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# Short-term effects of powerlifting-based training on hormonal, metabolic, and lipid profile markers in male basketball players: a randomized controlled trial

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## Abstract

**Background** Powerlifting-based resistance training is increasingly incorporated into athletic conditioning programs; however, its short-term endocrine and metabolic responses remain insufficiently explored. Therefore, this study aimed to examine the short-term, exercise-induced changes associated with a powerlifting-based training program on selected hormonal, metabolic, and lipid profile parameters in male basketball players.

**Methods** This randomized controlled experimental study was conducted in accordance with CONSORT guidelines. Thirty male basketball players aged 18–24 years were randomly assigned to an exercise group (EG;  $n = 15$ ) or a control group (CG;  $n = 15$ ). Both groups continued their routine basketball training three days per week for six weeks, while the EG additionally performed a powerlifting-based training program. Serum concentrations of thyroid hormones (TSH, T3, and T4), insulin, glucose, growth hormone, testosterone, and lipid profile parameters were assessed before and after the intervention. Data were analyzed using two-way repeated-measures analysis of variance to evaluate group  $\times$  time interactions.

**Results** Significant group  $\times$  time interactions were observed for several biochemical parameters ( $p < 0.05$ ). In the exercise group, insulin levels increased by 53.31%, while pre-exercise glucose levels under standardized conditions decreased by 14.46%. Thyroid hormones (TSH, T3, T4) increased by 45.26%, 18.85%, and 18.25%, respectively. Growth hormone and testosterone levels increased by 28.49% and 18.22%, respectively. In contrast, total cholesterol, LDL cholesterol, and triglyceride levels decreased by 2.49%, 4.28%, and 3.76%, respectively, while HDL cholesterol increased by 5.63%. No significant changes were observed in the control group. Effect size analyses indicated large interaction effects for key variables (e.g., insulin  $\eta^2 = 0.749$ ; glucose  $\eta^2 = 0.757$ ). The concurrent increase in insulin and decrease in glucose may reflect transient alterations in glucose–insulin dynamics rather than a direct improvement in insulin sensitivity.

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**Conclusion** The inclusion of a powerlifting-based training program was associated with favorable short-term, exercise-induced changes in selected hormonal, metabolic, and lipid profile parameters in male basketball players. However, these findings should be interpreted with caution due to the limited sample size and intervention duration. Further studies employing larger cohorts and longer training periods are warranted to confirm these observations and to clarify their long-term physiological implications.

**Trial registration** ClinicalTrials.gov (NCT07398248), registered on 29/12/2025.

**Keywords** Powerlifting, Basketball, Hormonal Response, Biochemical Parameters, Strength Training

## Introduction

Basketball is one of the most popular team sports worldwide and has evolved into a highly competitive and physically demanding discipline. Modern basketball is characterized by frequent high-intensity actions, including rapid changes of direction, sprinting, jumping, and repeated accelerations performed under congested competition schedules. Time-motion analyses indicate that these intermittent activities place simultaneous demands on both aerobic and anaerobic systems, requiring players to sustain high neuromuscular workloads throughout the match [1, 2]. These demands require players to sustain repeated high-intensity efforts supported by both aerobic and anaerobic energy systems, while simultaneously producing substantial levels of strength and power during game-specific actions [3, 4]. Accordingly, the physiological and performance profiles of modern basketball necessitate the optimization of cardiorespiratory fitness, intermittent endurance, and sport-specific physical variables [5, 6]. To meet these increasing physical demands, strength-oriented training methods, including weightlifting-, powerlifting-, and complex-based exercises, are commonly integrated into basketball conditioning programs to optimize neuromuscular adaptations such as jumping, sprinting, and change of direction speed [5]. Recent scientific evidence emphasizes that functional training modalities and highly individualized strength protocols are critical for enhancing both physical fitness and skill-related performance markers while minimizing injury risks in male basketball players [7, 8]. While these approaches are primarily used to enhance neuromuscular performance, they also impose considerable metabolic and endocrine stress. In elite team sports settings, the continuous interaction between competitive or training-induced stress levels and acute hormonal responses has been shown to directly impact sustained athletic performance and recovery dynamics [9]. Exercise-induced physiological stress has been shown to influence biochemical and hormonal responses, which are often used as indicators of acute and short-term physiological responses to training stimuli [10]. Among endocrine markers, thyroid hormones-triiodothyronine

(T3) and thyroxine (T4)-play a central role in energy metabolism, thermoregulation, and neuromuscular function [11]. Alterations in thyroid hormone concentrations have been associated with changes in muscle contractile properties, mitochondrial activity, and cardiovascular function [12]. Previous research has demonstrated that both insufficient and excessive thyroid hormone levels may negatively affect musculoskeletal performance, while physical activity itself can influence hypothalamic-pituitary-thyroid axis activity [13]. Nevertheless, the direction and magnitude of hormonal responses to exercise remain highly variable and are influenced by factors such as exercise intensity, duration, training status, and overall energy availability [14, 15]. In this context, while high-intensity interval training (HIIT) modalities have been established as effective strategies for enhancing metabolic conditioning and intermittent endurance in basketball players [6], the endocrine and biochemical responses to high-load resistance training integrated alongside these regimens remain insufficiently explored in applied athletic contexts. Evidence from resistance-trained populations suggests that high-intensity strength training may induce short-term changes in thyroid hormone concentrations [16, 17]. However, findings remain inconsistent, and much of the existing literature has focused on isolated resistance training or endurance-based exercise models. In contrast, limited data are available regarding the short-term endocrine and biochemical responses to powerlifting-based training integrated within high-intensity team sports such as basketball. Furthermore, there is a lack of randomized controlled trials examining short-term physiological responses to strength-focused training embedded within sport-specific routines. In addition, the underlying physiological mechanisms linking high-load resistance training to endocrine responses, particularly those involving metabolic regulation and the hypothalamic-pituitary-thyroid axis, remain insufficiently explored in applied athletic contexts. Therefore, the aim of this study was to examine the short-term, exercise-induced changes associated with a powerlifting-based training program on selected hormonal, metabolic, and lipid profile parameters in male basketball players.

