ORIGINAL ARTICLE

Effects of resistance and strength training on serum phosphorus levels in male footballers: implications for physical educators and sports trainers

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Abstract

Background and Study Aim Sports performance and overall health of athletes are highly dependent on various physiological markers. Among these, blood biochemistry is of great importance and should be carefully considered in athletes' training regimens. However, the effect of strength and resistance training on serum phosphorus levels still requires further clarification and more effective solutions. The aim of this study was to determine the effect of strength and resistance training on serum phosphorus levels in elite male soccer players.

Material and Methods A sample of 90 volunteers was recruited from football athletes in the Peshawar division. Thirty participants were selected from each of the under-16, under-19, and under-23 age groups. They were divided into three groups: the Resistance Training Group (RTG), the Strength Training Group (STG), and the Control Group (CG). Each group consisted of 30 participants, with 10 from each age category. Phosphorus levels and anthropometric measurements (height, weight, BMI, waist circumference, hip circumference, and waist-to-hip ratio (WHR)) were assessed before and after a 12-week strength and resistance training intervention. Analysis of Variance (ANOVA) and paired sample t-tests were used to evaluate changes over time.

Results Significant improvements were observed in serum phosphorus levels in the Resistance Training Group (4.77±0.258 vs. 3.66±0.207, $P<0.001$) and in the Strength Training Group (4.31±0.304 vs. 3.66±0.209, $P<0.001$). A 12-week regimen of strength and resistance training significantly improved serum phosphorus levels among the participants. Analysis of variance indicated that both strength and resistance training significantly affected serum phosphorus levels after 12 weeks of intervention. Tukey's HSD test revealed that the effects of resistance training were more pronounced than those of strength training.

Conclusions This study highlights the importance of incorporating both strength and resistance training in athletic programs. These training approaches are crucial for optimizing physical health and performance. The findings underscore the need for educators and trainers to adapt and refine their methods to maximize the benefits of these interventions. By doing so, they can enhance the effectiveness of training regimens and contribute to the overall well-being of athletes.

Keywords: weight, BMI, 12-week, intervention, bone mineral content

Introduction

Resistance training (RT) and strength training (ST) are fundamental components of programs aimed at developing physical qualities. While the positive effects of RT and ST on muscle mass, strength, and power are well-documented, their impact on electrolytes, particularly serum phosphorus, in this specific population remains less explored. This gap in knowledge is particularly important when considering broader issues such as osteoporosis, a condition characterized by reduced bone mineral density (BMD) that leads to an increased risk of fractures. Osteoporosis is on the rise as the world's population ages, bringing serious emotional, physical, and financial consequences, including impairment, lower quality of life for seniors, and expensive treatment [1]. Developing countries, particularly in Asia, are experiencing a rapid increase in the occurrence of osteoporotic fractures, with Pakistan being one such example where millions are currently affected, and the numbers are projected to rise further [2]. Bone functions as a significant calcium reservoir in the body, with regulation primarily governed by endogenous hormones such as Parathyroid Hormone (PTH), and to a lesser extent, calcitriol and calcitonin [3]. The mineral composition of bones comprises approximately 80-90% calcium and phosphorus, which are essential for skeletal mineralization [4]."

Resistance training (RT) and strength training play a pivotal role in comprehensive programs for

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children and healthy adults. Their significance lies in enhancing bone strength through improvements in muscular power, nerve conduction, mineral deposition, and the maintenance of body balance [5]. Furthermore, resistance training contributes to the augmentation of musculoskeletal strength, favorable alterations in body composition, and improvements in psychological well-being, while simultaneously reducing cardiovascular risk factors [6].

To prevent osteoporosis in adulthood, it is important to maximize peak bone mass during childhood. Researchers have adopted this assumption despite the absence of conclusive proof. This suggests that the susceptibility to bone fractures and the decline in bone density associated with osteoporosis in old age can be mitigated by accumulating bone mineral content (BMC) during childhood [7]. Maximizing age-specific bone mass during growth can be particularly beneficial for preventing fractures, especially in the upper limbs. Implementing strategies to enhance and sustain bone health in the early stages of life may effectively reduce the risk of fractures and other skeletal system-related ailments [8].

