures from the same condition p<0.05
¥ A Significant difference from 10 minutes measures from the same condition p<0.01
**Time and training model interactions*

An interaction effect was seen between the two training models in HR values, as indicated in Table 2. There was no statistically significant difference between the two training models in the pre-tests conducted to measure HR values (Figure 3). In all training modalities, there was a consistent pattern of HR elevation at the 5-minute mark, followed by a subsequent decline at the 10-minute mark. Following the S+HIIT intervention, HR values at the 5-minute mark exhibited a statistically significant increase when compared to the baseline measurement (p<0.001). Subsequently, at the 10-minute mark, there was a substantial drop in HR values (p<0.05). Following the administration of S+HIFT, there was a substantial increase in HR values at the 5-minute mark compared to the baseline measurement (p<0.001). Subsequently, there was a significant drop in HR values at the 10-minute mark (p<0.01).

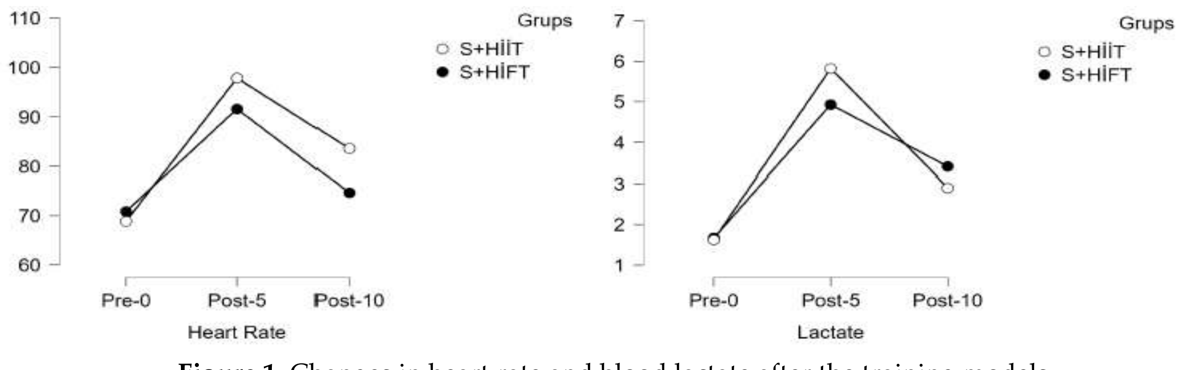

Figure 1. Changes in heart rate and blood lactate after the training models

Upon analysis of the CMJ data (Table 3), it was seen that there existed a statistically significant distinction between the before and post test results in the S+HIIT group (p<0.05). Conversely, no statistically significant distinction was found between the pre and post test results in the S+HIFT training group (p>0.05). Furthermore, it is worth noting that there was no statistically significant disparity between the pre-test and post-test outcomes in terms of balancing measurements and the RPE (p>0.05).

Table 3. Within-group comparisons of dependent variables

Dependent variable (n=13)	Condition	Mean	Std. Deviation	p
S+HIIT CMJ	Pre	36.29	3.53	0.020*
	Post	37.67	4.01	
S+HIFT CMJ	Pre	37.63	4.17	0.098
	Post	36.35	4.23	
S+HIIT Balance	Pre	65.62	14.10	0.875
	Post	65.23	14.57	
S+HIFT Balance	Pre	56.39	16.93	0.095
	Post	62.31	13.86	
RPE	S+HIIT	13.15	2.15	0.913
	S+HIFT	13.08	1.32	

*p<0.05; CMJ = Counter movement jump; RPE = Ratings of perceived exertion

DISCUSSION AND CONCLUSION

The observed similarity in the increase of HR and blood lactate values in the concurrent training groups (S+HIIT and S+HIFT) in relation to the training intensity suggests that the intensity was appropriately adjusted in both training programs within the scope of this study. Upon evaluating the recovery processes of both training models, it was observed that the blood lactate value of the S+HIIT group exhibited a statistically significant decline at a faster rate compared to the S+HIFT group. The analysis of blood lactate outcomes according to different training models revealed significant differences between blood lactate pre0 and blood lactate post5, as well as between blood lactate post5 and blood lactate post10 in the S+HIIT group. Based on the observed outcomes, it was evident that the S+HIIT group exhibited a comparatively accelerated recovery rate in relation to the specific training modality. Significant differences were observed in the comparison of HR outcomes among various time points within the S+HIIT and S+HIFT groups. Specifically, significant differences were identified between HR pre0 and HR post5, HR pre0 and HR post10, and HR post5 and HR post10 in the S+HIIT group. Similarly, significant differences were observed between HR pre0 and HR post5, HR post5 and HR post5, and HR post5 and HR post10 in the S+HIFT group.

