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ORIGINAL RESEARCH

The effects of a combined recovery strategy during a match-congested period crossing Ramadan: a repeated measurements crossover study among professional male basketball players

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Abstract

Background: A good recovery process is a key factor to avoid fatigue and sports-related injuries in Muslim male basketball players, especially during some decisive phases of the sport season, such as the match congestion period coinciding with Ramadan intermittent fasting (RIF). The aim of the current research was to evaluate the effects of a combined recovery strategy involving 45-minute daytime napping and cold-water immersion during a basketball match congestion period coinciding with RIF on hormonal variations, perceived exertion (RPE), total quality of recovery (TQR) and wellbeing indices. **Methods**: The present study used a repeated measurements crossover design, and three male professional basketball teams were chosen, totaling 42 players. The first team used combined recovery (COMB, n = 14), the second team had a 45-minute napping (NAP, n = 14), and the third team served as the active control group (CON, n = 14). High adherence rates were observed across groups. Participants were evaluated through the initial and final weeks of the RIF for changes in testosterone (T), cortisol (C), RPE, TQR, and wellbeing indices (sleep, tiredness, stress and delayed onset of muscular soreness (DOMS)) as primary objectives. Secondary outcomes from the investigation were dietary intake, body composition and sleep quality. **Results**: The main results showed a significant decline in T/C ratio among the three groups at the conclusion of the trial ($p < 0.001$ with trivial effect size). Moreover, COMB had significantly better outcomes in RPE, TQR and DOMS compared to NAP and CON ($p < 0.001$ with a (trivial/small) effect size). **Conclusions**: This analysis revealed that the implemented combined recovery strategy may serve as a valuable recovery approach for athletes undergoing congestion game periods crossing the RIF.

Keywords
Fatigue; Performance; Sleeping; Ramadan intermitting fasting; Nutrition

1. Introduction

Basketball, like any other team sport, may face severe conditions throughout a season, such as increased game frequency, an in-season tournament, qualifying periods, or, in some countries, Ramadan intermittent fasting (RIF). During these times, professional athletes frequently train or compete on consecutive days. Each training session or match places a tremendous physical strain on players due to frequent high-intensity exercise, leaping, and the possibility of muscle injury from eccentric loadings [1, 2]. Several studies have demonstrated that some of these variables, such as an elevated game frequency period [3] or RIF [4], may impact players' recovery throughout the competitive season, particularly if they occur concurrently (*e.g.*, higher game frequency during the RIF among Muslim players) [5, 6]. In reality, the RIF is characterized by considerable changes in sleep, lifestyle rhythms, body composition, metabolic markers and physical activity level, all of which have been shown to impact athletic performance [4, 7–12].

During this phase, coaches and athletic trainers should control workloads and implement suitable recovery procedures to achieve peak performance, minimize injuries and maintain drowsiness [3, 4, 13]. However, the literature on this topic yields conflicting results, with some authors arguing that RIF changes may necessitate a reduction in the training load undertaken by Muslim athletes, while others report that basketball players can maintain good performances while training at the prescribed load [4, 5]. As a result, further research employing novel methodologies is required to determine what it takes to increase player performance and manage tiredness during these important intervals.

Taking a diurnal siesta was shown to be a successful technique for reducing fatigue and improving physical and cognitive function during the RIF [14–16]. Furthermore, several studies investigated the effect of sleep extension and napping in basketball players [13, 17, 18], and found that an increase in nap duration (40 minutes) was associated with a lower subjective sensation of fatigue as well as improved reaction time, sprint speed, shooting accuracy, free throw percentage and three-point percentage [17, 18]. Previous research has shown that stress can be caused by an increase in cortisol (C) and a drop in testosterone (T) levels [11], both of which are important components of chronic psychological and physical stress reactions [19, 20]. Testosterone and cortisol are part of the biological balance that governs psychologically and physically integrated human responses, and they are extensively investigated in sports medicine by assessing the T/C ratio as a marker of anabolic/catabolic activity [7, 11]. As another relevant method to counteract fatigue, Seco-Calvo *et al.* [21], reported that cold-water immersion is an effective strategy to reduce delayed onset muscle soreness (DOMS), and may improve recovery from muscle damage in professional basketball players during a regular season. This soreness is defined as a type I muscle strain injury and is characterized by tenderness and stiffness to palpation and/or movement [22]. Furthermore, Li *et al.* [23], found that during replicated game circumstances, amateur basketball players experienced a better and more persistent recuperation response from cold water immersion, despite early unfavorable effects. In the same context, previous study reported a shorter return to baseline performance in basketball players after exhaustive exercise [24].

Yet, to the best of our knowledge and according to the reports in the relevant literature, no prior research has been done on the effectiveness of a combined recovery strategy based on 45 days of sleep and cold-water immersion during a congested basketball game period bridging RIF which makes this subject crucial for coaches to effectively oversee workouts and prevent the consequences of exhaustion during such exigent conditions. Thus, this investigation's main objective was to find out how well a combined recovery strategy during a congested basketball game period crossing RIF affected professional basketball players' testosterone (T)/cortisol (C) ratio, perceived exertion (RPE), total quality of recovery (TQR), and wellbeing indices (sleep, fatigue, stress and delayed onset of muscular soreness (DOMS)). Moreover, sleep quality, body composition and food consumption were assessed throughout the experimentation as secondary outcomes. Taking into account the prior studies [3–5, 18, 24], it was expected that a combined recovery process during a congested basketball game period crossing RIF will reduce fatigue by improving the hormonal balance (T/C ratio), RPE, TQR and the wellbeing indices.

2. Methods

2.1 Study design and setting

The present investigation was carried out using a repeated measurements crossover design, and three professional male basketball teams from the Tunisian first division were chosen, totaling 42 players. The first team used combined recovery (COMB, n = 14), the second team had a 45-minute napping (NAP, n = 14), and the third team served as the active control group (CON, n = 14). During the entire duration of the experimental period, The COMB performed 45-min nap before each training session and game combined with cold-water immersion after training sessions and games. The NAP performed 45-min nap before training sessions and games while the CON continues their regular daily routine with no nap/cold water-immersion control. In terms of the napping procedure, participants went to bed around 13:45 in rooms that were quiet, dimly lighted, and generally between 22 and 25 °C to encourage sleep. Participants had 15 minutes to become used to the space before being invited to take a 45-minute nap. Since this time is linked to a marked decline in alertness and an increase in sensations of drowsiness, napping time began at 14:00. In order to give participants adequate time to prevent sleep inertia, the current study similarly chose 14:00 [25]. A licensed professionals from the staff oversees each room to ensure that everyone takes a 45-minute nap throughout the trial time and reports any instances in which the nap is broken. Five minutes after the match ended, the lower limb (up to the iliac crest) was intermittently submerged five times for two minutes in a cold-water bath at 11 °C. The immersion was followed by a two-minute rest period in ambient air (sitting, room temperature at 20 °C) [24]. Ice was added to the bath at regular intervals to maintain the temperature at 11 + 0.7 °C. The water was continuously circulated by a jacuzzi system to keep warmer layers from accumulating close to the participants' bodies [24]. The participants were instructed to remain still in the bath. On the other hand, during the study period, which was strictly observed by the research members, CON did not snooze or have any chance to immerse themselves in cold water.

