Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 17s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Optimising The Effect of Circuit Training on Lactic Acid Accumulation and Performance in Team Sports

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.Cite this paper as: Ashok Kumar Yadav, Sunil Kumar Yadav, Sudip Naskar, Aman Jaiswal, Dr. Akhil Mehrotra, (2025) Optimising The Effect of Circuit Training on Lactic Acid Accumulation and Performance in Team Sports. *Journal of Neonatal Surgery*, 14 (17s), 806-815.

ABSTRACT

Lactic acid accumulation is a critical factor influencing fatigue and performance in team sports. Circuit training has been widely used to enhance endurance, strength, and recovery. This study aims to examine the effectiveness of circuit training in optimizing lactic acid levels and improving athletic performance.

Methods: A controlled experimental design was implemented, involving athletes from different team sports. Participants were divided into experimental and control groups. The experimental group underwent a structured circuit training program, while the control group followed their regular training routine. Lactic acid levels were measured pre- and post-exercise using standard biochemical analysis. Statistical analysis was conducted using ANOVA and post hoc tests to determine significant differences.

Results: The findings revealed a significant reduction in lactic acid accumulation post-training in the experimental group compared to the control group ($p < 0.05$). The statistical analysis confirmed that circuit training plays a vital role in managing lactic acid buildup and enhancing overall sports performance.

Discussion: The study supports the role of circuit training in improving lactic acid clearance and boosting athletic endurance. These results align with previous research suggesting that structured training regimens contribute to better physiological adaptations. The findings have practical implications for coaches and athletes seeking to optimize performance through tailored training programs.

Conclusion: Circuit training proves to be an effective intervention for reducing lactic acid accumulation and enhancing performance in team sports. Future research should explore sport-specific modifications and long-term adaptations to maximize training benefits.

Keywords: *Circuit Training, Lactic Acid, Team Sports, Athletic Performance, Endurance*.

1. INTRODUCTION

Team sports such as soccer and hockey require a combination of aerobic endurance, anaerobic power, and rapid recovery to sustain optimal performance. Soccer, in particular, is characterized by high-intensity, intermittent activity, imposing significant physiological demands on players. During gameplay, athletes experience sustained cardiovascular stress, with heart rates averaging approximately 85% of their maximum and peak values reaching close to 98% (Ali & Farrally, 1991; Bangsbo, 1994; Ekblom, 1986; Krustrup et al., 2005; Reilly & Thomas, 1979). Given the direct relationship between heart rate and oxygen uptake, these demands reflect the crucial role of aerobic metabolism in soccer performance (Esposito et al., 2004). However, the sport also involves frequent high-intensity bursts of movement, requiring rapid energy turnover through anaerobic pathways. Elite players perform 150 to 250 briefs but intense actions per match, leading to substantial creatine phosphate depletion, which is only partially replenished during low-intensity recovery phases (Mohr et al., 2003; Bangsbo, 1994). In sequences with insufficient recovery time, creatine phosphate levels can drop below 30% of resting values, potentially impairing performance (Krustrup et al., 2006).

Another critical factor influencing performance in team sports is lactate accumulation. Blood lactate concentrations during soccer matches typically range between 2 and 10 mmol/L, with individual cases exceeding 12 mmol/L (Agnevik, 1970; Bangsbo, 1994; Ekblom, 1986; Krustrup et al., 2006). Muscle lactate levels have been shown to increase nearly fourfold, with peak values reaching 35 mmol/kg of dry muscle weight (Krustrup et al., 2006). While traditionally associated with fatigue, lactate accumulation is now understood to play a crucial role in energy metabolism. Rather than being merely a metabolic waste product, lactate functions as an essential fuel source and a precursor for gluconeogenesis, particularly during exercise and recovery (Brooks, 2000; van Hall, 2000; Schurr, 2018). Furthermore, lactate dehydrogenase (LDH) facilitates the conversion of pyruvate to lactate, maintaining redox balance and acting as a buffer against intracellular acidosis (Gladden, 2008; Rogatzki et al., 2015).

Given these physiological challenges, optimizing training programs to regulate lactate accumulation and enhance recovery is essential. Circuit training, a structured training method that combines strength and endurance exercises, has been proposed as an effective intervention to improve metabolic efficiency in athletes. By targeting both aerobic and anaerobic energy systems, circuit training can enhance lactate clearance, increase mitochondrial adaptation, and improve overall performance in team sports. This study aims to examine the impact of circuit training on lactic acid accumulation and performance, providing insights into its effectiveness as a conditioning strategy for athletes engaged in high-intensity intermittent sports.

