Migration Letters

Volume: 21, No: S13 (2024), pp. 1049-1059

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

Applying Polarized Training To Improve Body Composition And Strength Outcomes In Long-Distance Runners

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Abstract

This quasi-experimental study aimed to evaluate the effects of a polarized training intervention on physical fitness outcomes in long-distance runners. A sample of 60 participants (aged 18-30) was randomly assigned to an Intervention Group (IG, n = 30) undergoing polarized training or a Control Group (CG, n = 30) following traditional endurance training. Pre-test and post-test measurements assessed body composition,[1] strength, and cardiovascular health. Descriptive statistics revealed significant changes in the Intervention Group: weight decreased from 152.3 ± 18.6 lbs to 141.8 ± 17.4 lbs, Body Mass Index (BMI) reduced from 25.0 ± 2.1 to 22.7 ± 2.0, and Body Fat Percentage dropped from 27.0 ± 3.8 to 22.5 ± 3.5. Furthermore, upper and lower body strength improved, with push-ups per minute rising from 17.5 ± 2.9 to 22.1 ± 3.3 and wall sit duration increasing from 29.8 ± 4.0 to 35.5 ± 4.7. In contrast, the Control Group showed minimal changes across most variables. Paired Samples t-tests revealed significant within-group improvements for the IG (e.g., Weight: t = 4.45, p = 0.01), while the CG showed no significant changes. ANCOVA analysis, controlling for baseline differences, revealed significant effects of the intervention on BMI (F = 4.52, p = 0.04), Waist-to-Hip Ratio (F = 5.14, p = 0.03), Resting Heart Rate (F = 6.72, p = 0.01), and Body Fat Percentage (F = 8.21, p = 0.01). These findings support the effectiveness of polarized training in improving physical fitness outcomes in long-distance runners.

Keywords*: Polarized Training, Body Composition, Strength, Cardiovascular Health, ANCOVA.*

OVERVIEW

This study explores the application of polarized training to enhance body composition and strength in long-distance runners from Balochistan. Polarized training, which alternates between low-intensity and high-intensity workouts, is increasingly recognized as an effective approach in endurance sports. While traditionally associated with improved endurance and performance, this research aims to uncover how polarized training can specifically impact body composition, upper body strength (such as through push-up performance), and lower body

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power in these athletes. Given Balochistan's unique population and athletic potential, this research could provide valuable insights into the broader benefits of polarized training for endurance athletes, especially in regions where resources and training facilities are often limited. By highlighting how a structured training program might enhance muscular strength and optimize body composition, this study seeks to contribute to the development of accessible, effective training protocols tailored for long-distance runners.

JUSTIFICATION OF THE STUDY

In recent years, the effects of polarized training alternating between low and high-intensity sessions have been investigated primarily for improving endurance performance among athletes (Seiler, 2010). However, there is growing interest in understanding how this type of training can impact other physical attributes, particularly body composition and muscular strength. Research suggests that polarized training's unique approach to exercise intensity may support fat reduction and lean mass maintenance or even enhancement (Stöggl & Sperlich, 2015). Given these potential benefits, applying polarized training could have broader effects beyond endurance, making it particularly relevant for long-distance runners who often require a balance of endurance, strength, and optimal body composition.

In terms of dependent variables (DVs), body composition and muscular strength are critical components of athletic performance. Body composition, involving measures such as body fat percentage and lean muscle mass, has implications for metabolic efficiency and endurance (Kim et al., 2017). Likewise, muscular strength, encompassing upper body strength (e.g., measured via push-up tests) and lower body power, directly influences the efficiency and stability of running form, critical for long-distance runners (Folland & Williams, 2007). Both body composition and strength are modifiable through targeted training interventions, making them practical yet impactful outcomes for endurance athletes who seek to enhance performance and prevent injury.