## Materials and methods

### Participants

This study has a pre-test-post-test randomized controlled experimental design conducted in accordance with CONSORT guidelines [18]. However, it should be acknowledged that the trial was retrospectively registered, which diverges from the gold-standard recommendation of prospective registration and is discussed as a methodological limitation. The study included semi-professional male basketball players competing in organized leagues who had a history of regular and systematic training. Inclusion criteria for participants were: being between 18 and 24 years of age, having at least two years of regular sports experience, training at least three days a week, having no chronic diseases, and not having suffered a serious musculoskeletal injury in the last six months. Furthermore, all participants voluntarily participated in the study and provided written informed consent. Prior to the study, all participants underwent a standard medical evaluation to confirm their suitability for exercise. Sample size was pre-calculated using repeated measures analysis of variance (ANOVA) with G\*Power software (version 3.1.9.2; Düsseldorf, Germany). The power analysis indicated that a minimum of 15 participants per group was required, assuming a medium-to-large effect size ( $f=0.35$ ),  $\alpha=0.05$ , and statistical power ( $1-\beta=0.89$ ). Accordingly, a total of 30 participants ( $n=15$  in each group) were included in the study [19, 20]. The assumed effect size was based on resistance training studies conducted in similar athletic populations; however, the possibility of an overestimation in effect sizes ( $\eta^2$ )-which are frequently high in short-term physical interventions with limited sample sizes-was acknowledged as a statistical limitation. To ensure allocation concealment, participants were assigned to the exercise group (EG) or control group (CG) using a computer-based random number generator. The allocation sequence was generated by an independent statistician not involved in data collection or exercise supervision. The assignment was delivered to the participants via sealed, opaque, sequentially numbered envelopes, ensuring that the researchers recruiting the athletes were blinded to the assignment. Baseline measurements were taken before the intervention, and final measurements were taken 48 h after the last training session. This 48-hour testing window was selected to balance acute recovery against initial adaptation; however, it remains possible that these post-intervention values reflect residual acute exercise-induced stress rather than permanent metabolic or endocrine adaptations. For the baseline performance and anthropometric testing, participants refrained from food intake for at least 3 h prior to testing under standardized pre-exercise metabolic conditions. All participants completed the planned intervention program in its entirety throughout the study, and

no participants were dropped. Throughout the training period, all basketball practices were planned and implemented by an experienced basketball coach. The research was conducted in accordance with the ethical principles established by the World Medical Association [21] and approved by the Dicle University Ethics Committee (Decision No: 2025/E-31679287-663.05-523405, September 2025). Furthermore, the study was retrospectively registered into the ClinicalTrials.gov database to enhance methodological transparency.

### Inclusion and exclusion criteria for the research group

#### Inclusion criteria

Athletes meeting the following criteria were included in the study: being 18–24 years of age; having at least two years of regular sports experience; training regularly at least three days a week; not having a chronic illness; not having suffered a serious musculoskeletal injury within the last six months; and not having any medical condition that would prevent them from exercising. Additionally, all participants were required to participate voluntarily and sign an informed consent form.

#### Exclusion criteria

Athletes who participated in less than 10% of the planned training sessions or who were unable to continue the intervention during the study due to injury, illness, or medical problems were excluded. Additionally, to prevent potential confounding effects, participants who did not adhere to the research protocol or who performed additional strength or conditioning training outside of the program defined for the study during the intervention period were excluded. For safety reasons, individuals exhibiting signs of acute injury, excessive fatigue, or cardiovascular abnormalities during the intervention were evaluated for exclusion.

### Experimental design

In this study, both the control group (CG) and the exercise group (EG) participated in routine basketball training sessions lasting 60 min, three days per week, over a six-week period. In addition to routine basketball training, the exercise group completed a structured weightlifting-based resistance training program. Data collection was conducted during the first week (pre-test) and repeated during the final week (post-test) of the intervention. Participants visited the laboratory on three separate occasions before and after the intervention, with at least one day between visits. During the first visit, participants received a detailed explanation of all study procedures and completed baseline assessments. During the second visit, biochemical parameters, including thyroid hormones, blood lipid profiles, and selected hormonal variables-were collected and analyzed. To