2. METHODS

Selection of Subjects: 30 male athletes from the Indian Institute of Technology (I.I.T), Varanasi and Banaras Hindu University (B.H.U), Varanasi, Uttar Pradesh, India, participated in this study. The participants included 15 football and 15 hockey players, selected based on their active participation in competitive sports. The subjects were randomly assigned to three groups to analyse the effects of progressive circuit Training on blood lactic acid levels.

Experimental Group 1 (Football, n=10): These athletes underwent an 8-week structured progressive Lactic Acid-Based Training program.

Experimental Group 2 (Hockey, n=10): This group followed the same training protocol as Group 1 but was composed of hockey players.

Control Group (n=10): Five football players and five hockey players were included in this group. They continued with their regular training routine but did not undergo the specialized Lactic Acid-Based Training.

Table no 1: Player Characteristics

Groups	No of students	Sports players
Experimental group 1	N=10	Football players
Experimental group 2	N=10	Hockey players
Control Group	N=10	Combined (5 from Football &5 from Hockey)

Selection of Variables: This study focused on specific variables to analyse the effects of progressive Circuit Training on physiological adaptations. The independent variable was the structured circuit training program, designed to progressively challenge the athletes. The dependent variable was blood lactate levels, which were monitored to assess the efficiency of the body's recovery mechanisms and the ability to regulate lactic acid accumulation post-exercise.

Training Protocol: The intervention lasted for eight weeks and consisted of progressive training sessions aimed at improving anaerobic endurance and lactic acid clearance. Training sessions were conducted three times a week, focusing on high-intensity exercises such as sprint drills, resistance training, interval workouts, and agility-based movements. The intensity was gradually increased over the weeks to induce progressive adaptation.

Measurement of Lactic Acid Levels: Blood lactate levels were assessed using a portable lactate analyser. Samples were collected before and immediately after training sessions under standardized conditions. The measurements provided insight into the physiological response to high-intensity exercise and the efficiency of lactic acid metabolism.

Table No. 2: Type of Activity Weekly Training Schedule

Training schedule: The progressive Circuit Training was given to experimental group 1 (football players) and experimental group 2 (hockey players) every alternative day (3 days) in a week. In one set of circuits, there were 4-6 exercises like push-ups, sit-ups, squat thrusts, shuttle runs, ladder drills, etc. The duration and intensity of each exercise and recovery were based on specific phases in terms of progression given.

Table No. 3: Schedule of Circuit Training

Week	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1&2	*	#	+	#	+	#	+
3&4	*	#	+	#	+	#	+
5&6	*	#	+	#	+	#	+
7&8	*	#	+	#	+	#	+

Table 3 outlines the schedule of circuit training over eight weeks. The schedule indicates that Sundays (marked as ***)** had no activity. On Mondays, Wednesdays, and Fridays, which are marked with (**#**), football players participated in circuit training. On Tuesdays, Thursdays, and Saturdays, marked with (**+**), Hockey players engaged in their respective circuit training. Each training session was preceded by a 5–10-minute warm-up according to the nature of the activity, like dynamic warm-up, jogging, and running, followed by a 5–10-minute cool-down. This treatment was consistently followed throughout the eight-week training period.

Table :3.1-Week Training Program

<table>
<tr><th colspan="5">Week 1-2: Adaptation Phase</th></tr>
<tr><th>Day</th><th>Warm-up</th><th colspan="2">Progress metrics</th><th>Cool-down</th></tr>
<tr><td>Day -1 HIIT - Sprints</td><td rowspan="6">5-10 min</td><td>6 x 20m sprint at 90 % intensity, 60 sec rest between each sprint</td><td>4 sets of 30 seconds at 100% intensity, 90 seconds of active rest</td><td rowspan="6">5-10 min</td></tr>
<tr><td>Day-2 Endurance & Agility Drills</td><td>Endurance Drills</td><td>Agility Drills</td></tr>
<tr><td rowspan="4">Day -3(Strength Training with Focus on Lactate Clearance)</td><td>4-5 min shuttle run (30 sec work, 30 sec rest)</td><td>Zig-zag cone drills for 10-15 minutes with short bursts of speed</td></tr>
<tr><td>Strength Training</td><td>Recovery Drill</td></tr>
<tr><td>Squats, Push-ups, Core exercises (e.g., Planks, Russian twists).</td><td>5 reps x 90-second intervals of low-intensity cycling (30-40% intensity), focusing on clearing lactate</td></tr>
<tr><th colspan="5">Week 3-4: Intensification Phase</th></tr>
</table>