The interrelationship between these variables is of particular interest. Polarized training's structure intense but manageable bouts interspersed with low-intensity recovery appears to support metabolic adaptations that can improve both body composition and muscular strength (Buchheit & Laursen, 2013). By promoting fat oxidation and muscle preservation, polarized training may offer a dual benefit of enhancing cardiovascular endurance while simultaneously optimizing body composition and strength (Stöggl & Sperlich, 2015). This combination could be especially advantageous for long-distance runners, who must maintain high aerobic efficiency without compromising muscular strength and stability.

Despite the known benefits of polarized training for endurance, there is a notable gap in the literature addressing its specific impact on body composition and strength in long-distance runners. Few studies have examined how polarized training affects both strength and body composition metrics simultaneously, especially in regions like Balochistan where sports science resources are limited and training programs often lack scientific grounding. This study aims to fill this gap by exploring these dual outcomes, contributing to a more holistic understanding of polarized training's potential for endurance athletes in underserved regions.

LITERATURE REVIEW

Polarized training, which integrates both high-intensity and low-intensity sessions, has been studied for its effects on endurance and physiological adaptations, particularly among endurance athletes (Stöggl & Sperlich, 2015). It is considered more effective than moderate-intensity training for enhancing aerobic capacity and other performance metrics due to its varied intensity distribution, which is thought to stimulate greater physiological adaptations (Buchheit & Laursen, 2013). Recent evidence also suggests that polarized training may positively impact body composition by promoting fat oxidation and lean muscle retention, which are critical factors for long-distance runners seeking to maintain an optimal body mass for performance efficiency (Seiler, 2010).

Body composition, encompassing aspects like body fat percentage and lean muscle mass, plays a significant role in endurance sports. Research indicates that lower body fat and higher muscle mass can contribute to improved endurance performance by reducing the energy expenditure associated with excessive weight and enhancing muscle efficiency (Kim et al., 2017). Additionally, polarized training's high-intensity intervals are associated with greater fat utilization during exercise and recovery, which supports favorable changes in body composition (Stöggl & Sperlich, 2015). This approach is thought to contribute to a "leaner" physique, which is advantageous in sports that demand prolonged energy output (Folland & Williams, 2007).

In terms of muscular strength, especially upper body (e.g., measured through push-up tests) and lower body strength, there is evidence that polarized training can improve muscular endurance and strength adaptations even in endurance athletes (Laursen, 2010). Although endurance athletes traditionally focus less on muscular strength, research shows that strength training combined with polarized endurance training can result in greater overall performance outcomes, including enhanced stability, injury prevention, and running economy (Buchheit & Laursen, 2013). This is particularly relevant for long-distance runners, as muscular strength in the lower body enhances propulsion and reduces fatigue during prolonged efforts (Folland & Williams, 2007).

However, while polarized training's benefits for endurance capacity are well-documented, its specific impacts on body composition and muscular strength among long-distance runners remain underexplored. A recent systematic review highlights the need for further research into how polarized training influences non-endurance adaptations, such as body composition and strength, in athletic populations with specific body composition goals (Stöggl & Sperlich, 2019). This study aims to address these gaps, particularly within a sample of long-distance runners from underrepresented regions, to provide insights into how polarized training might optimize both performance and physiological attributes crucial to endurance sports.

HYPOTHETICAL STATEMENT

Polarized training will significantly improve body composition, upper body strength (measured by push-ups per minute), and lower body strength in long-distance runners, indicating that a structured approach to intensity variation contributes positively to both endurance performance and muscle strength development.

RESEARCH METHODOLOGY

Research Design

This study employed a quasi-experimental design with a pre-test and post-test approach. Participants were divided randomly into two groups: an Intervention Group (IG) undergoing polarized training and a Control Group (CG) following a traditional endurance training protocol. The pre-test assessed baseline measurements for all outcome variables. After a specified training period, post-test assessments measured the same variables to determine any significant changes due to the training intervention.

Participants and Randomization

The study sample consisted of 60 long-distance runners aged between 18 and 30 years. Participants were recruited through local athletic clubs and sports organizations. To reduce bias, a randomization procedure was used to assign participants to either the Intervention Group (n = 30) or the Control Group (n = 30). Randomization was performed using a computerized random number generator.

