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ORIGINAL RESEARCH

Effects of collagen supplementation on the physical, functional, and metabolic parameters in male soccer players: a randomized, double-blind, placebo-controlled study

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Abstract

Background: Collagen supplementation in athletes has been associated with physical and functional performance. Accordingly, the effects of collagen on various parameters, such as body composition, strength, flexibility, speed, hydration status and heart rate, which are important determinants of performance and endurance, are extensive. This study aims to comprehensively evaluate the effects of collagen supplementation on physical, functional, and metabolic parameters in male soccer players. **Methods**: This randomized, double-blind, placebo-controlled clinical trial was conducted with 13 volunteer male soccer players (placebo = 7 and collagen = 6) aged 19–24 years. Hydration analysis, lactate measurement, heart rate (HR), body composition analysis, 30 m sprint test, vertical jump, anaerobic power test, single leg hop tests (SLHT), sit-and-reach test, isometric mid-thigh pull test, proprioceptive sense evaluation, gastrointestinal symptom rating scale (GSRS), visual analog scale (VAS), and rating of perceived exertion scale (RPE) results were evaluated before and after 8 weeks of PROFIN® type I and type III bovine collagen peptides supplementation. **Results**: In the collagen group, statistically significant improvement was observed in the RPE score (p = 0.037) and VAS value (p = 0.043) between baseline and final assessments. No specific significance was detected in the Analysis of Variance (ANOVA) interactions for the other physical, functional, and metabolic parameters included in the study. **Conclusions**: 8-week supplementation with PROFIN® type I and type III bovine collagen peptides specifically reduced pain perception and perceived training exertion levels in male soccer players, but had no significant effect on various physical, functional, and metabolic parameters. **Clinical Trial Registration**: The study was retrospectively registered in the Iranian Clinical Trials Registry on 13 December 2024 with the number IRCT20240411061470N5, https://trialsearch.who.int/Trial2.aspx?TrialID=IRCT20240411061470N5.

Keywords

Collagen supplement; Soccer player; Functional performance; Endurance; Body composition

1. Introduction

In recent years, there has been a growing interest among athletes in nutritional supplements to manage the physiological stress of high-intensity training and sustainably improve their performance [1, 2]. In parallel with this increased interest, the number of studies examining the effects of different nutritional supplements on performance and recovery in athletes has also increased significantly [3–5]. Collagen, one of these supplements, stands out as one of the basic structural proteins in the body. In addition, collagen is an important component that provides the structure and durability of various tissues, especially tendons, ligaments, cartilage and bone, which are important determinants of athlete performance [6, 7]. Collagen is recognized as an important nutrient to support and regenerate connective tissues that wear out more, especially in sports with high physical intensity [8, 9]. The importance of collagen for athletes spans a wide range of areas, such as maintaining joint health, promoting muscle recovery, and enhancing connective tissue endurance [10–12]. Research reveals that collagen supplementation shows chondroprotective effects on joint health, contributing to the maintenance of articular cartilage by promoting type II collagen synthesis [13, 14]. Glucosamine and collagen-based supplements have also been reported to help maintain cartilage integrity and reduce joint pain and inflammation by suppressing matrix metalloproteinases involved in joint deterioration [15, 16].

The effects of collagen supplementation on functional performance are also of interest. For example, studies have shown that collagen and vitamin C supplementation can improve athletes' jumping and strength development capacities by increasing tendon and ligament endurance [6, 17]. These findings suggest that collagen may not only reduce injuries, but also support athletic endurance by enhancing neuromuscular performance [18]. There is strong evidence that collagen supplementation has positive effects on strength and jumping performance, especially in sports that require explosive strength [19]. Collagen supplementation in athletes is not limited to physical and functional performance benefits, but also supports many metabolic improvements [20]. Collagen has a wide range of effects on performance and endurance-related parameters, such as body composition, hydration status, and heart rate (HR) in athletes [20, 21]. Collagen is high in amino acids, such as glycine and proline, which are considered important for muscle tissue regeneration and support of general metabolic functions [22]. Beyond maintaining the structural integrity of skin and connective tissues, these amino acids may also contribute to fat oxidation and muscle protein synthesis, which is especially important for maintaining muscle mass in aging athletes [23]. In addition, collagen-based peptides have been suggested to have the potential to improve recovery in athletes by reducing oxidative stress and optimizing energy metabolism [9, 24]. Collagen, the primary structural component of the airway extracellular matrix, plays an important role in structural support, cell adhesion, and tissue development [25].

Despite these wide-ranging benefits of collagen supplementation, the general focus in the literature is on examining its effects on joint and connective tissue-related diseases [8, 10, 26]. In addition, studies examining the effects of collagen supplementation on athletes have also focused on examining the combined effects of these supplements with training methods, rather than their direct effects [6, 18, 27–29]. Therefore, focused studies in athletes are needed to better understand the specific effects of collagen supplementation. This study aims to comprehensively examine the effects of collagen supplementation on various physical, functional, and metabolic parameters that are thought to be effective in athlete performance. In the study, it was hypothesised that collagen supplementation would provide positive effects in terms of physical, functional, and metabolic parameters in athletes and reveal significant correlations between these parameters.

2. Materials and methods

2.1 Investigational products

The study product was provided by PROFIN® Collagen (Halavet Food, Türkiye) with local Ministry of Agriculture and Forestry production approval. The products were packaged as a meal in a 5000 mg stick sachet. PROFIN® Collagen contained type I and type III bovine collagen peptides with >97% purity and an average molecular weight of 2000 Da. The placebo product contained 5000 mg maltodextrin, and this was chosen as a placebo since it is known to be a digestible non-fermentable carbohydrate that is completely metabolised in the small intestines [30]. Both products contained sweeteners with the same flavor. All products had the same look, taste, and texture.

2.2 Study design

This randomized, double-blind, placebo-controlled clinical trial evaluated the effects of 8 weeks of supplementation with PROFIN® type I and type III bovine collagen peptides on various physical, functional, and metabolic test and scale outcomes in male soccer players. The study included 13 male soccer players who completed written informed consent forms.

During the first visit, participants were introduced to the measurements to be carried out in the study, and trial measurements were carried out. During the following two days, the athletes completed the pre-test measurements according to the prescribed flow (Table 1). After completion of the pre-tests, participants were randomised into one of the two treatment groups (collagen, n = 6; placebo, n = 7) using computer-validated software (https://www.random.org/). Randomisation was performed by a researcher not involved in data collection to ensure allocation concealment. Participants were allocated with an equal ratio (1:1), without stratification. Blinding of products was done using blinding codes in sealed envelopes. Participants and researchers responsible for data collection were blinded to treatment allocation. Participants were instructed to consume the products at the same time of the day (17:30–18:00) according to the manufacturer's recommendation by dissolving 1 sachet per day in 1 glass (200 mL) of water for 8 weeks. For a better follow-up period, participants were assigned paired log cards (for both the subjects and the researcher) and their product use was recorded dually through daily interviews. In addition, compliance with supplementation was monitored using daily consumption records. Compliance was calculated as the percentage of sachets consumed relative to the total number provided. The overall compliance rate was 97%, indicating a high level of adherence to the supplementation protocol. Participants were also asked to maintain their sleep schedule, overall diet, and exercise routines throughout the study, and to avoid alcohol and similar stimulants. Nutritional routines and training status were monitored through daily online interviews but not recorded. Participants returned after 8 weeks of product use and post-tests were completed on two consecutive days, following the same flow as the pre-tests (Fig. 1). All measurements were carried out in the same performance laboratory and at the same time of day (13:00–15:00) to maintain similar experimental conditions. The room temperature ranged from 19 to 22 °C and the humidity from 52 to 60 percent. In order to obtain more reliable test results, athletes in both data collection sessions spent the previous day without training. In addition, athletes consumed a standardised meal following a 12-hour overnight fast 2 hours before the measurement sessions. The primary

TABLE 1. Measurement flow.