Resistance training and strength training have been shown to significantly affect various blood parameters in athletes. Resistance training interventions can lead to healthier metabolite profiles, including changes in dyslipidemia biomarkers and improvements in muscle strength and size [9]. In young boys, resistance training resulted in a significant increase in serum phosphorus levels [10]. Furthermore, Clemente [11] highlighted the impact of elite soccer training on blood parameters, demonstrating changes in creatinine and other electrolytes. These findings collectively suggest that resistance and strength training can influence blood parameters, such as phosphorus concentration, indicating the potential for metabolic adaptations and improvements in athletes' physiological profiles [12]. Moreover, serum phosphorus plays a vital role in various physiological processes essential for athletic performance, including energy metabolism, muscle function, and bone health [13].

Despite the well-documented benefits of resistance and strength training on muscle strength and athletic performance, there is a paucity of research examining their effects on serum phosphorus levels in elite athletes. Phosphorus, a vital component of ATP, is integral to energy transfer and muscular contractions, both of which are critical for high-intensity sports like football [14]. Alterations in serum phosphorus levels can have significant implications for bone health, muscle function, and overall athletic performance. Previous research suggests that exercise can influence phosphorus homeostasis [15]. Studies investigating the effects of exercise on calcium metabolism have shown increased serum calcium levels following RT and ST in athletes [13]. Since phosphorus often follows a similar pattern to calcium due to their intertwined metabolic pathways [14], it is crucial to explore its specific response to RT and ST. However, limited research has specifically focused on the effects of RT and ST on serum phosphorus levels in elite male football athletes.

The effectiveness of strength and resistance training in enhancing bone mineral density and content has been demonstrated across various populations, including athletes. Therefore, it is imperative to investigate how different training regimens influence serum phosphorus levels to develop evidence-based guidelines that optimize both performance and health in elite football athletes. Additionally, this line of research could enhance the pedagogical perspectives of physical educators and sports trainers, improving their knowledge and approaches to athlete safety and performance enhancement. This study aims to fill the gap in the literature by providing a comprehensive analysis of the effects of resistance and strength training on serum phosphorus levels in elite male football athletes. Specifically, it will examine how a 12-week strength and resistance training program impacts serum phosphorus levels in the blood of these athletes.

Material and Methods

Participants

A total of 90 athletes were randomly selected from three age categories: Under-16, Under-19, and Under-23 (n=30 from each). They were divided into three groups: Resistance Training Group (RTG=30), Strength Training Group (STG=30), and Control Group (CG=30). The participants in the Resistance and Strength groups underwent a 12-week intervention, while the Control Group did not participate in any training programs. Instead, they continued with their regular daily activities. Informed written consent was obtained from all participants.

Research Design

Training Protocol. Two distinct training protocols were developed based on a comprehensive review of the relevant literature and underwent rigorous pilot testing, validation, and reliability assessments.

Strength Training Protocol The strength training protocol involved five days of training per week, including dynamic stretching and a series of strength exercises such as chest press, lateral pulldown, arm curls, squats, calf raises, back extensions, crunches, leg presses, pull-ups, leg curls, heel raises, deadlifts, and jump rows. The total duration of training increased gradually over twelve weeks.

Resistance Training Protocol. Similarly, the resistance training protocol also involved five days of training per week, with exercises such as supine bench press, leg extension, bicep curls, shrugs, triceps extension, wrist curls, 10m sprints, one-leg jumps, pop squats, burpees, medicine ball throws, and incline weighted sit-ups. The duration and intensity were gradually adjusted over the twelve-week period.

Statistical Analysis

For statistical analysis, the researcher used measures such as the mean, standard deviation, and frequency distribution. To test the hypotheses, paired t-tests, analysis of variance (ANOVA), and Tukey's HSD were employed to identify any differences in blood phosphorus levels before and after the intervention and across the groups.

Results

Table 1 shows the results of the Shapiro-Wilk test of normality for serum phosphorus concentrations before and after the intervention in three groups: the control group, the strength training group, and the resistance training group. For the resistance training group, the Shapiro-Wilk statistic is 0.942 with a significance level of 0.105 before the intervention and 0.940 with a significance level of 0.093 after the intervention. The p-values (0.105 and 0.093) are greater than 0.05, indicating that the phosphorus concentrations are normally distributed.

