



Detraining and retraining in badminton athletes following 1-year COVID-19 pandemic on psychological and physiological response

Igor Almeida Silva¹ · Arilene Maria da Silva Santos¹ · Alberto Jimenez Maldonado² · Helton Pereira dos Santos Nunes de Moura¹ · Priscila Almeida Queiroz Rossi³ · Lucas Melo Neves^{4,5} · Marcos Antonio Pereira dos Santos⁶ · Dionis Castro Dutra Machado⁷ · Sergio Luiz Galan Ribeiro⁷ · Fabricio Eduardo Rossi^{8,9}

Received: 20 September 2021 / Accepted: 30 March 2022 / Published online: 27 April 2022
© The Author(s), under exclusive licence to Springer-Verlag Italia S.r.l., part of Springer Nature 2022

Abstract

Purpose Badminton is a racket sport, with fast and explosive movements and mental skills employed to anticipate the opponent's movements. The COVID-19 pandemic, led to social restriction in Brazil and sport event cancellations, subsequently, sports training was banned. Thus, the objective of this study was to compare the impact of long-period detraining due to COVID-19 social restriction (8 months and 1-year) on cardiorespiratory fitness, body composition, nutritional behavior, and profile of mood states in badminton athletes and to verify if the athletes who returned to their regular training 4 months earlier than athletes who stopped their daily training routine during 1-year would improve these variables.

Methods Twenty-three young badminton athletes were analyzed: retrained group (14 athletes who stopped their daily training routine for 8 months due to the COVID-19 pandemic plus 4 months of retraining), and detrained group (9 athletes who stopped their daily training routine during 1 year of the COVID-19 pandemic but performed home-based training). We evaluated body composition, cardiorespiratory fitness, nutritional behavior, and mood states profiles.

Results Retrained athletes showed lower body fat (-24.1% vs. $+20.8\%$, $p < 0.001$) and higher fat-free mass ($+6.0\%$ vs. -0.2% , $p = 0.007$) after 1 year compared with the detrained group. For cardiorespiratory fitness [retrained: baseline = 55.5 ± 5.3 (47.1, 63.9) and after 1 year = 58.1 ± 2.4 (54.2, 61.9), ES = 0.65 vs. detrained: baseline = 53.4 ± 6.7 (47.2, 59.5) and after 1 year = 53.1 ± 5.6 (48.0, 58.3), ES = -0.03] and nutritional behavior, including sauces and spices [retrained: baseline = 8.9 ± 7.0 (4.5, 13.4), and after 1 year = 3.4 ± 2.9 (1.8, 5.5), ES = -1.11 vs. detrained: baseline = 6.8 ± 6.7 (1.6, 11.9) and after 1 year = 6.3 ± 5.5 (2.1, 10.6), ES = -0.08], the ESs were medium and large, respectively, for Retrained but trivial for detrained group. For depression, ES was trivial in the retrained [baseline = 2.7 ± 3.3 (0.7, 4.7) and after 1 year = 2.6 ± 2.9 (0.8, 4.4), ES = 0.03] and moderate for detrained [baseline = 1.0 ± 1.5 (-0.1 , 2.1) and after 1 year = 1.8 ± 2.7 (-0.3 , 3.8), ES = 0.50].

Conclusions Young badminton athletes who returned to their regular daily training 4 months earlier than athletes who stopped their daily training routine during 1-year due to COVID-19 social restriction decreased fat mass and increased fat-free mass. There were no significant differences between groups for cardiorespiratory fitness, nutritional behavior, and profile of mood state response.

Keywords Coronavirus · Athletes · Sports · Body composition · Depression · Dietary habits

Introduction

Badminton is a racket sport with an average heart rate greater than 90% of the maximum heart rate during the match. Fast, explosive movements and mental skills are employed to anticipate the opponent's movements and make decisions associated with the strategy during a game, therefore,

✉ Fabricio Eduardo Rossi
fabriciorossi@ufpi.edu.br

Extended author information available on the last page of the article

physiological and psychological variables are considered essential characteristics for success during a match [1].