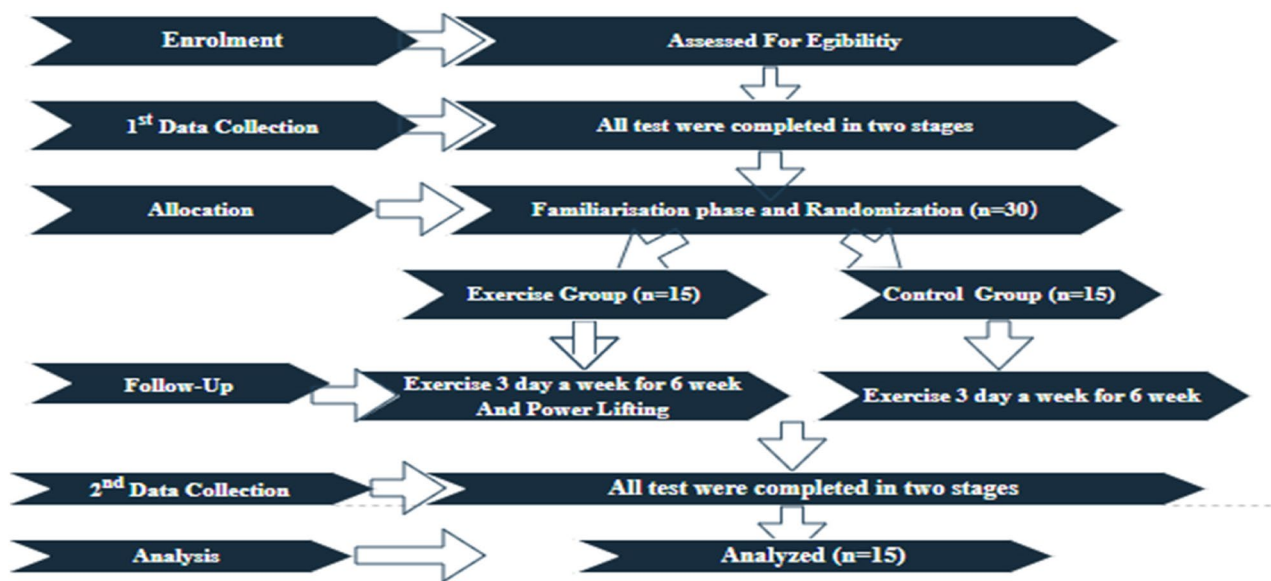


**Fig. 1** Experimental Design of the Study

minimize potential confounding factors, participants were instructed to avoid strenuous physical activity for at least 24 h prior to testing, maintain their habitual dietary and sleep routines, and undergo overnight fasting (8–10 h) before the blood collection. Measurements were conducted under standardized pre-exercise metabolic conditions following a 3-hour period of food restriction. Participants were also instructed to consume approximately 500 mL of water two hours before testing [22]. Dietary intake was not strictly controlled; however, participants were instructed to maintain their usual dietary habits throughout the six-week intervention period and were monitored through weekly self-reported dietary recall forms to ensure stability of eating patterns. Participants were also instructed to refrain from the use of nutritional supplements, ergogenic aids (e.g., creatine, caffeine-based products), and medications that could influence hormonal or metabolic parameters throughout the study period. Sleep duration was not experimentally manipulated; however, participants were encouraged to maintain healthy sleep habits consistent with current recommendations for adults (7–9 h per night) [23]. Training load was monitored throughout the intervention using session rating of perceived exertion (sRPE), and total weekly training load was calculated to ensure consistency between sessions and adherence to the prescribed program. Following eligibility screening, a total of 30 athletes were randomly assigned to either the exercise group ( $n = 15$ ) or the control group ( $n = 15$ ). Both groups adhered to their respective training protocols throughout the intervention period. After completion of the six-week program, all assessments were repeated using identical standardized procedures. Due to the nature of

**Table 1** Demographic Information of Athletes Participating in the Study

| Group | Variable    | Mean   | SD   |
|-------|-------------|--------|------|
| EG    | Age (years) | 21.33  | 2.35 |
|       | Height (cm) | 187.06 | 4.77 |
|       | Weight (kg) | 87.73  | 5.10 |
| CG    | Age (years) | 21.73  | 2.25 |
|       | Height (cm) | 187.53 | 5.48 |
|       | Weight (kg) | 88.40  | 6.31 |

EG Exercise Group, CG Control Group, SD Standard Deviation

the exercise intervention, participants and field coaches could not be blinded to group assignments. Furthermore, blinding of the clinical laboratory technicians and analysts was maintained to reduce potential expectancy or outcome assessment bias. A schematic overview of the participant screening, randomization, and study design in accordance with CONSORT guidelines is presented in Fig. 1.

Table 1 presents the demographic characteristics of the exercise group (EG) and the control group (CG) participating in the study. Comparison of the two groups revealed similar characteristics in terms of age, height, and body weight. These findings indicate that the groups were demographically homogeneous and that baseline differences in age, height, and weight were unlikely to affect the results.

#### Anthropometric and biochemical measurements

Participants' body composition measurements were performed in the laboratory of the Faculty of Physical Education and Sports at Dicle University using a bioelectrical impedance analysis system (Gaia 359 Plus Body-Pass). This device estimates body composition parameters by

analyzing tissue resistance to low-level electrical currents. Measurements included height, body weight, body mass index (BMI), and body fat percentage. Participants stood barefoot on the device and were instructed to remove outer clothing and all metallic accessories prior to assessment. All measurements were conducted under standardized environmental conditions. Anthropometric circumferences, including chest, neck, arm, abdomen, and shoulder measurements, were obtained in accordance with the International Society for the Advancement of Kinanthropometry (ISAK) guidelines [24]. Measurements were performed using a non-elastic measuring tape with a width of 7 mm, and participants wore minimal clothing during assessment to ensure accuracy. Venous blood samples were collected in the morning following an overnight fast (8–10 h) during both pre- and post-intervention assessments. To minimize circadian variation, all blood samples were collected between 08:00 and 09:00 while participants were in a resting seated position. Circadian timing is critical for endocrine markers due to diurnal fluctuations in hormonal secretion patterns [25]. Samples were drawn by trained medical personnel. Blood samples were collected into serum separator tubes (SST; 13 × 100 mm, 5 mL; BD Vacutainer). After collection, samples were allowed to clot and then centrifuged to obtain serum. Serum samples were aliquoted and stored at  $-80^{\circ}\text{C}$  until biochemical analysis to ensure long-term stability of hormonal parameters. Hematological analyses were performed using a fully automated Coulter STKS hemogram analyzer. Biochemical and hormonal analyses, including thyroid hormones (TSH, T3, T4), insulin, growth hormone (GH), and testosterone, were determined using commercially available ELISA kits (Roche Diagnostics, Mannheim, Germany) according to the manufacturers' instructions. It must be noted that the concurrent changes observed in insulin and glucose concentrations should be viewed as exploratory indicators of metabolic regulation. Without direct measures of insulin sensitivity (e.g., hyperinsulinemic-euglycemic clamp or HOMA-IR calculations), any interpretations regarding direct improvements in insulin sensitivity remain preliminary. All biochemical assays were performed using a microplate ELISA reader. The intra-assay and inter-assay coefficients of variation (CV) were below 10% for all measured parameters, indicating acceptable analytical reliability. All pre- and post-intervention samples were processed using identical protocols to ensure methodological consistency and minimize analytical bias. It should be noted that certain hormonal parameters, particularly growth hormone (GH), may exhibit high biological variability due to pulsatile secretion and sensitivity to circadian rhythm, stress, and sleep. Therefore, GH results should be interpreted with caution [26, 27].