For the strength training group, the Shapiro-Wilk statistic is 0.936 with a significance level of 0.070 before the intervention and 0.941 with a significance level of 0.098 after the intervention. The p-values (0.070 and 0.098) are greater than 0.05, indicating that the phosphorus concentrations are normally distributed.

Similarly, for the control group, the Shapiro-Wilk statistic is 0.945 with a significance level of 0.123 before the intervention and 0.949 with a significance level of 0.160 after the intervention. The p-values (0.123 and 0.160) are greater than 0.05, indicating that the phosphorus concentrations are normally distributed.

Table 2 summarizes the pre-test and post-test mean values with standard deviations for various anthropometric measurements in the three groups: Resistance Training Group (RTG), Strength Training Group (STG), and Control Group (CG) (n=30 per group). These findings suggest that the RT program resulted in the most significant changes in body composition compared to the ST program and the control group. This is evident in the reductions observed in weight, BMI, and waist circumference for the RTG. Although all groups experienced decreases in hip circumference, the CG exhibited the greatest change. The waist-to-hip ratio remained relatively

Table 1. Shapiro-Wilk Test Results for Normality of Data of Phosphorous for all three groups

Group	Tests	Shapiro-Wilk		
		Statistic	**Df**	**Sig.**
Resistance Training Group	Pretest	0.942	30	0.105
	Post Test	0.940	30	0.093
Strength Training Group	Pretest	0.936	30	0.070
	Post Test	0.941	30	0.098
Control Group	Pretest	0.945	30	0.123
	Post Test	0.949	30	0.160

Table 2. Anthropometric measurements of Resistance Training, Strength Training and Control Group

Anthropometric measurements	Tests	RTG (n=30) Mean ± SD	STG (n=30) Mean ± SD	CG (n=30) Mean ± SD
Height	Pre Test	1.61 ± 0.033	1.60 ± 0.032	1.61 ± 0.035
	Post Test	1.62 ± 0.041	1.60 ± 0.032	1.61 ± 0.034
Weight	Pre Test	55.83 ± 4.449	55.83 ± 4.14	54.56 ± 5.84
	Post Test	54.93 ± 4.250	55.96 ± 4.48	55.47 ± 5.72
BMI	Pre Test	21.56 ± 2.06	21.77 ± 1.51	21.03 ± 2.22
	Post Test	21.21 ± 1.98	21.76 ± 1.61	21.34 ± 2.14
Waist Circumference	Pre Test	75.53 ± 2.67	75.06 ± 2.46	75.23 ± 2.42
	Post Test	74.4 ± 2.74	74.13 ± 2.60	75.92 ± 2.52
Hip Circumference	Pre Test	95.46 ± 2.66	95.26 ± 2.70	95.18 ± 2.65
	Post Test	94.23 ± 2.60	94.53 ± 2.78	95.51 ± 2.42
WHR	Pre Test	0.79 ± 0.016	0.78 ± 0.013	0.79 ± 0.014
	Post Test	0.78 ± 0.17	0.78 ± 0.016	0.79 ± 0.015

stable across all groups throughout the study.

Table 3 shows paired statistics for serum phosphorus levels in the Resistance Training group, Strength Training group, and Control group. The statistics indicated a significant difference in serum phosphorus levels during the post-intervention period for the resistance and strength training groups. The changes in phosphorus levels were significant, as shown by the increase from 3.66 mg/dl to 4.77 mg/dl (p < .000) in the resistance training group and from 3.66 mg/dl to 4.31 mg/dl (p < .000) in the strength training group. The intervention demonstrated that resistance and strength training had a significant impact on serum phosphorus levels among the athletes in both training groups.

In contrast, the control group showed minimal change in phosphorus levels (3.65 mg/dl to 3.64 mg/dl, p = .326), indicating that athletes who did not participate in any training program experienced no significant impact on serum phosphorus levels.