In March 2020, the COVID-19 pandemic, caused by SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus-2) [2, 3] led to social restriction in Brazil and sport event cancellations. Subsequently, sports training was banned [4], and social restriction drastically reduced the physical activity levels and increased sedentary time in badminton athletes [5]. Furthermore, social isolation increased the risk of suffering anxiety, depression, addictions, and other mental health concerns in athletes [6]. Additionally, the changes in dietary habits are another negative impact generated by the COVID-19 pandemic [7].

Despite the lockdown, scientists recommended that the athletes must maintain their performance through individual training at home [8]. In this regard, social restriction caused by the COVID-19 pandemic was unprecedented in the current period. In this sense, scientific investigations were performed to characterize athletes' responses to the lockdown, however, the findings were not concordant. Specifically, Fikenzler et al. [9] and Grazioli et al. [10] demonstrated that a short period of lockdown (2 months) did not affect the cardiorespiratory fitness in highly trained handball and soccer players. However, over the same period, the fat mass increased in soccer players [10]. Additionally, Spyrou et al. [11] reported that 70 days of lockdown declined the performance in sprint, countermovement jump, rate of force development, peak power, velocity, and landing peak force in elite futsal players. Finally, recent reports show the COVID-19 pandemic detraining did not affect the performance of swimmers [12] but affected performance of volleyball and soccer athletes [13].

In regard to badminton athletes, to the best our knowledge, only the study of Valenzuela et al. [14] investigated the effects of COVID-19 lockdown in detraining and retraining, however, this work involved a relatively short period (7–10 weeks of lockdown, and 6–8 weeks of retraining). In their study, the authors reported a significant reduction in the countermovement jump (− 6.5%) and 1-repetition maximum performance (− 11.5%) during the lockdown, however, after the retraining phase, all measures returned to similar values to those found at baseline.

The negative effects of the social restriction for athletes are not restricted only to physiological systems, but are also reflected in psychological symptoms. Chen et al. [15] showed that the population of athletes suffers the most from mental issues such as anxiety, obsessive–compulsive disorder and depression during the COVID-19 pandemic at equivalent or even higher rates than non-athletes. Furthermore, home confinement can result in dietary changes, leading to excessive food intake and frequent consumption of ultra-processed foods, which may not only promote weight

gain and fat-free mass loss but also increased risk of injury or gastrointestinal discomfort [16, 17].

Despite the different statements recommending the safe return to training and competition after lockdown caused by the COVID-19 pandemic [18–21], the retraining period effect on these variables is not yet clear after a long detraining season (≥ 8 months) in highly trained badminton players. Therefore, monitoring athlete routines during the long-term training restriction and retraining period may be useful for coaches, sport physiologists, and athletes when making decisions concerning initial load and progressions during the return to training and matches. Also, safe and healthy strategies can be developed to mitigate physiological and psychological responses for athletes to return to competition-level readiness [19].

Therefore, the objective of this study was to compare the impact of long-period of detraining due to COVID-19 social restriction (8-months and 1-year) on cardiorespiratory fitness, body composition, nutritional behavior, and profile of mood states in highly trained badminton athletes and verify if the athletes who returned to their regular training 4 months earlier than athletes who stopped their daily training routine during 1 year would improve these variables.

Methods

Study design and participants

This 1-year follow-up study was conducted between June 2020 and June 2021 with young, highly trained badminton athletes. According to the state laws during the pandemic, Brazilian citizens and athletes must adhere to local laws and social isolation. Therefore, athletes were requested to stop their regular training routine in March 2020. Thus, we performed the baseline assessments on 32 athletes in June 2020, after 3 months of COVID-19 social restriction. Then, in February 2021, 28 athletes were randomized into two groups: retrained group = 14 athletes, who stopped their daily training routine for 8 months due to COVID-19 social restriction plus 4 months of retraining; and detrained group = 14 athletes, who stopped their daily training routine for 1 year due to COVID-19 social restriction. After 4 months (June 2021), the athletes were evaluated again, and at this time, the retrained group was comprised of seven women and seven men; for the detrained group, six women and three men were analyzed (Fig. 1). The main reasons for dropouts in the detrained group were athletes who missed the second assessment due to personal reasons or who remained detrained for 1 year and became demotivated and abandoned the sport during the pandemic. Thus, the final sample analyzed was 23 young badminton athletes.

