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Exploration of the biological basis and training strategies for building athletes' psychological resilience

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Abstract: Background: Psychological resilience (PR) is crucial for athletes to perform at their best and recover from failures. However, its biological basis and effective training strategies remain under-explored. Many athletes face psychological challenges that affect their overall well-being and performance. Furthermore, resilience training can benefit from a greater awareness of the biomechanical components of athletes' performance. To help athletes achieve their best, trainers and sports psychologists must understand resilience's molecular principles and develop effective training strategies that integrate psychological and biomechanical components. **Objective:** The study aims (1) to explore the resilience profiles of athletes categorized as high resilience group and moderate resilience group, (2) to assess the biomechanical characteristics associated with these resilience profiles through sensor data, and (3) to determine the relationships between resilience, health-related behaviors, well-being, and perceived social support. **Methodology:** A cross-sectional online survey with 120 participants was conducted to assess health-related behaviors and well-being pre- and post-intervention. Additionally, biomechanical sensors were used to capture athletes' movement and performance during training sessions. Data was collected using the social support scale and resilience scale. Descriptive statistics, ANOVA, and correlation analyses were used to analyze the data. Qualitative interviews with athletes provided additional insights into the relationship between resilience profiles and associated characteristics. **Result:** The findings revealed that athletes in the high resilience group exhibited significantly healthier lifestyle choices, greater overall well-being, and higher perceived social support compared to the moderate resilience group. Correlational analyses showed stronger relationships between resilience scores and associated characteristics in the high resilience group, suggesting that biomechanical efficiency contributes to their resilience. **Conclusion:** The characteristics and correlates of resilience profiles in athletes can advise tailored interventions to influence PR and biomechanical performance, benefiting their performance and mental health.

Keywords: psychological resilience; athletes; training; mental health

1. Introduction

PR is an essential component to impact the athlete's longevity, mental health, and performance in the professional sports world. Athletes endure increasing mental stresses with their physical demands [1]. Intense circumstances were common for athletes, to contribute the physical skill and capacity to handle stress, failures, and the unavoidable demands of competition. PR can adjust the difficulties, and stay focused, contributing to significant factors in determining sports performance. Creating efficient training plans to foster resilience which was essential for sports. Training programs have traditionally focused on improving physical capabilities, and ignoring the mental components has an impact on the performance of athletes [2]. The

developments in sports psychology constitute the comprehension of mental health attention and comprehensive strategy for athlete development. Mental abilities like emotional control, focus, and coping mechanisms were recognized by practitioners for the athlete's toolbox. The necessity of training plans emphasizes PR to prioritize physical resilience [3]. A resilient attitude is fostered by the distinct contributions made by sports domains in improving athletes' capacity to endure stress and bounce back from setbacks. Experience learning, supportive surroundings, exercises, and mental skills training were the distinct categories of training programs for PR development [4]. Athletes develop resilience and confidence for psychological challenges to reinforce positive thinking and imagine achievement. Athletes improve their PR with the help of mindfulness activities. Athletes practice mindfulness activities to focus on sports, regulate emotions, and control anxieties with an open mind [5]. Athletes improve their ability to handle stress by practicing mindfulness, deep breathing exercises, and body scans, which constitute a greater awareness of thoughts and feelings for athletes. Resilience training programs include mindfulness as a regular component, for emotional control, general well-being, and attentiveness [6].

Psychological resilience in athletes

Environments make athletes feel appreciated, encouraged, and ideal. For building PR supportive environments were needed. Through encouraging risk-taking, open communication, and mentality, coaches, players, and support play essential roles in atmosphere creation [7]. Athletes develop their skills in a friendly environment for PR. Athletes resiliently developed challenges posed by competitive sports for interpersonal links and a strong feeling of community [8]. Athletes possess tenacity, and adaptability, and overcoming difficulties exposed by events in their comfort zones. The experiences might include challenging training sessions, competitive simulations, and injury recuperation [9]. Athletes can recognize their strengths and shortcomings, build coping strategies, and improve their ability to handle challenging circumstances. Coaches provided athletes with the opportunity to exercise resilience in the real world by providing obstacles for training sessions [10]. Resilience training gradually included the athlete's regimen, for physical training that possessed consistency and advancement. The athletes contributed to the development of mental talents and physical careers, reflection, and strategy adaptation. Sports resilience constitutes a lifetime adventure rather than a permanent quality [11]. Diverse cultural origins might impact how resilience training is perceived and how successful it restricting the static application of athletes.

The study's aim is to explore the resilience profiles of athletes categorized into high resilience and moderate resilience groups. The study will assess the biomechanical characteristics associated with these resilience profiles through sensor data and determine the relationships between resilience, health-related behaviors, well-being, and perceived social support.

The article is divided into the subsequent parts as follows: Part 2 presents the related work with an overview of the research, part 3 provides the details of the study's strategy for the suggested approach in methodology, the evaluation result is outlined

in the experimental result in part 4 and part 5 contributes the discussion and part 6 concludes the research with the conclusion.

2. Related works

The study aimed to investigate athletes' PR and stress management techniques, examining how these factors are interrelated [12]. Gender variations contributed to athlete's psychological toughness and stress management techniques. Experiential learning and PR constitute a negative and positive correlation. The experimental outcome demonstrates the mental performance of athletes. To investigate mental toughness in elite teams and strategies for developing athlete resilience [13]. The active and spatial character of resilience led to the use of a sustained qualitative technique. The experimental outcome demonstrated the psychological toughness of athletes.

