Original Paper DOI: https://doi.org/10.5114/biolsport.2021.109950

Are elite track and field athletes on track? The impact of COVID-19 outbreak on sleep behavior and training characteristics

AUTHORS: Jacopo Antonino Vitale[1], Stefano Borghi[2], Roberto Codella[2], Michele Lastella[3], Mathieu Nedelec[4], Giuseppe Banfi[1,5], Antonio La Torre[1,2]

[1] IRCCS Istituto Ortopedico Galeazzi, Milan, Italy
[2] Università degli Studi di Milano, Milan, Italy
[3] The Appleton Institute for Behavioural Science, Central Queensland University, Adelaide, Australia
[4] Laboratory of Sport, Expertise and Performance, French National Institute of Sport (INSEP), Paris, France
[5] Vita-Salute San Raffaele University, Milan, Italy

Corresponding author:
Jacopo Vitale
IRCCS Istituto Ortopedico Galeazzi, Milan, Italy
Email: jacopo.vitale@grupposandonato.it

ORCID:
Jacopo A. Vitale
0000-0002-7537-079X

Stefano Borghi
0000-0002-2435-3412

Roberto Codella
0000-0003-1608-1899

Mathieu Nedelec
0000-0001-8095-9163

Michele Lastella
0000-0003-1793-3811

Giuseppe Banfi
0000-0001-9578-5338

Antonio La Torre
0000-0002-4987-2024

ABSTRACT: The Covid-19 outbreak forced many governments to enter a nationwide lockdown. The aim of this study was to evaluate, by means of a survey, changes in sleep parameters and physical activity characteristics of elite track and field athletes in three periods: before the lockdown (T0), during the lockdown (09th March – 03rd May 2020, T1) and the first month after the lockdown (T2). This study was conducted from May 2020 to June 2020 and data were collected using an offline survey with 89 elite track and field athletes (mean age: 24.7 ± 5.4; n = 43 males; n = 46 females). The survey consisted of demographic data and questions on physical activity and sleep behavior at T0, T1 and T2. Athletes reported lower sleep quality scores at T1 compared to T0 and T2 ($p < 0.0001$) and registered delayed bedtime, wake-up time and longer sleep latency during the lockdown compared to pre-lockdown and post-lockdown whereas no changes in total sleep time were reported. No inter-group differences were detected in sleep characteristics between short- and long-term disciplines and between genders. The weekly training volume decreased from 16.1 ± 5.7 hours at T0 to 10.7 ± 5.7 hours at T1 ($p < 0.0001$) whereas no significant differences were detected in training volume during the lockdown in relation to the square footage of the house ($p = 0.309$). Alcohol ($p = 0.136$) and caffeine intake ($p = 0.990$) and use of electronic devices ($p = 0.317$) were similar pre-, during, and post-lockdown. The unprecedented circumstances of the Covid-19 pandemic had negative impacts on the Italian track and field athletes' sleep and training volumes.

Key words:
Sleep quality
Sleep-wake cycle
Lockdown
Sars-Cov-2
Pandemic
Exercise

CITATION: Vitale JA, Borghi S, Codella R et al. Are elite track and field athletes on track? The impact of COVID-19 outbreak on sleep behavior and training characteristics. Biol Sport. 2021;38(4):741–751.

Received: 2021-03-21; Reviewed: 2021-05-22; Re-submitted: 2021-06-11; Accepted: 2021-09-26; Published: 2021-10-16.

INTRODUCTION

In December 2019, a new coronavirus (SARS-CoV-2) emerged in China and the virus outbreak has spread rapidly and widely throughout the world [1]. In January 2020, the World Health Organization declared the outbreak of a new disease, renamed Covid-19, to be a Public Health Emergency of International Concern and, in March 2020, the World Health Organization declared Covid-19 as a pandemic [2]. Italy was the first European country to enter a nationwide lockdown [3] and between the 09th March 2020 and 3rd May 2020, the Italian Government adopted severe containment measures to counteract the possible collapse of the Italian health care system and the virus spread [4, 5]. Several activities were temporarily closed, including universities and schools, restaurants, gyms and sports centers and not even outdoor activities were allowed [6]. An inevitable behavior determined by the home confinement was the increase of time spent sitting and engaging in activities that involve low rates of energy expenditure, such as television viewing, use of electronic device, desk-bound work and videogames [6, 7] and people had an increase in anxiety, stress, irritability, poor concentration causing deterioration of work performance, and depressive symptoms too [3, 8]. Recent studies examined the association between psychological health and the change in physical activity behavior, smoking and alcohol use in the general population during the lockdown. It was observed that the negative changes in both physical activity, smoking and alcohol intake were associated with higher depression, anxiety and stress. Thus, it was suggested that governments should give public health warnings about excessive alcohol consumption during isolation [9, 10] (cit).

It has been shown that home confinement leads to poor and inappropriate sleep quality and duration [7]. Living 24 h/day at home determines reduced activity levels and a lower exposure to daylight and, given that environmental light is the primary synchronizer (i.e. "*zeitgeber*") of the human's body clock, this may result in altered sleep patterns and lead to a de-synchronized circadian expression in humans [6]. In line with this, data from the Italian population indicate that poor sleep quality and duration were common during lockdown [11]. Cellini and colleagues [11] observed that sleep-wake rhythms change dramatically during home confinement with people going to bed and waking up later and spending more time at bed than usual. However, those behaviors were associated with lower levels of sleep quality. In addition, the decrease in sleep quality was more severe among those with higher levels of stress and anxiety [11].

The world of professional sport experienced an unknown and extreme situation due to the Covid-19 outbreak and all competitions were postponed with any organized training or practice banned or severely limited during the first phase of the virus spread [12]. The health of spectators, athletes and coaches became a priority and the major regional, national and international competitions, such as the Olympic Games in Tokyo, were canceled [1, 12]. International-caliber elite athletes need to preserve an optimal psychophysical condition during the entire competitive season. Nonetheless, the lockdown prevented athletes from training in their habitual settings, causing changes in their physical activity patterns and daily training routine. In addition, home confinement may alter several physical and mental aspects of athletes including physical deconditioning, altered sleep patterns, or feelings of depression and the re-adjustment to normal life and return to sport will undoubtedly be challenging [13–15].

Therefore, the primary aim of this study was to evaluate, by means of a survey, changes in subjective sleep parameters and physical activity characteristics of Italian elite track and field athletes in three different periods: the month preceding the lockdown (T0), during the lockdown (09th March – 03rd May 2020, T1) and the first month after the lockdown (T2). Secondary aims were: to assess sleep and physical activity changes between short- and long-term disciplines and between genders; to evaluate the differences in alcohol intake, caffeine intake, and the use of electronic devices before bedtime among T0, T1 and T2. We hypothesized that subjective sleep parameters and physical activity characteristics would be negatively influenced by the home confinement during the lockdown.