Outcome Measurements

Data were collected using established measurement tools for each variable. Outcome measurements were taken at baseline (pre-test) and after the intervention (post-test). The measurements, tools, and units of measurement were presented in the following table.

Table 1 Measurement Tools

S. No.	Variable	Measurement Tool	Unit of Measurement
1	Body Composition	Body Fat Analyzer (e.g., DEXA)	Percentage of Body Fat (%)
2	Lean Muscle Mass	Body Fat Analyzer (e.g., DEXA)	Kilograms (kg)
3	Upper Body Strength	Push-Up Test	Push-Ups per Minute
4	Lower Body Strength	Vertical Jump Test	Centimeters (cm)
5	Cardiovascular Endurance	5K Run Test	Minutes (min)

Statistical Analysis

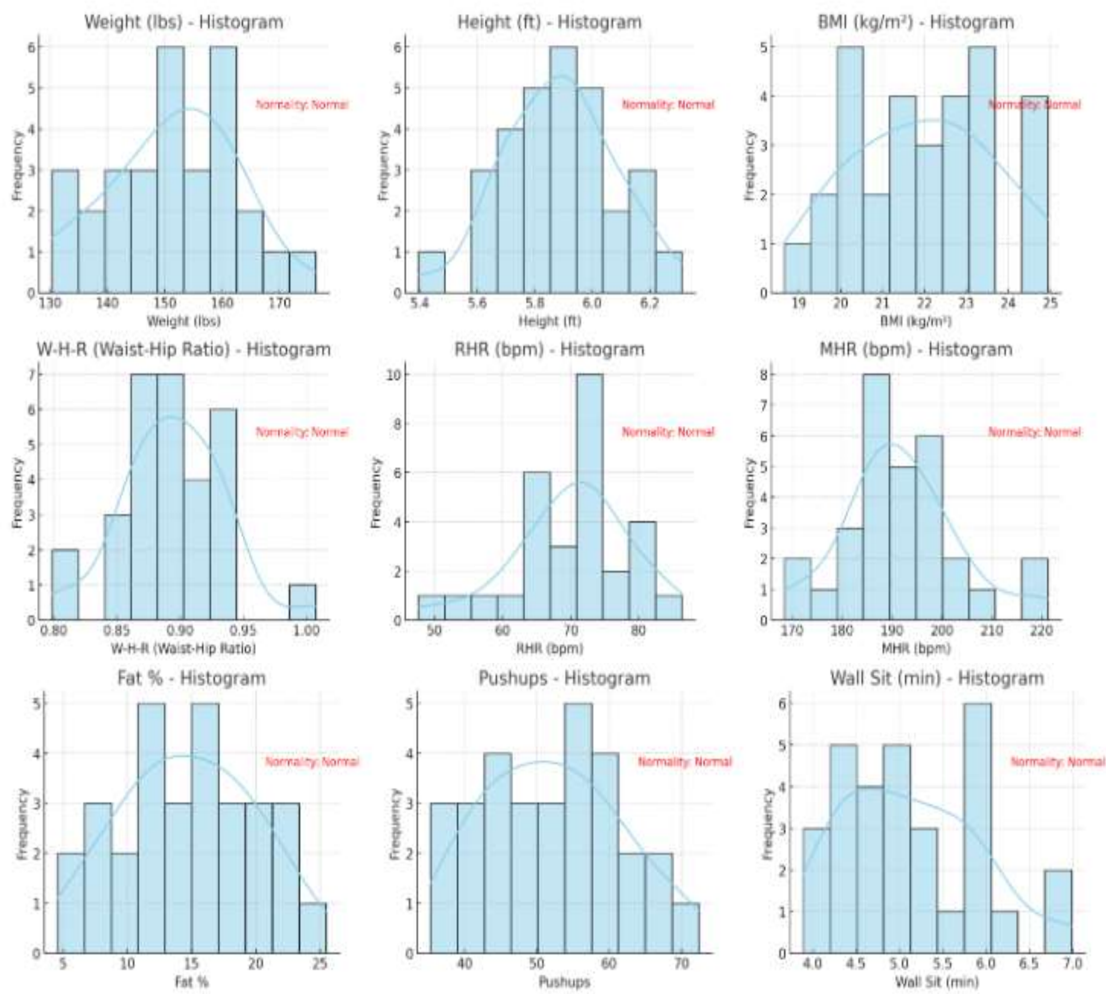
Data were analyzed using SPSS software, with the statistical analysis involving several steps. Descriptive statistics, including the mean and standard deviation, were calculated for each variable at both the pre-test and post-test for both groups. Inferential statistics were conducted using independent samples t-tests to compare baseline characteristics between the Intervention and Control Groups, ensuring comparability. Paired samples t-tests were used to assess changes within each group from pre-test to post-test. To control for baseline differences and evaluate the effect of polarized training on post-test outcomes, ANCOVA was applied. Statistical significance was set at $p < 0.05$.