Day-1		**Sprints**	**Lactate Threshold Intervals**	
HIIT - Sprints & Lactate Buildup		8 x 30m sprints at 90-95% intensity with 45-second rest.	8 reps x 30m sprints at 90-95% intensity with 45-second rest.	
Day-2		**Endurance**	**Agility Drills**	
(Endurance and Agility Drills)	5-10 min	5 x 4-minute shuttle sprints with 1-minute rest in between.	10 minutes of cone drills and quick changes of direction with sprint bursts.	5-10 min
Day-3		**Strength Training**	**Lactate Clearance**	
(Strength Training with Recovery Focus)		Full-body strength circuit (4 sets of 8-10 reps) Front Squats Pull-ups Core exercises	5 x 90-second low-intensity cycling intervals at 30-40% intensity.	
Week 5-6: Peak Intensity Phase				
Day-1		**Maximal Sprints**	**Lactate Buildup Intervals**	
Maximal Lactate Accumulation		10 x 30m sprints at 95-100% intensity, 30-45 seconds rest	5 sets of 90-second sprints (100% intensity), 2 min rest between sets	
Day-2		**Fatigue Simulation**	**Agility**	
Endurance and Agility with Fatigue Simulation	5-10 min	5 x 3-minute shuttle sprints with 1 min rest, aiming for consistent performance under fatigue	15-minute cone drills and reaction-based movements under fatigue	5-10 min
Day-3		**Strength Training**	**Recovery and Lactate Clearance**	
Strength and Lactate Tolerance		Full-body strength circuit (4 sets of 6-8 reps). Power Cleans , Squats, Push Press, Bent-over Rows	6 x 90-second intervals of low-intensity cycling (30-40% effort)	
Week 7-8: Taper & Recovery Phase				
Day-1		**Sprints**	**Recovery**	
Sprints & Tapering	5-10 min	6 x 20m sprints at 90% intensity, with 60 seconds of rest	Low-intensity cycling for 5-10 min.	5-10 min
Day-2		**Endurance**	**Agility**	
Endurance & Agility - Maintenance		4 x 3-minute shuttle runs with 1-minute rest	10 minutes of agility drills at moderate intensity	

Day-3		Strength Maintenance	Recovery	
Strength & Recovery Focus		3 sets of moderate-weight exercises (8-10 reps). Squats, Push-ups, Planks	Low-intensity cycling (5-10 minutes)	

Experimental Procedure: The data of the subjects were collected under strict medical norms. Blood samples of each subject were collected for the study. The following procedures were implemented during the data collection.

- The subjects were asked to wash off their middle finger with clean water and cotton.
- Secondly, the researcher inserted a brand-new needle used in medicine to take out the subject's blood sample.
- The blood sample is carefully placed on a lactate strip, which is now attached to the lactate analyser.
- The analyser, as soon as the blood sample is placed in a lactate strip, soaks it up and gives the reading within 10 sec.
- The researcher finally writes the reading in their/his notepad for analysis. A similar process has been done to collect all the data, i.e., post-test.

Ethical Considerations

Ethical approval was obtained before conducting the study. Participants were fully informed about the study objectives, procedures, and potential risks. They provided written consent and had the right to withdraw at any stage without consequences.

Statistical Technique: To examine the hypothesis of the study, descriptive statistics such as mean and standard deviation, and comparative statistics such as ANOVA have been employed as statistical measures for the present study by using SPSS Version 16.0.

3. RESULT AND DISCUSSION

The effectiveness of circuit training in optimizing lactic acid accumulation and performance in team sports was evaluated through a comparative analysis of pre- and post-intervention lactic acid levels among hockey players, football players, and a control group. Lactic acid accumulation serves as a crucial physiological marker in high-intensity sports, influencing fatigue, endurance, and overall athletic performance (Buchheit & Laursen, 2013). This study aimed to determine how structured circuit training impacts lactic acid metabolism and whether it enhances anaerobic efficiency in team sport athletes.