Table 4 presents the descriptive statistics for phosphorus levels in three groups: Resistance Training, Strength Training, and Control group. In the pre-intervention phase, both the Resistance and Strength Training groups had mean phosphorus levels of 3.660 mg/dl and 3.663 mg/dl, with standard deviations of 0.207 and 0.207, respectively. The Control Group had a slightly lower mean phosphorus level of 3.653 mg/dl with a standard deviation of 0.209. However, the analysis indicates no statistically significant difference between the groups' mean phosphorus levels (F = 0.018, p = 0.982). These findings suggest that the type of training (resistance or strength) may not have a significant impact on phosphorus levels.

Table 5 shows the descriptive statistics for serum phosphorus levels in three groups: Resistance Training, Strength Training, and Control Group. The post-intervention Resistance Training group has the highest mean serum phosphorus level (4.773 mg/dl) with a standard deviation of 0.258, followed by the Strength Training group (4.316 mg/dl) and the Control group (3.646 mg/dl) with standard deviations of 0.304 and 0.208, respectively. The analysis indicates a significant change in the mean serum phosphorus levels between the groups (F =

Table 3. Paired Samples T-test for Resistance, Strength and Control Group

Variable Name	Group	Tests	N	Mean	S.D	Df	F	Sig.
Phosphorous	Resistance Training Group	Pre test	30	3.660	.207	29	-35.521	.000
		Post test	30	4.773	.258			
Phosphorous	Strength Training Group	Pre test	30	3.663	.209	29	-11.099	.000
		Post test	30	4.316	.304			
Phosphorous	Control Group	Pre test	30	3.653	.209	29	1.000	.326
		Post test	30	3.646	.208			

Table 4. ANOVA Statistical Analysis for Serum Phosphorous (Pre-Test)

Variable Name Phosphorous Pre-Test	N	Mean	S.D	Df	F	Sig.
Resistance Training Group	30	3.660	.207	89		
Strength Training Group	30	3.663	.207		0.018	.982
Control Group	30	3.653	.209			

The mean difference is significant at the 0.05 level.

Table 5. ANOVA Statistical Analysis for Serum Phosphorous (Post-Test)

Variable Name Phosphorous Post Test	N	Mean	S.D	Df	F	Sig.
Resistance Training Group	30	4.773	.258	89		
Strength Training Group	30	4.316	.304		142.667	.000
Control Group	30	3.646	.208			

The mean difference is significant at the 0.05 level

Table 6. Tukey's HSD for Phosphorous

Dependent Variable: Phosphorous Post

Tukey HSD

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	Strength Training	-.67000*	.06710	.000	-.8300	-.5100
	Resistance Training	-1.12667*	.06710	.000	-1.2867	-.9667
Strength Training	Control	.67000*	.06710	.000	.5100	.8300
	Resistance Training	-.45667*	.06710	.000	-.6167	-.2967
Resistance Training	Control	1.12667*	.06710	.000	.9667	1.2867
	Strength Training	.45667*	.06710	.000	.2967	.6167

The mean difference is significant at the 0.05 level. Mean Values (Resistance Training=4.77, Strength Training=4.31, Control Group=3.64)

142.667, p = 0.000). These results suggest that both resistance and strength training have a significant effect on post-test serum phosphorus levels, with resistance training having the greatest impact.

Table 6 presents the results of a Tukey Honest Significant Difference (HSD) test conducted on the post-intervention phosphorus levels in three groups: Control, Strength Training, and Resistance Training.

Pairwise Comparisons:

1. *Control vs. Strength Training*: Mean Difference: -0.67000. The Control group has a mean phosphorus level that is 0.67 mg/dL lower than the Strength Training group. This difference is highly statistically significant with a p-value of less than 0.001.
2. *Control vs. Resistance Training*: Mean Difference: -1.12667. The Control group has significantly lower phosphorus levels compared to the Resistance Training group by 1.12667 mg/dL. This difference is highly significant (p < 0.001).
3. *Strength Training vs. Control:* This comparison is the inverse of the first, showing that the Strength Training group has higher phosphorus levels compared to the Control group by 0.67 mg/dL.
4. *Strength Training vs. Resistance Training*: Mean Difference: -0.45667. The phosphorus levels in the Strength Training group are significantly lower than those in the Resistance Training group by 0.45667 mg/dL (p < 0.001), indicating a significant difference.
5. *Resistance Training vs. Control and Strength Training*: The results show that the Resistance Training group has the highest phosphorus levels among the three groups, as indicated by the positive mean differences compared to the Control and Strength Training groups. These differences are statistically significant.