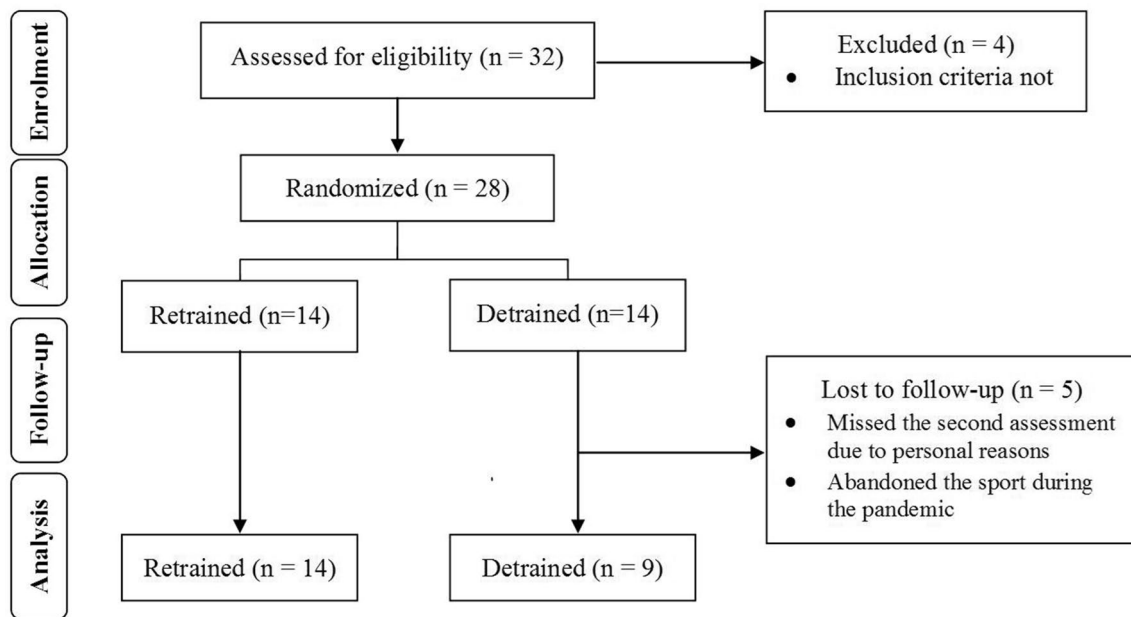


Fig. 1 CONSORT chart

The athletes were recruited by convenience through contact with the Brazilian Badminton Confederation coaches, ten men (age = 18.7 ± 3.0 years), and 13 women (age = 17.8 ± 2.1 years). The inclusion criteria in the study were: being over 15 years old at the date of collection; not presenting injuries or cognitive problems during the evaluation period; having no cardiovascular system contraindications or musculoskeletal disorders; not having used any medication. Written informed consent was obtained from all subjects after the participants had been informed about the purpose and risks of the study. In addition, parents or guardians signed the written informed consent (when age < 18 years), both previously approved by the Ethics and Research Committee of the Federal University of Piauí (Protocol: 2.552.506). Furthermore, we developed protocols according to the Declaration of Helsinki [22].

All athletes had at least 2 years of experience in badminton and participated in national and international competitions. During the pandemic, the coaches used video classes on the Google Meet platform, three times a week for about 60 min per day to guide their athletes at home to keep themselves fit and healthy, focusing only on physical capabilities, such as flexibility, aerobic capacity, and agility, and not on technical or tactical training. The routine was accordingly used by Fikenzler et al. [23].