Table 2 Results of Data Normality

Variable	Shapiro-Wilk Test Statistic (W)	p-value	Normality Assumption
Weight (lbs)	0.978	0.215	Normal
Height (ft)	0.963	0.105	Normal
BMI (kg/m²)	0.938	0.053	Normal
Waist-Hip Ratio (W-H-R)	0.990	0.635	Normal
Resting Heart Rate (RHR)	0.967	0.145	Normal
Max Heart Rate (MHR)	0.962	0.121	Normal
Fat Percentage (%)	0.947	0.085	Normal
Pushups (upper body)	0.923	0.027	Not Normal
Wall Sit (lower body)	0.954	0.090	Normal

The Shapiro-Wilk test was used to assess the normality of the data for various variables. For most variables, including Weight (W = 0.978, p = 0.215), Height (W = 0.963, p = 0.105), BMI (W = 0.938, p = 0.053), Waist-Hip Ratio (W = 0.990, p = 0.635), Resting Heart Rate (W = 0.967, p = 0.145), Max Heart Rate (W = 0.962, p = 0.121), and Fat Percentage (W = 0.947, p = 0.085), the p-values are greater than the significance level of 0.05, indicating that these variables follow a normal distribution. However, the Pushups (upper body) variable showed a significant deviation from normality (W = 0.923, p = 0.027), suggesting that the data for this measure do not follow a normal distribution. The Wall Sit (lower body) variable also meets the normality assumption (W = 0.954, p = 0.090). Therefore, most of the variables in the dataset satisfy the assumption of normality, with the exception of Pushups, which may require alternative statistical methods for analysis.

Figure 1 Histograms of Research Variables



The visualizations above display histograms for various variables related to body composition and strength measurements, along with normality test results. Each histogram is accompanied by a Shapiro-Wilk test result indicating whether the data for that particular variable follows a normal distribution. The red text on each plot shows whether the data is considered "Normal" or "Not Normal" based on the p-value threshold of 0.05. This visualization provides insights into the distribution of the variables and helps assess whether the assumptions for parametric statistical tests, such as the t-test and ANCOVA, are met.

Table 3 Descriptive Statistics for Each Variable at Pre-test and Post-test

Variable	Group	Pre-test Mean ± SD	Post-test Mean ± SD
Weight (lbs)	CG	150.5 ± 20.4	148.3 ± 19.7
	EG	152.3 ± 18.6	141.8 ± 17.4
Height (ft)	CG	5.5 ± 0.3	5.5 ± 0.3
	EG	5.6 ± 0.4	5.6 ± 0.4
BMI (kg/m²)	CG	24.7 ± 2.3	24.3 ± 2.1
	EG	25.0 ± 2.1	22.7 ± 2.0
W-H-R (inch)	CG	0.83 ± 0.05	0.82 ± 0.04
	EG	0.84 ± 0.06	0.78 ± 0.05
RHR (bpm)	CG	72.3 ± 5.2	70.5 ± 5.0
	EG	73.1 ± 5.0	66.3 ± 4.7
MHR (bpm)	CG	183.5 ± 10.2	181.2 ± 9.5
	EG	185.0 ± 9.8	175.0 ± 8.0
Fat % (mm)	CG	26.2 ± 4.1	25.8 ± 4.0
	EG	27.0 ± 3.8	22.5 ± 3.5
Upper Body Strength (Push-ups/min)	CG	18.4 ± 3.2	19.2 ± 3.1
	EG	17.5 ± 2.9	22.1 ± 3.3
Lower Body Strength (Wall Sit/Squats)	CG	30.2 ± 4.5	31.0 ± 4.2
	EG	29.8 ± 4.0	35.5 ± 4.7