Day	Timepoint		Measurement
1	Initial		Height, Weight
	Consecutive		Body Composition VAS, GSRS HR, Lactate, Hydration 15 min Warm-up
	Consecutive (With 3 min passive rest between tests)		Vertical Jump Isometric Mid-thigh Pull Test Sit-and-Reach Test Proprioceptive Sense SLHT
2	Initial		15 min Warm-up
	Consecutive (With 3 min passive rest between tests)		30 m Sprint Test RAST
	Consecutive		RPE
	After RAST	1st min 5th min 10th min	HR, Lactate, Hydration

VAS: visual analog scale; GSRS: gastrointestinal symptom rating scale; HR: heart rate; SLHT: single leg hop tests; RAST: running-based anaerobic sprint test; RPE: rating of perceived exertion.

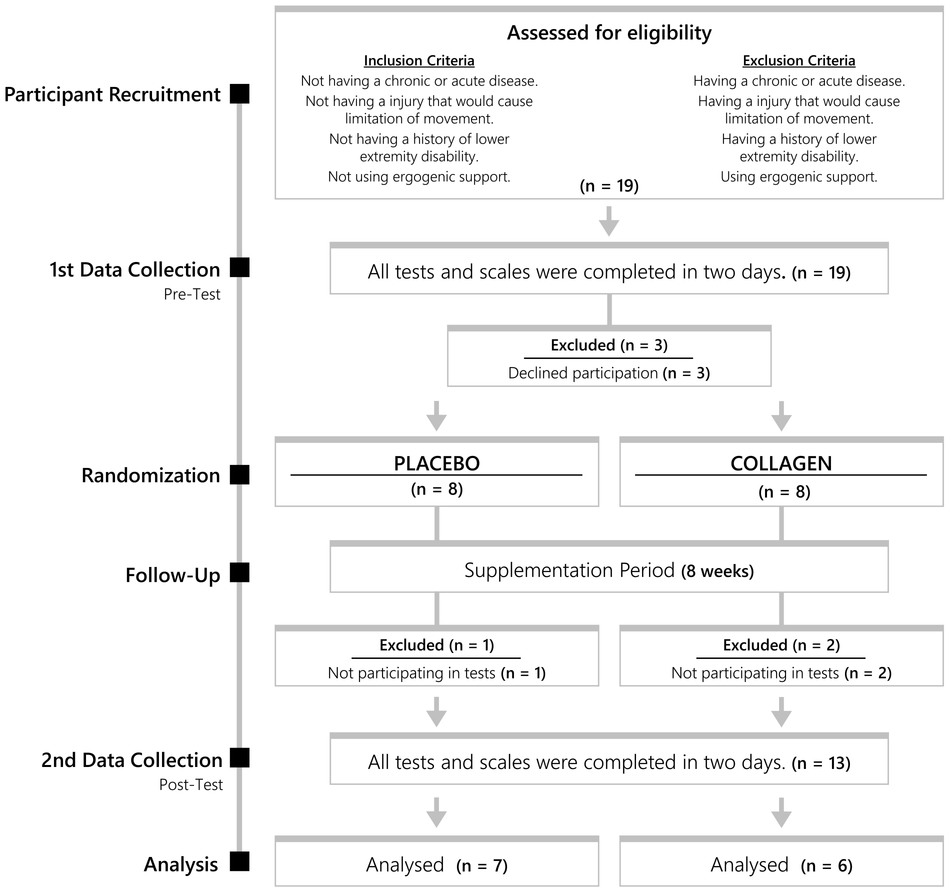


FIGURE 1. Flowchart of participant recruitment and study procedure.

endpoint of the study was the successful completion of the final tests after 8 weeks of product use, and the secondary endpoints were the patient's unwillingness to continue the study for various reasons, discontinuation of product use earlier than 8 weeks, and the development of hypersensitivity to the product used in the study.

This study was designed according to Consolidated Standards of Reporting Trials (CONSORT) guidelines and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and ICH Good Clinical Practice guidelines. Ethics committee approval was obtained from Sinop University Human Research Ethics Committee (protocol no: 2023/181) and registered in the Iranian Registry of Clinical Trials with the number IRCT20240411061470N5.

2.3 Participants

The study involved 13 volunteer male soccer players between the ages of 19–24 years who are active in sports at Sinop University Faculty of Sport Sciences (Sinop, Türkiye). In the power analysis conducted using the G*Power 3.1 software (Heinrich Heine University Düsseldorf, Düsseldorf, NRW, Germany), according to the effect size (f = 0.74) measured for the muscle volume value, which had a significant difference in the related study [31], a sample size of 6 per group was calculated with 80% power ($1 - \beta$) and $\alpha = 0.05$ error. However, one soccer player in the collagen group could not participate in the final measurements, so the initial measurement values were excluded from the study. All athletes in the study were in the university team and had the same training routine 3 days a week. Athletes were recruited for the 2024–2025 soccer season. The inclusion criteria for the study were being healthy, not having any chronic or acute disease, not having any injury that would cause limitation of movement, not having any history of lower extremity disability, and not using ergogenic support. The exclusion criteria were having a chronic or acute illness, any injury that would cause limitation of movement, a history of lower extremity disability, and the use of ergogenic support. All inclusion and exclusion criteria were followed on the basis of the participants' self-reports.

2.4 Study evaluations

2.4.1 Anthropometric measurements

The height of the athletes was measured in cm using a portable height measuring device (Seca 213, Seca GmbH & Co. KG, Hamburg, HH, Germany) and their body weight (without sportswear and shoes) was measured in kg using a body composition analyzer (Inbody 120 Bioimpedance, Seoul, South Korea).

2.4.2 Body composition analysis

High sensitivity Inbody 120 Bioimpedance Body Composition Analyzer with 8-point contact "Tetrapolar Electrodes" was used. Body fat mass, muscle tissue, body water, metabolic rate, protein, and mineral components were measured.

2.4.3 Visual analog scale (VAS)

The VAS is a 100 mm scale applied through self-assessment by the patient. Participants marked the point that best represented the intensity of their current pain perception on a scale of 0–10, and their marking was identified using a ruler [32].

2.4.4 Gastrointestinal symptom rating scale (GSRS)

The GSRS is a 15-question, 5-point Likert-type scale that assesses symptoms in five subcategories: abdominal pain, reflux, diarrhea, indigestion, and constipation. The total score obtained from the scale ranges from 15–105; higher scores indicate more severe symptoms [33].

2.4.5 Heart rate (HR) measurement

With the HR monitor (Polar V800, Kempele, Finland), the HR was obtained in beats per minute (bpm) via a sensor placed on the chest, which transmitted the HR to the arm-worn device. HRs of athletes were measured at rest before supplementation and then at 1, 5, and 10 minutes after Running-Based Anaerobic Sprint Test (RAST).

2.4.6 Lactate measurement

Blood lactate levels were measured with a portable lactate analyzer (Lactate Pro 2, Arkray Inc., Kyoto, Japan) using blood taken from the earlobe area before and after the test. Measurements of the athletes were performed at rest during the pretest before supplementation and then at the 1st, 5th, and 10th minutes after RAST. The hand to be used for blood sampling was gloved and dried with cotton wool. Next, the participant's earlobe was punctured using a lancet and gently squeezed. After wiping the first blood from the earlobe, the participant's earlobe was squeezed again and the blood was collected with a disposable strip. Results are shown in mmol/L.

2.4.7 Hydration analysis

Body hydration levels of the athletes were measured using a portable hydration tester (MX3 Diagnostics LAB Pro, Melbourne, VIC, Australia) at rest in the pretest before supplementation and then at the 1st, 5th, and 10th minutes post-RAST [34]. Saliva samples were collected from the tongue per sterilization rules and the test strip was changed each time saliva was collected from the athletes. The samples were then analyzed with a hydration test strip connected to the device ($\leq$65 Good Hydration, 65–100 = Low-Level Dehydration, 101–150 = Medium Dehydration, $>$150 = High Level (severe) Dehydration) [35].