2.2 Study participants

For this investigation, 42 professional male basketball players from three First Division clubs in Tunisia volunteered (Table 1). Prior to the experiment, each of the three teams had around eight hours of practice per week and (13.12 ±

TABLE 1. Anthropometric parameters of the participants.

Groups	Age (yr)	Height (m)	BM (kg)	BMI (kg/m^2)
COMB (n = 14)	25.5 ± 2.4	1.99 ± 0.06	90.86 ± 5.72	23.04 ± 1.02
NAP (n = 14)	25.3 ± 2.3	1.98 ± 0.05	89.41 ± 5.77	22.86 ± 1.50
CON (n = 14)	25.7 ± 2.6	1.97 ± 0.06	89.64 ± 6.59	23.01 ± 0.68

Standard deviations and means are used to report data. COMB: combined recovery strategy group; NAP: 45-minute napping group; CON: control group; BM: body mass; BMI: body mass index.

1.21) years of training history. An a priori power calculation (G*Power Version 3.0, University of Dusseldorf, Dusseldorf, NRW, Germany) indicates that a power of 0.80 requires a minimum sample size of 12. Basketball players' technical and physical skill sets are known to be greatly impacted by their activities on the court, therefore before to the study's commencement, participants completed a series of tests to ascertain their initial levels of skill and physical fitness [26]. Baseline testing revealed no discernible differences between the groups. Research participants had to meet the subsequent requirements in order to be eligible: (1) participate in at least 90% of the workouts; (2) fast as Islamic religion during the RIF; (3) be in excellent condition (no suffering or serious injuries); and (4) not use drugs, ergogenic aids or other substances. The flow chart of the study design was represented in Fig. 1. The study was done throughout the competitive season and was authorized by the local Clinical Research Ethics Committee of the Higher Institute of Sports and Physical Education of Kef, University of Jendouba, Kef, Tunisia (permission No. 9/2018), with the procedure following the Declaration of Helsinki (World Medical Association, [27]). All individuals gave written informed consent to participate in the study.

2.3 Procedures and study training

The present experimentation was carried out in 2021–2022 sport season and spanned four weeks in length. The RIF started in April 2022, and the trial phase lasted until May 2022. Days of fasting lasted 15–16 hours, with exercise sessions taking place between 5:00 and 6:30 PM with temperatures of 25.3 ± 3.4 °C and 43.1 ± 9.8% relative humidity. Both groups played two games per week (on Wednesday and Saturday) and worked out four times a week during the RIF period. Players were completely conversant with every technique prior to starting the trial. Training sessions were conducted at the same time of day to lessen the effect of daily variations. Participants were required to wear the same pair of shoes for each testing session. Each group's training session began with dynamic stretching, skipping exercises and low-intensity jogging for five minutes. Fundamental basketball movements, specialized techniques, technical principles and fundamental defensive movements were the next topics of technical and tactical drills for the groups. The participants in the research exercised for around 90 minutes per session. Participants were evaluated through the initial and final weeks of the RIF for changes in testosterone (T), cortisol (C), RPE, TQR and wellbeing indices (sleep, tiredness, stress and delayed onset of muscular soreness (DOMS)) as primary objectives. Secondary outcomes from the investigation were dietary intake, body composition and sleep quality (Fig. 2).

2.3.1 Internal load monitoring

The session rating of perceived exertion (RPE) training score was obtained after every workout to see if the participants' overall workload during training was constant throughout the trial. According to the protocols described by [28], the participants were asked to rate the overall intensity of the exercises and games using the category ratio-10 RPE scale around 30 minutes after the training sessions. By multiplying the session RPE by the duration (minutes), we were able to construct a daily training/game load. The weekly load was calculated by adding the daily loads for each athlete for each week. RPE has an intraclass correlation coefficient (ICC) of 0.92. Heart rate was monitored using heart rate (HR) monitors (Polar Team Sport System®; Polar-Electro OY, Kempele, Finland) every five seconds during the training session. In an attempt to prevent errors in HR tracking, all players were encouraged to often check their HR monitors throughout training sessions and games. The HR data was represented using both absolute HR and the percentage of HRmax (%HRmax). The HR data were relativized using the HRmax that each Yo-Yo Intermittent Recovery Test Level 1 (Yo-YoIR1) participant submitted. The %HRmax was determined using the equation that follows: %HRmax = (HRmean/HRmax) × 100%. HRavg or HR average, was selected as the variable. The mean values for the entire week of each duration was then used to compute the weekly HRavg.

2.3.2 Study anthropometric measurements

With a regular adjustment of the electronic weighing system, body mass was measured in kilograms with an accuracy of 0.1 kg. The players were measured wearing loose clothing along with no footwear. With an accuracy of 0.1 centimeters, height was measured utilizing a transportable stadiometer (Seca®, Maresten, UK). Next, the body mass (kg) was divided by the square of the height (m) to get the body mass index (BMI). Using pliers (Harpenden® caliper), the four skin folds technique (biceps, triceps, subscapular and suprailiac skin folds) was used to calculate the body fat percentage. Body density was computed using the following equation: (0.29288 × sum of all the skinfolds (mm)) − (0.0005 × sum of all the skinfolds squared) + (0.15845 × age (years)) − 5.76377. Body density can be used to estimate body fat percentage: (BF%) = (4.95/body density − 4.5) × 100 [29]. The International Society for the Advancement of Kinanthropometry's (ISAK) guidelines were followed for taking anthropometric measurements. A competent technician took all of these measures.