MATERIALS AND METHODS

Study Design and Ethical Approval

This was a cross-sectional study conducted at the IRCCS Istituto Ortopedico Galeazzi (Milan, Italy). The study was approved by the Ethical Committee of Vita-Salute San Raffaele University (ref. n.: 95/INT/2020) and all procedures were performed in compliance with laws and regulations governing the use of human subjects (Declaration of Helsinki). The study protocol was registered at clinicaltrials.gov (ClinicalTrials.gov Identifier: NCT04632615). All participants received explanation of purpose, methods of the study and written informed consent was obtained from all subjects. Data were collected using an offline survey and the methodology of this data collection was compliant to the national legislation concerning social distancing during the pandemic. The results of the survey were reported following specific guidelines [16].

Sample size

The elite athletes of the Italian Track and Field Federation (FIDAL) are ≈120. Therefore, based on a maximum 120 responses, at least 84 participants would be needed to achieve a statistical precision at 90% confidence intervals with type I error rate of 5%.

Participants

Participants were Italian elite athletes from the FIDAL, recruited upon invitation by their coaches and physicians. One hundred and twenty-two participants were screened for eligibility using the following inclusion criteria: male or female, all ethnicity, age between 18 and 40 years, elite athletes of FIDAL. The exclusion criteria were as follows: recreational or semi-elite athletes, shift- or part-time workers, injuries that influence the frequency of training, and pregnant women. Participants who met the above inclusion and exclusion criteria were recruited in the study.

Survey

All athletes received the survey in a printed form, answered to all questions and then returned the document by e-mail to an investigator of the study (J.V.). The subjects completed the survey in June 2020 and the data were manually exported to an Excel file (Microsoft, Edmond, USA) for data analysis. The survey was composed by four sections: 1) demographic data; 2) physical activity and sleep behavior in the last month before the lockdown (T0); 3) during the lockdown (T1); 4) in the first month after the lockdown (T2). Demographics included information on gender, sport discipline (short-term: jumps, throws, 60 m – 400 m sprints; long-term: 800 m – marathon/march), training and kind of sports material, home characteristics (e.g. square footage, presence of garden or terrace, type of house) and region of origin. Subjects were classified in athletes resident in the most infected regions of Italy (Lombardy, Emilia-Romagna, Veneto and Piedmont) or in the less infected regions (all other Italian regions). Primary outcomes of physical activity were hours of training per week, hours of training per day, and number of training sessions per week whereas subjective sleep parameters included wake-up time, bedtime, sleep latency, total sleep time and sleep quality. In detail, we utilized questions 1, 2, 3, 4, and 6 of the Italian version of the Pittsburgh Sleep Quality Index to assess sleep parameters [17, 18]. Data on alcohol and caffeine intake throughout the day and use of electronic devices 1 hour before bedtime were also collected using single self-report question. Approximately fifteen minutes were required to complete the survey. A total of 89 elite track and field athletes met the inclusion/exclusion criteria and completed the entire survey (mean age: 24.7 ± 5.4; mean BMI: 20.7 ± 3.0; n = 43 males [48.3%] and n = 46 females [51.7%]).

Statistical analysis

Data are expressed as mean ± SD. Each physical activity and sleep parameter was evaluated three times (T0, T1, and T2) and then checked with the Shapiro–Wilk test. Given a non-normal distribution, the Friedman test followed the by Dunn's multiple comparisons was performed to detect possible differences in physical activity and sleep among T0, T1, and T2. Partial eta-squared (η^2_p) was used to determine the magnitude of the effect for significant outcomes ($\alpha = .05$) using the small (< .13), medium (.13–.25), and large (> .25) interpretation [19] while effect sizes for pairwise comparison were calculated using Cohen's d and considered to be either trivial (effect size: < 0.20), small (0.21–0.60), moderate (0.61–1.20), large (1.21–2.00), or very large (> 2.00) [20].

The two-way ANOVA was used to test intra-group and inter-group differences for physical activity and sleep parameters in: 1. male vs female athletes and 2. short-term vs long-term disciplines among T0, T1 and T2.

A chi-square test ($\chi2$) was used to test the differences between the observed and expected values among T0, T1, and T2 for all categorical variables (sleep quality, alcohol and caffeine intake, and use of electronic devices). The $\chi2$ was also applied to sleep quality for male and female athletes alone and for subjects coming from the most and less infected regions. In addition, to test the differences in hours of training per week during the lockdown (T1) in relation to the square footage of the house (< 50 m^2, 50–90 m^2, > 90 m^2), a non-parametric Kruskal-Wallis test followed by the Dunn's multiple comparisons was applied. The level of significance was set at $p \leq .05$. Statistical analysis was performed using GraphPad Prism (GraphPad Software, San Diego, CA).

RESULTS

Eighty-nine elite track and field athletes completed the study: N = 43 elite athletes (48.3%) were from the most infected regions while n = 46 (51.7%) were resident in the least infected regions. Table 1 shows the summary of demographic data.

TABLE 1. Summary of demographic data.

Variable	Descriptive Statistics	Values
Age (years)	Mean ± SD	24.7 ± 5.4
	Range (min – max)	18–40
	Lower and upper 95% C.I.	23.6–25.9
Height (cm)	Mean ± SD	174.1 ± 8.8
	Range (min – max)	157–193
	Lower and upper 95% C.I.	172.3–176.0
Weight (kg)	Mean ± SD	63.1 ± 13.3
	Range (min – max)	39–125
	Lower and upper 95% C.I.	60.3–65.9
Sports discipline	Jumps	13 (14.6%)
	Throws	5 (5.6%)
	Short distance (60–400 m)	28 (31.5%)
	Middle distance (800–10000 m)	23 (25.8%)
	Long distance (> 10000 m)	19 (21.4%)
	Pentathlon	1 (1.1%)
House size	< 50 m^2	12 (13.5%)
	> 50 m^2 and < 90 m^2	29 (32.6%)
	> 90 m^2	48 (53.9%)
Training setting at T1	Indoor	27 (30.3%)
	Outdoor	60 (67.4%)
	No training	2 (2.3%)
Type of training at T1*	Aerobic (e.g. run, bike)	15 (17.2%)
	Anaerobic (e.g. resistance training)	23 (26.4%)
	Combined	49 (56.4%)
Use of sports materials at T1*	Yes	70 (80.5%)
	No	17 (19.5%)

Note: Data are reported as absolute (and percentages) values. *: the total number of subjects is n = 87 since n = 2 athletes did not perform any training during T1, as specified in "training setting at T1". *Abbreviations*: SD: Standard Deviation; C.I.: Confidence interval; T1: Lockdown period.

Sleep and physical activity parameters

Athletes reported significant changes in sleep-wake times ($p < 0.0001$), sleep latency ($p < 0.0001$) and subjective sleep quality ($p < 0.0001$) among T0, T1 and T2 whereas no significant differences were observed in total sleep time ($p = 0.695$). Specifically, athletes registered delayed bedtime (00:13 ± 1:05) and wake-up time (8:41 ± 1:20) and longer sleep latency (28.1 ± 29.8 min) at T1 compared to T0 (bedtime: 23:27 ± 0:45; wake-up time: 7:57 ± 1:05; sleep latency: 18.1 ± 14.4 min) and T2 (bedtime: 23:38 ± 0:44; wake-up time: 8:04 ± 0:53; sleep latency: 19.4 ± 15.9 min). Similarly, training volume and frequency significantly changed during the three periods ($p < 0.0001$) with lower values registered at T1 compared to T0 and T2. In detail, the weekly training volume decreased from 16.1 ± 5.7 hours at T0 to 10.7 ± 5.7 hours at T1 and 2 athletes reported no training during the lockdown. Table 2 presents the mean ± SD of physical activity and sleep parameters at T0, T1 and T2.