The Tukey HSD test results indicate statistically significant differences in post-intervention phosphorus levels among the Control, Strength Training, and Resistance Training groups. The Resistance Training group has the highest phosphorus levels, followed by the Strength Training group, and lastly, the Control group.

These findings suggest that physical training, especially resistance training, may lead to increased phosphorus levels. This could reflect the increased demand for phosphorus in metabolic and physiological processes associated with exercise. Elevated phosphorus levels can be important for energy production, bone health, and cellular function.

Table 7 shows the educational implications of the study on resistance and strength training on serum phosphorus levels. The research involved participants from different educational levels, specifically those enrolled in the Under-16 (8th, 9th, and 10th grades), Under-19 (9th, 10th, 11th, and 12th grades), and Under-23 (Bachelor's degree students, with four groups based on credit load: 1st Semester, 2nd & 3rd Semesters, or ADP 1st & 2nd). These diverse educational groups highlight the potential for using the study results to further age-appropriate physical education curricula.

By presenting the physiological outcomes of the structured training program, this study provides a foundation for improving teaching approaches across these educational levels. The findings could be used by physical educators, trainers, coaches, and students to develop specific training exercises that enhance physical performance and advance the science of physical education.

Table 7. Educational Implications

S.NO	Categories	Educational Level/ Class Enrolled
1	Under-16	8th, 9th & 10th class
2	Under-19	9th, 10th, 11th & 12th class
3	Under-23	BS: 1st, 2nd & 3rd semester/ ADP 1st & 2nd

From a didactic perspective, the results suggest that incorporating resistance and strength training into physical education classes can help students at various educational levels understand the need for specialized training. This approach can contribute more scientifically to the pedagogical practices of physical education and the achievement of both physical and academic learning goals. Moreover, these findings could encourage the development of teaching practices that support different educational processes within sports training settings.

Discussion

The purpose of this study was to assess the impact of resistance and strength training on serum phosphorus levels in male elite football players in Peshawar, Pakistan. The intervention outcomes indicated that the two training regimes, RT and ST, implemented over a 12-week program, enhanced mean serum phosphorus concentrations. The RTG demonstrated a higher level of increase compared to the STG, which experienced a slight increase. These findings were further supported by Analysis of Variance (ANOVA) and Tukey's HSD tests, which confirmed the superior capability of resistance training over strength training in altering serum phosphorus levels. In addition to the biochemical advancements observed with physical training, significant positive changes in anthropometric factors were also recorded, highlighting the importance of structured exercise. Accordingly, it can be asserted that both forms of training are critical not only for improving biochemical markers such as serum phosphorus but also for achieving significant anthropometric results.

Bone mineral content (BMC) is a critical factor in both bone health and overall athletic performance. Adequate BMC is necessary for maintaining strong bones, thereby reducing the risk of fractures and other sports-related injuries [4]. Monitoring serum calcium, phosphorus, and parathyroid hormone (PTH) levels is essential for assessing bone health and mineral status in athletes. Calcium and phosphorus are crucial for the formation and maintenance of bones, while the regulation of bone remodeling and turnover is controlled by parathyroid hormone (PTH) [16].

Strength and resistance training have been shown to significantly impact bone mineral content, including serum calcium and phosphorus levels. The interplay between strength training, resistance training, and bone mineral content is complex. These athletes undergo rigorous training regimens that place high demands on their musculoskeletal system, including their bones. Calcium and phosphorus homeostasis plays a crucial role in supporting bone health and adaptation to exercise-induced stress [17]. This is particularly important for male elite football athletes, who are subjected to high-intensity loads during training and competition.

Phosphorus collaborates with calcium to provide the structural framework of bones and teeth. Similarly, phosphorus levels can fluctuate during exercise, as the body utilizes more energy and metabolic functions intensify. Studies suggest that 'post-exercise serum phosphorus levels were high due to increased energy production and muscle activity during exercise' [18]. This balanced change in phosphorus is important for supporting bone health and enhancing exercise performance. The study further found that the exercise-induced rise in PTH levels is partially driven by an increase in calcium levels, highlighting the importance of physical activity in regulating PTH secretion.