2.4.8 Vertical jump and anaerobic power test

A digital vertical jump device belt (Takei 5406 Jump-MD Vertical Jump Meter, Tokyo, Japan) was strapped to the umbilicus, and measurements were performed without shoes. Subjects jumped from an upright posture to a position of 90° knee flexion with freely swinging arms for maximum height. There was a 1-minute rest between 2 repetitions. The best jump was recorded in cm with an accuracy of $\pm$1 cm [36]. Participants' anaerobic power was calculated using the Lewis formula (Eqn. 1) [37]:

$$Anaerobic\ Power\ (W) = \sqrt{4.9 \times Weight\ (kg)} \times \sqrt{Vertical\ Jump\ (m)} \quad (1)$$

2.4.9 Isometric mid-thigh pull test

Leg strength was measured with a digital dynamometer (Takei TKK 5402; Takei Scientific Instruments Co. Ltd., Tokyo, Japan). Subjects were positioned with their arms extended and both hands on the handgrip placed at mid-thigh (knee angle ∼110°) [38]. From here, while maintaining proper spinal alignment and feet flat on the floor, subjects pulled the handle upwards as hard as possible, trying to extend their legs [39]. The test was repeated twice and the best value was recorded.

2.4.10 Sit-and-reach test

The flexibility of the athletes' lower extremity and waist extensors was measured using the sit-and-reach test. The athletes sat with their ankles at a 90-degree angle and the soles of their bare feet touching the sit-and-reach board and were instructed to tilt their torso forward and, without bending their knees, push the ruler on the stand with their hands to the last place they could reach and stay there for 2 seconds. Two attempts were performed and the best flexibility degree was recorded in cm.

2.4.11 Proprioceptive sense assessment

A one-degree sensitive digital goniometer (2176-300 Insize Digital Angle Meter) was fixed to the athlete's knee joint with electromyography (EMG) bandages and 3 different angle targets (15°, 30°, and 45°) were set for the measurements. In the first application, the goniometer was zeroed and the target angle was verbally communicated to the athlete with the athlete lying prone (P), eyes closed, hips in neutral position, and knees in full extension. The athlete focused on the specified angle and held the knee in this position for 5 seconds to fully perceive the target angle [40]. Then, the athlete was asked to position the knee at the target angle and the measurements were repeated 3 times for each target angle and the angular errors of each measurement were averaged. All stages were repeated while the athlete was lying on the supine (S) and the test was applied to both knees.

2.4.12 Single leg hop tests (SLHT)

SLHT were performed on a single line with the parameters single hop for distance (SH), triple hop for distance (TH), cross triple hop for distance (CH), medial side triple hop for distance (MSTH), and medial rotation (90°) hop for distance (MRH) [41, 42]. For use in the test, a 0.3 m strip with a length of 6 m and a width of 5 cm was drawn from the center of the line determined as the starting point. After all tests were attempted by the participant, 3 attempts were made for the actual test, and the best score was taken between the starting line and the heel of the participant and recorded in cm. During the test, care was taken to ensure that the participant was balanced so that the limb being tested was on the line. Loss of balance and being on the line on a limb other than the test limb were considered criteria for failing the test and the test was repeated. There were no restrictions on arm swing. A 30-second rest period was given between each attempt (Fig. 2).

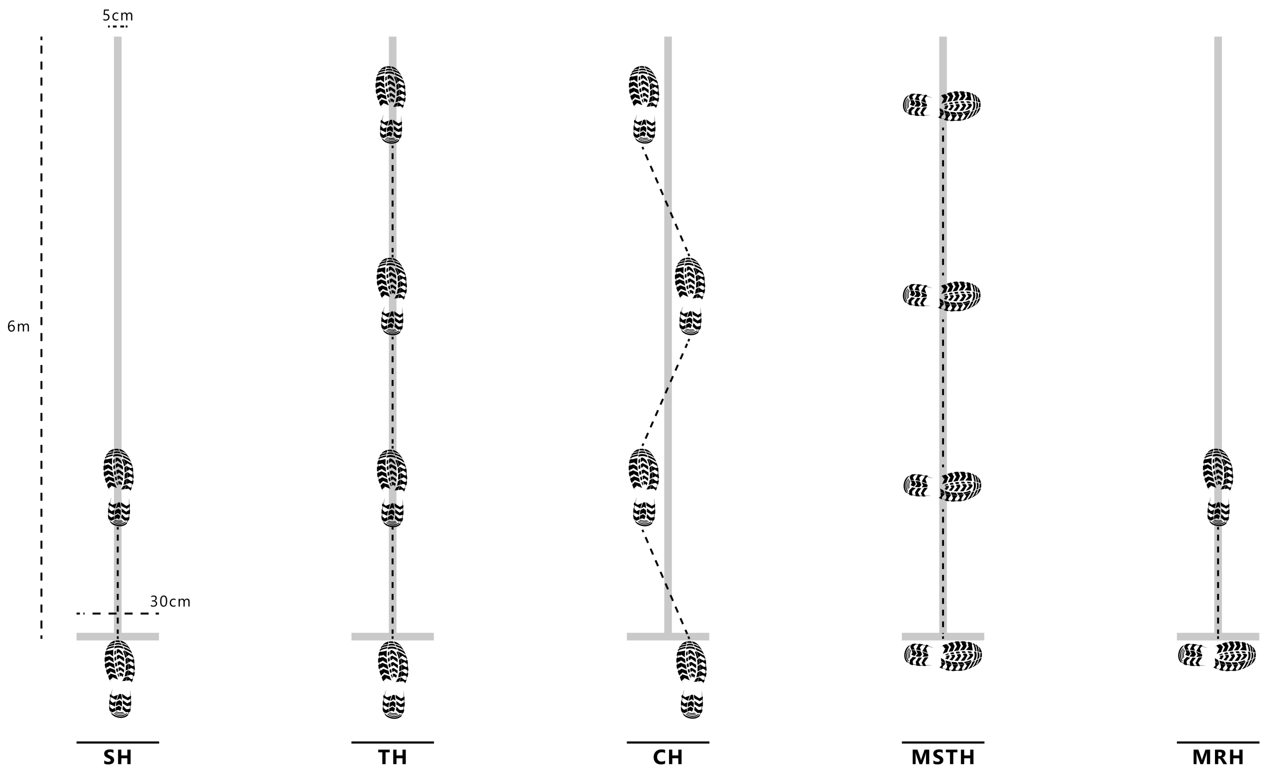


FIGURE 2. Single leg hop tests. SH: single hop for distance; TH: triple hop for distance; CH: cross triple hop for distance; MSTH: medial side triple hop for distance; MRH: medial rotation (90°) hop for distance.

2.4.13 30 m sprint test

The 30 m sprint tests of the athletes were completed by running 30 m with maximum effort between the start and end photocells (±0.01 s accuracy) (Seven, SE-165 Photocell Chronometer, İstanbul, Turkey) at a height of 70 cm on an artificial turf field. Athletes started their sprint 1 m behind the starting photocells. Between two repetitions of the test, 3 minutes of passive rest was performed and recorded in seconds [43].

2.4.14 Running-based anaerobic sprint test (RAST)

Each trial was performed with six 35 m maximum sprints with 10 s recovery between trials. Subjects performed repeated sprints in alternating directions on a grass field under outdoor conditions. Before the test, the subjects warmed up with a 5-minute jogging at a pace of their choice, stretching exercise, and 10–15 m sprints. RAST was evaluated with the variables maximum power, minimum power, average power, and fatigue index [44]. The power output for each trial was determined using the following formula (Eqn. 2):

$$Power = [Weight\,(kg) \times Distance^2\,(m)] \div Time^3\,(s) \quad (2)$$

2.4.15 Rating of perceived exertion (RPE)

RPE is a subjective method used to measure the effort expended by athletes during physical exercise. RPE refers to values between 0–10 or 6–20 and the difficulty levels indicated against them. RPE was collected away from other players within 30 minutes of completing the test session to avoid any peer influence during reporting.