The psychological skill training (PST) of athletes, trainers, and counselors constitutes achieving optimal performance in sports attention. Furthermore, despite the interest in bibliographies possessed by PST [14]. The experimental result findings showed PST has peak performance across a range of strategies, including anxiety and stress reduction. To investigate the proof athletes in different sports [15]. Several mental traits linked to athletic performance, such as psychological aptitude and mental illness are favorably correlated with psychological attentiveness. The experimental outcome demonstrated the athlete's mindfulness, psychological skills, and mental toughness.

The delicate and significant task of recovering both physically and mentally from the strain of competitive sports performance was necessary for endurance athletes [16]. The research intends to examine how self-regulation modes and fundamental psychological needs connect resilience in endurance athletes. The experimental outcome demonstrated the empowerment and endurance of athletes' resilience. The pressure training (PT) approach exposes athletes to pressure during practice to simulate the psychological strain of competition [17]. This method aims to explore the mechanisms behind pressure in physical training and how it improves athletes' performance. The experimental results demonstrated how practitioners contribute to the complexity of a task and its repercussions on performance under pressure.

Resilient training urged to interact with individual mental wellness [18]. To assess the resilience training programs that constitute the inconsistent practices and poor application of PR. The experimental outcome demonstrates the relational and emotional elements of the surface. The psychological training programs worked to reduce burnout and mental disorders, boosting self-esteem and elevating athlete spiritual realms [19]. The psychological training broadened participants' perspectives and improved the athlete's spiritual realms. The experimental outcome demonstrated the positive outcomes of psychological therapy.

The ability to cultivate PR in both life and sports enables one to improve interpersonal connections and reinterpret adverse circumstances [20]. The multi-session programs contributed to magnifying the effects and boosting team interactions and cooperation. The experimental findings demonstrated the sports psychologist's resilience for sports populations. Athletes experience burnout from traumatic

experiences, psychological stress, and playing professionally. Stress from psychological issues causes athletes to burn out and decide to change careers [21]. The psychological capital (PsyCap) was beneficial for reducing stress. To investigate how PsyCap affected athletes' performance and professional growth, especially under stressful situations. The experimental outcome demonstrated that the PsyCap element seemed to have a favorable effect on athlete performance.

The athlete's personnel frequently operate through cognitively complicated systems under high-stress situations [22]. The mental and physical tasks under pressure, result in significant consequences, which are recognized as athlete strategies for success. Stress-related cognitive impairment constitutes the effects on military operation's combat situations. The experimental outcome demonstrated the intricacy of an athlete's resilience circumstances. Psychotherapy recognizes the benefits of mindfulness-based therapies and sports psychology pays more attention to treatments that help athletes perform better or deal with psychological stress [23]. The control active elements include Mindfulness Acceptance Commitment (MAC), to determine the athlete's levels of grit and self-compassion. The experimental outcome showed the emotional and physical wellness of athletes.

Athletes are prepared for high-pressure situations through deliberate training, which includes physical therapy during their training period. The pressure-creation techniques contributed to the physical therapy's efficiency [24]. The efficiency of sport psychology resilience influenced by practitioner delivers. The experimental outcome demonstrated the PT transport in the practical contexts of sport psychologists. The study aimed to investigate the connection between athlete burnout in weightlifters and the mental toughness and motivation necessary to mitigate the occurrence of burnout [25]. Athlete fatigue significantly impacts both the growth and performance of athletes in sports. The experimental results demonstrated the mental state of athletes.

3. Methodology

3.1. Study design

To gather detailed information from participants, the study utilized a structured survey encompassing several key metrics, including quantitative insights (QI), well-being indicators (WBI), health-related behaviors (HRB), perceived social support (PSS), resilience factors (RF), and biomechanical characterizing (BC). This comprehensive approach aimed to capture a complete view of the athletes' experiences and mental states. Each metric was carefully chosen to provide valuable insights into the factors influencing participants' psychological and physical health. Also, the study presents a comprehensive explanation of the data collection process, detailing how participants were selected and structured questionnaires administered to gather relevant information. This questionnaire was designed to assess various aspects of athlete wellbeing and resilience. Additionally, the statistical analysis methods employed in the study are clearly outlined, ensuring transparency in how the data was processed and interpreted as shown in **Figure 1**.



Figure 1. Factors of PR.

Resilience factors (RF): The psychological characteristics and other resources that help individuals to adjust and face difficulties are known as resilience factors. The ability to regulate an individual's emotions through circumstances is termed emotional regulation. Coping mechanisms among the resilience factors has self-efficacy for achievement. The PR of athletes is to improve their health and performance.

Biomechanical characteristics (BC): This variable describes the mechanical and physical aspects of an athlete's performance-related motions and mechanics of the body. The muscle groups constitute muscle activation patterns, which enhance the overall biomechanical characteristics efficiency. Comprehending the attributes facilitates the customization of training regimens to optimize efficiency and minimize the possibility of injuries.

Health-related behaviors (HRB): This variable describes the behaviors and habits of individuals, which constitute the impact on general health and well-being. A balanced diet and consistent exercise were essential for athletes to achieve peak performance. A healthy sleep schedule and stress-reduction strategies support mental toughness and emotional stability. Healthy habits are essential for reducing the risk of injury, improving athletic performance, and fostering long-term health benefits.

Well-being indicators (WBI): This variable refers to evaluating a person's general well-being, contentment, and quality of life. Furthermore, aspects of physical health, including sleep patterns and exercise routines impact general well-being. To assess the psychological well-being and resilience, impact the performance and recovery. The athlete's health and functionality are improved by the psychological resilience of WBI.