Although the outcomes exhibit comparable graphical representations, it is hypothesized that the discrepancies in significance levels can be attributed to the divergent compositions of the employed training models. The observed disparity in the rate of blood lactate increase and recovery decline between the S+HIIT and S+HIFT groups following loading can perhaps be attributed to the S+HIIT group's greater reliance on the cardiorespiratory system in comparison to the S+HIFT group. The enhanced functionality of the cardiorespiratory system demonstrated that the physiological reactions to high-intensity and continuous training were notably more efficient in the S+HIIT cohort. Nevertheless, no significant difference observed between the two groups ($p>0.05$). The present study found no significant difference between the post5 and post10 blood lactate levels in the S+HIFT group, suggesting that metabolic responses in this group were relatively lower. Conversely, the difference in blood lactate levels between post5 and post10 was larger in the S+HIIT group, indicating a more pronounced metabolic response in this group ($p<0.05$). Keytsman et al. (27), Medica et al. (33) and Cerexhe et al. (11) have documented comparable alterations in blood lactate dimensions in their respective investigations including HIIT. The study done by Kang et al. (25) aimed to investigate the potential correlation between maximal oxygen consumption (VO_{2max}) following resistance training and post-exercise HR and blood lactate levels. According to the paper, there was a positive correlation observed between persons with higher aerobic capacity and a more pronounced reduction in HR and blood lactate during the recovery phase following strength training. This correlation was particularly evident at the 5 and 10-minute intervals post-training. The utilization of the crossover design in our study effectively mitigated the presence of this interaction. Similar changes in max LA have been reported in studies using HIIT training (22). Furthermore, it has been observed that HIIT leads to more significant enhancements in mitochondrial content, enzyme activity, and potentially skeletal muscle recruitment when compared to moderate intensity training, as highlighted by Cerexhe et al (11). A meta-analysis study was conducted to investigate the association between the HIIT model and cardiovascular health (7,13). In a similar vein, a separate investigation documented that the restoration of HR and blood lactate to their initial levels occurred within a span of 15-20 minutes, contingent upon the intensity and duration of the training session (3). The study also indicated that when implementing Strength + Endurance or Endurance + Strength training regimens, comparable levels of blood lactate were observed in both concurrent training models. However, a higher concentration of blood lactate was reported in concurrent training compared to strength or endurance training performed individually. According to Arsoniadis et al. (3), engaging in swimming training prior to strength training resulted in greater metabolic responses compared to engaging in endurance training following strength training on the same training day. In contrast, a study conducted by Drummond et al. (15) examined the effects of strength-endurance training compared to an endurance-strength training sequence. The findings revealed that both blood lactate and oxygen consumption exhibited an increase during the 5-minute recovery interval. Regardless of the circumstances, the response of blood lactate in the body reflects the impact of the previous exercise session, whether it focused on strength or endurance. This response can serve as an indicator of the intensity of the activity, but its usefulness in evaluating the effectiveness of strength and endurance training or recuperation may be restricted.

This study found that the changes in balance performance were comparable across the S+HIIT and S+HIFT groups before and after training. There was a lack of statistical significance observed in the comparison of balance performance between the S+HIIT and S+HIFT. In line with our investigation, Ozer (38) arrived at the finding that the balance capabilities of wrestlers were unaltered under conditions of high-intensity activity. According to Mahmood et al. (31), engaging in moderate intensity anaerobic exercise has been found to have a favorable impact on dynamic balancing performance, likely attributed to the warm-up effect. However, it is worth noting that engaging in high intensity exercise may have a detrimental effect on dynamic balance ability, maybe related to the onset of tiredness. Furthermore, Sarikaya et al. (46) conducted a study examining the impact of static warm-up exercises on various performance measures in basketball players. The findings revealed that engaging in static warm-up exercises resulted in immediate improvements in jump and balance performances. However, it was observed that these exercises had a detrimental influence on leg strength.

The analysis of explosive strength performance revealed a disparity in the pre- and post-training change in CMJ between the S+HIIT and S+HIFT groups. The S+HIIT group exhibited a rise in CMJ, while the S+HIFT group had a decrease in CMJ.

The temporal relationship between the two types of training (pre-training, 5 minutes and 10 minutes after training) had a statistically significant impact on CMJ explosive strength performance ($F_{1/12}=17.7$, $p<0.01$). The observed variations in loading requirements and metabolic resistance of functional workouts conducted with body weight in the S+HIFT group can be attributed to the relatively slower reduction in blood lactate values during the recovery period, as compared to the S+HIIT group.

Furthermore, it is plausible that the decline in CMJ performance seen in the S+HIFT group, characterized by the execution of body weight functional movements, can be attributed to muscle structure and peripheral fatigue. To clarify, the use of jumping activities within this workout paradigm serves as an indication of inducing weariness. According to Sparkes et al. (52), it has been posited that the decline in CMJ explosive strength performance during concurrent training can be attributed to factors such as muscle exhaustion and peripheral fatigue. In a separate investigation conducted by Coutinho et al. (12), it was shown that the implementation of half squat exercises among soccer players resulted in a discernible decline in jump performance. The inclusion of running-based workouts in the S+HIIT group may suggest the presence of Post-Activation Potentiation (PAP) effect, as noted by Ribeiro et al. (43), Nicol et al. (37), and Low et al. (30). The study conducted by Ribeiro et al. (30) found that although the RPE showed equal fatigue levels, the running-based S+HIIT group demonstrated PAP effect as revealed by the CMJ.

In summary, both cardiorespiratory-based S+HIIT and functional-based S+HIFT demonstrated comparable outcomes, underscoring the need of considering branch-specific requirements when choosing between these training modalities. The observation that both heart rate (HR) and blood lactate concentration (LA) values exhibited similar increases in the concurrent training groups (S+HIIT and S+HIFT) in relation to the training intensity suggests that the intensity was appropriately calibrated in both training programs within the scope of this study. It was observed that the S+HIIT group exhibited a statistically significant and more rapid decrease in the blood lactate value compared to the S+HIFT group. When the explosive force performance (CMJ) was analyzed; S+HIFT explosive force value was found to be lower than the baseline value, while this value was higher in the S+HIIT group compared to the baseline value. In our study, it was determined that the changes in balance performance before and after training were similar in both groups ($p>0.05$). The selection of models for concurrent training applications should prioritize their ability to fulfill the physical and physiological requirements of the specific sports discipline. The training models presented in our study can serve as exemplar training models that address these demands. The anticipated outcomes and conclusions of this study are expected to contribute valuable insights to the existing body of literature by addressing the ambiguities surrounding concurrent training and the ongoing disputes regarding its consequences.

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