2.5 Statistical analysis

The normality of the data was assessed using the Shapiro-Wilk test, as well as skewness and kurtosis values, and all variables were found to be normally distributed ($p > 0.05$). A Repeated Measures Mixed Design Analysis of Variance (ANOVA) was applied to examine within-factor (time) and between-factor (group) effects, as well as their interaction. Sphericity was evaluated using Mauchly's test, and in cases where the assumption of sphericity was violated, the Greenhouse-Geisser correction was applied (all variables had $\mathcal{E} > 0.75$). *Post-hoc* paired *t*-tests were conducted only for variables showing a significant main effect of time to evaluate pre- to post-intervention changes within each group. For variables showing a significant time × group interaction, the source of the interaction was examined using paired *t*-tests (within-group) and independent sample *t*-tests (between-group), and these results are presented in the figures. No additional *t*-tests were performed for variables where ANOVA did not indicate a significant effect. All previously reported *t*-test results without ANOVA justification have been removed, and figures have been updated accordingly. Descriptive statistics are presented as mean ± standard deviation. Effect sizes were calculated for significant variables ($p < 0.05$). Cohen's d was used for paired (within-group) and independent (between-group) comparisons. Between-group effect sizes were calculated using change scores. Effect sizes were categorized as trivial (<0.20), small (0.20–0.49), moderate (0.50–0.80), and large (>0.80) [45]. All statistical significance was considered at $p < 0.05$. All data were analyzed using the SPSS 27.0 package program (IBM Corp., Armonk, NY, USA).

3. Results

Descriptive data of the subjects are presented in Table 2.

Fig. 3 includes pre- and post-comparisons of body composition between groups. However, the pre- and post-placebo and collagen groups showed similar intra- and inter-group results in all parameters and no statistically significant result was observed ($p > 0.05$).

Pre- and post-GSRS parameters were compared in Fig. 4. Abdominal pain, Reflux syndrome, Diarrhoea syndrome, Indigestion syndrome, Constipation syndrome, and GSRS Total pre- and post-scores did not show a statistically significant difference with similar intra- and inter-group results ($p > 0.05$).

TABLE 2. Descriptive data of study participants.

	Placebo (n = 7) Mean ± SD	Collagen (n = 6) Mean ± SD	*t*	*p*
Age (yr)	21.29 ± 0.95	21.67 ± 1.75	−0.498	0.628
Sport age (yr)	13.14 ± 2.67	10.67 ± 2.73	1.788	0.101
Training age (yr)	11.43 ± 4.04	9.67 ± 3.20	0.860	0.408
Competition age (yr)	9.43 ± 3.74	9.17 ± 2.04	0.153	0.881
Height (cm)	171.71 ± 7.57	172.83 ± 9.99	−0.230	0.822
Pre Weight (kg)	66.44 ± 7.55	73.18 ± 10.20	−1.368	0.198
Post Weight (kg)	67.69 ± 6.77	74.08 ± 9.82	−1.386	0.193
Pre BMI (kg/m^2)	22.54 ± 2.28	24.48 ± 2.49	−1.467	0.170
Post BMI (kg/m^2)	22.96 ± 1.80	24.78 ± 2.19	−1.651	0.127

t: independent samples t test results; SD: standard deviation; BMI: body mass index.

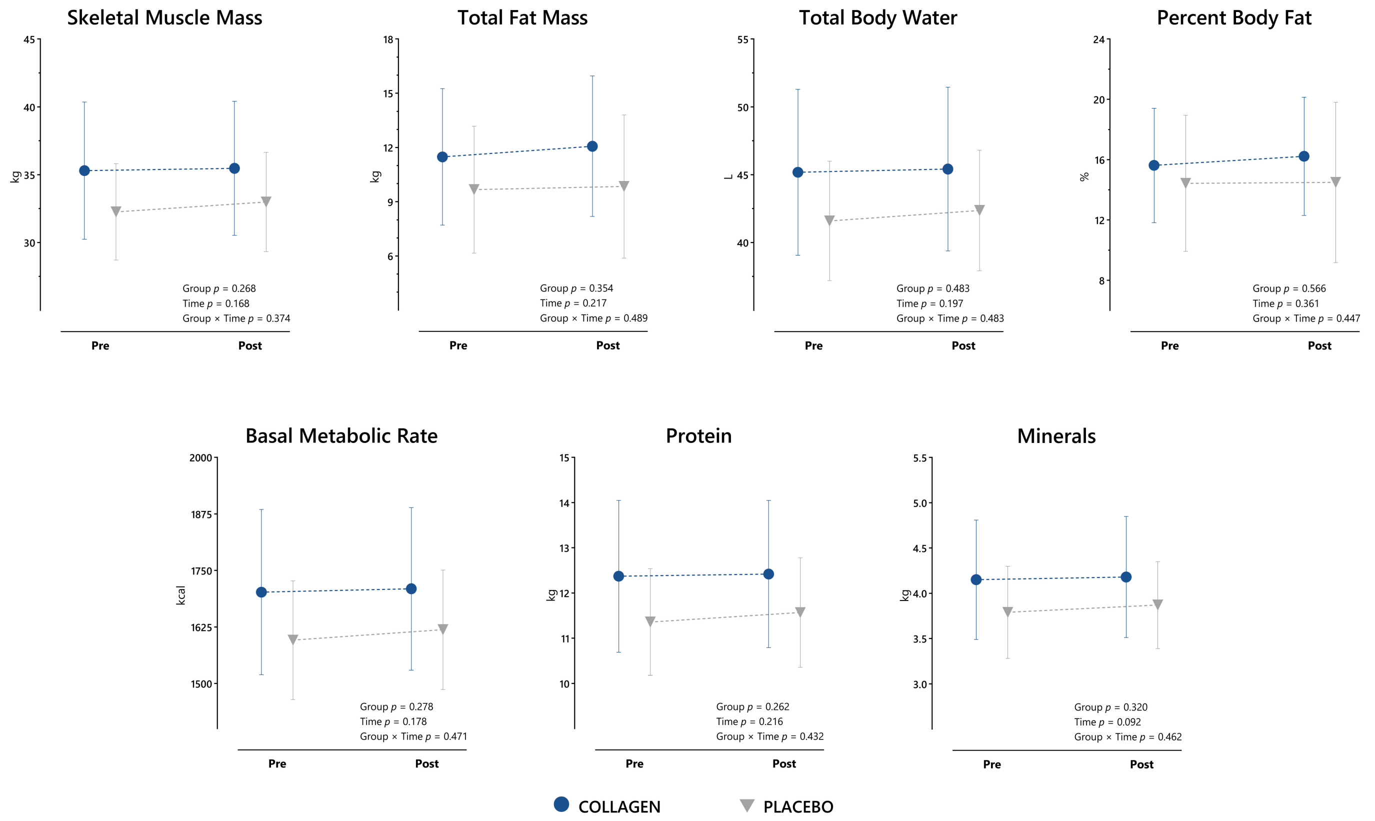


FIGURE 3. Comparison of pre- and post-body composition parameters in placebo and collagen groups.