### Exercise programme

Participants who met the predefined eligibility criteria were enrolled in a six-week training intervention conducted three days per week. Both groups completed structured training sessions lasting 60 min, consisting of a standardized 15-minute warm-up, a 30-minute main training phase, and a 15-minute cool-down and stretching period. The control group (CG) performed only routine basketball training sessions designed to maintain technical skills, tactical awareness, and general physical conditioning. In contrast, the exercise group (EG) followed a concurrent training model combining resistance training and high-intensity conditioning, integrated into their regular basketball training sessions. The resistance training component was designed to develop maximal strength, power output, and core stability through multi-joint movements. The resistance training load was prescribed based on estimated one-repetition maximum (1RM) values. 1RM values were determined during a familiarization session using submaximal (3–5RM) testing and estimated via the Brzycki equation. The strength training program emphasized three primary lifts—squat, bench press, and deadlift—performed on separate training days. Training intensity and volume were progressively adjusted across the six-week period to ensure adequate overload while minimizing injury risk. Accessory exercises targeting lower-body strength, upper-body musculature, and trunk stabilization were incorporated to support the main lifts and enhance functional performance. Explosive movements and core-focused exercises were also included to improve anaerobic capacity and neuromuscular efficiency. In addition to the resistance training component, the exercise group performed high-intensity, multi-joint bodyweight conditioning exercises aimed at improving anaerobic endurance and movement efficiency. These exercises included jump lunges, star burpees, mountain climbers, jump squats, knee tucks, explosive surfer movements, knee push-ups, and push-ups. Exercises were performed in 20-second bouts and repeated according to the weekly training schedule (Table 4). This concurrent training approach was intended to enhance strength, power, and core endurance while reflecting the intermittent and high-intensity nature of basketball performance. All training sessions were supervised by qualified coaching staff to ensure correct technique, protocol adherence, and participant safety. Participants were monitored throughout the intervention, and no injuries or adverse events were reported. The detailed structure of the exercise program is presented in Tables 2, 3, and 4. To quantify training load, both external and internal load parameters were monitored throughout the intervention. External training load was calculated as:  $\text{training load} = \text{load (kg)} \times \text{sets} \times \text{repetitions}$ .

**Table 2** Resistance training program applied to the exercise group

| Day                           | Focus                      | Main Movement                | Accessory Exercises                                                                 | Core / Explosive                                                      |
|-------------------------------|----------------------------|------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| Day 1 (Lower Body – Squat)    | Strength + Explosive Power | Back Squat 5 × 5 (75–90% RM) | - Walking Lunge 3 × 10/side - Jump Squat (light load) 3 × 5                         | - Box Jump 3 × 5 - Plank / Leg Raise 3x                               |
| Day 2 (Upper Body – Bench)    | Chest, Back, Shoulders     | Bench Press 5 × 5            | - Pull-Ups 4 × 8 - Incline Dumbbell Press 3 × 10 - Face Pull + Band Rotation 3 × 15 | - Side Plank / Russian Twist 3x                                       |
| Day 3 (Total Body – Deadlift) | Total Strength + Core      | Deadlift 5 × 3–5             | - Bulgarian Split Squat 3 × 8/side - Dumbbell Row 4 × 10 - Farmer's Walk 3 × 20 m   | - Broad Jump / single-leg hop 3 × 4 - Ab Roll-out / Cable Core 3 × 10 |

**Table 3** Powerlifting training program applied to the exercise group

| Week   | Main Lift (Squat / Bench / Deadlift) | Target Sets x Reps | Intensity     | Notes             |
|--------|--------------------------------------|--------------------|---------------|-------------------|
| Week 1 | 75% 1RM                              | 5 × 5              | Moderate      | Form, technique   |
| Week 2 | 80% 1RM                              | 5 × 4              | Moderate-High | Stability & tempo |
| Week 3 | 85% 1RM                              | 5 × 3              | High          | Explosiveness     |
| Week 4 | 80% 1RM                              | 5 × 5              | Moderate      | Active recovery   |
| Week 5 | 87% 1RM                              | 5 × 3              | High          | Power peak        |
| Week 6 | 90% 1RM                              | 3 × 2              | Very High     | Taper & test      |

Weekly total training load was progressively increased in accordance with the periodization model presented in Table 3. Internal training load was assessed using the Rating of Perceived Exertion (RPE) scale. Participants reported their perceived exertion following each training session, allowing for the assessment of individual physiological and perceptual responses to training stress. The content of the routine basketball training performed by the control group consisted of technical drills (e.g., passing, shooting, and ball handling), tactical exercises, and low- to moderate-intensity gameplay designed to maintain sport-specific performance without additional structured strength training. The inclusion of both external and internal load monitoring provides a comprehensive assessment of training stimulus and aligns with current recommendations in exercise science literature [28, 29].

#### Data analysis

Statistical analyses were performed using SPSS (version 26.0; IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation. Normality of data distribution was assessed using the Shapiro–Wilk test, and homogeneity of variances was

examined using Levene's test. The level of statistical significance was set at  $p < 0.05$  for all analyses. A two-way repeated-measures ANOVA was used to assess the effects of group, time, and group × time interaction. When significant effects were identified, Bonferroni-adjusted post hoc tests were applied to control for multiple comparisons. Sphericity was evaluated using Mauchly's test, and Greenhouse-Geisser correction was applied when necessary. Effect sizes were calculated using partial eta-squared ( $\eta^2$ ) for ANOVA results and Cohen's  $d$  for pairwise comparisons, and interpreted according to established thresholds [30, 31]. Due to the relatively high interaction effect sizes observed (e.g.,  $\eta^2 > 0.70$ ), which are frequent in small-cohort randomized trials, these values were interpreted with appropriate caution regarding sample size constraints. 95% confidence intervals (95% CI) were reported where appropriate to provide additional estimation precision.

#### Research ethics

Ethical approval was obtained from the Ethics Committee of Dicle University (Decision No: 2025/E-31679287-663.05-523405, dated September 2025). The study was retrospectively registered at ClinicalTrials.gov (Identifier: NCT07398248).

#### Results

Prior to the experimental intervention, an independent samples  $t$ -test was performed to assess baseline demographic and physiological characteristics between the groups. The analysis confirmed that the exercise group ( $n = 15$ ) and the control group ( $n = 15$ ) were statistically equivalent in all parameters tested, including age ( $t(28) = -0.48$ ,  $p = 0.636$ ), height ( $t(28) = -0.25$ ,  $p = 0.804$ ), and body weight ( $t(28) = -0.32$ ,  $p = 0.752$ ), demonstrating structural baseline homogeneity. Following the six-week intervention, a two-way repeated measures ANOVA

**Table 4** Weekly Training Program for the Exercise Group: Duration, Frequency, and Sequence of Exercises

| Weeks     | Training Duration | Training Frequency | Movement Series                                                                                                            |
|-----------|-------------------|--------------------|----------------------------------------------------------------------------------------------------------------------------|
| 1–3 Weeks | 20 s × 8          | 3 days/week        | Jumping lunges, burpee with star, mountain climbers, jumping squat, knee tucks, explosive surfer, knee push up, push ups.  |
| 4–6 Weeks | 20 s × 8          | 3 days/week        | Jumping lunges, burpee with star, mountain climbers, jumping squat, knee tucks, explosive surfer, knee push-ups, push-ups. |