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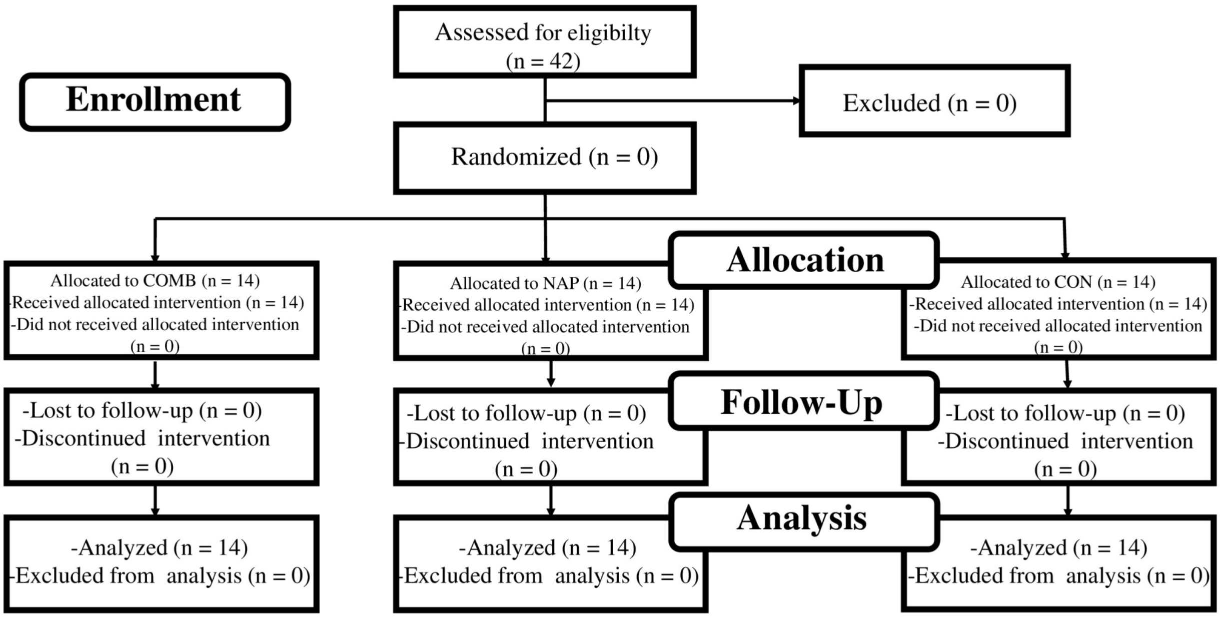

FIGURE 1. Flow graphic represents the study's progression through the periods in accordance with the CONSORT declarations. COMB: combined recovery strategy group; NAP: 45-minute napping group; CON: control group.

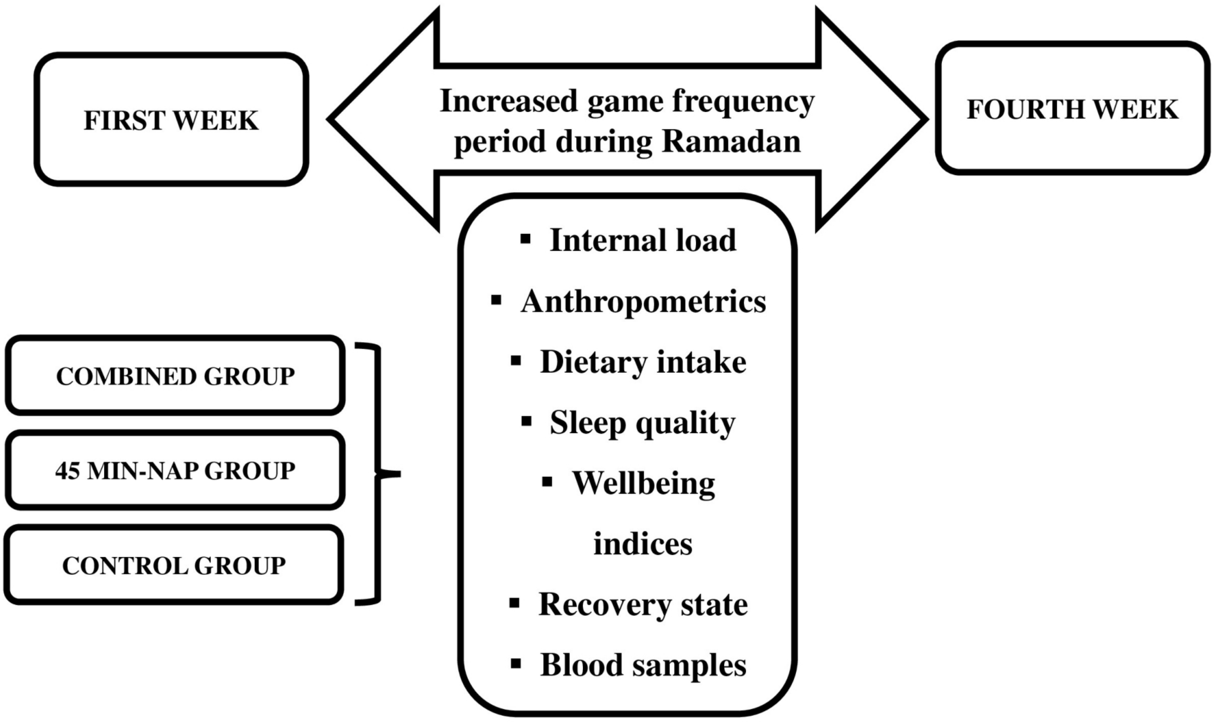

FIGURE 2. Experimental design. NAP: 45-minute napping group.

2.3.3 Dietary intake

A professional sports nutritionist interviewed and examined the participants, who also kept a record of all the meals they had during the trial, including the kinds and quantities of food and liquids they had taken. The food-composition tables of the Tunisian National Institute of Statistics (1978) and the software program Bilnut (S.C.D.A. NUTRISOFT-BILNUT, version 2.01, Cerelles, France) were used to examine the results.

2.3.4 Pittsburgh sleep quality index

Overall sleep quality over the preceding month was assessed using the approved Arabic form of the Pittsburgh Sleep Quality Index (PSQI) [30, 31]. Nineteen questions were included in the test, addressing the following seven aspects of sleep: length, quality, latency, efficiency, disruptions, dysfunction throughout the day and usage of sleeping pills. The overall score is a number between 0 and 21, where 0 means there are no issues and 21 means there are serious issues with all aspects of sleep. PSQI has an ICC of 0.89.

2.3.5 Psychometric markers

Each participant was asked to rate their level of well-being (sleep quality, exhaustion, stress and DOMS) fifteen minutes before to the warm-up. These ratings were to be completed taking into account the time interval between the end of the last training/game session and the start of the current one. Participants scored each index on a seven-point scale: 1 represented "very, very low" (fatigue, stress and DOMS) or "good" (quality of sleep), and 7 represented "very, very high" (fatigue, stress and DOMS) or "bad" (quality of sleep) [32]. The Hooper index (HI) was computed using the total of these four scores. An increased HI score denotes a more unfavorable level of wellbeing. For the parameters examined in this investigation, the ICC varied between 0.72 and 0.88, suggesting excellent reliability. The TQR scale was used to assess each player's recovery level once they had finished their well-being indices [33]. Six on the TQR scale denotes "very, very poor recovery", while 20 signifies "very, very good recovery". This measure has been used to measure athletes' reported recovery in earlier research [33]. TQR has an ICC of 0.87.