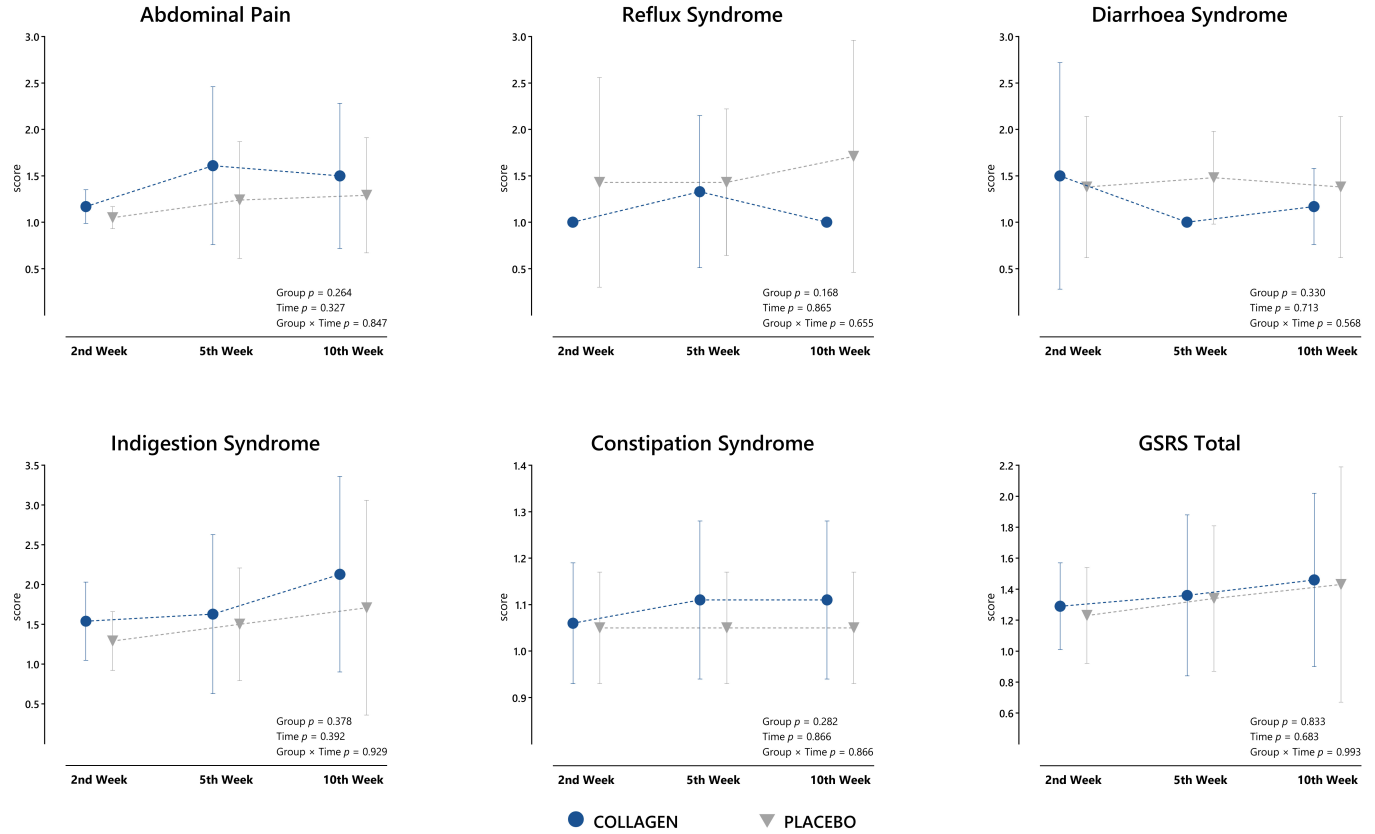


FIGURE 4. Comparison of pre- and post-gastrointestinal symptom rating scale in placebo and collagen groups. GSRS: gastrointestinal symptom rating scale.

Fig. 5 includes a comparison of pre- and post-SLHT and SLHT limb symmetry index (LSI) in the placebo and collagen groups. The time interaction was significant in the MSTH ($p = 0.018$) and MRH ($p = 0.047$) test results on the right side, but there was no significant difference between the pre- and post-test results ($p > 0.05$). On the left side, there was a time interaction in the MRH ($p = 0.046$) test results and a significant difference between the placebo group's pre- and post-test results ($p = 0.045$). Additionally, there was significance in the left side SH ($p = 0.004$) and TH ($p = 0.011$) test results for the group × time interaction and in the placebo group's pre- and post-test results (SH: $p = 0.031$; TH: $p = 0.021$), but there was no significance between groups ($p > 0.05$) (Fig. 5).

Fig. 6 shows the pre- and post-comparison of proprioceptive sensory assessments in the placebo and collagen groups. Significance was found in the time interaction for Right P 30° ($p = 0.010$), Left P 30° ($p = 0.048$), and Left S 30° ($p = 0.043$), but there was no significance between pre- and post-test results ($p > 0.05$). Similarly, there was significance in the time interaction for Right P 15° ($p = 0.006$) and Left S 15° ($p = 0.033$), and there was significance between the pre-post test results of the placebo group ($p = 0.019$; $p = 0.004$). The group × time interaction was significant for Left P 45° ($p = 0.036$) and Left P 60° ($p = 0.028$), and there was a significant difference between groups in the pre-test at Left P 45° ($p = 0.010$), but no significance in the other data ($p > 0.05$) (Fig. 6).

In Fig. 7, Vertical Jump, Isometric Mid-thigh Pull, 30 m Sprint, Sit-and-Reach, RPE, and VAS evaluations in the placebo and collagen groups are shown pre- and post. Time interaction was significant for RPE ($p = 0.001$), VAS ($p = 0.016$), and 30 m Sprint ($p = 0.024$) scores. There was no significant difference between the pre- and post-test results of the groups in the 30 m Sprint test ($p > 0.05$), while there was a significant difference between the pre- and post-test results of the Placebo ($p = 0.007$) and Collagen ($p = 0.037$) groups in the RPE scores. Furthermore, the difference in VAS scores between pre- and post-test results was only significant in the Collagen group ($p = 0.043$) (Fig. 7).

In Fig. 8, RAST parameters are presented pre and post in placebo and collagen groups. There was no statistically significant difference in max power, min power average power, and fatigue index evaluations pre and post within and between collagen and placebo groups ($p > 0.05$).

In Fig. 9, pre- and post-lactate levels, hydration levels, and HR were evaluated in the placebo and collagen groups. There was no statistically significant difference between the collagen and placebo groups or within the groups in terms of lactate levels, hydration levels, and HR assessments ($p > 0.05$).