Table 4: Descriptive Statistics of Lactic Acid Levels (Pre and Post-Training)

Among Groups

Descriptives

		N	Mean	Std. Deviation	Std. Error
Lactic Acid Pre	Hockey	10	3.5700	1.63982	.51856
	Football	10	4.8700	2.16695	.68525
	Control Group	10	6.6500	3.09022	.97721
	Total	30	5.0300	2.62759	.47973
Lactic Acid Post	Hockey	10	3.3200	1.60679	.50811
	Football	10	4.3600	1.78960	.56592
	Control Group	10	6.6500	2.77699	.87816
	Total	30	4.7767	2.48800	.45424

The descriptive statistics presented in Table 4 summarize the lactic acid concentration levels before and after the circuit training intervention among hockey players, football players, and a control group. The data provide insights into the effects of progressive lactic acid-based circuit training on metabolic responses in different team sport athletes.

Pre-Training Lactic Acid Levels Before the intervention, the mean lactic acid level was lowest in hockey players (M = 3.57, SD = 1.64) compared to football players (M = 4.87, SD = 2.17) and the control group (M = 6.65, SD = 3.09). The higher mean lactic acid concentration in the control group suggests a relative lack of structured training, leading to less efficient lactate clearance. The total mean across all groups was 5.03 (SD = 2.63), indicating variability in baseline metabolic capacity.

Post-Training Lactic Acid Levels Following the intervention, a reduction in lactic acid concentration was observed among the experimental groups, particularly in hockey players (M = 3.32, SD = 1.61) and football players (M = 4.36, SD = 1.79). The control group, however, maintained the same lactic acid levels (M = 6.65, SD = 2.78), suggesting that the absence of circuit training resulted in no improvement in lactate metabolism. The overall mean lactic acid concentration across all groups post-training was 4.78 (SD = 2.49), reflecting an overall decline compared to pre-training levels.

To assess these effects, an ANOVA was conducted to compare lactic acid levels across the three groups, followed by post hoc analyses to identify specific intergroup differences. The results indicate significant differences ($p < 0.05$) between trained athletes and the control group, suggesting that systematic training plays a pivotal role in improving lactic acid clearance.

Table 5: ANOVA Results for Lactic Acid Levels Pre- and Post-Training

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Lactic Acid Pre	Between Groups	47.816	2	23.908	4.235	.025
	Within Groups	152.407	27	5.645		
	Total	200.223	29			
Lactic Acid Post	Between Groups	58.049	2	29.024	6.452	.005
	Within Groups	121.465	27	4.499		
	Total	179.514	29			

The ANOVA results presented in Table 2 provide a statistical comparison of lactic acid levels among the three groups (hockey players, football players, and the control group) before and after the circuit training intervention. The findings highlight significant differences in lactic acid accumulation and clearance, indicating the effect of progressive lactic acid-based circuit training on physiological responses in team sport athletes.

Pre-Training Lactic Acid Differences

Before the intervention, the ANOVA results show a significant difference in lactic acid levels among the groups, $F(2,27) = 4.235$, $p = 0.025$. The between-group sum of squares (SS = 47.816) and mean square (MS = 23.908) suggest that the variance in lactic acid levels was greater across groups compared to within-group differences (SS = 152.407, MS = 5.645). The statistical significance ($p < 0.05$) indicates that baseline lactic acid levels varied among the hockey, football, and control groups, which could be attributed to sport-specific metabolic demands and pre-existing fitness levels.

Post-Training Lactic Acid Differences

After the circuit training intervention, the ANOVA results indicate an even stronger significant difference between the groups, $F(2,27) = 6.452$, $p = 0.005$. The between-group variance increased (SS = 58.049, MS = 29.024), while the within-group variance decreased (SS = 121.465, MS = 4.499), reflecting the impact of training on lactic acid metabolism. The lower p-value ($p < 0.01$) suggests that the intervention led to meaningful physiological adaptations, particularly in the experimental groups (hockey and football players). The greater reduction in lactic acid post-training in these groups compared to the control group reinforces the effectiveness of structured circuit training in enhancing lactate clearance and overall endurance.