The exercises and durations are specified for weeks 1-3 and 4-6

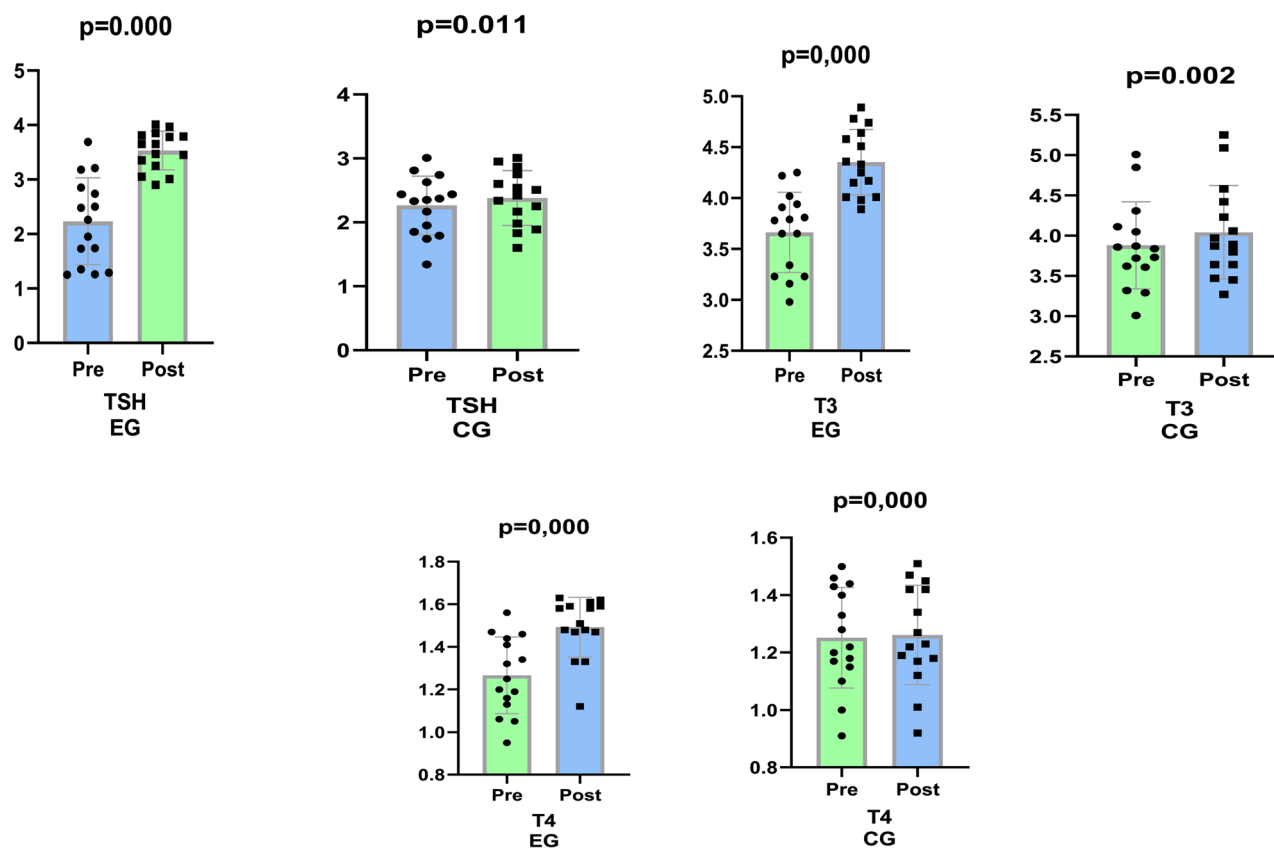


**Fig. 2** Changes in thyroid hormone concentrations (TSH, T3, and T4) before and after intervention in the exercise and control groups

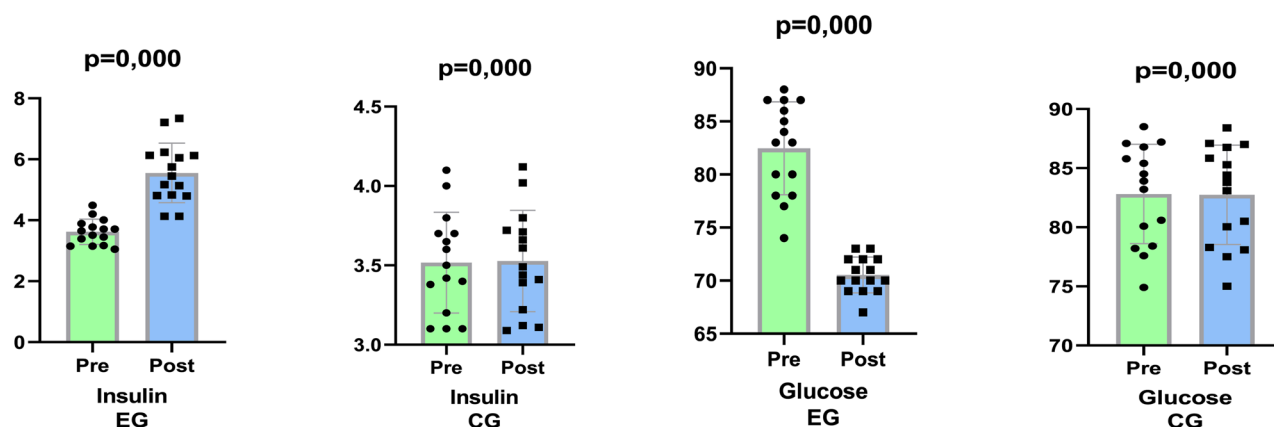


**Fig. 3** Changes in insulin and glucose levels before and after intervention in the exercise and control groups

revealed significant group  $\times$  time interactions in multiple biochemical parameters, demonstrating a measurable effect of the training stimulus. Baseline comparisons across all measured biomarkers confirmed no significant difference between groups ( $p > 0.05$ ). Furthermore, no statistically significant changes were observed in any of the variables measured from pre-test to post-test in the control group ( $p > 0.05$ ). In contrast, the exercise group showed significant changes in endocrine, metabolic, and lipid profile markers throughout the intervention period.