Perceived social support (PSS): This variable describes an individual's perception of the accessibility of support from social networks, including friends, family, and coworkers. The PSS in sports environments has an impact on an athlete's drive, performance, and capacity to handle pressure or failure. It was essential for creating a good atmosphere, raising self-esteem, and developing mental toughness. Elevated perceptions of social support are linked to less stress, improved coping mechanisms, and an increased ability to bounce back from setbacks.

Qualitative insights (QI): This variable describes the comprehension of an athlete's resilience attained by personal narratives and experiences. The qualitative data emphasize individual variances in resilience profiles and offer valuable contextual information about quantitative assessments. The perceived obstacles and

enablers constitute the path to gaining resilience, providing insightful direction for creating customized treatments. QI enhances the athlete's psychological resilience.

3.2. Data collection

A total amount of 120 participants were selected to evaluate well-being and health-related behaviors, divided into pre-intervention and post-intervention groups. The pre-intervention phase assessed athletes' mental toughness, emotional stability, and psychological resilience before implementing any specific programs. It served to establish a baseline for their mental health and performance. The post-intervention phase, conducted after applying targeted resilience programs, measured improvements in these areas. This approach allowed the study to track changes, assess the effectiveness of interventions, and offer insights for developing more refined, athlete-focused strategies in the future.

Altogether 120 participants were included in the study to assess health-related behaviors and well-being pre-intervention and post-intervention. The participant characteristics were carefully examined across multiple areas to ensure meaningful comparisons, and the findings are summarized in both tabular and graphical formats. The pre- and post-intervention participant characteristics results were compared in depth across several areas and subcategories in the table and there are various aspects of participants. It consists of gender, age range, sport type, social support score, resilience score, mental training participation, and perceived stress level. Such detailed categorization ensures that subtle variations between the two intervention phases are highlighted.

Gender is divided into two categories: male (55) and female (65). The pre-intervention of gender has 30 males and 35 females, while the post-intervention has 25 males and 30 females. Age is further categorized into four distinct groups, which enables more precise insights into how participants across different age groups responded to the interventions. Whereas the 18–25 age group has 30 participants. The pre-and post-intervention has 15. The age group 26–35 has 45 participants with a pre-intervention of 25 and a post-intervention of 20. The 36–45 age group has 30 participants, with pre-intervention of 10 and post-intervention of 20. The age group above 46 has 15 participants with a pre-intervention of 5 and a post-intervention of 10. Sport types are distinct into two categories, such as individual and team with the same participants 60 (50.0%). Individual and team sport type has pre-intervention of 30 and post-intervention of 3. The social support score has five distinct ranges. The range (1–2) has participants of 15 with a pre-intervention of 10 and post-intervention of 5 whereas the range (3) has participants of 30, with a pre-intervention of 20 and post-intervention of 10. This decrease in lower social support scores post-intervention indicates improved social interactions among participants. The range (4) has participants 60 with a pre-intervention of 25 and a post-intervention of 35. Where the range (5) has participants of 15, with pre-intervention of 5 and post-intervention of 10 where the resilience score value is distinct into four groups.

Resilience scores are divided into four groups. This allows for a more nuanced analysis of psychological resilience. The value (1–40) has participants of 20, with a pre-intervention of 15 and a post-intervention of 5. The value (41–60) has participants

of 30 with a pre-intervention of 10 and a post-intervention of 20. The value (61–80) has participants of 45, with a pre-intervention of 15 and a post-intervention of 25. The value (81–100) has participants of 25 with a pre-intervention of 5 and a post-intervention of 20. Mental training participation is distinct into two categories, such as participated and non-participated. The participated mental training has participants were 55 with pre-intervention of 20 and post-intervention of 35.

The non participated mental training has participants of 65 with pre-intervention of 35 and post-intervention of 30. This slight reduction indicates a shift towards adopting mental training methods among participants.

The perceived stress level is divided into three category levels where levels 1–3 have participants of 25, with a pre-intervention of 15 and a post-intervention of 10. Level 4–6 has participants of 50 with a pre-intervention of 25 and the post-intervention has the same 25. Levels 7–10 have participants 45, with a pre-intervention of 15 and a post-intervention of 30. **Table 1** represents the demographic details of 120 participants with pre-intervention and post-intervention. To further illustrate these patterns, **Figure 2a** visualizes the age distribution, while **Figure 2b** highlights the mental training participation rates, offering additional clarity and insight into the participants' characteristics and engagement levels.

Table 1. Demographic details.

Category	Subcategory	Pre-Intervention (%)	Post-Intervention (%)	Total Participants (%)
Gender	Male	30 (25.0%)	25 (20.8%)	55 (45.8%)
	Female	35 (29.2%)	30 (25.0%)	65 (54.2%)
Age range	18–25 years	15 (12.5%)	15 (12.5%)	30 (25.0%)
	26–35 years	25 (20.8%)	20 (16.7%)	45 (37.5%)
	36–45 years	20 (16.7%)	10 (8.3%)	30 (25.0%)
	46+ years	5 (4.2%)	10 (8.3%)	15 (12.5%)
Sport type	Individual	30 (25.0%)	30 (25.0%)	60 (50.0%)
	Team	30 (25.0%)	30 (25.0%)	60 (50.0%)
Social Support Score (1–5)	1–2	10 (8.3%)	5 (4.2%)	15 (12.5%)
	3	20 (16.7%)	10 (8.3%)	30 (25.0%)
	4	25 (20.8%)	35 (29.2%)	60 (50.0%)
	5	5 (4.2%)	10 (8.3%)	15 (12.5%)
Resilience Score (1–100)	1–40	15 (12.5%)	5 (4.2%)	20 (16.7%)
	41–60	10 (8.3%)	20 (16.7%)	30 (25.0%)
	61–80	20 (16.7%)	25 (20.8%)	45 (37.5%)
	81–100	5 (4.2%)	20 (16.7%)	25 (20.8%)
Mental Training Participation	Participated	20 (16.7%)	35 (29.2%)	55 (45.8%)
	Non-participated	35 (29.2%)	30 (25.0%)	65 (54.2%)
Perceived Stress Level (1–10)	1–3	15 (12.5%)	10 (8.3%)	25 (20.8%)
	4–6	25 (20.8%)	25 (20.8%)	50 (41.7%)
	7–10	15 (12.5%)	30 (25.0%)	45 (37.5%)