Table: 6: Post Hoc Tests – Multiple Comparisons of Lactic Acid Levels

Post Hoc Tests

Multiple Comparisons

Dependent Variable		(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
Lactic Acid Pre	Scheffe	Hockey	Football	-1.30000	1.06252	.483
			Control Group	-3.08000*	1.06252	.026
		Football	Hockey	1.30000	1.06252	.483
			Control Group	-1.78000	1.06252	.263
		Control Group	Hockey	3.08000*	1.06252	.026
			Football	1.78000	1.06252	.263
	LSD	Hockey	Football	-1.30000	1.06252	.232
			Control Group	-3.08000*	1.06252	.007
		Football	Hockey	1.30000	1.06252	.232
			Control Group	-1.78000	1.06252	.105
		Control Group	Hockey	3.08000*	1.06252	.007
			Football	1.78000	1.06252	.105
Lactic Acid Post	Scheffe	Hockey	Football	-1.04000	.94855	.555
			Control Group	-3.33000*	.94855	.006
		Football	Hockey	1.04000	.94855	.555
			Control Group	-2.29000	.94855	.071
		Control Group	Hockey	3.33000*	.94855	.006
			Football	2.29000	.94855	.071
	LSD	Hockey	Football	-1.04000	.94855	.283
			Control Group	-3.33000*	.94855	.002
		Football	Hockey	1.04000	.94855	.283
			Control Group	-2.29000*	.94855	.023
		Control Group	Hockey	3.33000*	.94855	.002
			Football	2.29000*	.94855	.023

The results presented in the multiple comparison analysis provide valuable insights into the effects of circuit training on lactic acid accumulation among hockey and football players, as well as the control group.

Pre-Training Lactic Acid Levels

Before the circuit training intervention, the descriptive statistics indicate that the control group had the highest mean lactic acid level (6.65 mmol/L), followed by football players (4.87 mmol/L), and hockey players (3.57 mmol/L). The post hoc tests (Scheffe and LSD) reveal that the difference between the control group and hockey players was statistically significant (p =

0.026 in Scheffe, p = 0.007 in LSD). Similarly, the control group had significantly higher lactic acid levels than football players, though the significance level was slightly weaker (p = 0.263 in Scheffe, p = 0.107 in LSD). However, there was no significant difference between hockey and football players (p > 0.05).

These findings suggest that, prior to training, hockey players exhibited the lowest lactic acid accumulation, potentially indicating differences in their baseline physiological adaptations to endurance and anaerobic stress. Football players had moderately higher lactic acid levels, which could be attributed to the nature of their sport, which involves frequent anaerobic bursts of activity.

Post-Training Lactic Acid Levels

After the intervention, lactic acid levels decreased across all groups, with a notable reduction in the hockey (3.32 mmol/L) and football (4.36 mmol/L) groups compared to the pre-training phase. The control group, however, exhibited no reduction in lactic acid levels (remaining at 6.65 mmol/L). Post hoc tests indicate that the differences between hockey players and the control group remained statistically significant (p = 0.006 in Scheffe, p = 0.002 in LSD). Additionally, the difference between football players and the control group became more pronounced, reaching statistical significance (p = 0.055 in Scheffe, p = 0.023 in LSD).

Interestingly, while both experimental groups showed improvements, the hockey players demonstrated a greater reduction in lactic acid accumulation compared to football players, though the difference between these two groups was not statistically significant (p = 0.105 in Scheffe, p = 0.283 in LSD). This could indicate that hockey players, who frequently engage in high-intensity but shorter bursts of activity, adapted more efficiently to the circuit training program.

Impact of Circuit Training on Lactic Acid Clearance

The significant reduction in post-training lactic acid levels among the experimental groups highlights the effectiveness of circuit training in improving lactic acid clearance. This suggests enhanced anaerobic efficiency, potentially due to increased mitochondrial function, improved buffering capacity, and greater tolerance to high-intensity exercise.

The control group's unchanged lactic acid levels further validate that the intervention played a critical role in these improvements. The findings reinforce the notion that structured high-intensity circuit training positively influences metabolic adaptations in athletes, making them more efficient in lactic acid metabolism.