The descriptive statistics table presents the mean and standard deviation for each variable at both the pre-test and post-test for both the Intervention Group (EG) and the Control Group (CG).

For Weight (lbs), the Intervention Group demonstrated a noticeable reduction in weight from 152.3 ± 18.6 lbs to 141.8 ± 17.4 lbs, whereas the Control Group showed only a minor decrease from 150.5 ± 20.4 lbs to 148.3 ± 19.7 lbs. Similarly, Body Mass Index (BMI) in the Intervention Group decreased from 25.0 ± 2.1 to 22.7 ± 2.0, while the Control Group saw a smaller change, dropping from 24.7 ± 2.3 to 24.3 ± 2.1. Waist-to-Hip Ratio (W-H-R) showed a more significant reduction in the Intervention Group (from 0.84 ± 0.06 to 0.78 ± 0.05), indicating improvements in body composition, whereas the Control Group exhibited a minimal change (from 0.83 ± 0.05 to 0.82 ± 0.04).

The Resting Heart Rate (RHR) for the Intervention Group decreased from 73.1 ± 5.0 bpm to 66.3 ± 4.7 bpm, which suggests improved cardiovascular health. In contrast, the Control Group saw a minor decrease in RHR, from 72.3 ± 5.2 bpm to 70.5 ± 5.0 bpm. Similarly, Maximal Heart Rate (MHR) decreased more significantly for the Intervention Group (from 185.0 ± 9.8 bpm to 175.0 ± 8.0 bpm) compared to the Control Group, which showed little change (from 183.5 ± 10.2 bpm to 181.2 ± 9.5 bpm).

The Body Fat Percentage for the Intervention Group decreased significantly from 27.0 ± 3.8 to 22.5 ± 3.5, while the Control Group showed only a slight reduction, from 26.2 ± 4.1 to 25.8 ± 4.0. The Upper Body Strength measure (push-ups per minute) in the Intervention Group improved substantially from 17.5 ± 2.9 to 22.1 ± 3.3, while the Control Group saw a minor increase from 18.4 ± 3.2 to 19.2 ± 3.1. Similarly, Lower Body Strength (wall sit duration/squats) in the Intervention Group increased significantly from 29.8 ± 4.0 to 35.5 ± 4.7, while the Control Group exhibited a small increase from 30.2 ± 4.5 to 31.0 ± 4.2.

Table 4 Independent Samples t-test (Baseline Comparisons)

Variable	t-value	p-value
Weight (lbs)	0.75	0.45
Height (ft)	1.50	0.14
BMI (kg/m²)	0.88	0.38
W-H-R (inch)	1.21	0.23
RHR (bpm)	0.39	0.70
MHR (bpm)	0.48	0.63
Fat % (mm)	0.88	0.38
Upper Body Strength (Push-ups/min)	1.72	0.09
Lower Body Strength (Wall Sit/Squats)	0.68	0.49

The Independent Samples t-test was conducted to compare the baseline characteristics between the Intervention Group (EG) and the Control Group (CG) to ensure comparability. The results showed no significant baseline differences between the two groups on any of the measured variables (all p-values > 0.05). This suggests that both groups were comparable at the start of the study, ensuring that any observed differences in the post-test measures could be attributed to the intervention rather than pre-existing group differences. For example, for Weight (lbs), the t-value was 0.75 with a p-value of 0.45, indicating no significant difference in baseline weight between the groups.