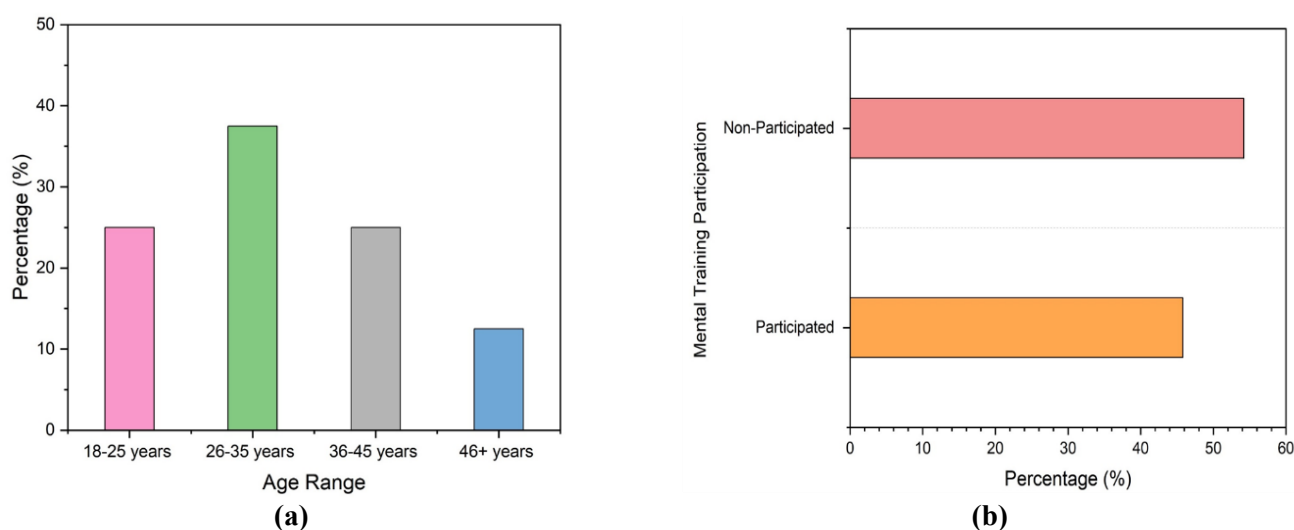


Figure 2. Demographic data analysis of study participants **(a)** Age range; **(b)** Mental training participation.

3.3. Questionnaire design

The research used a structured questionnaire that was designed to elicit data on six critical variables: resilience factors, biomechanical characteristics, health-related behaviors, well-being indicators, perceived social support, and qualitative insights. Each variable has been defined carefully and in great detail so that the respondents can give clear answers pertinent to them. Participants indicate how frequently they agree with items about perceived social support, health-related activities, and psychological resilience using a 3-point Likert scale. With this strategy, athletes will have a more comprehensive view of resilience profiles. An examination of the variables impacting athlete resilience will be made easier by understanding, and developing customized therapies to improve athlete's psychological and physical performance. Details of the questionnaire can be found in Appendix.

3.4. Statistical analysis

The data analysis software utilized SPSS (version 13). The SPSS constitutes the need to conduct a rigorous quantitative assessment of the responses gathered from the survey. The procedure of analysis involved many crucial stages, such as gathering data via structured questionnaires biomechanical assessments, and statistical assessments. Athlete interviews also provided qualitative information that improved the understanding of resilience profiles and related traits. For instance, descriptive statistics was employed to present the basic characteristics of the data such as means, medians, modes, and frequencies. An improved comprehension of the general trends and patterns made possible by the statistical approach's summary of the respondents of resilience profiles. The research included an analysis of the resilience profiles of athletes, emphasizing the differences in patterns found with high and moderate resilience. Descriptive statistics analysis, ANOVA, and correlation analysis were employed to compare quantitative variables of psychological resilience.

4. Experimental result

4.1. Descriptive statistics analysis

The descriptive statistics analysis constitutes the quantification of psychological resilience in athletes by stress levels, coping mechanisms, and general mental health. Through the analysis of descriptive data, resilience tendencies and patterns in athletes contribute to the psychological variables that impact well-being and performance. The training plans and mental health therapies were specifically designed to improve athlete's psychological resilience. A fundamental technique in data analysis, descriptive statistics analysis gives a description of a dataset's salient features, facilitating a clear comprehension of its overall trends and patterns. Measures such as mean, standard deviation, minimum, and maximum values effectively illustrate major trends. The arithmetic average is indicated as the mean, while the midway value in a set of data is known as the median. Measures of dispersion like variance, standard deviation, and range were included in descriptive statistics. The distributions of frequency, which display the frequency at each value and graphical representations like box plots and histograms could be used in descriptive statistics. The descriptive statistics analysis aided in the detection of anomalies and the comprehension of the distributional structure of the data. **Figure 3a** illustrates the error graph of pre-intervention, showing the discrepancies and variations in participant responses before the intervention. It provides insights into areas where participants demonstrated higher or lower levels of resilience, engagement, and well-being. **Figure 3b** represents the error graph of post-intervention, highlighting the reduction in errors or inconsistencies compared to the pre-intervention phase. It reflects improved performance, enhanced psychological resilience, and more consistent engagement following the intervention. **Table 2** represents the results of the descriptive statistics analysis of pre- and post-intervention.