2.3.6 Blood samples

As a way to evaluate the levels of both testosterone and plasma cortisol, blood samples were drawn from the antecubital vein while the subject was fasting throughout the first and fourth weeks of the RIF at the same time of day (between 09:30 and 10:00 AM). On Thursdays, 48 hours following the most recent intense training session, blood was collected. The serum sample was kept at −20 °C until it was analyzed. The ELFA (Enzyme Linked-Fluorescent-Assay) was used to assess the levels of testosterone and cortisol by a computerized analyzer approved kits.

2.4 Statistical analysis

Both the mean and the standard deviation (SD) of the data are displayed. The Shapiro-Wilk test (<50) was used to evaluate and validate the data's normality. To verify if the data were homoscedastic, the Levene test was used. With a one-way analysis of variance (ANOVA), baselines for group differences were calculated. Initially, a 3 (groups: COMB, NAP, CON) × 2 (time: first week of RIF, fourth week of RIF) repeated measures ANOVA was conducted to examine the change (first week to fourth week) of hormonal and psychometric variables. *Post-hoc* Bonferroni adjusted tests were computed if a statistically significant interaction effect was discovered. Furthermore, partial eta-squared was converted to Cohen's d in order to calculate effect sizes (ES) from the ANOVA result [34]. Hopkins *et al.*'s [35] findings led to the classification of ES as trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), big (1.2–2.0) and very high (2.0–4.0). $p < 0.05$ was designated as the significant level. SPSS for Windows, version 20.0 (SPSS Inc®., Chicago, IL, USA), was used when performing all statistical analyses.

3. Results

Everyone who participated finished the study without suffering any permanent damage or incapacitating discomfort over the whole trial period. For all variables, there were no between-group differences at the beginning of the experimentation.

Table 2 shows the variations in body composition and the predicted daily food consumption across the experimentation. For BF%, there was a significant group × time interaction ($p <$ 0.001, ES = 0.51, small). For all three groups, at the conclusion of the experimental period, bonferroni-corrected *post hoc* tests showed a significant decline (COMB: −13.46%, $p < 0.001$, ES = 0.29, small; NAP: 8.12%, $p < 0.001$, ES = 0.21, small; CON: 2.72%, $p < 0.05$, ES = 0.16, trivial, respectively). Regarding the amount of carbohydrates consumed, a significant group × time interaction was found ($p = 0.01$, ES = 0.36, small). The three groups revealed a significant reduction according to the results of the Bonferroni-corrected *post hoc* tests (COMB: −8.41%, $p < 0.001$, ES = 0.52, small; NAP: 3.63%, $p < 0.001$, ES = 0.24, small; CON: 2.39%, $p < 0.001$, ES = 0.31, small).

After four weeks of RIF, Table 3 displays changes in internal load, recovery state, well-being indices and sleep quality. A noteworthy group × time interaction was seen for RPE (p = 0.017, ES = 0.35, small). The RPE of both groups increased significantly, with a lower value favoring COMB (COMB: 13.02%, $p = 0.001$, ES = 0.16, trivial; NAP: −13.63%, $p < 0.001$, ES = 0.14, trivial; CON: −24.06%, $p < 0.001$, ES = 0.15, trivial; respectively), according to Bonferroni-corrected *post hoc* tests. Regarding the HR average, there was also a significant group × time interaction ($p = 0.011$, ES = 0.40, small). An analysis of the three groups' HR averages using Bonferroni-corrected *post hoc* tests showed a substantial decrease (COMB: −1.36%, $p < 0.001$, ES = 0.28, small; NAP: 1.50%, $p < 0.001$, ES = 0.27, small; CON: 0.84%, $p < 0.001$, ES = 0.17, trivial, respectively). For TQR and DOMS, there were noteworthy group × time interactions ($p = 0.011$, ES = 0.39, small; $p = 0.033$, ES = 0.29, small; respectively).

For both of the groups, the results of the Bonferroni-corrected *post hoc* tests showed a significant increase in DOMS and a significant decrease in TQR, with a better value for COMB (COMB: −25.06%, $p < 0.001$, ES = 0.42, small; NAP: 26.08%, $p < 0.001$, ES = 0.48, small; CON: 35.06%, $p < 0.001$, ES = 0.49, small; COMB: 129.62%, $p < 0.001$, ES = 0.22, small; NAP: −99.03%, $p < 0.001$, ES = 0.25, small; CON: 156.77%, $p < 0.001$, ES = 0.31, small; respectively).

Figs. 3,4,5 illustrate changes in T, C, and T/C over the trial phase. For T, there was a significant group × time interaction ($p = 0.50$, ES = 0.26, small). For each of the three groups, the end-of-period Bonferroni-corrected *post hoc* tests showed a significant decline (COMB: −5.70%, $p < 0.001$, ES = 0.09, trivial; NAP: −4.65%, $p < 0.001$, ES = 0.006, trivial; CON: −11.05%, $p < 0.05$, ES = 0.18, trivial, respectively). For C, there was a significant group × time interaction ($p = 0.001$, ES = 0.54, moderate).

When the three groups' experimental phases came to end, the results of Bonferroni-corrected *post hoc* tests showed a substantial drop (COMB: 53.11%, $p < 0.001$, ES = 8.23, very large; NAP: 45.96%, $p < 0.001$, ES = 8.75, very large; CON: 70.2%, $p < 0.001$, ES = 4.95, very large, respectively).

TABLE 2. Body composition and estimated daily dietary intake recorded during the experimental period.