Subjective sleep quality was evaluated as a categorical variable (Table 3). The $\chi2$ highlighted differences in sleep quality among T0, T1 and T2 for the entire group of elite athletes ($p < 0.0001$), for male and female subjects alone ($p = 0.048$ and $p = 0.023$ respectively) and for subjects resident in the most infected regions ($p = 0.001$) and in the least infected regions ($p = 0.033$) separately. No inter-group differences in sleep quality were observed between the most infected regions vs the least infected regions. Overall, it was observed a decrease in sleep quality at T1 compared to T0 and T2: the answer "*very bad*" and "*not good*" increased at T1 (7.8% and 22.5%) compared to T0 (1.1% and 3.4%) whereas the answers "*good*" or "*excellent*" decreased at T1 (to 47.2% and 22.5%) compared to T0 (67.4% and 28.1%).

TABLE 2. Physical activity and self-reported sleep parameters at T0 (pre-lockdown), T1 (lockdown) and T2 (post-lockdown)

	T0	T1	T2	Friedman test	Partial eta-squared	Dunn's multiple comparisons
Weekly training (hours)	16.1 ± 5.7	10.7 ± 5.7	14.0 ± 5.0	$p < 0.0001$	$F_{2,88} = 85.3$ $\eta^2_p = 0.66$, large	T0 > T1 ($p < 0.0001$; ES: 1.01); T2 > T1 ($p < 0.0001$; ES: 0.61); T0 > T2 ($p < 0.002$; ES: 0.39)
Daily training (hours)	2.5 ± 0.9	1.8 ± 0.9	2.2 ± 0.8	$p < 0.0001$	$F_{2,88} = 39.0$ $\eta^2_p = 0.47$, large	T0 > T1 ($p < 0.0001$; ES: 0.76); T2 > T1 ($p < 0.0001$; ES: 0.44); T0 > T2 ($p = 0.015$; ES: 0.38)
Training sessions per week (number of sessions)	6.2 ± 0.8	5.4 ± 1.5	5.9 ± 0.9	$p < 0.0001$	$F_{2,88} = 76.8$ $\eta^2_p = 0.63$, large	T0 > T1 ($p < 0.0001$; ES: 0.65); T2 > T1 ($p = 0.040$; ES: 0.43);
SL (minutes)	18.1 ± 14.4	28.1 ± 29.8	19.4 ± 15.9	$p < 0.0001$	$F_{2,88} = 22.9$ $\eta^2_p = 0.34$, large	T0 < T1 ($p = 0.002$; ES: 0.43); T2 < T1 ($p = 0.027$; ES: 0.36);
BT (hh:mm)	23:27 ± 0:45	00:13 ± 1:05	23:38 ± 0:44	$p < 0.0001$	$F_{2,88} = 60.8$ $\eta^2_p = 0.58$, large	T0 < T1 ($p < 0.0001$; ES: 0.82); T2 < T1 ($p < 0.0001$; ES: 0.63);
WT (hh:mm)	7:57 ± 1:05	8:41 ± 1:20	8:04 ± 0:53	$p < 0.0001$	$F_{2,88} = 60.8$ $\eta^2_p = 0.58$, large	T0 < T1 ($p < 0.0001$; ES: 0.60); T2 < T1 ($p < 0.0001$; ES: 0.55);
TST (mimutes)	483.9 ± 56.3	477.7 ± 76.7	480.2 ± 57.6	$p = 0.695$	-	-

Note: Comparison among T0, T1, and T2 physical activity and sleep parameters. The data are reported as mean ± SD. All variables were not normally distributed and therefore they were subjected to the nonparametric Friedman test followed by Dunn's procedure. *Abbreviations*: SL: Sleep Latency (min); BT: Bedtime; WT: Wake up Time; TST: Total Sleep Time.

TABLE 3. Subjective sleep quality at T0 (pre-lockdown), T1 (lockdown) and T2 (post-lockdown)

Subjective sleep quality	T0	T1	T2	Chi-square test (χ^2)
Total (n = 89)				
Very bad	1 (1.1)	7 (7.8)	1 (1.2)	p < 0.0001
Not good	3 (3.4)	20 (22.5)	5 (5.6)	
Good	60 (67.4)	42 (47.2)	65 (73.0)	
Excellent	25 (28.1)	20 (22.5)	18 (20.2)	
Males (n = 43)				
Very bad	0 (0.00)	2 (4.7)	0 (0.0)	p = 0.048
Not good	1 (2.3)	6 (13.9)	1 (2.3)	
Good	31 (74.4)	21 (51.2)	28 (67.4)	
Excellent	10 (23.3)	13 (30.2)	13 (30.3)	
Females (n = 46)				
Very bad	0 (0.0)	2 (4.4)	0 (0.0)	p = 0.023
Not good	1 (2.2)	7 (15.2)	1 (2.2)	
Good	33 (73.9)	23 (50.0)	31 (67.4)	
Excellent	11 (23.9)	14 (30.4)	14 (30.4)	
Most infected regions (n = 43)				
Very bad	0 (0.0)	1 (2.3)	0 (0.0)	p = 0.001
Not good	2 (4.6)	12 (27.9)	1 (2.3)	
Good	31 (72.1)	20 (46.5)	35 (81.4)	
Excellent	10 (23.3)	10 (23.3)	7 (16.3)	
Less infected regions (n = 46)				
Very bad	1 (2.2)	5 (11.1)	1 (2.2)	p = 0.033
Not good	1 (2.2)	8 (17.8)	3 (6.5)	
Good	30 (65.2)	22 (48.9)	31 (67.4)	
Excellent	14 (30.4)	10 (22.2)	11 (23.9)	

Note: The data are reported as number of answers and percentage (%).

Gender differences

Only a significant time effect (intra-group) was detected for all physical activity parameters ($p < 0.0001$): overall, significantly lower values of weekly and daily physical activity were observed at T1 compared both to T0 and T2 for female and male athletes separately. Similarly, data on bedtime, wake-up time and sleep latency highlighted a significant effect of time ($p < 0.0001$) but no effect of group and interaction were detected. Specifically, bedtime and wake-up time were delayed and sleep latency was longer at T1 compared to T0 and T2 both for female and male athletes separately. On the contrary, total sleep time did not show any significant inter- and intra-group difference ($p = 0.468$) (Figure S1).

Short- vs long-term disciplines

A significant time effect ($p < 0.0001$) was detected for all physical activity and sleep parameters with the only exception of total sleep time that did not show a time effect ($p = 0.545$). Therefore, no differences between short- and long-term disciplines were observed in T0, T1, and T2 for sleep and training but overall worse values were observed during the lockdown compared to pre- and post-lockdown for both groups (Figure S2).