Table 2. Descriptive statistics results of pre- and post-intervention.

Variables	Pre-Intervention (<i>Mean</i> ± <i>SD</i>)		Post-Intervention (<i>Mean</i> ± <i>SD</i>)	
Resilience Factors	3.2 ± 0.8	<i>Min</i> = 2.4 <i>Max</i> = 4.0	4.1 ± 0.6	<i>Min</i> = 3.5 <i>Max</i> = 4.7
Biomechanical Characteristics	12.5 ± 3.2	<i>Min</i> = 9.3 <i>Max</i> = 15.7	16.8 ± 2.9	<i>Min</i> = 13.9 <i>Max</i> = 19.7
Health-Related Behaviors	4.0 ± 1.0	<i>Min</i> = 3.0 <i>Max</i> = 5.0	5.2 ± 0.8	<i>Min</i> = 4.0 <i>Max</i> = 6.4
Well-Being Indicators	6.0 ± 1.5	<i>Min</i> = 4.5 <i>max</i> = 7.5	8.0 ± 1.2	<i>Min</i> = 6.8 <i>Max</i> = 9.2
Perceived Social Support	3.8 ± 1.1	<i>Min</i> = 2.7 <i>Max</i> = 4.9	4.5 ± 0.9	<i>Min</i> = 3.6 <i>Max</i> = 5.4
Qualitative Insights	3.4 ± 0.9	<i>Min</i> = 2.5 <i>Max</i> = 4.3	4.2 ± 0.8	<i>Min</i> = 3.4 <i>Max</i> = 5.0

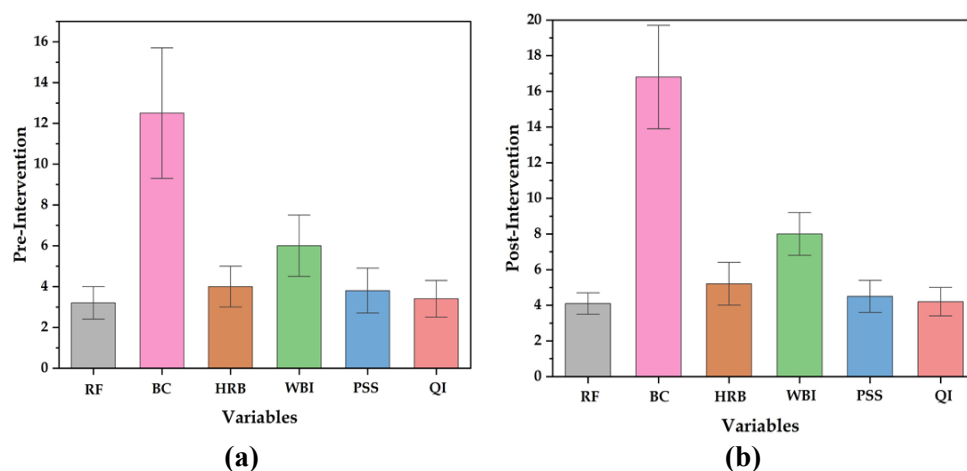


Figure 3. Outcome of descriptive statistics result (a) pre-intervention; (b) post-intervention.

RF: The pre-intervention has a mean of (3.2 ± 0.8), with a range of 2.4 to 4.0, but the post-intervention has a mean of (4.1 ± 0.6), with a range of 3.5 to 4.7. This implies a significant improvement in resilience.

BC: The pre-intervention has a mean of (12.5 ± 3.2), with a range from 9.3 to 15.7 and the post-intervention has a mean of (16.8 ± 2.9), with a range of 13.9 to 19.7. The biomechanical characteristics advancement in the physical factors associated with biomechanics.

HRB: The pre-intervention has a mean of (4.0 ± 1.0) with a range of 3.0 to 5.0 and the post-intervention has a mean of (5.2 ± 0.8), with a range of 4.0 to 6.4. The HRB constitutes better health practices.

WBI: The pre-intervention has a mean of (6.0 ± 1.5), with a range of 4.5 to 7.5, but the post-intervention has a mean of (8.0 ± 1.2), with a range of 6.8 to 9.2 showing overall well-being.

PSS: The pre-intervention has a mean of (3.8 ± 1.1) with a range of 2.7 to 4.9 and the post-intervention has a mean of (4.5 ± 0.9), with a range of 3.6 to 5.4 constituted stronger support systems.

QI: The pre-intervention has a mean of (3.4 ± 0.9), with a range of 2.5 to 4.3 and the post-intervention has a mean of (4.2 ± 0.8), with a range of 3.4 to 5.0 showing a qualitative understanding.