Parathyroid hormone regulates calcium and phosphorus levels in the body. Additionally, clinicians sometimes advise against exercise due to the potential excretion of parathyroid hormone induced by resistance training, which can lead to a moderate increase in urinary calcium and inorganic phosphates, reducing plasma ionized calcium and phosphorus. Studies have shown that acute bouts of exercise can cause transient increases in parathyroid hormone levels, which help regulate calcium levels in the blood [19]. This hormonal response is essential for maintaining calcium homeostasis and bone health during physical activity [20].

The findings of this research support the hypothesis that there are significant differences in serum phosphorus levels among the resistance training, strength training, and control groups after the completion of the training program. These results are consistent with recent research demonstrating the impact of exercise interventions on mineral metabolism parameters [3, 8]. The observed differences in blood calcium and phosphorus levels may reflect specific adaptations induced by resistance and strength training modalities, such as alterations in bone turnover and mineral accretion [21]. Additionally, the changes in PTH levels suggest a regulatory response to exercise-induced stress, potentially involving adjustments in calcium homeostasis and parathyroid gland activity [22].

The significant differences in mineral metabolism parameters among the groups underscore the importance of tailoring exercise interventions to achieve specific physiological outcomes. Resistance training may be particularly effective for enhancing bone mineral density and calcium absorption, while strength training may exert distinct effects on phosphorus metabolism and hormonal regulation [15]. Moreover, the observed differences between the trained groups and the control group (CG) highlight the unique contributions of exercise to mineral metabolism, beyond those attributable to normal physiological variation or environmental factors.

The sample for this study was taken from educational institutions, suggesting that the findings could significantly contribute to the educational sector, particularly in the pedagogical aspects of physical education curriculum and syllabus design. This study provides deeper insights for physical educators and sports trainers, helping them improve their teaching methods both in classroom settings and on the field. Additionally, sports trainers could potentially enhance their training environment and culture, optimizing training activities to better support their athletes.

Conclusions

This study reinforces the critical role of both resistance and strength training in improving key health markers and physical attributes among elite football athletes. By implementing these findings, sports practitioners can enhance the health and performance outcomes of athletes, fostering a more scientifically informed approach to athletic training. The implications of this study could potentially improve the pedagogical approaches of physical educators, trainers, coaches, and students, facilitating the development of specific training exercises that enhance students' physical performance and advance the science of physical education.

Limitations and Recommendations

This study was not conducted as a randomized controlled trial, and therefore, we did not control or consider dietary intake, hydration status, or physical activities outside the training protocols. These factors could yield more valid results in future investigations. The study sample was taken from Peshawar, the capital of the Khyber Pakhtunkhwa (KP) province of Pakistan, so the results can only be generalized to elite footballers in different regions of KP. Additionally, the results cannot be generalized to female athletes, as they were not included in this study. Future research is encouraged to include female participants to better understand the effectiveness of both training protocols across genders.

The sample for this study was taken from educational institutions, suggesting that the findings could contribute significantly to the educational sector, particularly in the pedagogical aspects of physical education curriculum and syllabus design. This study provides deeper insights for physical educators and sports trainers, helping them improve their teaching methods both in classroom settings and on the field. Moreover, sports trainers could potentially enhance their training environment and culture, optimizing training activities to better support their athletes.

Highlights

1. Coaches, trainers, and sports scientists should prioritize resistance and strength training in conditioning programs for elite football athletes.
2. Strength and resistance training have the potential to engage a large number of students and athletes simultaneously. It is therefore recommended that comprehensive strength and resistance training programs be implemented in all educational and physical training institutions. This could contribute to improving the pedagogical approaches of physical education teachers, promoting strong and healthy bones, and reducing the risk of future bone fractures and osteoporosis.
3. Regular blood tests for calcium, phosphorus, and parathyroid hormone levels should be conducted for the diagnosis and treatment of any disorders related to bone health.
4. The same training protocols can be applied to female athletes to broaden the scope of the study.

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Conflicts of Interest

The authors declare no conflict of interest.

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