Thyroid hormone levels exhibited significant group  $\times$  time interactions, evident with increasing post-exercise concentrations (Fig. 2). Metabolic responses showed concurrent changes, particularly with increasing insulin concentrations and decreasing resting glucose levels (Fig. 3). Additionally, while significant increases in anabolic hormones were observed (Fig. 4), positive adaptations were recorded in lipid profile parameters, including decreases in total cholesterol, LDL, and triglycerides, and increases in HDL (Fig. 5, Table 5). All statistically significant

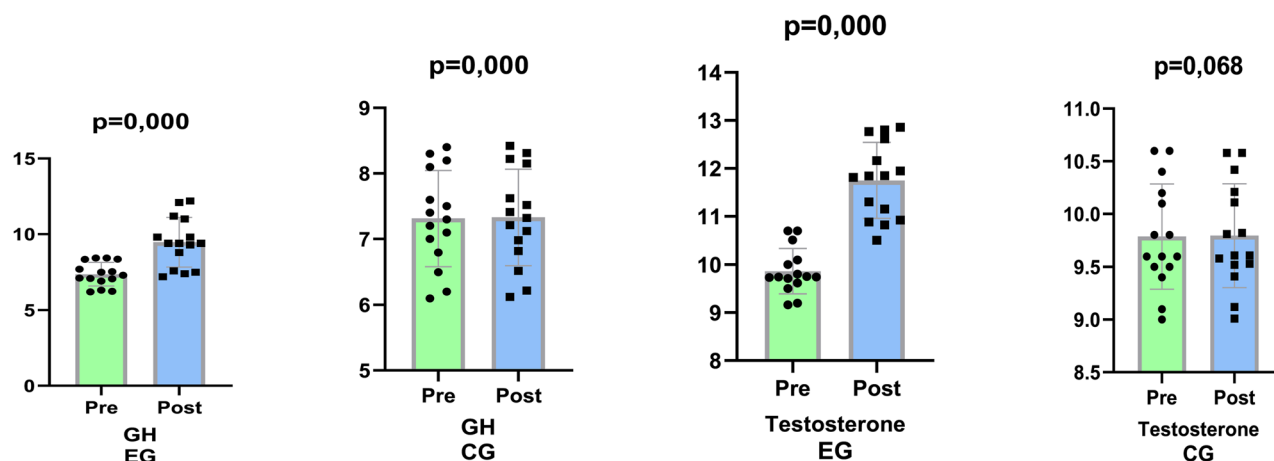


**Fig. 4** Changes in GH and testosterone levels before and after intervention in the exercise and control groups

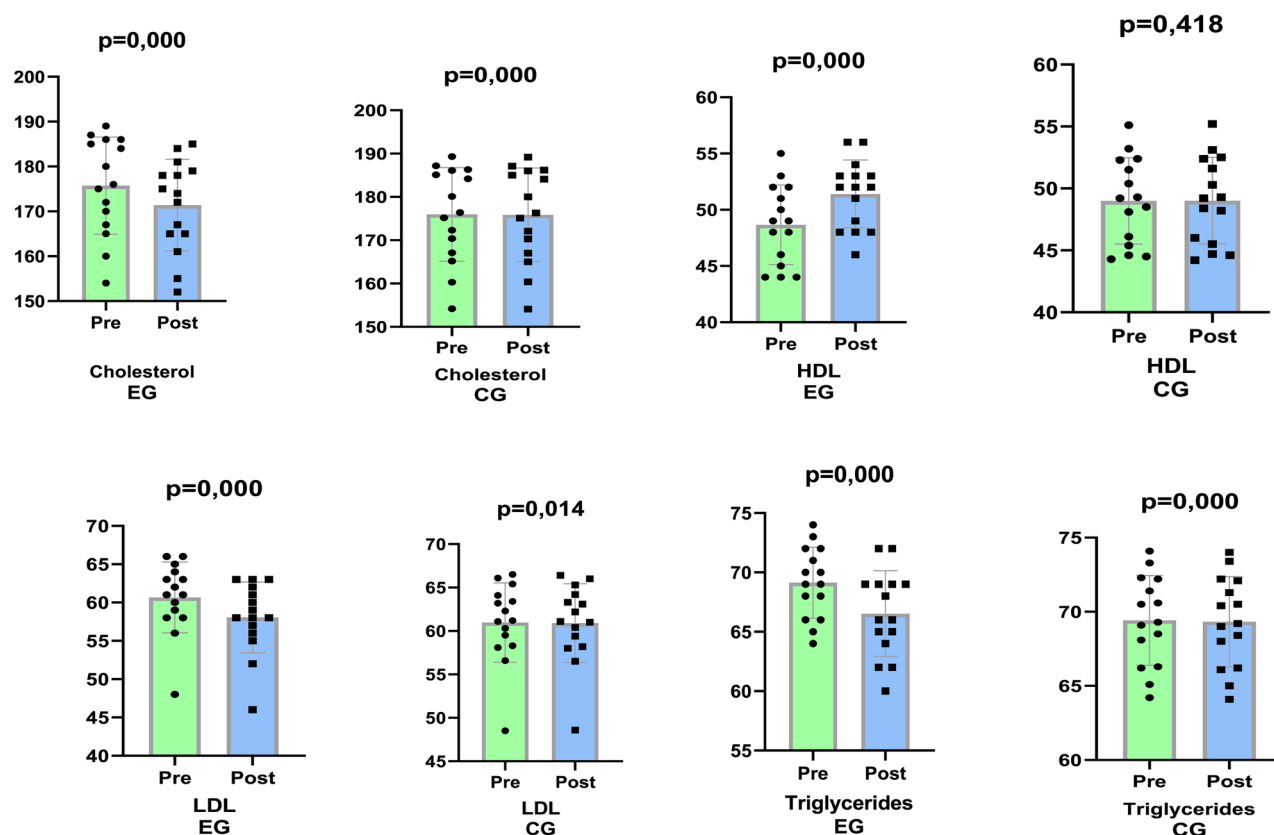


**Fig. 5** Changes in lipid profile parameters before and after the intervention in the exercise and control groups

findings remained significant after Bonferroni-adjusted post hoc correction.