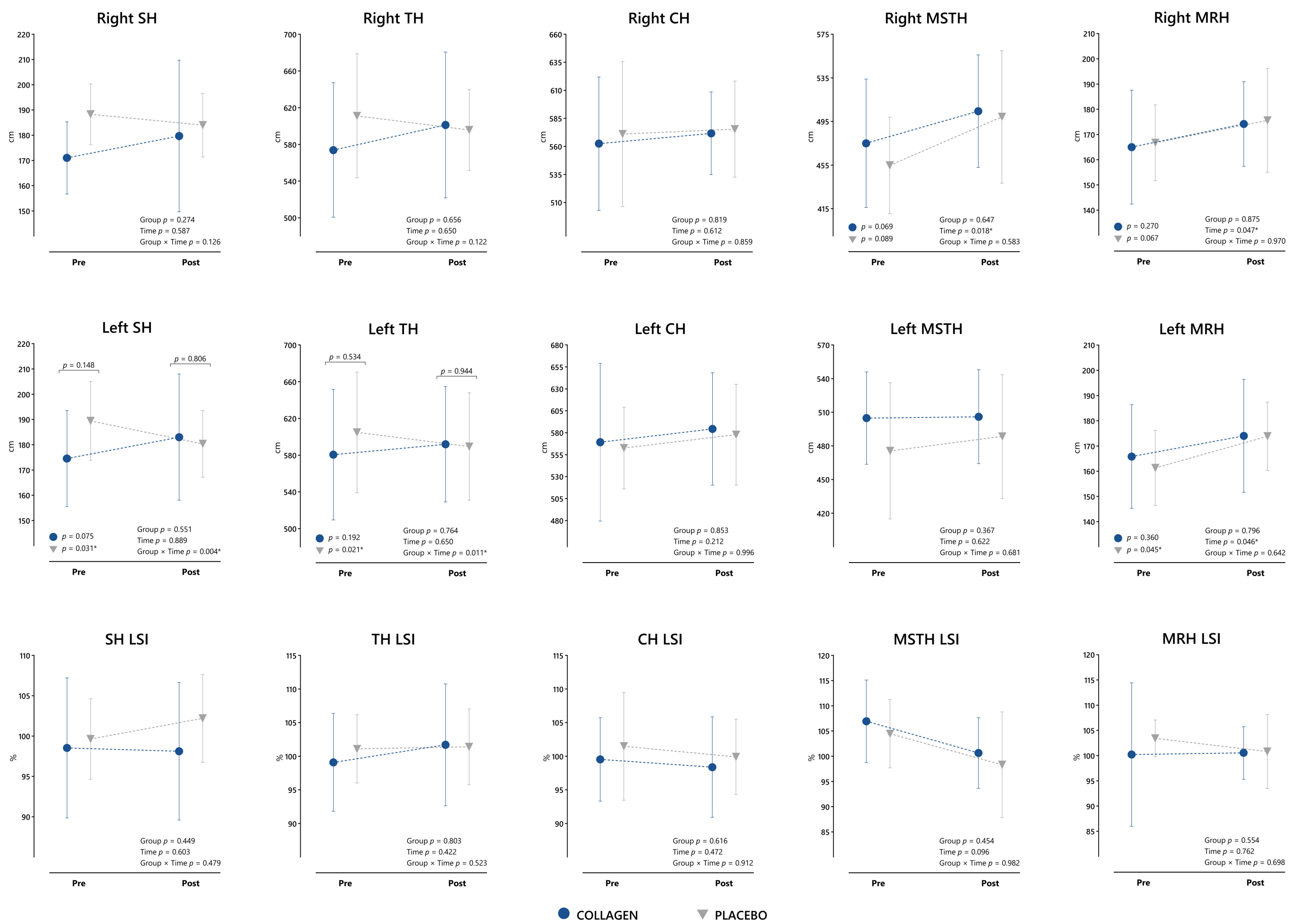
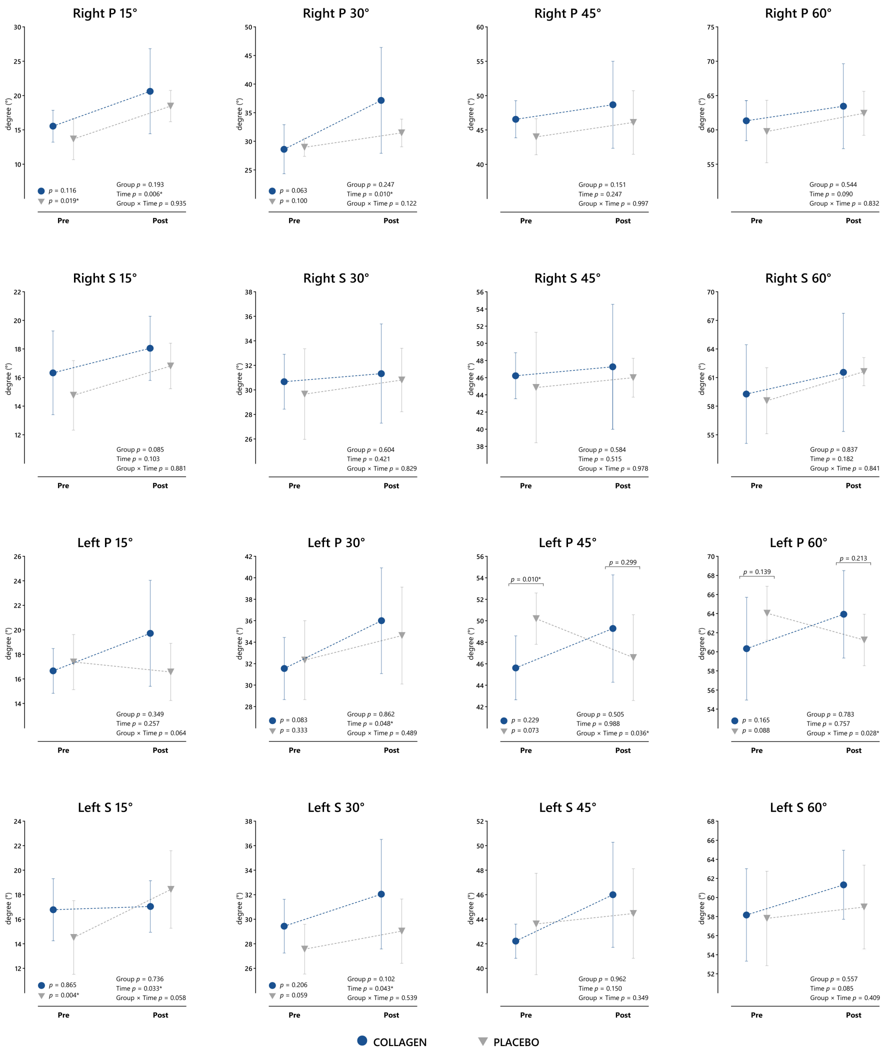
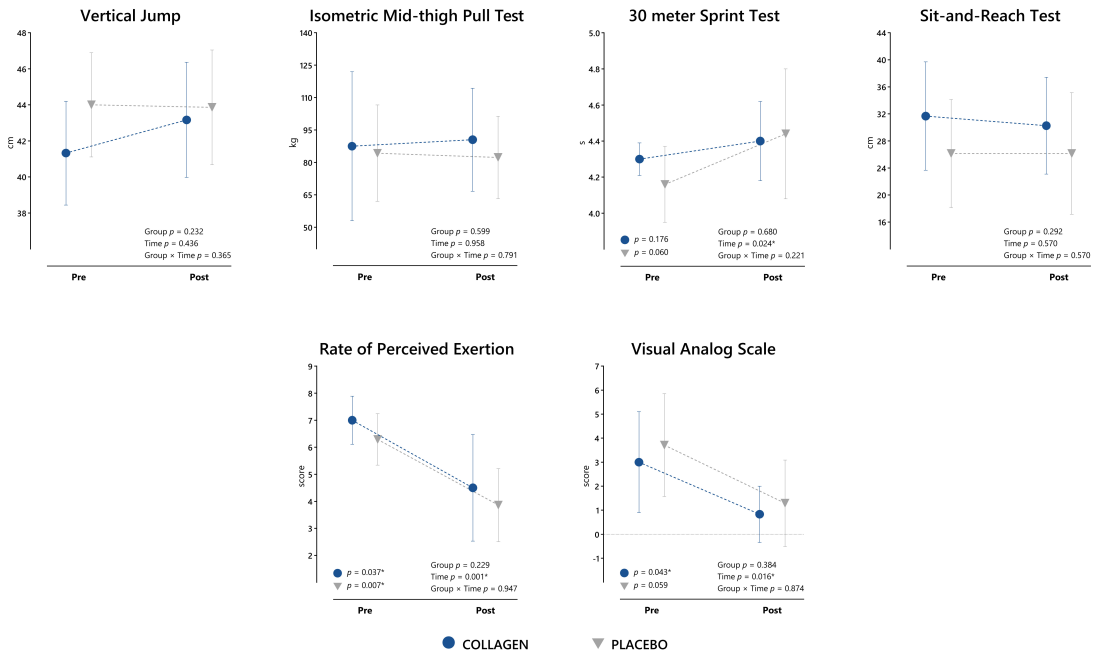


FIGURE 5. Pre- and post-comparison of single leg hop tests and limb symmetry index in placebo and collagen groups. $^*p < 0.05$. SH: single hop for distance; TH: triple hop for distance; CH: cross triple hop for distance; MSTH: medial side triple hop for distance; MRH: medial rotation (90°) hop for distance; LSI: limb symmetry index.



F I G U R E 6. Pre- and post-comparison of proprioceptive sensory assessments in placebo and collagen groups. *$p < 0.05$. P: Prone; S: Supine.



F I G U R E 7. Pre- and post-comparison of vertical jump, isometric mid-thigh pull, 30 m, flexibility, rate of perceived exertion, and visual analog scale assessments in placebo and collagen groups. *$p < 0.05$.