Alcohol and caffeine intake, electronic devices and home characteristics

Alcohol and caffeine intake throughout the day and the use of electronic devices before bedtime were assessed as categorical variables and data are presented in Table 4. The $\chi2$ highlighted no significant differences in alcohol ($p = 0.136$) and caffeine intake ($p = 0.990$) and in the use of electronic devices ($p = 0.317$) among the three time points. In addition, no significant differences were detected in the hours of training per week at T1 in relation to the square footage of the house ($p = 0.309$). However, we observed that athletes who lived with a square footage < 50 m^2 were the ones that had the lowest values of weekly training (8.5 ± 3.0 hours) than the other groups (50–90 m^2: 11.6 ± 6.0 hours; > 90 m^2: 10.7 ± 5.9 hours).

TABLE 4. Use of electronic device, alcohol and caffeine intake during T0 (pre-lockdown), T1 (lockdown) and T2 (post-lockdown)

	T0	**T1**	**T2**	**Chi-square test (χ^2)**
Electronic device				
Never	5 (5.6)	2 (2.3)	3 (3.4)	p = 0.3178
Sometimes	14 (15.7)	18 (20.2)	22 (24.7)	
Often	44 (49.5)	33 (37.1)	38 (42.7)	
Always	26 (29.2)	36 (40.4)	26 (29.2)	
Alcohol				
Yes	49 (55.1)	36 (40.4)	45 (50.6)	p = 0.1362
No	40 (44.9)	53 (59.6)	44 (49.4)	
Intake (days per week)	1.4 ± 0.6	1.9 ± 1.3	1.6 ± 1.1	p = 0.2103*
Caffeine				
0 mg	28 (31.5)	28 (31.5)	27 (30.3)	p = 0.9901
0–75 mg	13 (14.6)	17 (19.1)	15 (16.9)	
75–150	25 (28.1)	23 (25.8)	26 (29.2)	
> 150 mg	23 (25.8)	21 (23.6)	21 (23.6)	

Note: The data are reported as number of answers and percentage (%). Alcohol intake is reported as mean ± SD of days of consumption per week. *: differences among T0, T1 and T2 are calculated with the Friedman test followed the by Dunn's multiple comparisons.

DISCUSSION

It is common for high-level athletes to experience changes to sleep during competition or during over-reaching or over-training periods [21]. The present study reveals that such sleep disturbances were exacerbated by the unprecedented event of the Covid-19 pandemic. Many recent studies investigated changes in physical activity and sleep in the general population as a result of lockdown and home confinement [8, 22, 23]. However, few data are available about the impact on training and sleep of elite athletes. One of the strengths of this study is that we recruited only elite athletes of a single specific sport federation and the results showed lockdown-induced negative changes to training and sleep. Our initial hypotheses were confirmed. These findings clearly highlight the need to develop effective strategies to maintain optimal performance and sleep. In fact, until a herd-immunity against SARS-CoV-2 will not be achieved, the pandemic containment measures would be protracted in the future.

The Covid-19 pandemic and associated restrictions led to significant changes in lifestyle habits and daily social schedules. Home confinement can reduce the level of exposure to daylight, increase sedentary time and the level of stress due to social isolation. All these variables, which are the main entrainment factors for biological rhythms [24], may ultimately determine changes in humans' rest-activity circadian expression and sleep behavior [23, 25]. In the present study, we observed a ≃45 min delay in bedtimes and wake-up times during the lockdown compared to both pre- and post-lockdown period. Further, subjective sleep latency showed a high inter-individual variability and a significant + 64% delay (i.e. + 10 min) during the lockdown compared to pre-lockdown. We also analyzed data on sleep quality and athletes reported significantly lower values at T1 compared to pre- and post-lockdown but no changes in total sleep time were observed. These results are partially in line with previous studies that evaluated sleep characteristics of the Italian population during the lockdown: Cellini et al. [11] showed that 1310 people living in Italy registered delayed bedtime, woke up later but also spent more time in bed than usual during home confinement and Marelli et al. [26] found also a worsening of sleep quality and insomnia symptoms. From a chronobiologic point of view the human circadian rhythms and sleep result from the balance between the external social time (e.g. work/training hours) and the individual's internal biological time [27]. The shift in bedtime and wake-up time observed during the lockdown in our study, indicates that sleep timing and training schedules should be adapted in elite athletes, when possible, to prevent a possible discrepancy between social and biological time.

Sleep is a biological process having essential physiological functions for recovery and physical performance however, elite athletes do not often reach the recommended levels of night-time sleep duration and quality per night [28, 29]. It has been shown that sleep restriction could negatively impact both sport-specific and athletic performance in different sport disciplines [30–32] and sleep disturbances in athletes may be explained by their constant exposure to many stressors that impair sleep, such as high-intensity training sessions, long-haul travels or high levels of pre-competition anxiety [33]. Unfortunately, among these variables, it has recently been demonstrated that also the home confinement determined by the Covid-19 pandemic may negatively influence the sleep of elite athletes [34, 35]. To the best of our knowledge, only two studies examined the impact of Covid-19 pandemic on sleep and training in athletes [13, 36]. Pillay et al [13] investigated with a survey the perceptions of elite and semi-elite South African athletes on the maintenance of physical conditioning, sleep, nutrition and mental health during the pandemic and they observed that a large proportion of athletes reported changes in sleep routine whereas no gender differences in sleep-wake times and restful sleep were detected. In line with these findings, we observed no differences in sleep parameters between genders and in short- vs long-term track and field disciplines at T0, T1 and T2. These results are however partially in contrast with previous studies that reported different sleep-wake patterns in male and female subjects and in athletes from various sports disciplines [5, 37–40]. Similarly, Facer-Childs et al [36] surveyed how the Covid-19 pandemic affected the lives of elite and sub-elite athletes across multiple sports. In comparison to pre-lockdown, sleep onset and offset times shifted later and the time in bed and total sleep time significantly increased during the pandemic. Further, there was a 25% increase in sleep latency during lockdown which was strongly associated with the time spent on electronic devices before bed [36]. In contrast, we did not detect any significant increase in the use of electronic devices before bedtime and in alcohol or caffeine intake throughout the day during the lockdown (Table 4). It is known that alcohol intake may negatively impact sleep quality by increasing the amount of stage N1 sleep and reducing slow wave sleep [41] and that the consumption of caffeine delays sleep onset latency and decreases slow wave sleep [42]. Our results are in contrast with previous studies highlighting a negative impact of home confinement on alcohol consumption: Stanton and colleagues [9] evaluated the associations between psychological distress and changes in health behaviors since the onset of Covid-19 in Australian adults and they observed that 25% of the sample had an increase in alcohol consumption, 40% had sleep problems and both these negative behavioral changes were associated with higher depression, anxiety and stress symptoms [9]. Similar results were observed in athletes by Håkansson and colleagues [43] as the 16% of the surveyed athletes reported drinking more alcohol during the pandemic and the authors showed that increased alcohol intake was associated with concerns over about one's future in sports but not with other covariates (i.e., anxiety, depression or gambling) [43] (cit). In our study, elite athletes were possibly resilient to the negative effects of lockdown on alcohol and caffeine intake. Therefore, one of the possible explanation for the worsening of sleep behavior in elite athletes may be related to the outdoor light exposure. Exposure to daylight was inevitably reduced during the home confinement and this reduction during wakefulness has been shown to negatively impact subsequent sleep [44]. Lastly, no differences in sleep behavior were observed between athletes resident in the "most-infected" versus "less-infected "regions; this might be explained by ubiquitous containment measures that led athletes to experience identical lockdown circumstances.