Variables	First week			Fourth week			p value (ES)		
	COMB	NAP	CON	COMB	NAP	CON	Time	Group	Group × Time
Body mass (kg)	90.86 ± 5.72	89.4 ± 5.8	89.6 ± 6.7	86.71 ± 5.77	85.5 ± 5.9	85.1 ± 7.3	<0.001 (0.97)	0.538 (0.03)	0.456 (0.05)
BMI (kg/m^2)	23.04 ± 1.02	22.9 ± 1.5	23.0 ± 0.7	21.98 ± 1.06	21.8 ± 1.6	21.9 ± 0.9	<0.001 (0.97)	0.869 (0.006)	0.415 (0.05)
Body fat (%)	12.32 ± 2.26	12.1 ± 2.3	12.3 ± 2.5	10.59 ± 1.72	11.1 ± 2.0	12.0 ± 2.5	<0.001 (0.75)	0.246 (0.10)	<0.001 (0.51)
Total energy intake (kcal)	2804.29 ± 147.69	2766.4 ± 173.0	2811.4 ± 92.5	2252.14 ± 215.62	2217.9 ± 183.7	2369.3 ± 175.4	<0.001 (0.90)	0.039 (0.21)	0.337 (0.08)
Carbohydrate intake									
(g)	312.86 ± 20.54	310.7 ± 19.8	309.3 ± 16.9	285.71 ± 15.04	284.3 ± 16.0	297.1 ± 14.9	0.001 (0.62)	0.366 (0.07)	0.009 (0.36)
(%)	44.72 ± 3.43	45.1 ± 3.6	44.0 ± 2.6	51.21 ± 5.95	51.6 ± 5.6	50.4 ± 3.9	<0.001 (0.66)	0.419 (0.06)	0.959 (0.001)
Protein intake									
(g)	87.86 ± 5.36	88.2 ± 5.0	86.5 ± 3.9	84.07 ± 4.70	83.4 ± 4.7	83.0 ± 3.8	<0.001 (0.83)	0.635 (0.03)	0.479 (0.05)
(%)	12.57 ± 1.03	12.8 ± 1.1	12.3 ± 0.6	15.03 ± 1.40	15.1 ± 1.3	14.1 ± 1.4	<0.001 (0.83)	0.059 (0.21)	0.388 (0.06)
Fat intake									
(g)	123.57 ± 10.82	122.9 ± 11.4	123.2 ± 9.3	99.64 ± 10.28	95.1 ± 7.4	103.1 ± 12.7	<0.001 (0.83)	0.237 (0.10)	0.100 (0.18)
(%)	39.77 ± 4.08	40.1 ± 4.3	39.5 ± 2.8	39.99 ± 4.04	38.9 ± 4.3	39.1 ± 3.7	0.740 (0.009)	0.700 (0.03)	0.539 (0.04)

Standard deviations and means are used to report data. COMB: combined recovery strategy group; NAP: 45-minute napping group; CON: control group; BMI: body mass index; ES: effect size.

TABLE 3. Measurement of the subjective quality of sleep, well-being indices, recovery state and internal load recorded during the experimental period.

Variables	First week			Fourth week			*p* value (ES)		
	COMB	NAP	CON	COMB	NAP	CON	Time	Group	Group × Time
Quality of sleep									
Sleep latency (min)	14.29 ± 1.14	14.78 ± 0.89	14.93 ± 0.92	14.43 ± 0.94	14.86 ± 0.95	15.07 ± 1.14	0.300 (0.08)	0.100 (0.17)	0.920 (0.002)
Sleep efficiency (%)	94.07 ± 0.92	94.36 ± 0.84	94.93 ± 1.07	94.21 ± 1.42	94.57 ± 1.60	94.92 ± 1.64	0.630 (0.02)	0.040 (0.25)	0.889 (0.004)
Sleep duration (h)	9.93 ± 0.92	9.71 ± 1.44	9.79 ± 1.53	7.50 ± 1.22	7.00 ± 1.11	7.43 ± 0.94	<0.001 (0.79)	0.357 (0.07)	0.710 (0.03)
Total score of PSQI	4.29 ± 0.98	4.78 ± 0.89	4.86 ± 0.95	4.07 ± 0.99	4.43 ± 1.02	4.86 ± 0.86	0.709 (0.41)	0.040 (0.25)	0.559 (0.03)
Well-being indices									
Sleep (1–7)	3.86 ± 0.52	3.92 ± 0.46	4.14 ± 0.69	6.29 ± 0.37	6.35 ± 0.36	6.24 ± 0.38	<0.001 (0.95)	0.519 (0.04)	0.218 (0.12)
Fatigue (1–7)	3.63 ± 0.42	3.86 ± 0.44	4.27 ± 0.64	5.60 ± 0.58	5.65 ± 0.58	6.04 ± 0.78	<0.001 (0.94)	0.009 (0.42)	0.588 (0.02)
Stress (1–7)	3.67 ± 1.19	3.61 ± 1.29	4 .0± 1.03	5.78 ± 0.48	5.88 ± 0.51	5.72 ± 0.61	<0.001 (0.85)	0.660 (0.02)	0.310 (0.08)
DOMS (1–7)	2.11 ± 0.65	2.55 ± 0.61	2.22 ± 0.58	4.38 ± 0.34	4.77 ± 0.53	5.27 ± 0.84	<0.001 (0.92)	0.001 (0.52)	0.033 (0.29)
HI	13.29 ± 1.76	13.94 ± 1.92	14.64 ± 2.01	22.04 ± 1.19	22.66 ± 1.34	23.28 ± 1.53	<0.001 (0.96)	0.014 (0.16)	0.920 (0.001)
Recovery state									
TQR (out of 28)	13.48 ± 1.29	12.91 ± 1.42	13.66 ± 1.12	10.02 ± 0.80	9.43 ± 1.01	8.80 ± 0.64	<0.001 (0.90)	0.017 (0.35)	0.011 (0.39)
Internal load									
RPE (0–10)	5.90 ± 0.52	5.94 ± 0.53	5.91 ± 0.40	6.61 ± 0.31	6.71 ± 0.30	7.30 ± 0.32	<0.001 (0.87)	0.008 (0.40)	0.017 (0.35)
W load	2307.86 ± 156.81	2397.86 ± 171.52	2359.28 ± 112.62	2590.71 ± 94.58	2584.29 ± 89.50	2674.28 ± 108.39	<0.001 (0.79)	0.046 (0.40)	0.047 (0.40)
HR average	167.29 ± 2.28	167.45 ± 2.30	166.36 ± 2.61	165.0 ± 2.14	164.93 ± 2.18	164.97 ± 2.62	<0.001 (0.91)	0.510 (0.03)	0.011 (0.40)

Standard deviations and means are used to report data. COMB: combined recovery strategy group; NAP: 45-minute napping group; CON: control group.; HR: heart rate; RPE: The rating of perceived exertion; PSQI: sleep quality index; DOMS: delayed onset of muscle soreness; TQR: Total Quality Recovery; W load: weekly load; HI: Hooper Index (sum of scores for sleep, fatigue, stress and DOMS); ES: effect size.