4.2. ANOVA test

The psychological resilience of athletes constitutes the analysis of variance (ANOVA) test that might be used to determine the various elements like training schedules, sports specializations, and competitive levels that influence athlete's resilience levels. To ascertain whether there was a statistically significant difference across the medians of many groups, the ANOVA test was utilized. It was useful to group the variance to ascertain to result from a specific factor or random chance. The ANOVA compares the group-to-group variability of the data variation in each group. If the variability among the groups is much higher than the variability in each group, at least one distinct group mean was displayed. When assessing the effects of various

circumstances or treatments on variables, the ANOVA test was widely used. The results of the ANOVA test were commonly described using the F -measure and p -measure. **Table 3** indicates the ANOVA results of pre-intervention. **Figure 4a** illustrates the ANOVA result of pre-intervention, presenting the statistical differences among various participant groups before the intervention. It highlights the variance in psychological resilience, engagement levels, and well-being indicators, helping identify baseline disparities.

Table 3. ANOVA results of pre-intervention.

Groups	Pre-intervention			
	The sum of Squares (SS)	Mean Square (MS)	F -measure	p -measure
Resilience Factors	10.50	10.50	5.20	0.025
Biomechanical Characteristics	15.20	15.20	7.80	0.005
Health-Related Behaviors	8.30	8.30	4.90	0.028
Well-Being Indicators	12.00	12.00	6.50	0.015
Perceived Social Support	5.50	5.50	3.60	0.063
Qualitative Insights	7.80	7.80	4.50	0.036

RF: The pre-intervention of ANOVA has a mean square and SS of 10.50, with 5.20 F -measure and 0.025 p -measure. It demonstrated considerable influence on psychological resilience.

BC: The pre-intervention of ANOVA has a mean square and SS of 15.20, with 7.80 F -measure and 0.005 p -measure. It demonstrated the significant outcome of potent influence on biomechanical characteristics.

HRB: The pre-intervention of ANOVA has a mean square and SS of 8.30, with 4.90 F -measure and 0.028 p -measure. It showed enhancement in habits related to health.

WBI: The pre-intervention of ANOVA has a mean square and SS of 12.00, with 6.50 F -measure and 0.015 p -measure. It indicated the beneficial impact on health and well-being.

PSS: The pre-intervention of ANOVA has a mean square and SS of 5.50, with a 3.60 F -measure and 0.063 p -measure.

QI: The pre-intervention of ANOVA has a mean square and SS of 7.80, with 4.50 F -measure and 0.036 p -measure. **Table 4** represents the post-intervention ANOVA results. **Figure 4b** illustrates the ANOVA result of post-intervention.

Table 4. ANOVA results of post-intervention.

Groups	Post-intervention			
	The sum of Squares (SS)	Mean Square (MS)	F -measure	p -measure
Resilience Factors	15.75	15.75	9.23	0.003
Biomechanical Characteristics	20.40	20.40	12.10	0.001
Health-Related Behaviors	10.50	10.50	6.60	0.012
Well-Being Indicators	25.20	25.20	14.75	0.0005
Perceived Social Support	8.10	8.10	4.50	0.036
Qualitative Insights	12.80	12.80	7.80	0.008

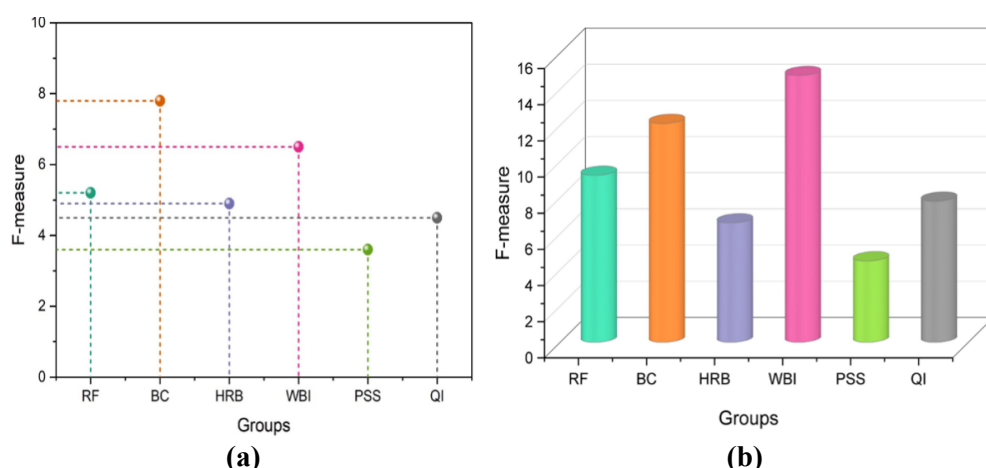


Figure 4. Visual representation of ANOVA result **(a)** pre-intervention; **(b)** post-intervention.

RF: The post-intervention of ANOVA has a mean square and SS of 15.75, with a 9.23 F -measure and 0.003 p -measure. The post-intervention showed statistically significant improvement in resilience by low p -value.

BC: The post-intervention of ANOVA has a mean square and SS of 20.40, with a 12.10 F -measure and 0.001 p -measure. It demonstrated significant modifications in biomechanical elements.

HRB: The post-intervention of ANOVA has a mean square and SS of 10.50, with 6.60 F -measure and 0.012 p -measure. The post-intervention indicated a significant improvement in health-related behaviors.

WBI: The post-intervention of ANOVA has a mean square and SS of 25.20, with 14.75 F -measure and 0.0005 p -measure. It showed significant improvement in well-being.

PSS: The post-intervention of ANOVA has a mean square and SS of 8.10, with 4.50 F -measure and 0.036 p -measure.