In regard to physical activity levels, the Covid-19 lockdown impacted on athletes following a J-shaped curve at the mirror, i.e. a bimodal one with two bumps. In fact, the national restrictions imposed a drastic reduction of overall athletes' activities (T0 > T1), with a recovery afterward (T2 > T1). In detail, our results showed a significant change in the volume and frequency of training sessions during the lockdown: elite athletes trained less frequently and for shorter periods of time compared to pre-lockdown values (-33% of training hours per week). During the lockdown, a large proportion of athletes (80.5%) used specific sports material to train (treadmills, steppers, stationary bikes, dumbbells, and barbells) whereas the remaining 19.5% performed body-weight exercises and the sessions mainly (56.4%) consisted of combined (cardio and resistance) training. Sixty-seven percent of the study sample performed exercise in outdoor settings without breaking the law (garden, backyard or area near the house) whereas only 2 athletes (2.3%) totally suspended their training routine. In view of future lockdowns, delivering specific sports material at every athlete's home in advance could potentially reduce the risk of detraining [40, 44]. Nevertheless, the re-start at T2 was not sufficient to match pre-lockdown physical activity levels. The re-opening of the sport centers and the return to specific training sessions did not bring the training volume back to normal levels since some restrictive measures have been introduced following the lockdown: in sports centers the entrances have been scheduled in order to maintain proper distancing among athletes, leading to limitations in training time. This might explain a resumed training frequency mismatching training volume. Our results are in line with the study by Facer-Child et al. [36] where the authors reported a significant reduction in the number of training sessions per week during home confinement and a decrease in the duration of training sessions in sub-elite and elite athletes. Similarly, Pillay et al. [13] observed that South-African athletes decreased both duration and intensity of training during the lockdown highlighting the negative impact of Covid-19 on physical and mental health.

Physical exercise is an essential component of professional athletes' life and a reduction of training volume is inevitably linked to detraining and therefore represents a big issue for their performance and health too [45]. It has been ascertained that the levels of physical activity significantly affect sleep behaviors and the quality of sleep and that changes in societal- and work-schedules lead to alterations in sleep [46, 47]. Considering that physical activity constitutes the core of the job for elite athletes, one can understand the adjunctive and summing effect of the described conditions. Irremediably, the training volume of the athletes was decreased in the time-between and has to be re-shaped and "re-thought" under such unprecedented situation. A significant change in the critical variables of the training sessions (frequency, duration, and timing) confirms the need for such an extraordinary flexibility of the athletes. The psychosocial mechanisms behind these athletes' responses can be quite similar to those delineated for the general population [8]. Given the companion involvement of other psychosocial and mood moderators (anxiety, depression, stress), it stands obvious for athletes, as we have already demonstrated for the general population [8], that the key element for coping with such a situation is the autonomous motivation. In fact, when individuals whose motivation to enact physical activity is self-determined have positive attitudes toward exercise. Conversely, when motivation is external, athletes are less supported and would have worst attitudes.

Some limitations of this study should be acknowledged. First, we only collected self-reported data such that objective information on sleep and physical activity parameters, such as heart rate variability, wrist actigraphy, and hormone profiles (e.g., cortisol, serotonin, melatonin) are lacking. Second, we used five selected questions of the PSQI to assess sleep parameters and no validated questionnaires were used to evaluate alcohol and caffeine intake; Third, since it was not possible to foresee the Covid-19 pandemic, we had to collect data about the pre-lockdown period by retrospective self-report which could be subjected to recall bias; nevertheless, our study procedures are similar to other works that evaluated sleep with surveys during the Covid-19 pandemic in athletes [13, 36]. Fourth, athletes' napping behavior was not evaluated; recent studies reported an increased napping frequency and duration in the general population during the lockdown [48] and it is known that a diurnal nap is an advantageous intervention to enhance recovery process and counteract the negative effect of partial sleep deprivation on physical and cognitive performance in athletes [49–51].

CONCLUSIONS

In summary, the Covid-19 lockdown measures determined a significant decrease in training volume and frequency along with a worsening in sleep quality, sleep latency, and a delay in bedtimes and wake-up times in elite Italian track and field athletes. Nevertheless, no inter-group differences were detected in sleep characteristics between short- and long-term disciplines and between genders and no differences in training volume were detected during the lockdown in relation to the square footage of the house. Alcohol and caffeine intake and use of electronic devices were similar pre-, during, and post-lockdown.

Practical Applications

With continuous spikes in Covid-19 cases in Italy and with the government reinstituting local/regional lockdowns, these results provide important insights to better manage sleep and training in a population for whom optimal performance is essential. Future studies should assess mental health and cognitive performances in athletes during home confinement. Under lockdown circumstances athletes and their coaching staff should enhance sleep hygiene strategies to maintain the correct sleep-wake patterns [52, 53] and plan *a priori* training sessions. The ultimate aim would be to avoid training load fluctuations potentially increasing the injury risk factors [54]. In addition, to assist elite athletes in case of further lockdowns, strength coaches should encourage setting goals during training periods. In fact, goal setting has proved to be effective in increasing motivation and reducing anxiety in sport [52, 54]. In conclusion, given the previous experience with the 2011 lockdown in the NFL where athletes were exposed to a greater injury risk [55], a sport-specific stepwise return to training is advised.

Acknowledgments

The authors wish to thank the athletes for their voluntary participation in the study and in the experimental procedures. This work was supported by the Italian Ministry of Health (Ricerca Corrente).

Conflict of interests

The authors declare no conflict of interest.

REFERENCES

1. Hoang VT, Al-Tawfiq JA, Gautret P. The Tokyo Olympic Games and the Risk of COVID-19. Curr. Trop. Med. Reports. 2020; 1–7. https://doi.org/10.1007/s40475-020-00217-y.
2. World Health Organization. Mental health and psychosocial considerations during the COVID-19 outbreak. 2020. https://www.who.int/docs/default-source/coronaviruse/mental-health-considerations.pdf
3. Gualano MR, Lo Moro G, Voglino G, Bert F, Siliquini R. Effects of Covid-19 Lockdown on Mental Health and Sleep Disturbances in Italy. Int. J. Environ. Res. Public Heal. 2020; 17(13):4779. https://doi.org/doi:10.3390/ijerph17134779.
4. Government of Italy. Decree of the President of the council of Ministers. 11 March 2020. https://www.gazzettaufficiale.it/eli/id/2020/03/11/20A01605/sg
5. Vitale JA, Perazzo P, Silingardi M, Biffi M, Banfi G, Negrini F. Is disruption of sleep quality a consequence of severe Covid-19 infection? A case-series examination. Chronobiol. Int. 2020; 37(7):1110–1114. https://doi.org/10.1080/07420528.2020.1775241.
6. King AJ, Burke LM, Halson SL, Hawley JA. The Challenge of Maintaining Metabolic Health During a Global Pandemic. Sport. Med. 2020; 50(7):1233–1241. https://doi.org/10.1007/s40279-020-01295-8.
7. Chen P, Mao L, Nassis GP, Harmer P, Ainsworth BE, Li F. Coronavirus disease (COVID-19): The need to maintain regular physical activity while taking precautions. J. Sport Heal. Sci. 2020; 9(2):103–104. https://doi.org/10.1016/j.jshs.2020.02.001.
8. Chirico A, Lucidi F, Galli F, Giancamilli F, Vitale J, Borghi S, La Torre A, Codella R. COVID-19 Outbreak and Physical Activity in the Italian Population: A Cross-Sectional Analysis of the Underlying Psychosocial Mechanisms. Front. Psychol. 2020; 11:2100. https://doi.org/10.3389/fpsyg.2020.02100.
9. Stanton R, To QG, Khalesi S, Williams SL, Alley SJ, Thwaite TL, Fenning AS, Vandelanotte C. Depression, anxiety and stress during COVID-19: Associations with changes in physical activity, sleep, tobacco and alcohol use in Australian