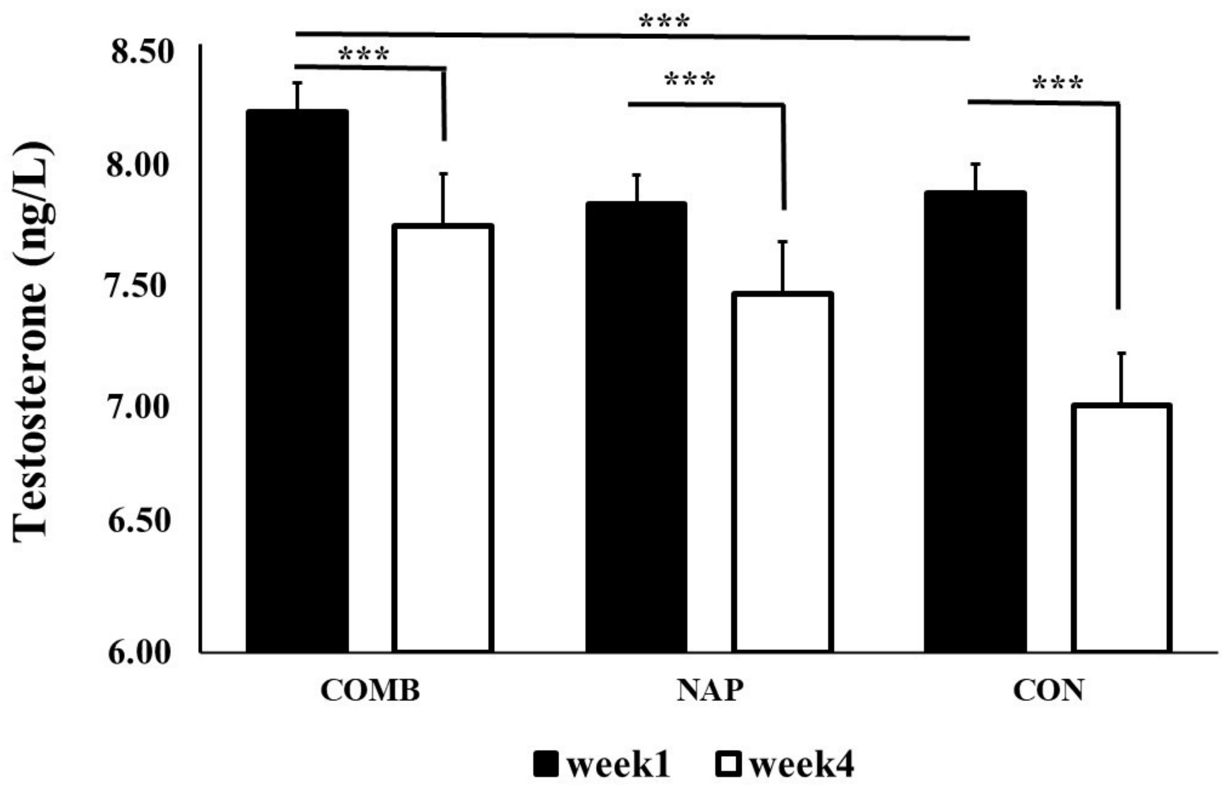

FIGURE 3. Testosterone changes through the experimental period for COMB, NAP and CON groups. Legends: COMB: combined recovery strategy group; NAP: 45-minute napping group; CON: control group; ***: $p < 0.001$.

Regarding T/C, a significant group × time interaction was seen ($p = 0.05$, ES = 0.22, small). At the conclusion of the trial, all three groups indicated an important reduction according to the findings of the Bonferroni-corrected *post hoc* tests (COMB: −36.28%, $p < 0.001$, ES = 0.003, trivial; NAP: −32.45%, $p < 0.001$, ES = 0.003, trivial; CON: −47.24%, $p < 0.05$, ES = 0.002, trivial, respectively).

4. Discussion

The purpose of the current study was to assess the effects of a combined recovery strategy involving 45-minute daytime napping and cold-water immersion during a basketball match congestion period coinciding with RIF on hormonal variations, RPE, TQR and wellbeing indices. The main results showed a significant decline in T/C ratio among the three groups at the conclusion of the trial. Moreover, COMB had significantly better outcomes in RPE, TQR and DOMS compared to NAP and CON. These findings support the hypothesis of the current experimentation.

4.1 The impacts of different recovery interventions on internal load

The study's weekly load outcomes were greater than those documented in basketball players during RIF conditions, but they were comparable to the workload recorded during the competition period (2400 AU) [3, 4]. The three groups' RPE scores significantly increased at the end of the RIF, according to our findings. This increase in muscle fatigue, particularly during the congested period, may have contributed to the significant increase in RPE and fatigue sensation. This interpretation is consistent with earlier studies that found more tiredness during the RIF [4, 36, 37]. In addition, the finding of the pre-sent study showed a significant lower RPE value in favor of COMB and NAP compared to the CON and a better value in favor of COMB compared to NAP. Our results are essentially explained by the combined effects of daytime napping and the cold-water immersion. The results of the present investigation were similar with earlier researches that reported a decline in RPE mean values by following 40-min napping. Especially, that nap opportunity may lead to a reduction in sensation of fatigue and give a more recovery chances for players also more physical muscular recovery with sleep before training sessions and official games which consequently lead to a lower RPE values [14, 38, 39].

In addition, several studies reported the beneficial effects of cold-water immersion on fatigue and RPE which was in accordance with the finding of the present study in which the participant reported that the treatment was beneficial for recovery and would improve their subsequent performance [40, 41]. In this context, Xiao *et al.* [40] reported that post-exercise cold-water immersion reduced RPE immediately, but with no significant effect at 24 and 48 h. Moreover, Halson *et al.* [41] reported that cold-water immersion enhanced the perception of recovery after a simulated 20-min cycling time-trial compared with a passive rest condition. Although these results suggest that cold-water immersion enhances the perception of recovery after exercise, the potential mechanism responsible for this effect remains to be identified. Concerning the average HR, our results showed a notable decline for all