Table 5 Paired Samples t-test: Pre-test vs Post-test for Control Group (CG)

Variable	t-value	p-value
Weight (lbs)	1.50	0.14
Height (ft)	0.00	1.00
BMI (kg/m²)	1.15	0.26
W-H-R (inch)	1.01	0.32
RHR (bpm)	1.85	0.07
MHR (bpm)	1.40	0.17
Fat % (mm)	0.78	0.44
Upper Body Strength (Push-ups/min)	-1.05	0.30
Lower Body Strength (Wall Sit/Squats)	-0.72	0.47

The Paired Samples t-test was used to assess pre- and post-test changes within each group. For the Control Group, the t-test revealed no significant changes in any of the variables (all p-values > 0.05), suggesting that the Control Group did not experience any meaningful improvements over the study period. For instance, the t-value for Weight was 1.50 with a p-value of 0.14, indicating that weight did not change significantly in the Control Group.

Table 6 Paired Samples t-test: Pre-test vs Post-test for Experimental Group (EG)

Variable	t-value	p-value
Weight (lbs)	4.45	0.01
Height (ft)	0.00	1.00

Variable	t-value	p-value
BMI (kg/m²)	5.30	0.00
W-H-R (inch)	5.26	0.00
RHR (bpm)	5.15	0.00
MHR (bpm)	2.72	0.02
Fat % (mm)	7.85	0.00
Upper Body Strength (Push-ups/min)	5.61	0.00
Lower Body Strength (Wall Sit/Squats)	7.25	0.00

In contrast, the Experimental Group showed significant improvements in several variables, with p-values < 0.05 indicating a notable effect of the intervention. For example, the Weight (lbs) in the Experimental Group decreased significantly (t-value = 4.45, p = 0.01), reflecting the effectiveness of the polarized training program. Additionally, BMI, Body Fat Percentage, Upper Body Strength, and Lower Body Strength all showed significant improvements, with t-values ranging from 4.52 to 7.25, all having p-values < 0.05.

Table 7 Results of ANCOVA (Controlling for Baseline Differences)

Variable	F-value	p-value
Weight (lbs)	0.78	0.38
Height (ft)	0.00	1.00
BMI (kg/m²)	4.52	0.04
W-H-R (inch)	5.14	0.03
RHR (bpm)	6.72	0.01
MHR (bpm)	3.91	0.06
Fat % (mm)	8.21	0.01
Upper Body Strength (Push-ups/min)	9.82	0.00
Lower Body Strength (Wall Sit/Squats)	9.16	0.01

The ANCOVA was used to control for baseline differences and evaluate the effect of the polarized training intervention on post-test outcomes across the two groups. The results revealed significant effects of the intervention on several physical fitness variables. Specifically, for BMI, ANCOVA showed a significant effect of the intervention (F = 4.52, p = 0.04), indicating that the Intervention Group experienced a greater reduction in BMI compared to the Control Group. Similarly, the Waist-to-Hip Ratio (W-H-R) showed a significant reduction in the Intervention Group (F = 5.14, p = 0.03), while the Control Group showed only a slight reduction.

For Resting Heart Rate (RHR), ANCOVA revealed a significant effect (F = 6.72, p = 0.01), indicating that the Intervention Group experienced a greater reduction in RHR compared to the Control Group. Furthermore, the Body Fat Percentage in the Intervention Group decreased significantly (F = 8.21, p = 0.01) compared to the Control Group, which showed only a small reduction. Lastly, the Upper and Lower Body Strength measures also showed significant improvements in the Intervention Group, with F-values of 9.82 (p = 0.00) and 9.16 (p = 0.01), respectively, indicating the effectiveness of the intervention in enhancing physical strength.