adults. Int. J. Environ. Res. Public Health. 2020; 17(11):4065. https://doi.org/10.3390/ijerph17114065.

10. Clay JM, Parker MO. Alcohol use and misuse during the COVID-19 pandemic: a potential public health crisis?. Lancet Public Heal. 2020; 5(5):e259. https://doi.org/10.1016/S2468-2667(20)30088-8.
11. Cellini N, Canale N, Mioni G, Costa S. Changes in sleep pattern, sense of time and digital media use during COVID-19 lockdown in Italy. J. Sleep Res. 2020; 29(4):e13074. https://doi.org/10.1111/jsr.13074.
12. Jukic I, Calleja-gonzález J, Cos F, Cuzzollin F, Olmo J, Terrados N, Njaradi N, Sassi R, Requena B, Milanovic L, Krakan I, Chatzichristos K, Alcaraz PE. Strategies and Solutions for Team Sports Athletes in Isolation due to COVID-19. Sports (Basel). 2020; 8(4):56.
13. Pillay L, Christa DC, Van Rensburg J, Jansen A, Rensburg V. Nowhere to hide: the significant impact of coronavirus disease 2019 (COVID-19) measures on elite and semi-elite South African athletes. J Sci Med Sport. 2020; 23(7):670–679.
14. Yousfi N, Bragazzi NL, Briki W, Zmijewski P, Chamari K. The COVID-19 pandemic: how to maintain a healthy immune system during the lockdown – a multidisciplinary approach with special focus on athletes. Biol Sport. 2020; 37(3):211–216.
15. Bisciotti GN, Eirale C, Corsini A, Baudot C, Saillant G, Chalabi H. Return to football training and competition after lockdown caused by the COVID-19 pandemic: medical recommendations. Biol Sport. 2020; 37(3):313–319.
16. Artino AR, Durning SJ, Sklar DP. Guidelines for reporting survey-based research submitted to academic medicine. Acad. Med. 2018; 93(3):337–340. https://doi.org/10.1097/A CM.0000000000002094.
17. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. Psychiatry Res. 1989; 28(2):193–213. https://doi.org/10.1016/0165-1781(89)90047-4.
18. Curcio G, Tempesta D, Scarlata S, Marzano C, Moroni F, Rossini PM, Ferrara M, De Gennaro L. Validity of the Italian Version of the Pittsburgh Sleep Quality Index (PSQI). Neurol. Sci. 2013; 34(4):511–9. https://doi.org/10.1007/s10072-012-1085-y.
19. Bakeman R. Recommended effect size statistics for repeated measures designs. Behav. Res. Methods. 2005; 37(3):379–84. https://doi.org/10.3758/BF03192707.
20. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med. Sci. Sports Exerc. 2009; 41(1):3–13. https://doi.org/10.1249/MSS.0b013e31818cb278.
21. Gupta L, Morgan K, Gilchrist S. Does Elite Sport Degrade Sleep Quality? A Systematic Review. Sports Med. 2017; 47(7):1317–1333. https://doi.org/10.1007/s40279-016-0650-6.
22. Vitale JA, Bonato M, Borghi S, Messina C, Albano D, Corbetta S, Sconfienza LM, Banfi G. Home-Based Resistance Training for Older Subjects during the COVID-19 Home-Based Resistance Training for Older Subjects during the COVID-19 Outbreak in Italy: Preliminary Results of a Six-Months RCT. 2020; 17(24):9533. https://doi.org/10.3390/ijerph17249533.
23. Blume C, Schmidt MH, Cajochen C. Effects of the COVID-19 lockdown on human sleep and rest-activity rhythms. Curr. Biol. 2020; 30(14):R795–R797. https://doi.org/10.1016/j.cub.2020.06.021.
24. Skeldon AC, Phillips AJK, Dijk DJ. The effects of self-selected light-dark cycles and social constraints on human sleep and circadian timing: A modeling approach. Sci. Rep. 2017; 7:45158. https://doi.org/10.1038/srep45158.
25. Leone MJ, Sigman M, Golombek DA. Effects of lockdown on human sleep and chronotype during the COVID-19 pandemic. Curr. Biol. 2020; 30(16):R930–R931. https://doi.org/10.1016/j.cub.2020.07.015.
26. Marelli S, Castelnuovo A, Somma A, Castronovo V, Mombelli S, Bottoni D, Leitner C, Fossati A, Ferini-Strambi L. Impact of COVID-19 lockdown on sleep quality in university students and administration staff. J. Neurol. 2021; 268(1):8–15. https://doi.org/10.1007/s00415-020-10056-6.
27. Wittmann M, Dinich J, Merrow M, Roenneberg T. Social jetlag: Misalignment of biological and social time. Chronobiol. Int. 2006; 23(1–2):497–509. https://doi.org/10.1080/07420520500545979.
28. Walsh NP, Halson SL, Sargent C, Roach GD, Nédélec M, Gupta L, Leeder J, Fullagar HH, Coutts AJ, Edwards BJ, Pullinger SA, Robertson CM, Burniston JG, Lastella M, Le Meur Y, Hausswirth C, Bender AM, Grandner MA, Samuels CH. Sleep and the athlete: Narrative review and 2021 expert consensus recommendations. Br. J. Sports Med. 2021. https://doi.org/10.1136/bjsports-2020-102025.
29. Halson SL. Stealing sleep: Is sport or society to blame?. Br. J. Sports Med. 2016; 50(7):381. https://doi.org/10.1136/bjsports-2015-094961.
30. Filipas L, Ferioli D, Banfi G, La Torre A, Vitale JA. Single and combined effect of acute sleep restriction and mental fatigue on basketball free-throw performance. Int. J. Sports Physiol. Perform. 2021; 16(3):415–420. https://doi.org/10.1123/IJSPP.2020-0142.
31. Fullagar HHK, Skorski S, Duffield R, Hammes D, Coutts AJ, Meyer T. Sleep and Athletic Performance: The Effects of Sleep Loss on Exercise Performance, and Physiological and Cognitive Responses to Exercise. Sport. Med. 2015; 45(2):161–86. https://doi.org/10.1007/s40279-014-0260-0.
32. Vitale JA, Bonato M, Petrucci L, Zucca G, La Torre A, Banfi G. Acute Sleep Restriction Affects Sport-Specific But Not Athletic Performance in Junior Tennis Players. Int. J. Sports Physiol. Perform. 2021; 1–6. https://doi.org/10.1123/ijspp.2020-0390.
33. Roberts SSH, Teo WP, Warmington SA. Effects of training and competition on the sleep of elite athletes: A systematic review and meta-analysis. Br. J. Sports Med. 2019; 53(8):513–522. https://doi.org/10.1136/bjsports-2018-099322.
34. Trabelsi K, Ammar A, Masmoudi L, Boukhris O, Chtourou H, Bouaziz B, Brach M, Bentlage E, How D, Ahmed M, Mueller P, Mueller N, Hsouna H, Romdhani M, Hammouda O, Paineiras-Domingos LL, Braakman-Jansen A, Wrede C, Bastoni S, Pernambuco CS, Mataruna-Dos-Santos LJ, Taheri M, Irandoust K, Khacharem A, Bragazzi NL, Strahler J, Washif JA, Andreeva A, Bailey SJ, Acton J, Mitchell E, Bott NT, Gargouri F, Chaari L, Batatia H, Khoshnami SC, Samara E, Zisi V, Sankar P, Ahmed WN, Ali GM, Abdelkarim O, Jarraya M, El Abed K, Moalla W, Souissi N, Aloui A, Souissi N, van Gemert-Pijnen L, Riemann BL, Riemann L, Delhey J, Gómez-Raja J, Epstein M, Sanderman R, Schulz S, Jerg A, Al-Horani R, Mansi T, Dergaa I, Jmail M, Barbosa F, Ferreira-Santos F, Šimunič B, Pišot R, Pišot S, Gaggioli A, Steinacker J, Zmijewski P, Clark CCT, Apfelbacher C, Glenn JM, Ben Saad H, Chamari K, Driss T, Hoekelmann A. Globally altered sleep patterns and physical activity levels by confinement in 5056 individuals: ECLB COVID-19 international online survey. Biol Sport. 2021; 38(4):495–506. https://doi.org/10.5114/biolsport.2021.101605.
35. Ammar A, Trabelsi K, Brach M, Chtourou H, Boukhris O, Masmoudi L, et al. Effects of home confinement on mental health and lifestyle behaviours during the COVID-19 outbreak: Insights from the ECLB-COVID19 multicentre study. Biol Sport. 2021; 38(1):9–21. https://doi.org/10.5114/biolsport.2020.96857.