## Discussion

The present study examined the short-term endocrine, metabolic, and lipid profile responses associated with a powerlifting-based exercise intervention in physically active young men. The main findings indicate that participation in the exercise program was associated with

acute, transient exercise-induced responses in multiple biochemical and hormonal markers, whereas no significant alterations were observed in the control group. These findings should be interpreted as acute physiological responses rather than long-term adaptations, given the relatively short intervention period and the timing of post-intervention measurements. While the exercise group exhibited significant changes in several biomarkers, the execution of multiple comparisons across

**Table 5** Pre- and post-training biochemical parameters and percentage changes in exercise and control groups

| Parameters            |      | Control<br>Mean $\pm$ SD | % Change* | Exercise<br>Mean $\pm$ SD | % Change* | F       | $\eta p^2$ | p           |
|-----------------------|------|--------------------------|-----------|---------------------------|-----------|---------|------------|-------------|
| TSH ( $\mu$ U/mL)     | Pre  | 2.26 $\pm$ 0.45          | 5.30      | 2.43 $\pm$ 1.15           | 45.26     | 16.015  | 0.309      | $p < 0.001$ |
|                       | Post | 2.38 $\pm$ 0.42          |           | 3.53 $\pm$ 0.35           |           |         |            |             |
| T3 (pg/mL)            | Pre  | 3.88 $\pm$ 0.54          | 4.12      | 3.66 $\pm$ 0.39           | 18.85     | 29.627  | 0.357      | $p < 0.001$ |
|                       | Post | 4.04 $\pm$ 0.58          |           | 4.35 $\pm$ 0.32           |           |         |            |             |
| T4 (ng/dL)            | Pre  | 1.25 $\pm$ 0.17          | 0.80      | 1.26 $\pm$ 0.17           | 18.25     | 48.096  | 0.632      | $p < 0.001$ |
|                       | Post | 1.26 $\pm$ 0.17          |           | 1.49 $\pm$ 0.14           |           |         |            |             |
| Insulin ( $\mu$ U/mL) | Pre  | 3.58 $\pm$ 0.38          | 0.27      | 3.62 $\pm$ 0.41           | 53.31     | 83.469  | 0.749      | $p < 0.001$ |
|                       | Post | 3.59 $\pm$ 0.39          |           | 5.55 $\pm$ 0.97           |           |         |            |             |
| Glucose (mg/dL)       | Pre  | 82.81 $\pm$ 4.21         | -0.08     | 82.46 $\pm$ 4.37          | -14.46    | 87.187  | 0.757      | $p < 0.001$ |
|                       | Post | 82.74 $\pm$ 4.19         |           | 70.53 $\pm$ 1.68          |           |         |            |             |
| GH (ng/mL)            | Pre  | 7.31 $\pm$ 0.73          | 0.27      | 7.37 $\pm$ 0.78           | 28.49     | 27.911  | 0.499      | $p < 0.001$ |
|                       | Post | 7.33 $\pm$ 0.73          |           | 9.47 $\pm$ 1.63           |           |         |            |             |
| Testosterone (ng/mL)  | Pre  | 9.85 $\pm$ 0.65          | 0.10      | 9.93 $\pm$ 0.63           | 18.22     | 77.901  | 0.739      | $p < 0.001$ |
|                       | Post | 9.86 $\pm$ 0.64          |           | 11.74 $\pm$ 0.79          |           |         |            |             |
| Cholesterol (mg/dL)   | Pre  | 175.96 $\pm$ 10.82       | -0.05     | 175.73 $\pm$ 10.83        | -2.49     | 44.072  | 0.611      | $p < 0.001$ |
|                       | Post | 175.86 $\pm$ 10.81       |           | 171.40 $\pm$ 10.19        |           |         |            |             |
| HDL (mg/dL)           | Pre  | 48.99 $\pm$ 3.48         | 0.04      | 48.66 $\pm$ 3.53          | 5.63      | 66.995  | 0.705      | $p < 0.001$ |
|                       | Post | 49.01 $\pm$ 3.49         |           | 51.40 $\pm$ 3.01          |           |         |            |             |
| LDL (mg/dL)           | Pre  | 60.97 $\pm$ 4.58         | -0.09     | 60.66 $\pm$ 4.62          | -4.28     | 115.838 | 0.805      | $p < 0.001$ |
|                       | Post | 60.91 $\pm$ 4.53         |           | 58.06 $\pm$ 4.62          |           |         |            |             |
| Triglyceride (mg/dL)  | Pre  | 69.41 $\pm$ 3.02         | -0.12     | 69.13 $\pm$ 2.99          | -3.76     | 44.759  | 0.615      | $p < 0.001$ |
|                       | Post | 69.32 $\pm$ 3.04         |           | 66.53 $\pm$ 3.60          |           |         |            |             |

\*% Change was calculated as [(Post – Pre) / Pre]  $\times$  100, F values represent group  $\times$  time interaction effects from repeated measures AN

numerous independent outcomes elevates the risk of family-wise Type I error. Consequently, these findings should be considered exploratory, and the high partial eta-squared ( $\eta p^2$ ) values observed across parameters should be interpreted with appropriate caution regarding sample size constraints.

The observed increases in TSH, T3, and T4 concentrations following the intervention may reflect a short-term modulation rather than a sustained response of the hypothalamic-pituitary-thyroid (HPT) axis, potentially driven by acute metabolic stress, increased energy demand, and sympathetic activation during resistance exercise. Thyroid hormones are involved in the regulation of basal metabolic rate, substrate mobilization, and neuromuscular efficiency, suggesting that even short-term perturbations in training load may temporarily influence endocrine signaling to support increased energy turnover [32]. However, these changes should be interpreted as acute physiological adjustments rather than long-term endocrine response, particularly given the short duration of the intervention. These findings are partially consistent with previous studies reporting exercise-related alterations in thyroid hormone dynamics [12, 33, 34], although the literature remains inconsistent, with some studies reporting no change or transient suppression depending on training load and recovery status [35, 36]. Such variability likely reflects differences in exercise intensity, energy availability, and hypothalamic

sensitivity to metabolic stress signals [37]. Mechanistically, resistance exercise may activate adenosine monophosphate-activated protein kinase (AMPK), which plays a central role in cellular energy sensing and may contribute to increased peripheral thyroid hormone conversion through enhanced deiodinase activity and mitochondrial biogenesis, thereby supporting increased T3 availability during periods of elevated energy demand [38, 39].