Athletes who returned to their routine in February were training consistently (5–6 times a week, about 4–5 h a day, over 30 h per week). The routine included general strength and endurance training, basic techniques, and techno-tactical skills. The detrained group continued training individually

to keep themselves fit and healthy, focusing only on physical capabilities: flexibility, aerobic capacity, and agility using the video classes on the Google Meet platform, according as previously described and suggested by Fikenzler et al. [23]. Nobody had the COVID-19 infection during this current study.

Procedures

Initially, the athletes went to the laboratory between 8:00 to 9:00 AM in June 2020 and they recorded Profile of Mood State test and Food Frequency Questionnaire. Next, they were assessed for anthropometrics and body composition. Last, the athletes performed the aerobic power test. After 1 year (June 2021), the athletes repeated all assessments personally (Fig. 2).

Anthropometry, body composition, and nutritional behavior

We measured body mass using an electronic scale (Filizola PL 50, Filizola Ltda, Brazil), with an accuracy of 0.1 kg and a maximum capacity of 150 kg, height using a fixed stadiometer from the Sanny brand (Sanny, São Paulo, Brazil), with an accuracy of 0.1 cm and body composition using a spectral bioelectrical impedance analysis (model BIA 310e, Biodynamics Body Composition, Seattle, WA, USA) to measure total body water (TBW), fat mass (FM), and fat-free mass (FFM) in kilograms and body fat percentage (%BF). The

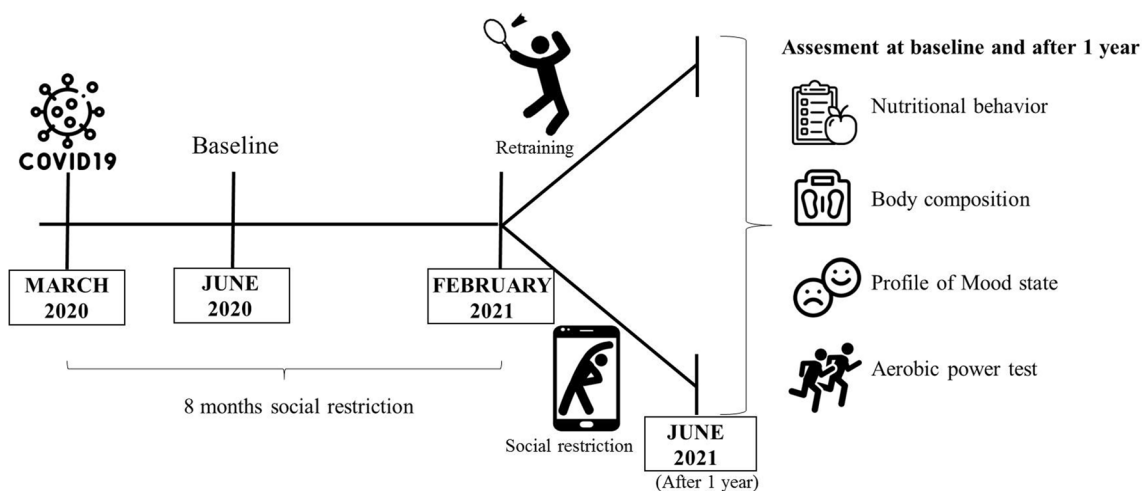


Fig. 2 Experimental design

assessments were performed at the same time (8:00 AM to 9:00 AM) to ensure chronobiological control. With the fasted state subject, we instructed them to perform no physical activity on the test day and remove all removable metal items from their body and avoid alcoholic beverages for at least 12 h before the test. The participants were positioned in a supine position with their limbs at a distance from the trunk, the arms forming an angle of approximately 30° and the legs forming an angle of 45° and remained still throughout the examination, and they were wearing light clothing [24]. According to the recommendations for BIA using the foot-to-hand technique in athletes, we placed the surface electrodes in four anatomic points [25]. Based on results of a small pilot study ($n = 8$), the test–retest intraclass correlation coefficients (ICC) from our lab was TBW (0.99), FM (0.97), %BF (0.96) and FFM (0.99).