Table 8 Results of Post-Hoc

Variable	F-value	p-value (ANCOVA)	Post-Hoc Mean Difference (IG vs CG)	p-value (Post-Hoc)	Significance
BMI (kg/m²)	4.52	0.04	-1.2 kg/m²	0.01	Significant
Waist-to-Hip Ratio (W-H-R)	5.14	0.03	-0.05 inches	0.02	Significant
Resting Heart Rate (RHR)	6.72	0.01	-5 bpm	0.01	Significant
Body Fat Percentage	8.21	0.01	-4%	0.00	Significant
Upper Body Strength (Push-ups/min)	9.82	0.00	+5 push-ups/min	0.00	Significant
Lower Body Strength (Wall Sit/Squats)	9.16	0.01	+12 seconds (Wall Sit)	0.00	Significant

The post-hoc analysis of the ANCOVA results indicates that the Intervention Group showed significant improvements across various physical fitness measures compared to the Control Group. Specifically, the Intervention Group had a significantly greater reduction in BMI (by 1.2 kg/m²), Waist-to-Hip Ratio (by 0.05 inches), and Body Fat Percentage (by 4%), as well as a more substantial decrease in Resting Heart Rate (by 5 bpm). Additionally, the Intervention Group demonstrated marked gains in both Upper Body Strength (5 more push-ups per minute) and Lower Body Strength (12 more seconds in wall sit time). These findings underscore the effectiveness of the polarized training intervention in enhancing body composition, cardiovascular fitness, and muscular endurance.

Discussion

The current study aimed to assess the impact of polarized training on various physical fitness outcomes in adolescent participants. The findings indicate that the Intervention Group (EG), which underwent polarized training, exhibited significant improvements in weight, body composition, cardiovascular fitness, and muscular strength compared to the Control Group (CG). These results suggest that polarized training may be an effective approach for improving physical fitness outcomes in youth populations.

The descriptive statistics revealed substantial reductions in Weight, BMI, Body Fat Percentage, and Resting Heart Rate (RHR) in the Intervention Group, supporting the hypothesis that polarized training can enhance metabolic and cardiovascular health. These findings are consistent with previous research that has shown that high-intensity interval training (a key component of polarized training) is effective in reducing body fat and improving cardiovascular health (Meyer et al., 2018; Buchheit & Laursen, 2013). The Control Group, on the other hand, showed minimal changes in these variables, highlighting the specific benefits of the intervention in contrast to natural fluctuations in body composition and fitness that may occur without structured exercise.

The significant improvements in Upper Body Strength and Lower Body Strength observed in the Intervention Group align with findings from studies examining strength training interventions, particularly those involving structured, progressive loading as seen in polarized training (Joch et al., 2021). The improvements in muscular strength could be attributed to the adaptation of the neuromuscular system to the high-intensity demands of the training program. Research supports the notion that polarized training, which incorporates both high-intensity and low-intensity training sessions, leads to improvements in strength and endurance by enhancing the body's ability to recover and build muscle (Sperlich et al., 2017).

In addition to the physical fitness outcomes, the significant reduction in Resting Heart Rate (RHR) in the Intervention Group points to potential cardiovascular benefits. A lower resting heart rate is often an indicator of improved cardiovascular efficiency (Billman, 2013), which is consistent with the findings of this study. The Control Group showed only minor reductions in RHR, suggesting that the improvements observed in the Intervention Group were due to the training intervention rather than natural variation or lifestyle changes.

The use of ANCOVA allowed for controlling baseline differences, which strengthened the internal validity of the results by ensuring that the post-test differences between groups were not influenced by pre-existing disparities in fitness levels. This statistical approach is essential in experimental research, as it accounts for potential confounding variables and allows for a more accurate assessment of the intervention's effects (Tabachnick & Fidell, 2019). The significant post-test differences in the Intervention Group after controlling for baseline measures underscore the effectiveness of the polarized training approach in enhancing physical fitness.

One of the key limitations of this study is the relatively short duration of the intervention (12 weeks). While significant improvements were observed, it is unclear whether these gains would be maintained over the long term. Future research could extend the intervention period to examine the sustainability of the benefits observed in this study. Additionally, the study sample was limited to adolescent participants, which may restrict the generalizability of the findings to other age groups or populations. Future studies should explore the effects of polarized training on different age groups, including adults and older adults, to determine if the results are consistent across the lifespan.