With respect to metabolic regulation, the concurrent increase in insulin concentration and reduction in pre-exercise metabolic measurements under standardized conditions observed in the exercise group should not be interpreted as improved insulin sensitivity. Instead, this pattern may reflect transient alterations in glucose-insulin dynamics, compensatory insulin secretion, or residual post-exercise metabolic effects. Given the absence of direct measures of insulin sensitivity (e.g., HOMA-IR, QUICKI, or clamp techniques), these findings remain exploratory and should be interpreted with caution [40]. This pattern may reflect enhanced skeletal muscle glucose uptake through insulin-dependent and insulin-independent pathways, including contraction-mediated GLUT-4 translocation. Importantly, insulin elevation in this context should not be interpreted as reduced insulin sensitivity; instead, it may reflect short-term compensatory pancreatic responses and altered glucose-insulin dynamics during the post-intervention period. These findings align with evidence suggesting that exercise can acutely

influence glucose uptake and insulin signaling pathways [41–43], although inter-individual variability remains high depending on baseline metabolic status and training history [44–46]. The magnitude of change observed in insulin and glucose is physiologically notable and may reflect altered post-exercise insulin dynamics and improved glucose handling, glycogen replenishment processes, and altered hepatic glucose output following repeated high-intensity resistance exercise sessions. The timing of blood sampling (post-intervention recovery phase) may have partially contributed to the observed changes in insulin and pre-exercise metabolic parameters under standardized conditions. The metabolic measurements should be interpreted within the context of a standardized pre-exercise state rather than a true fasting condition.

In terms of anabolic indicators, the elevated levels of growth hormone and testosterone observed 48 h post-exercise are consistent with systemic neuroendocrine responses to high-intensity resistance training. However, it is essential to emphasize that growth hormone displays notable biological variability and pulsatile secretion patterns. Given our single-point post-test sampling, these elevated GH values should be viewed as transient fluctuations rather than evidence of a sustained anabolic adaptation. At the cellular level, these acute hormonal elevations may temporarily support tissue repair, neuromuscular recovery, and mTOR signaling pathways [47]. The increases observed in growth hormone and testosterone concentrations are consistent with established acute neuroendocrine responses to high-intensity resistance exercise, driven by hypothalamic stimulation, lactate accumulation, and metabolic stress [48]. From a mechanistic perspective, growth hormone and testosterone responses may interact within a broader anabolic-catabolic regulatory network, where acute hormonal elevations facilitate substrate availability, tissue repair signaling, and neuromuscular recovery processes. At the intracellular level, these hormonal responses may contribute to activation of mammalian target of rapamycin (mTOR) signaling pathways and satellite cell activity, which are key regulators of muscle protein synthesis and adaptive remodeling following resistance exercise. However, it is important to emphasize that these responses represent short-term endocrine fluctuations rather than evidence of sustained anabolic response, and their translation into long-term morphological changes remains dependent on chronic training load, nutrition, and recovery status [49–51].

Improvements observed in lipid profile parameters, including increased HDL cholesterol and reductions in LDL cholesterol, triglycerides, and total cholesterol, may reflect early-phase cardiometabolic responsiveness to repeated exercise exposure, potentially mediated by

increased lipoprotein lipase activity and enhanced lipid oxidation [52]. Additionally, exercise-induced upregulation of hepatic lipid metabolism and increased skeletal muscle LPL activity may contribute to enhanced triglyceride clearance and improved lipid transport efficiency. However, these changes should be interpreted cautiously as short-term biochemical shifts rather than stable cardiometabolic remodeling, as longer interventions are typically required to confirm persistent lipid responses [53–55]. The consistently large partial eta-squared values observed across variables should be interpreted with caution due to potential small-sample bias and possible overestimation of effect magnitude. In particular,  $\eta^2$  values exceeding 0.70 for insulin, glucose, and lipid parameters indicate relatively large effect sizes compared to literature for short-term exercise interventions, suggesting that powerlifting-based training induces substantial systemic metabolic perturbations that warrant further investigation alongside typical effect magnitudes reported in resistance training literature.

### Practical applications

From a practical perspective, the integration of a powerlifting-based resistance training program alongside routine basketball training provides strength and conditioning coaches with a time-efficient strategy to optimize neuromuscular and metabolic stress in male basketball players. The observed biochemical responses suggest that short-term, high-load resistance training can be successfully embedded within sport-specific routines without inducing maladaptive endocrine signals, provided that adequate recovery time (at least 48 h post-exercise) is allowed before high-intensity performance testing.

### Limitations

This study has several limitations that should be acknowledged. First, the sample consisted exclusively of male basketball players, which limits the generalizability of the findings. Second, dietary intake was not objectively controlled via direct meal provision, and reliance on self-reported dietary recalls may introduce bias. Third, the exercise group followed a combined concurrent model of powerlifting-based training and high-intensity conditioning, making it difficult to isolate the specific effects of the powerlifting component. Fourth, the relatively small sample size ( $n=15$  per group) and the multiple statistical comparisons performed increase the risk of Type I error; thus, high effect sizes  $\eta^2 > 0.70$  should be interpreted with caution (Faul et al., 2009; Soslu et al., 2023). Fifth, no performance-based outcomes (e.g., strength or power) were included, limiting the practical interpretation of the biochemical changes. Sixth, the biochemical assays section lacks specific manufacturer details for the ELISA kits, which limits methodological reproducibility.

Finally, the trial was retrospectively registered, blinding of participants was not feasible, and post-intervention testing at 48 h may still capture acute exercise-induced stress rather than persistent adaptations.

## Conclusions

The present data indicate that a six-week powerlifting-based exercise intervention is associated with short-term alterations in thyroid hormones, insulin-glucose regulation, lipid profile parameters, and selected biochemical markers in male basketball players. These findings suggest that structured resistance training may contribute to transient endocrine and metabolic responses that reflect acute physiological responsiveness to training stimuli. However, these responses are influenced by multiple factors, including training history, exercise intensity, and program design, and therefore should be interpreted within the context of short-term physiological response rather than long-term endocrine remodeling. Future research should focus on longer intervention periods, inclusion of performance-based outcomes, and more diverse athletic populations to determine whether these acute biochemical responses translate into meaningful functional and chronic physiological responses.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13102-026-01832-4>.

Supplementary Material 1.

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## Authors' contributions

ET and RE conceived and designed the study, collected the data, performed the statistical analysis, and drafted the manuscript. All authors read and approved the final manuscript.

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## Data availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Dicle University Ethics Committee before the start of the study (Decision No: 2025/E-31679287-663.05-523405, September 2025). Written informed consent was obtained from all participants before participating in the study.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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