36. Facer-Childs ER, Hoffman D, Tran JN, Drummond SPA, Rajaratnam SMW. Sleep and mental health in athletes during COVID-19 lockdown. Sleep. 2021; zsaa261. https://doi.org/10.1093/sleep/zsaa261.
37. Lastella M, Roach GD, Halson SL, Sargent C. Sleep/wake behaviours of elite athletes from individual and team sports. Eur. J. Sport Sci. 2015; 15(2):94–100. https://doi.org/10.1080/17461391.2014.932016.
38. Vitale JA, La Torre A, Banfi G. If RAR's acrophase is influenced by the sport discipline, how actigraphy-based sleep parameters vary in triathlon, volleyball and soccer athletes?, Chronobiol. Int. 2019; 36(6):735–738. https://doi.org/10.1080/07420528.2019.1594246.
39. Vitale JA, Banfi G, Sias M, La Torre A. Athletes' rest-activity circadian rhythm differs in accordance with the sport discipline. Chronobiol. Int. 2019; 36(4):578–586. https://doi.org/10.1080/07420528.2019.1569673.
40. Silva A, Narciso FV, Rosa JP, Rodrigues DF, da Silva Cruz AA, Tufik S, Viana F, Bichara JJ, Dias Pereira SR, da Silva SC, de Mello MT. Gender differences in sleep patterns and sleep complaints of elite athletes. Sleep Sci. 2019; 12(4):242–248. https://doi.org/10.5935/1984-0063.20190084.
41. van Schrojenstein Lantman M, Roth T, Roehrs T, Verster JC. Alcohol Hangover, Sleep Quality, and Daytime Sleepiness. Sleep Vigil. 2017. https://doi.org/10.1007/s41782-017-0008-7.
42. Altena E, Baglioni C, Espie CA, Ellis J, Gavriloff D, Holzinger B, Schlarb A, Frase L, Jernelöv S, Riemann D. Dealing with sleep problems during home confinement due to the COVID-19 outbreak: Practical recommendations from a task force of the European CBT-I Academy. J. Sleep Res. 2020; 29(4):e13052. https://doi.org/10.1111/jsr.13052.
43. Håkansson A, Jönsson C, Kenttä G. Psychological distress and problem gambling in elite athletes during covid-19 restrictions—a web survey in top leagues of three sports during the pandemic. Int. J. Environ. Res. Public Health. 2020; 17(18):6693. https://doi.org/10.3390/ijerph17186693.
44. Wams EJ, Woelders T, Marring I, Van Rosmalen L, Beersma DGM, Gordijn MCM, Hut RA. Linking light exposure and subsequent sleep: A field polysomnography study in humans. Sleep. 2017; 40(12):zsx165. https://doi.org/10.1093/sleep/zsx165.
45. Mujika I, Padilla S. Detraining: Loss of training induced physiological and performance adaptation. Part I. Short term insufficient training stimulus. Sports Med. 2000; 30(2):79–87. https://doi.org/10.2165/00007256-200030020-00002.
46. Chennaoui M, Arnal PJ, Sauvet F, Léger D. Sleep and exercise: A reciprocal issue?. Sleep Med. Rev. 2015; 20:59–72. https://doi.org/10.1016/j.smrv.2014.06.008.
47. Barger LK, Sullivan JP, Blackwell T, O'Brien CS, St Hilaire MA, Rahman SA, Phillips AJK, Qadri S, Wright KP, Segar JL, McGuire JK, Vitiello MV, De La Iglesia HO, Poynter SE, Yu PL, Zee P, Sanderson AL, Halbower AC, Lockley SW, Landrigan CP, Stone KL, Czeisler CA. Effects on resident work hours, sleep duration, and work experience in a randomized order safety trial evaluating resident-physician schedules (ROSTERS). Sleep. 2019; 42(8):zsz110. https://doi.org/10.1093/sleep/zsz110.
48. Majumdar P, Biswas A, Sahu S. COVID-19 pandemic and lockdown: cause of sleep disruption, depression, somatic pain, and increased screen exposure of office workers and students of India. Chronobiol. Int. 2020; 37(8):1191–1200. https://doi.org/10.1080/07420528.2020.1786107.
49. Romdhani M, Hammouda O, Chaabouni Y, Mahdouani K, Driss T, Chamari K, Souissi N. Sleep deprivation affects post-lunch dip performances, biomarkers of muscle damage and antioxidant status. Biol Sport. 2019; 36(1):55–65. https://doi.org/10.5114/biolsport.2018.78907.
50. Romdhani M, Dergaa I, Moussa-Chamar I, Souissi N, Chaabouni Y, Mahdouani K, Abene O, Driss T, Chamari K, Hammouda O. The effect of post-lunch napping on mood, reaction time, and antioxidant defense during repeated sprint exercice. Biol Sport. 2021; 38(4):629–638. https://doi.org/10.5114/biolsport.2021.103569.
51. Lastella VM, Halson SL, Vitale JA, Memon AR, Vicent GE. To Nap or Not to Nap? A Systematic Review Evaluating Napping Behavior in Athletes and the Impact on Various Measures of Athletic Performance. Nature and Science of Sleep. 2021.
52. Vitale JA, La Torre A, Banfi G, Bonato M. Acute sleep hygiene strategy improves objective sleep latency following a late-evening soccer-specific training session: A randomized controlled trial. J. Sports Sci. 2019;37(23):2711–2719. https://doi.org/10.1080/02640414.2019.1661938.
53. Gabel V, Micheline M, Reichert CF, Chellappa SL, Schmidt C, Hommes V, Viola AU, Cajochen C. Effect of artificial dawn and morning blue light on daytime cognitive performance, well-being, cortisol and melatonin levels. Chronobiol Int. 2013; 30(8):988–97. doi: 10.3109/07420528.2013.793196.
54. Maupin D, Schram B, Canetti E, Orr R. The Relationship Between Acute: Chronic Workload Ratios and Injury Risk in Sports: A Systematic Review. Open Access J. Sports Med. 2020; 11:51–75. https://doi.org/10.2147/oajsm.s231405.
55. Myer GD, Faigenbaum AD, Cherny CE, Heidt RS, Hewett TE. Did the NFL lockout expose the achilles heel of competitive sports. J. Orthop. Sports Phys. Ther. 2011; 41(10):702–5. https://doi.org/10.2519/jospt.2011.0107.