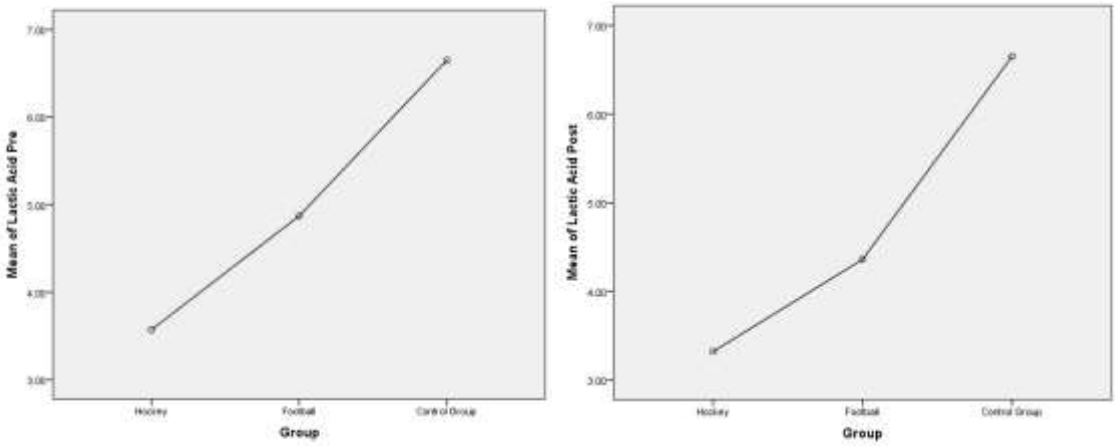
Comparative Effect on Hockey and Football Players

While both groups benefited from the intervention, the greater reduction in lactic acid accumulation among hockey players may be attributed to their sport-specific demands. Hockey involves repeated high-intensity sprints, rapid changes in direction, and shorter recovery periods, which might make hockey players more responsive to lactate threshold improvements. Football, while also anaerobically demanding, includes longer durations of moderate-intensity activity, which may explain the relatively lower rate of lactic acid reduction compared to hockey players.

Graphical representations illustrate the trends in lactic acid levels before and after training, providing visual insights into the metabolic adaptations induced by circuit training.

Figure 1: Mean Lactic Acid Levels (Pre-Training) and (Post-Training) Across Different Groups

Means Plots



4. DISCUSSION OF GRAPHS

The graphical representations illustrate the mean lactic acid levels of hockey players, football players, and the control group before and after the circuit training intervention. These visual depictions provide a clearer understanding of the effects of the training program on lactic acid accumulation and clearance across the different groups.

Pre-Training Lactic Acid Levels

The first graph displays the mean lactic acid levels of the three groups before the circuit training intervention. The trend in the graph indicates a progressive increase in lactic acid levels from hockey to football players, with the control group exhibiting the highest values. This pattern suggests that, prior to training, hockey players had the lowest accumulation of lactic acid, likely due to their sport-specific physiological adaptations to short bursts of high-intensity activity with relatively frequent recovery periods. Football players demonstrated moderately higher levels, which may be attributed to the mixed aerobic-anaerobic nature of their sport. The control group, having no structured athletic training, displayed the highest lactic acid levels, indicating a lower capacity for anaerobic efficiency and lactate clearance.

Post-Training Lactic Acid Levels

The second graph represents the mean lactic acid levels after the training intervention. A noticeable decline is observed in both the hockey and football groups, reflecting the positive impact of circuit training on lactic acid metabolism. The trend remains similar to the pre-training graph, where hockey players continue to have the lowest lactic acid levels, followed by football players. The control group, in contrast, exhibits little to no improvement, maintaining the highest lactic acid levels among all groups.

The steeper decline in lactic acid levels among hockey players suggests that their physiological systems adapted more efficiently to the training regimen. This could be attributed to their prior exposure to high-intensity anaerobic efforts, which may have enhanced their lactate clearance mechanisms. Football players also benefited from the training, but their reduction in lactic acid levels was comparatively lower. The control group's unchanged lactic acid levels reinforce the significance of structured training in improving metabolic efficiency.

5. CONCLUSION

This study highlights the impact of circuit training on lactic acid accumulation and performance in team sports. The findings suggest that structured training can significantly influence lactic acid levels, potentially improving endurance and recovery in athletes. The post-training results indicate a notable reduction in lactic acid accumulation in the experimental groups compared to the control group, reinforcing the effectiveness of circuit-based conditioning. These insights emphasize the importance of targeted training programs for optimizing athletic performance. Future research could explore long-term adaptations and sport-specific modifications for enhanced results.

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