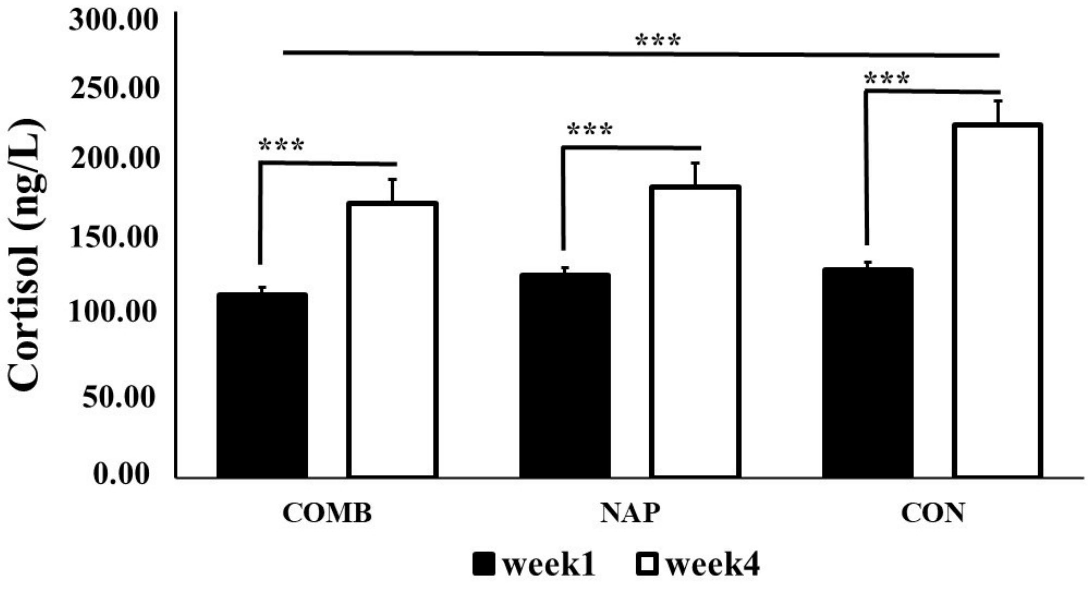

FIGURE 4. Cortisol changes through the experimental period COMB, NAP and CON groups. Legends: COMB: combined recovery strategy group; NAP: 45-minute napping group; CON: control group; ***: $p < 0.001$.

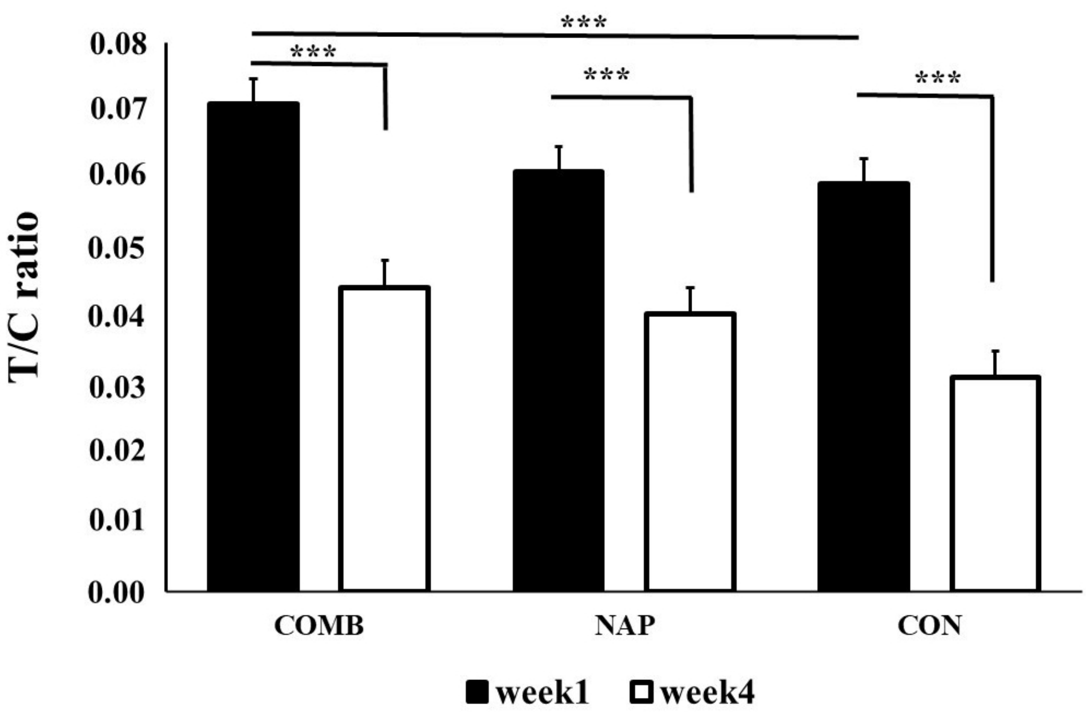

FIGURE 5. T/C ratio changes through the experimental period for COMB, NAP and CON groups. Legends: COMB: combined recovery strategy group; NAP: 45-minute napping group; CON: control group; T/C: testosterone/cortisol ratio; ***: $p < 0.001$.

three different groups at the conclusion of RIF compared to the beginning of the experimentation. This decline may be explained by the effect of RIF on biochemical and hormonal. Al Suwaidi *et al.* [42] justified this decline by linking fasting to catecholamine inhibition and decreased venous return, which lowers sympathetic tone and, in turn, lowers blood pressure, heart rate and cardiac output. Another theory is that taking a sleep lowers stress by lowering maximum heart rate during exercise and cortisol levels [43, 44].

4.2 The impacts of deferent recovery interventions on sleep quality

Adequate nighttime sleep is thought to be essential for effective training, competition and recuperation [45]. The current study's findings showed that three groups had a substantial negative effect at the conclusion of the RIF, with no group differences reported. The results of this study, which included professional basketball players, were consistent with those previously published by Brini *et al.* [4]. In a similar vein, Faris *et al.* [12] noted that sleep deprivation that builds up throughout RIF may cause a disturbance in the sleep-wake cycle, increasing exhaustion and impairing both mental and physical functioning. In the identical vein, Lolli *et al.* [46] found that Ramadan determined an abrupt reduction in time asleep of ~1 h 30 min in the first period of a night cycle and contributed to additional problems of heterogeneous sleep fragmentation that can impact optimal performance development processes [46]. According to past studies, participants may suffer from partial lack of sleep as a result of their RIF habits, which include waking early and having breakfast before daybreak. The central nervous system's higher cognitive centers will be severely impacted, which will have an undesirable influence on cognitive process, which has been proposed as the primary cause for performance reductions [37, 47].

4.3 The impacts of different recovery intervention on Body composition

Our findings showed that three groups' body composition had significantly decreased by the conclusion of the RIF. Our results were in line with other research showing a decline in body composition in athletes, particularly basketball players, during RIF [4, 5, 7]. These differences were mostly caused by changes in sleep habits, physical activity, food consumption, meal frequency and dietary patterns that occurred throughout the RIF for a variety of causes. For athletes who were attempting to sustain their level of physical performance during this demanding and draining period, this was particularly true. Furthermore, the substantial weight loss seen at the conclusion of the RIF in this study may possibly be related to the reduction in total calorie and macronutrient consumption, the decrease in fluid intake [48, 49], and the decrease in glycogen-bound water storage [37]. Given this, it has been proposed that the observed drop in body composition during RIF is due to hypohydration and a reduction in the amount of liquids consumed, with minimal body fat decline [4, 7, 8]. Moreover, our results didn't report a significant difference between groups. Our results coincide with the findings of Gesteiro *et al.* [50], how showed that sleep patterns influence body composition, being more related to female body composition as nocturnal and nap sleep were associated with higher fat mass, waist circumference and body shape index, while only short nap times were related to higher waist and hip circumference in males [50].