SUPPLEMENTARY MATERIALS

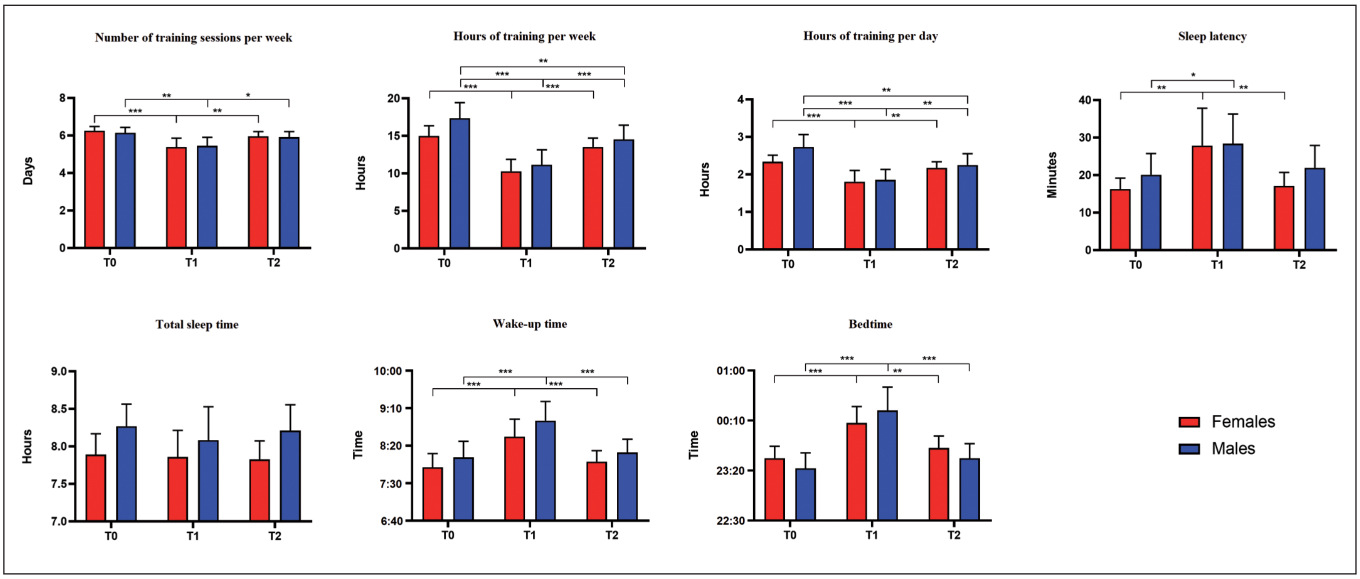

FIG. S1. Histograms report means with 95% CI of physical activity and sleep parameters for females (red) and males (blue) athletes. *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.0001$.

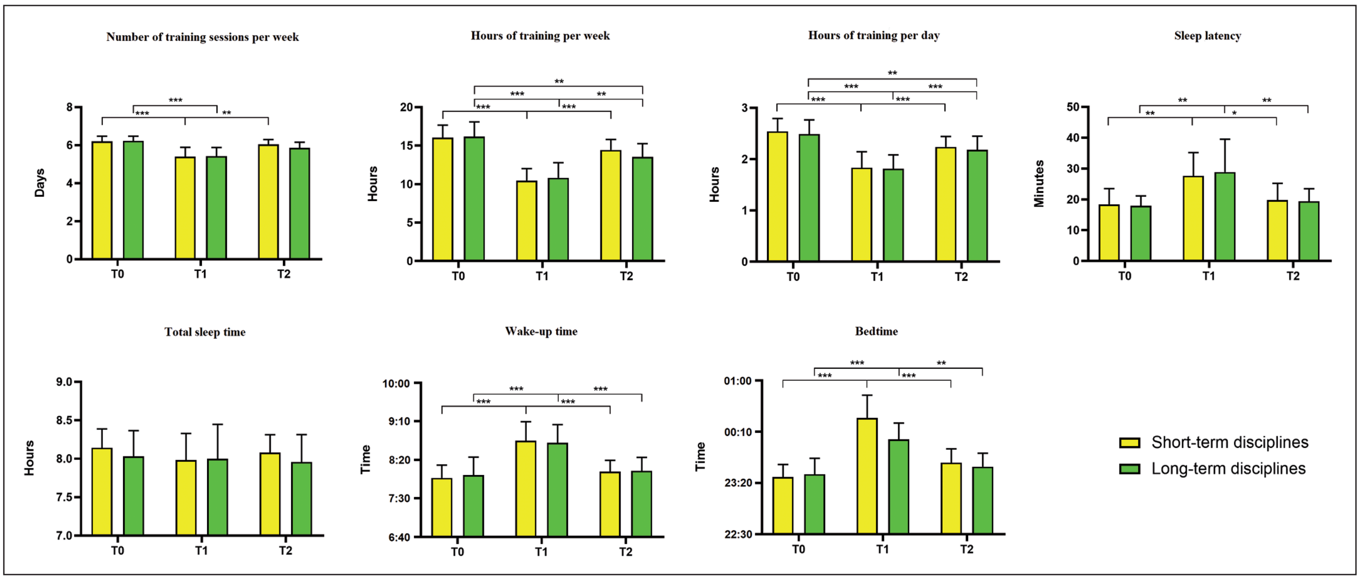

FIG. S2. Histograms report means with 95% CI of physical activity and sleep parameters for short-term (yellow) and long-term (green) disciplines. *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.0001$.