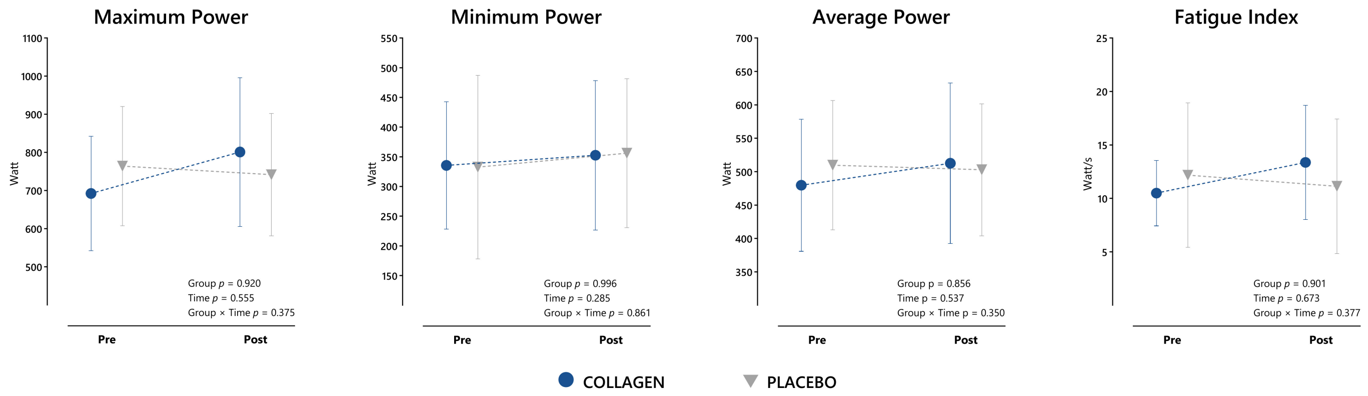


FIGURE 8. Pre- and post-comparison of collagen and placebo group running-based anaerobic sprint test parameters.

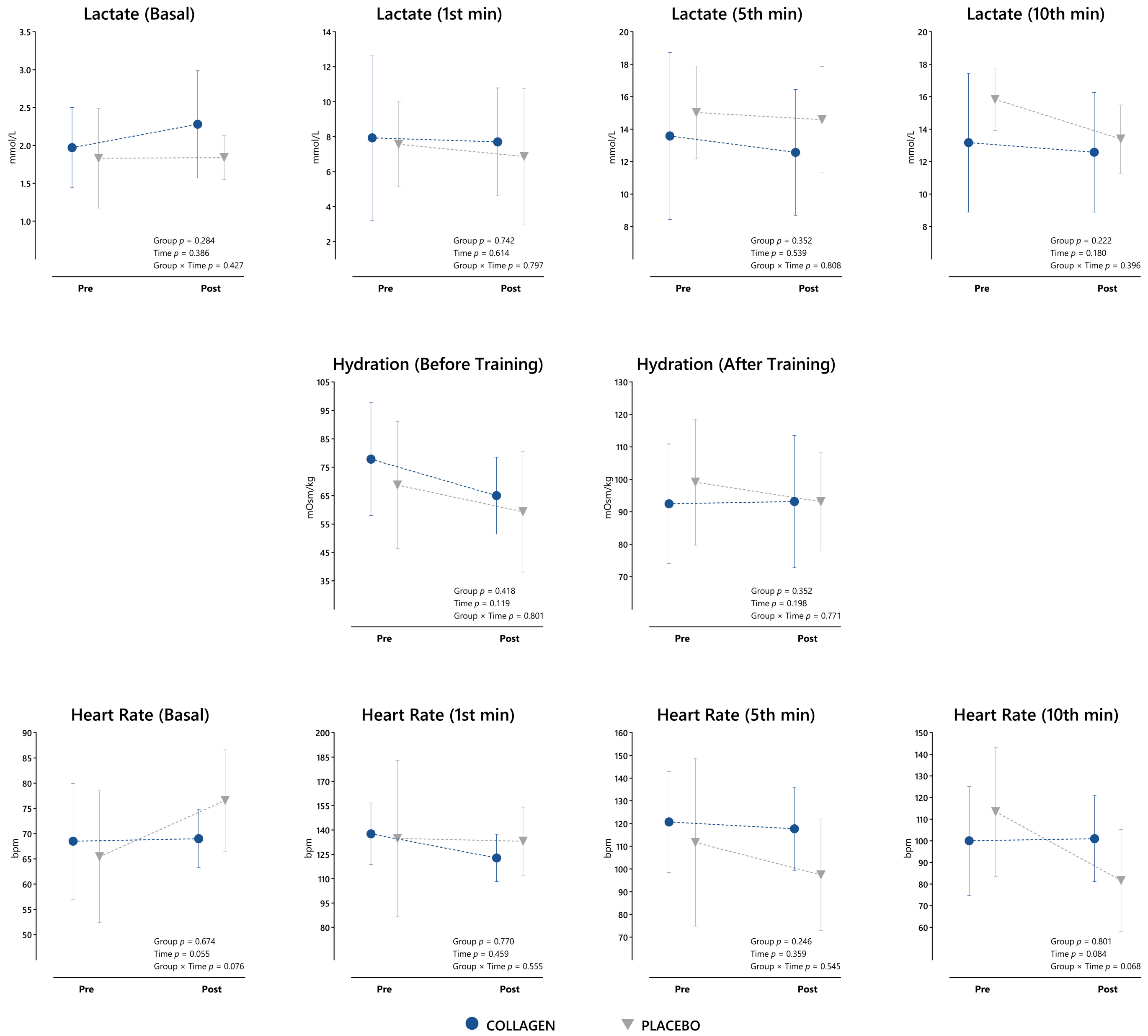


FIGURE 9. Comparison of pre- and post-lactic acid, hydration level, and heart rate parameters in placebo and collagen groups.

4. Discussion

This randomized, placebo-controlled study evaluated the effects of 8 weeks of supplementation with PROFIN® type I and type III bovine collagen peptides on various physical, functional, and metabolic tests and scale results in male soccer players. The main finding of the study was that 8 weeks of collagen supplementation significantly improved pain and perceived exertion levels in male soccer players, but did not produce significant changes in other physical, functional, and metabolic parameters.

The role of nutritional supplements in musculoskeletal health and recovery processes has attracted increasing interest in recent years [46–48]. The effects of collagen supplementation in various joint disorders, such as osteoarthritis and meniscal pathology, have been examined in numerous studies, with results highlighting collagen's potential benefits, particularly in enhancing healing [10, 26, 49–51]. Recently, collagen supplementation has also attracted significant interest in the field of sports nutrition, as it is anticipated to provide potential effects on athletic performance and recovery. Many studies have reported significant effects of collagen supplementation in reducing pain and promoting overall athletic performance [52–55]. Our study results also supported the literature and showed that pain assessed by VAS decreased significantly in the collagen group (Fig. 7). Giraldo-Vallejo *et al.* [7] emphasized that the positive effects of collagen supplementation on pain may be more pronounced, especially when combined with exercise. It has also been reported that athletes may have lower levels of pain perception compared with non-athletes due to their exposure to pain through training [56]. Similarly, in RPE, another self-evaluation-based scale in our study, it was found that collagen supplementation positively affected the level of perceived exertion (Fig. 7). The findings suggest that hydrolysed collagen in particular may alleviate collateral ligament pain and indirectly perceived levels of difficulty through mechanisms that extend beyond purely structural repairs [57]. Although there were no significant differences in physiological markers, the decrease in RPE scores indicates the intervention's modulatory effect on the central nervous system [58]. Furthermore, collagen's effect on physiological and metabolic adaptations is generally described in the literature as a process requiring medium to long-term use (approximately 3–6 months or more) [19]. Therefore, the 8-week collagen supplementation protocol applied in our study represents a relatively short time frame for potential structural or biochemical changes to emerge. This suggests that physiological improvement may not yet have begun or reached a measurable level. Therefore, considering that both pain and perceived exertion level evaluations are based on the subjective judgements of athletes, it should not be ignored that the psychological aspects of individuals may also be effective in the results. Nevertheless, it is important to examine the effects of supplementation, such as collagen, on athletes because their ability to measure and respond to pain and perceived exertion level can significantly influence their motivation and subsequent performance outcomes [59].