QI: The post-intervention of ANOVA has a mean square and SS of 12.80, with 7.80 F -measure and 0.008 p -measure. It demonstrated substantial improvements in the qualitative feedback.

4.3. Correlation analysis

The psychological resilience in athletes, correlation analysis constitutes the connection between psychological resilience and other variables, such as stress levels, performance results, and coping mechanisms. To improve athlete's performance and well-being, training plans and mental health therapies constitute resilience. Sports psychologists create plans for helping athletes to deal with stress. To determine the direction and degree of a link between two variables, statisticians employ correlation analysis. It establishes the degree of association between the variables, measuring it using a correlation coefficient that usually ranges from -1 to 1 . Although correlation analysis might be used to find possible relationships, it cannot establish causality, but it determines the relationship between changes in one variable to another variable. **Table 5** illustrates the pre-intervention of correlation analysis.

Table 5. Pre-intervention of correlation analysis.

Factors	Pre-intervention					
	Resilience Factors	Biomechanical Characteristics	Health-Related Behaviors	Well-Being Indicators	Perceived Social Support	Qualitative Insights
Resilience Factors	1.00	0.54*	0.48*	0.60**	0.50*	0.42*
Biomechanical Characteristics	0.54*	1.00	0.40*	0.35*	0.30	0.25
Health-Related Behaviors	0.48*	0.40*	1.00	0.55**	0.45*	0.38*
Well-Being Indicators	0.60**	0.35*	0.55**	1.00	0.40*	0.34*
Perceived Social Support	0.50*	0.30	0.45*	0.40*	1.00	0.32
Qualitative Insights	0.42*	0.25	0.38*	0.34*	0.32	1.00

Note: Here * represents the value $p < 0.05$ and ** indicates the value $p < 0.01$.

RF: The pre-intervention of RF shows positive correlations of (1.00). The WBI has strong correlations of (0.60**) and BC has (0.54*) moderate correlations, HRB has (0.48*), QI has (0.42*) and PSS has (0.50*). It shows resilient typically have greater HRB and overall WBI in addition to have the stronger social support.

BC: The pre-intervention of BC has RF of (0.54*), whereas HRB (0.40*) and WBI indicated (0.35*) weaker correlations. The PSS has 0.30 and QI has (0.25) with significant correlations.

HRB: The pre-intervention of HRB has a moderate correlation of WBI (0.55**), RF (0.48*), BC (0.40*), and PSS (0.45*). Where QI has a lower correlation of (0.48*). It shows the healthy habits of increased resilience and well-being.

WBI: The pre-intervention of WBI has positive correlations of RF (0.60**), HRB (0.55**), BC (0.35*), and moderate correlation of PSS (0.40*) and QI (0.34*).

PSS: The pre-intervention of PSS has moderate correlations of RF (0.50*), HRB (0.45*), BC (0.30), and WBI (0.40*) demonstrating the resilience of greater social support. Where QI has a lower correlation of (0.32).

Table 6. Correlation analysis of post-intervention.

Factors	Post-intervention					
	Resilience Factors	Biomechanical Characteristics	Health-Related Behaviors	Well-Being Indicators	Perceived Social Support	Qualitative Insights
Resilience Factors	1.00	0.70**	0.64**	0.75**	0.65**	0.58**
Biomechanical Characteristics	0.70**	1.00	0.65**	0.50*	0.45*	0.40*
Health-Related Behaviors	0.64**	0.65**	1.00	0.68**	0.55**	0.48*
Well-Being Indicators	0.75**	0.50*	0.68**	1.00	0.60**	0.55**
Perceived Social Support	0.65**	0.45*	0.55**	0.60**	1.00	0.48*
Qualitative Insights	0.58**	0.40*	0.48*	0.55**	0.48*	1.00

Note: Here * represents the value $p < 0.05$ and ** indicates the value $p < 0.01$.

QI: The pre-intervention of QI has moderate positive correlations of RF (0.42*), HRB (0.38*), and WBI (0.34*) showing improved qualitative knowledge and healthier

habits of psychological resilience. Where BC (0.25) and PSS (0.32) have a moderate correlation. **Table 6** represents the correlation analysis of post-intervention.

RF: The post-intervention of RF has strong positive correlations of WBI (0.75**), BC (0.70**), HRB (0.64**), PSS (0.65**) and QI (0.58**). The resilient exhibit healthier habits and improved well-being.

BC: The post-intervention of BC positively correlated with RF has (0.70**), HRB has (0.65**) illustrating physical characteristics of resilience. Where WBI (0.50*), PSS (0.45*) of moderate correlation. The QI (0.40*) of weaker correlation.

HRB: The post-intervention of HRB has a strong correlation of WBI (0.68**), RF (0.64**), and BC (0.65**) contributing to the enhanced well-being of resilience. The correlation of PSS (0.55**) and QI (0.48*) indicates the better health behaviors.

WBI: The post-intervention of WBI has strong correlations of RF (0.75**), BC (0.50*), and HRB (0.68**) constitute higher resilience for health practices.

PSS: The post-intervention of PSS shows moderate correlations of RF (0.65**), HRB (0.55**), and WRB (0.60**) exhibit better resilience of health behaviors. The correlation with QI (0.48*) is a weaker correlation.

QI: The post-intervention of QI has positive correlations of RF (0.58**), WBI (0.55**) and HRB (0.48*) constitute resilience of healthier behaviors. The correlation with PSS (0.48*) has a moderate correlation.