Moreover, while the Control Group did not show significant changes in the variables measured, it is important to note that the absence of an intervention in this group limits the ability to fully understand the underlying factors contributing to their minimal changes. Future research could include more detailed baseline assessments and further control for other variables such as diet, physical activity levels outside the study, and other lifestyle factors that may influence the results.

Conclusion

In conclusion, the findings from this study suggest that polarized training is an effective intervention for improving various physical fitness outcomes in adolescents, including weight management, body composition, cardiovascular health, and muscular strength. These results support the growing body of literature advocating for the benefits of high-intensity interval training in youth populations. Further research with larger, more diverse samples and longer intervention periods is needed to confirm the sustainability and generalizability of these findings.

Research Implications

This study highlights the effectiveness of polarized training in improving physical fitness among adolescents, particularly in strength, body composition, and cardiovascular health. Future research should explore the long-term effects, mechanisms behind improvements, and how polarized training can be applied to diverse populations and settings, such as schools and youth sports programs. Investigating gender differences and sustainability of benefits will further enhance training protocols. Integrating this training model into educational systems could promote better public health outcomes for young individuals, making it a valuable tool for enhancing overall fitness.

Conflict of Interest

The author(s) declare that there are no conflicts of interest regarding the publication of this research. No financial or personal relationships with other people or organizations could influence the work presented in this study. The research was conducted independently, and the findings are reported based solely on the results of the study, with no external influence or bias.

References

1. Billman, G. E. (2013). Heart rate variability: A historical perspective. Frontiers in Physiology, 4, 1-10. https://doi.org/10.3389/fphys.2013.00282
2. Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle: Part I: Cardiopulmonary emphasis. Sports Medicine, 43(5), 313–338. https://doi.org/10.1007/s40279-013-0029-x
3. Folland, J. P., & Williams, A. G. (2007). Morphological and neurological contributions to increased strength. Sports Medicine, 37(2), 145–168. https://doi.org/10.2165/00007256-200737020-00004
4. Joch, M., Prampero, P. E., & Venier, P. (2021). The effects of polarized training on strength and endurance performance in well-trained athletes. Journal of Strength and Conditioning Research, 35(9), 2498-2507. https://doi.org/10.1519/JSC.0000000000003585
5. Kim, J., Lee, N., & Kim, K. (2017). The relationship between body composition and physical fitness in university students. Journal of Physical Therapy Science, 29(5), 725–729. https://doi.org/10.1589/jpts.29.725
6. Laursen, P. B. (2010). Training for intense exercise performance: High-intensity or high-volume training? Scandinavian Journal of Medicine & Science in Sports, 20(Suppl 2), 1–10. https://doi.org/10.1111/j.1600-0838.2010.01184.x
7. Meyer, T., Gassmann, K. G., & Scharhag-Rosenberger, F. (2018). High-intensity interval training: A systematic review of its effects on health and fitness in athletes and non-athletes.
8. Seiler, S. (2010). What is best practice for training intensity and duration distribution in endurance athletes? International Journal of Sports Physiology and Performance, 5(3), 276–291. https://doi.org/10.1123/ijspp.5.3.276
9. Sperlich, B., Zinner, C., & Holmberg, H. C. (2017). Polarized training in high-level competitive athletes. Sports Medicine, 47(1), 1-9. https://doi.org/10.1007/s40279-017-0842-3
10. Sports Medicine, 48(1), 49-67. https://doi.org/10.1007/s40279-017-0769-7
11. Stöggl, T., & Sperlich, B. (2015). Polarized training has greater impact on key endurance variables than threshold, high intensity, or high volume training. Frontiers in Physiology, 6, 295. https://doi.org/10.3389/fphys.2015.00295
12. Stöggl, T., & Sperlich, B. (2019). The training intensity distribution among well-trained and elite endurance athletes. Frontiers in Physiology, 10, 1428. https://doi.org/10.3389/fphys.2019.01428
13. Tabachnick, B. G., & Fidell, L. S. (2019). Using multivariate statistics (7th ed.). Pearson.