The Food Frequency Questionnaire (FFQ) on the frequency of consumption of each item from a list of foods ranging from months to a year [26]. The FFQ used consists of 60 food items, with frequencies from 0 to 10 times, time unit (day, week, month, and year), and definition of portions (small, medium, large, and extra-large), according Fisberg et al. [27] and validated by Selem et al. [28] for a specific population. In addition, to nutritional behavior, the sum of food frequency of consumption of each item from a list of foods was calculated.

Profile of mood state test

The Brunel Mood Scale test was adapted from the Profile of Mood States (POMS) [29] and validated for the Brazilian population by Rohlfs et al. [30]. The six mood factors or affective states measured are tension, depression, anger, vigor, fatigue, and confusion [30]. The scale also provides a total score of mood disturbance (TMD),

obtained by the following formula: [(tension + depression + anger + fatigue + confusion) – vigor] + 100 [30]. All data were collected by the researchers in the laboratory.

Aerobic power test

The speed (km/h) of the last stage completed achieved in the Yo-Yo Endurance Test was used to estimate the maximal oxygen consumption (VO_{2max} ml/kg/min) with the following equation: $24.4 + 6 \times [\text{final velocity (km/h)}]$ for athletes aged ≥ 18 years or $31.025 + (3.238 \times \text{final velocity}) - (3.248 \times \text{age}) + 0.1536 \times (\text{final velocity} \times \text{age})$ for athletes aged < 18 years [31].

Statistical analysis

The data were analyzed using the Statistical Package for Social Sciences 17.0 (SPSS Inc. Chicago, IL, USA). We used the Shapiro–Wilk test to verify the normality of the data set and the sphericity was verified according to Mauchly’s W test, and the Greenhouse–Geisser correction was applied when necessary. Since the data were spherical, we showed it as mean and standard deviation. To compare outcomes, a two-way analysis of variance (ANOVA) [2 groups (detraining vs. retraining) \times 2 times (baseline vs. after 1 year)] was employed. The partial eta squared (η^2) was reported for Anova and confidence interval set at 95%. (95% CI) was calculated. We calculated effect sizes (ES) as the mean pre–post change divided by the pooled pretest standard deviation, whereby a value of > 0.20 was considered small, > 0.50 medium, and > 0.80 large [32]. Statistical significance was set at $p < 0.05$.

Results

Table 1 shows the characteristics of the participants. There was no significant difference between groups for all variables analyzed at baseline ($p > 0.05$).

Table 2 compares body composition and cardiorespiratory fitness in detrained and retrained badminton athletes after 1 year of COVID-19 social restriction. The variables presented in Table 2 showed normal distribution.

For fat mass, there was a significant group \times time interaction ($F = 41.782, p < 0.001, \eta^2 = 0.67$). Post hoc analysis showed a significant increment for detrained group ($p < 0.001$) and a reduction in the retrained athletes

($p < 0.001$) with a significant difference between groups after 1 year ($p < 0.001$). In concordance, there was a main interaction effect for BF %, ($F = 71.764, p < 0.001, \eta^2 = 0.77$). Bonferroni's post hoc demonstrated significant increments for detrained group ($p < 0.001$), in contrast, the BF % significantly reduced in the retrained group ($p < 0.001$); and there were significant differences between groups after 1 year ($p < 0.001$).

For FFM, there was a significant main interaction effect ($F = 9.072, p = 0.007, \eta^2 = 0.30$). The post hoc analysis showed a significant increase in FFM only for the retrained group ($p < 0.001$) but not in the detrained group ($p = 0.912$). Likewise, there was a significant main interaction effect ($F = 11.343, p = 0.003, \eta^2 = 0.35$) for TBW. Specifically, we observed a significant increase in the retrained group for TBW ($p < 0.001$) but there was no significant change in the detrained group ($p = 0.570$).