5. Discussions

The major findings on the differences in participation and engagement between athletes from pre-intervention and post-intervention were derived from descriptive statistics, ANOVA tests, and correlation analysis. The use of descriptive statistics allows for a straight forward comparison of mean scores between the two-time points, highlighting any notable changes in psychological attributes. On descriptive statistics, it is easily seen that mean resilience factor scores for athletes in pre-intervention have 3.2 with a standard deviation of 0.8 while the post-intervention has 4.1 with a standard deviation of 0.6. This large gap suggests that the athletes have a higher level of engagement and psychological resilience. This large gap suggests a substantial increase in psychological resilience and engagement among athletes, indicating that the intervention had a positive effect on their mental state. The decrease in standard deviation post-intervention also implies that the athletes' resilience levels became more consistent, reflecting a uniform improvement across the group. Findings from the ANOVA test also favor this trend, as the ANOVA statistic has a mean square and SS of (10.50) with a 5.20 *F*-measure and 0.025 *p*-measure for psychological resilience. This statistical analysis confirms that the observed difference in resilience scores is not only notable but also statistically significant indicating that the intervention successfully influenced athletes' psychological states. The athlete's psychological resilience and general performance were highly impacted by psychological resilience and overall performance. These findings emphasize the critical role of psychological resilience in enhancing athletic performance, suggesting that athletes who possess higher resilience are better equipped to face challenges and stressors inherent in competitive sports. This indicates that traditional platforms do not constitute the same levels of athlete engagement. However, significantly enhances participation by

facilitating quicker access to resources and streamlined communication, ultimately supporting the development of psychological resilience. However, the overall finding reveals that athlete participation significantly increased post-intervention, indicating relevant and faster engagement of psychological resilience among athletes.

6. Conclusions

This research emphasizes the importance of psychological toughness in athletes and the complex relationship between biomechanical performance and health-related actions. A cross-sectional online survey with 120 participants was conducted to assess health-related behaviors and well-being pre- and post-intervention. The analysis of the survey data revealed significant differences between the pre-intervention and post-intervention in terms of resilience factors, biomedical characteristics, health-related behaviors, well-being indicators, perceived social support, and qualitative insights connections among the variables in athletes. Using descriptive statistics, ANOVA, and correlation analyses, the study achieved significant p -values (< 0.005), indicating meaningful differences and relationships in the data. These analyses were conducted using SPSS software, ensuring reliable statistical processing and interpretation. Qualitative interviews with athletes provided additional insights into the relationship between resilience profiles and associated characteristics. The findings revealed that athletes in the high resilience group exhibited significantly healthier lifestyle choices, greater overall well-being, and higher perceived social support compared to the moderate resilience group. Correlational analyses showed stronger relationships between resilience scores and associated characteristics in the high resilience group, suggesting that biomechanical efficiency contributed the resilience. Athlete's psychological resilience and biomechanical performance are influenced by customized therapies of resilience profiles, which improve mental and physical well-being.

7. Limitations and future scope

Diverse cultural backgrounds may influence perceptions of resilience training and its effectiveness in enhancing the performance of athletes. Evaluating psychological resilience is inherently complex, and the instruments used to measure resilience may not adequately capture the intricate and varied aspects of an athlete's mental state. Future research should investigate the effectiveness of resilience training across different cultural contexts to gain a deeper understanding of how cultural variables impact training outcomes.

Ethical approval: Not applicable.

Conflict of interest: The author declares no conflict of interest.

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Appendix

Variables	Questions	Likert Scales
Resilience Factors	What statics do you find most beneficial in sustaining mental strength?	(1) Not effective (2) Somewhat effective (3) Highly effective
	Could you describe a time to overcome the hardship and triumphed?	(1) Not effective (2) Somewhat effective (3) Highly effective
	How do you handle difficulties and disappointments in your life?	(1) Not effective (2) Somewhat effective (3) Highly effective
Biomechanical Characteristics	Regarding your everyday activities; how would you rank your physical health?	(1) Poor (2) Fair (3) Good
	How frequently do you participate in physically demanding activities?	(1) Infrequently (2) Occasionally (3) Frequently
	How vital do you think physical fitness is to your overall health?	(1) Not needed (2) Somewhat needed (3) Needed
Health-Related Behaviors	How consistently do you follow healthy eating habits?	(1) Infrequently (2) Occasionally (3) Frequently
	How frequently do you practice stress-relieving techniques like mindfulness and physical activity?	(1) Infrequently (2) Occasionally (3) Frequently
	How do you organize your everyday activities to prioritize your health-related behaviors?	(1) Low priority (2) Medium priority (3) High priority
Well-Being Indicators	In what way do you feel content with your life right now?	(1) Unsatisfied (2) Somewhat satisfied (3) Satisfied
	How frequently does your life seem to have a purpose?	(1) Infrequently (2) Occasionally (3) Frequently
	What is your assessment of your mental health during the last month?	(1) Poor (2) Fair (3) Good
Perceived Social Support	How frequently do you feel that your friends and family are there for you when you need them?	(1) Infrequently (2) Occasionally (3) Frequently
	To what extent do you feel at ease asking for assistance from others when you are experiencing difficulties?	(1) Not comfortable (2) Somewhat comfortable (3) Comfortable
	Regarding the relationships you have with people who encourage you; how would you rate their quality?	(1) Poor (2) Fair (3) Good
Qualitative Insights	How would you describe your overall experience with resilience in your life?	(1) Negative (2) Neutral (3) Positive
	How significant do you think it share one's own experiences of resiliency with others?	(1) Never (2) Sometimes (3) Often
	How do you understand how resilience evolved?	(1) Poor (2) Fair (3) Good