Another potential factor supporting athletic performance in athletes is marked as body composition. Therefore, it is important to evaluate the possible effects of collagen supplementation on body composition. Zdzieblik *et al.* [60] emphasized that collagen supplementation, especially when combined with exercise, may be effective in reducing body fat and consequently improving overall body composition. Various studies conducted in different age groups also support this phenomenon [22, 61]. Collagen peptides are thought to prevent lipid accumulation in fat cells by suppressing the expression of adipogenic transcription factors that are crucial for fat cell differentiation and maintenance [22]. However, in our study, collagen supplementation had no specific effect on body fat percentage (Fig. 3). This may be because the subject group had high levels of fitness and physical activity even before the study. In addition, maintaining an appropriate level of hydration during athletic performance can reduce lactate accumulation and favour subsequent heart rate recovery [62, 63]. Therefore, it is important to examine all three parameters together in the evaluation of athlete performance. In our study, the fact that the pre- and post-test results of these parameters maintained similar levels contributed to a more objective evaluation of the study findings.

Joint stability and proprioceptive awareness play a critical role in maintaining balance during high-intensity activities in athletes. Considering collagen's supportive effects on joint health and function, it is thought that it may also have potential contributions to proprioception. However, our study results showed that 8 weeks of collagen supplementation did not cause a significant change in proprioceptive performance (Fig. 5). This finding is consistent with the current literature, which suggests that collagen has no direct effect on neural mechanisms or proprioceptive feedback processes [26, 64]. Proprioception is primarily dependent on neuromuscular adaptations, and this development is usually achieved through targeted neuromuscular training [64]. Collagen's contribution to proprioception can only manifest indirectly through long-term adaptations occurring in structural components such as tendons and connective tissue. Therefore, as an 8-weeks short-term intervention is insufficient for tissue remodelling, the absence of measurable changes in proprioception is an expected outcome.

It has been emphasized that collagen supplementation can positively affect muscle strength and recovery [27]. This suggests that collagen supplementation may have important effects in soccer where explosive strength and endurance are dominant. Hatchett *et al.* [27] have shown that collagen supplementation can improve muscle performance required for activities such as sprinting and shooting. In another study, Lis *et al.* [6] found that the combination of collagen and vitamin C increased the rate of lower extremity strength development, which is very important for movements requiring explosive strength. It is suggested that the combination of hydrolysed collagen and vitamin C may enhance eccentric strength production during jumps and facilitate faster force transmission, possibly due to improved extracellular matrix mechanics in muscles and tendons [6]. It has also been suggested that collagen's effects in helping to maintain tendon integrity and endurance may also support performance in high-impact activities. According to all this evaluation, the potential effects of collagen on various parameters, such as strength, speed, endurance, and explosive power important in athletic performance, were taken into consideration in the selection of performance tests in our study [6, 65, 66]. The study found that collagen supplementation did not cause any difference in SLHT (Fig. 5) and isometric mid-thigh pull (Fig. 7) tests. Our study findings clearly showed that collagen supplementation was not effective in both forward and multidirectional SLHTs, and also did not affect lateral asymmetries. As stated in the literature, the main purpose of SLHTs is to reveal the functional strength and asymmetry rates of athletes [67]. In healthy subjects, asymmetry rates are similar in all test types. For this reason, our current study showed that collagen supplementation did not affect the asymmetry ratios related to muscle strength and anaerobic power. In addition, the literature emphasizes the importance of nutritional strategies in improving anaerobic performance [66, 68]. In this context, our study included various anaerobic test results, such as RAST and vertical jump, and evaluated the possible effects of collagen supplementation. The results showed that collagen supplementation did not reveal a significant difference in both anaerobic test results and the corresponding lactate levels (Figs. 8,9).

Although the results of the study showed that collagen supplementation in general did not reveal significant differences, some limitations of the study may have played a role in this. The fact that the number of subjects in the study was close to the minimum threshold considered appropriate by the power analysis may be an important shortcoming in the evaluation of possible specific effects of supplementation. In addition, when the studies in the literature are examined, it is seen that the combined effects of collagen with various training methods are focused. Therefore, the individual training effects of the soccer players in our study may have caused differences in the results. In addition, the differences between the nutritional routines of the athletes may have been effective on the results. In addition, body weight and body mass index (BMI) were higher in the collagen group at the baseline compared with the placebo group, which may have affected performance tests and metabolic markers. Evaluating the injury history of the athletes on the basis of verbal statements and including them in the study accordingly may be another limitation of the study since it carries possible objectivity risks. Although the potential effects of collagen supplementation on muscle performance have been emphasized, it should not be overlooked that this may depend on many different variables, such as dose, duration of supplementation, sport, training frequency, health screening conditions, biochemical markers, gender, and age. Given that the physiological effects of collagen types I and III occur predominantly in tendons, connective tissue, and skin, the inclusion of young, healthy athletes without joint problems may have resulted in a limited response to collagen supplementation. However, the recent prominence of collagen use among athletes highlights the importance of selecting appropriate assessment tests to identify potential effects, and in this regard, there is a need for further studies focusing on collagen supplementation in athletes. Furthermore, the fact that collagen was administered over an 8-week period may have been insufficient to fully reveal the long-term physiological, functional, and performance-related effects of the supplement. In future studies, the evaluation of collagen supplements both directly and in combination with various training programs may contribute to a clearer understanding of the mechanisms of action. Moreover, it is important to evaluate supplements with a relatively higher number of subjects of different ages, genders, and sports branches to reveal the different effects of collagen. In addition, in studies to be conducted in different sports branches, the selection of branch-specific tests will be decisive in terms of examining the potential effects of collagen supplementation more clearly. Since the literature on collagen supplements for athletes is still quite limited, long-term follow-up, different doses, and comprehensive test selection in new studies may play an important role in determining potential effects and revealing normative values.

5. Conclusions

Our study showed that 8 weeks of collagen supplementation contributed to improvements in the subject-reported assessments of pain and perceived exertion in male soccer players. However, there was no specific effect of collagen supplementation on other physical, functional, and metabolic parameters. The findings of this study should be interpreted with caution due to the limited sample size, the evaluation of numerous variables in a small-scale randomised controlled trial, and the limited control over diet and training. The results should be regarded as exploratory findings indicating the potential effects of collagen supplementation in young athletes, rather than providing definitive conclusions. Larger and more controlled studies are required to validate these findings.

ABBREVIATIONS

BMI, body mass index; CH, cross triple hop for distance; EMG, electromyography; GSRS, gastrointestinal symptom rating scale; HR, heart rate; LSI, limb symmetry index; MRH, medial rotation (90°) hop for distance; MSTH, medial side triple hop for distance; P, prone; RAST, running-based anaerobic sprint test; RPE, rating of perceived exertion; S, Supine; SD, Standard Deviation; SH, Single Hop for Distance; SLHT, single leg hop tests; TH, triple hop for distance; VAS, visual analog scale; ANOVA, Analysis of Variance; CONSORT, Consolidated Standards of Reporting Trials.

AVAILABILITY OF DATA AND MATERIALS

Data supporting the findings of this study are available through the corresponding author, but restrictions apply to the availability of these data used for the current study and are therefore not publicly available. However, data are available from the corresponding author (akdemrenes@gmail.com) upon reasonable request.

AUTHOR CONTRIBUTIONS

SA, EA, BA, EKS, DK, AM, ZK, GK, AE, SHA and AKY—wrote the first draft of the manuscript and the revised

manuscript. AM, ZK and GK—completed the data analysis and suggested revisions to the manuscript. SA, AKY and SHA—participated in the design of the study and performed the statistical analysis. EA, BA, EKS, DK and AKY—conceived of the study and participated in its design and coordination and helped to draft the manuscript. EA, BA, EKS, DK and AE—completed the visualization. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was designed according to CONSORT guidelines and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and ICH Good Clinical Practice guidelines. Ethics committee approval was obtained from Sinop University Human Research Ethics Committee (protocol no: 2023/181) and registered in the Iranian Clinical Trials Registry on 13 December 2024 with the number IRCT20240411061470N5. Participants were included in the study after written informed consent forms were collected.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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