There was a main effect of time for body weight ($F = 4.792, p = 0.040, \eta^2 = 0.19$), but no main interaction effect was observed ($F = 3.133, p = 0.091, \eta^2 = 0.13$). For VO_{2max} (ml/kg/min) ($F = 0.443, p = 0.522, \eta^2 = 0.05$) and maximum velocity speed (km/h) ($F = 0.067, p = 0.802, \eta^2 = 0.007$) there were no significant interactions or main effects of time. However, the ES were medium (0.65; 0.62), for the retrained group and trivial in the detrained group ($-0.03; 0.18$), respectively.

Table 1 Characteristics of the badminton athletes, according to group and sex

Variables	Detrained athletes (n=9)	Retrained athletes (n=14)	p
Age (years)	18.6 ± 2.2	18.0 ± 2.8	0.618
Height (cm)	168.8 ± 5.6	168.0 ± 9.4	0.820
BMI (kg/m ²)	22.6 ± 1.5	21.7 ± 2.5	0.364
Badminton experience (years)	9.3 ± 2.3	9.5 ± 3.3	0.897

Data are shown as mean and standard deviation

BMI body mass index (kg/m²)

Table 2 Comparison of body composition and cardiorespiratory fitness in detrained and retrained badminton athletes after 1 year of COVID-19 social restriction

Variables	Detrained athletes (n=9)		ES	Retrained athletes (n=14)		ES	p
	Baseline	After 1 year		Baseline	After 1 year		
Body composition							
Body weight (kg)	64.2 ± 7.1 (58.8, 69.7)	67.0 ± 8.3 ^a (60.6, 73.4)	0.36	61.1 ± 11.3 (54.6, 67.7)	61.4 ± 10.2 ^a (55.5, 67.3)	0.03	0.091
Fat mass (kg)	13.8 ± 3.6 (11.0, 16.5)	16.6 ± 2.6 * (14.6, 18.6)	0.94	11.2 ± 2.9 (9.5, 12.9)	8.5 ± 2.3*, [‡] (7.2, 9.8)	-1.04	<0.001
Fat mass (%)	21.6 ± 5.6 (17.3, 25.9)	24.9 ± 3.6* (22.1, 27.7)	0.72	18.7 ± 5.1 (15.7, 21.6)	14.3 ± 4.9* [‡] (11.5, 17.1)	-0.88	<0.001
FFM (kg)	50.5 ± 7.8 (44.5, 56.5)	50.4 ± 7.6 (44.5, 56.2)	-0.01	49.9 ± 11.0 (43.5, 56.3)	52.9 ± 11.1* (46.5, 59.3)	0.27	0.007
TBW (l)	34.4 ± 5.2 (30.4, 38.4)	34.1 ± 5.2 (30.1, 38.1)	-0.06	35.3 ± 7.9 (30.7, 39.9)	37.3 ± 8.4 * (32.5, 42.2)	0.25	0.003
Cardiorespiratory fitness							
VO_{2max} (ml/kg/min)	53.4 ± 6.7 (47.2, 59.5)	53.1 ± 5.6 (48.0, 58.3)	-0.03	55.5 ± 5.3 (47.1, 63.9)	58.1 ± 2.4 (54.2, 61.9)	0.65	0.522
Velocity (km/h)	12.8 ± 1.2 (11.7, 13.9)	13.0 ± 1.0 (12.1, 14.0)	0.18	13.3 ± 0.9 (11.9, 14.7)	13.7 ± 0.4 (13.1, 14.4)	0.62	0.802