4.4 The impacts of deferent recovery interventions on DOMS and TQR

When comparing the fourth week of RIF to the beginning, the current study's findings showed a substantial shift in DOMS and TQR, which were significantly impacted. The results of our study were in line with other research in basketball and team sports, particularly during the RIF [4, 5, 37], which showed that training and games were linked with higher levels of tiredness, DOMS and TQR, as well as higher rates of sickness and injury [38]. Furthermore, a decline in physical function can raise the perception of exertion, cause weariness and DOMS to start earlier, and raise the risk of injuries or sickness [51]. Within the same setting, Davis [52] noted that exhaustion might modify neurotransmitter activity and/or lessen the depletion of muscle glycogen, which could have a deleterious impact on cognition and the execution of motor skills.

Moreover, our results revealed a significant better value in favor of COMB and NAP compared to the CON and a better value in favor of COMB compared to NAP. The findings of the present study could be explained by the combined effects daytime nap opportunity and the cold-water immersion. In this context, Bleakley *et al.* [53] reported that DOMS commonly results after sports and exercise activity and Cold-water immersion, which involves people immersing themselves in water at temperatures of less than 15 °C, is sometimes used to manage muscle soreness after exercise and to speed up recovery time. In the same context, Halson *et al.* [41] reported that cold-water immersion enhanced the perception of recovery and there was some evidence that cold-water immersion reduces muscle soreness at 24, 48, 72 and even at 96 hours after exercise compared with "passive" treatment with limited evidence from four trials indicated that participants considered that cold-water immersion improved recovery/reduced fatigue immediately after wards [53]. Concerning the use of napping strategy, Boukhris *et al.* [39], reported a significant correlation between recovery state and performances which could support the idea that napping may lead to an improved recovery status for the participants. Addition-ally, Brotherton *et al.* [54], showed that a 1-h nap positively affected subjective mood and ratings of tiredness and these authors suggested that nap may be related to the reduction of the perceived exertion which support the finding of the present study.

4.5 Deferent recovery intervention effects on T/C ratio

Concerning the hormonal statue of the participant all over the present experimentation, our results revealed a significant change on Testosterone and Cortisol levels at the fourth week in comparison with the beginning of RIF our findings revealed a significant decrease of T/C ratio for the three groups with a significant better value in favor of COMB and NAP compared to the CON and a better value in favor of COMB compared to NAP. The current findings supported the results of previous studies who reported that daytime napping and cold-water immersion might facilitate physiological and perceptual recovery through altering the hormonal milieu [43, 55]. In fact, Botonis *et al.* [43], reported that daytime nap-ping following a night of total sleep loss affected cortisol secretion significantly during both the nap and post nap periods however longitudinal effects of daytime napping still unclear and deeply depend on the (intensity/duration) of the (training/games). Concerning the cold-water immersion, Leppäluoto *et al.* [55] reported that plasma adrenocorticotropic hormone (ACTH) and cortisol levels seem to decrease significantly after a short time of regular cold-water exposure, probably due to acclimation or adaptation, suggesting that regular cold-water exposure has little effect on stimulating the pituitary-adrenal cortex axis.

Otherwise, our results were different from those reported by Tabben *et al.* [56], and Halson *et al.* [41], who showed no changes in cortisol or testosterone concentrations in response to post-exercise cold-water immersion. However, in those studies they exanimated only cold-water immersion only as a single recovery strategy in addition the nature of practiced sport (Basketball *vs.* Com-bat), the addition of RIF (additional stress for participants), the differences in training (levels/history), and the sampling methodology maybe a good explanation for these differences.

4.6 Limitation

There are a few constraints to take into account, even if this study provides new data. The exclusion of time-motion variables would have contributed an additional layer of data, such as distance traveled and the average number of sprints and high-intensity runs. Type and number of volunteers may have an impact on the results. A bigger and more varied population would probably provide different results from the same investigation. excluded groups (*e.g.*, control groups without training or sports, groups that did not observe Ramadan, *etc.*). Furthermore, the quasi-experimental form of this study lacks random assignment, which complicates the identification of a cause-and-effect link. It makes use of pre-existing groupings, which makes it more difficult to determine causes. Moreover, baseline data need to have been obtained before the RIF. In order to close this gap about naps and nocturnal sleep, further research is required. Finally, the season of Ramadan needs to be taken into account. Different results may be drawn from research looking at Ramadan under different weather circumstances.

5. Conclusions

The findings of the current experimentation demonstrated that a combined recovery strategy involving 45-minute daytime napping and cold-water immersion during a basketball match congestion period coinciding with RIF significantly declines the T/C ratio and leads to significantly better outcomes in RPE, TQR and DOMS. Thus, by implementing this combined recovery strategy under such conditions, it may serve as a valuable recovery approach for athletes to avoid fatigue and injury risks and maintain a minimal level of performance.

6. Practical applications

- The combination of cold-water immersion and daytime nap opportunity is a successful and non-expensive recovery method for professional basketball players undergoing some extreme conditions such RIF and congestion match period.
- The congestion basketball match period seems to have a several impact on performance (physiologically, physically and psychologically) especially when it crosses the RIF thus basketball coaches and physical trainers should seriously control players and well mange this critical period in order to avoid accumulated fatigue and prevent injuries.

AVAILABILITY OF DATA AND MATERIALS

The datasets generated during and analyzed during the current study are not publicly available due to confidential information about the participants but are available from the corresponding author on reasonable request at bseifeddine15@gmail.com.

AUTHOR CONTRIBUTIONS

SB and JRG—Conceptualization, Methodology. SB and GB—Data curation. JCG, SdGT and JRG—Formal analysis. SME and HA—Funding acquisition. SB, JCG, GB, SdGT, SME, AB, AD, UG and LPA—Investigation. SME—Project administration. SB and AB—Resources. SB—Software. AB, AD, UG and LPA—Supervision. JCG—Validation. GB, AB, AD, UG and LPA—Visualization. SB, FHY, JCG, GB, SdGT, JRG, SME, HA, AB, AD, UG and LPA—Writing-original draft, Writing-review & editing.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was done throughout the competitive season and was authorized by the local Clinical Research Ethics Committee of the Higher Institute of Sports and Physical Education of Kef, University of Jendouba, Kef, Tunisia (permission No. 9/2018), with the procedure following the Declaration of Helsinki (World Medical Association). All individuals gave written informed consent to participate in the study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Georgian Badicu is serving as one of the Editorial Board members of this journal. We declare that Georgian Badicu had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to DM.

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