The 95% CI are shown in parentheses

Data are shown as mean and standard deviation

FFM fat-free mass, TBW total body water (l), ES effect size

*Bonferroni's post hoc with significant difference between moments

[‡]Bonferroni's post hoc with significant difference between groups after 1 year

^aMain effect of time

Table 3 shows the comparison of nutritional behavior in the detrained and retrained groups after 1 year of COVID-19 social restriction. There was a main effect of time for sauces and spices ($F=5.190, p=0.034, \eta^2=0.21$), fruit ($F=9.506, p=0.006, \eta^2=0.33$) and beverage ($F=10.182, p=0.005, \eta^2=0.35$). However, the main interaction effects for all food groups analyzed were not observed. The ES was large for sauces and spices in the retrained group (-1.11) and trivial for the detrained (-0.08), while for fruit and beverage, the ESs were large in the detrained ($-1.10; -1.45$) and small for the retrained group ($-0.30; -0.23$), respectively.

Table 4 compares the profile of mood state response in the detrained and retrained badminton athletes after 1 year of COVID-19 social restriction. The variables presented

in Table 4 did not show normal distribution, and we showed data as median and interquartile range. We used for comparing groups across time, the Greenhouse–Geisser correction, and since data were spherical, the two-way ANOVA.

There was no significant difference between groups for all investigated profiles of mood state. However, the ES was medium for depression (0.50) and small (0.20) for confusion in the detrained group and trivial in the retrained group (0.03; -0.03), respectively. Concerning vigor, the retrained group showed small ES (-0.40) and trivial for detrained athletes (-0.14). Finally, the ES for the total score of mood disturbance was small in both groups (retrained group: 0.24, and detrained group: 0.31).

Table 3 Comparison of nutritional behavior in detrained and retrained badminton athletes after 1 year of COVID-19 social restriction

Variable	Detrained athletes (n=9)		ES	Retrained athletes (n=14)		ES	p
	Baseline	After 1 year		Baseline	After 1 year		
Soup and pasta	20.8±15.0 (9.3, 32.3)	18.7±14.7 (7.3, 30.0)	-0.14	15.9±11.6 (8.5, 23.3)	12.4±10.0 (6.1, 18.8)	-0.32	0.800
Meat and fish	23.3±10.0 (15.7, 31.0)	20.9±10.2 (13.1, 28.7)	-0.24	23.6±15.0 (14.0, 33.1)	19.8±17.7 (8.6, 31.1)	-0.23	0.831
Milk and dairy products	9.3±6.2 (4.6, 14.1)	8.0±5.3 (3.9, 12.1)	-0.23	10.8±5.5 (7.3, 14.3)	8.9±7.6 (4.1, 13.7)	-0.29	0.819
Vegetables and egg	11.3±3.7 (8.5, 14.2)	9.7±2.7 (7.6, 11.8)	-0.50	15.3±9.8 (9.1, 21.6)	13.0±8.5 (7.6, 18.4)	-0.25	0.837
Rice and seed products	16.3±7.8 (10.3, 22.4)	12.8±6.2 (8.0, 17.6)	-0.50	15.1±7.3 (10.4, 19.7)	15.3±13.6 (6.7, 24.0)	0.02	0.367
Leafy vegetables	10.3±4.4 (7.0, 13.7)	8.7±5.1 (4.7, 12.6)	-0.34	14.2±14.2 (5.1, 23.2)	12.6±14.2 (3.4, 21.6)	-0.11	0.970
Sauces and spices	6.8±6.7 (1.6, 11.9)	6.3±5.5 (2.1, 10.6) ^a	-0.08	8.9±7.0 (4.5, 13.4)	3.4±2.9 (1.8, 5.5) ^a	-1.11	0.070
Fruit	20.4±8.3 (14.1, 22.8)	13.0±5.1 (9.0, 17.0) ^a	-1.10	21.7±18.5 (10.0, 33.5)	16.5±15.8 (6.5, 26.5) ^a	-0.30	0.600
Beverage	16.0±4.5 (12.6, 19.4)	9.9±3.9 (6.9, 12.9) ^a	-1.45	11.5±6.2 (7.6, 15.4)	10.1±5.8 (6.4, 13.8) ^a	-0.23	0.061
Bread and biscuit	19.3±11.6 (10.4, 28.3)	15.8±8.4 (9.3, 22.3)	-0.35	17.0±8.1 (11.8, 22.1)	13.6±7.7 (8.7, 18.5)	-0.43	0.963
Candy and dessert	12.8±9.7 (5.3, 20.2)	8.8±5.8 (4.3, 13.3)	-0.52	8.9±6.8 (4.6, 13.2)	7.4±5.5 (3.9, 10.9)	-0.24	0.385

Data are shown as mean and standard deviation

ES=effect size

^aMain effect of time. The 95%CI are shown in parentheses

Table 4 Comparison of the profile of mood states in detrained and retrained badminton athletes after 1 year of COVID-19 social restriction

Variable	Detrained athletes (n=9)		ES	Retrained athletes (n=14)		ES	p
	Baseline	After 1 year		Baseline	After 1 year		
Tension	3.2±3.6 (0.5, 6.0)	3.2±3.7 (0.4, 6.0)	0.00	4.5±4.3 (1.9, 7.2)	3.3±3.1 (1.4, 5.2)	-0.32	0.363
Depression	1.0±1.5 (-0.1, 2.1)	1.8±2.7 (-0.3, 3.8)	0.50	2.7±3.3 (0.7, 4.7)	2.6±2.9 (0.8, 4.4)	0.03	0.579
Anger	2.0±3.0 (-0.3, 4.3)	2.8±2.6 (-0.8, 5.5)	0.30	1.5±2.0 (0.3, 2.7)	2.8±3.1 (1.0, 4.7)	0.50	0.344
Vigor	8.7±3.6 (5.9, 11.4)	8.2±3.8 (5.3, 11.1)	-0.14	9.5±2.3 (7.8, 11.1)	8.5±3.1 (6.7, 10.4)	-0.40	0.771
Fatigue	2.7±2.2 (0.9, 4.4)	4.1±4.1 (0.9, 7.3)	0.44	3.7±3.5 (1.6, 5.8)	5.2±3.8 (2.9, 7.5)	0.41	0.959
Confusion	2.0±4.0 (-1.0, 5.0)	2.7±3.5 (-0.02, 5.4)	0.20	3.2±3.4 (1.2, 5.3)	3.1±3.3 (1.0, 5.1)	-0.03	0.580
TMD	2.0±10.8 (-6.3, 10.3)	5.9±14.5 (-5.3, 17.1)	0.31	5.8±15.9 (-3.9, 15.4)	9.4±14.7 (0.5, 18.3)	0.24	0.962

Data are shown as mean and standard deviation. The 95% CI are shown in parentheses

TMD total score of mood disturb, ES effect size

Discussion

Recent studies and scientific opinions have provided guidelines for a safe return to training and competition after lockdown caused by the COVID-19 pandemic [18, 20]. However, to our best knowledge, this is the first study focused on assessing the physiological and psychological responses during the return to training after a long-period COVID-19 social restriction in highly trained badminton athletes. The main finding of the present study was that young badminton athletes who returned to regular daily training 4 months earlier than athletes who stopped daily training routine during 1 year due to COVID-19 social restriction improved the body composition (we observed lower fat mass and higher fat-free mass). Notwithstanding, there was no significant difference between groups for cardiorespiratory fitness, nutritional behavior, and profile of mood states. However, the ES was medium for cardiorespiratory fitness, sauces, and spices in the retrained and trivial in the detrained group. For depression, fruit and beverage intake detrained showed medium to large effect and the retrained group, trivial effect.

Our data are concordant with previous works [14]. Valenzuela et al. [14] evaluated seven elite badminton players during 4 weeks of normal training (baseline), short period of lockdown (7–10 weeks), and 6–8 weeks of retraining and they found a significant reduction in heart rate variability (−2.0%), power (−6.5%) and 1-repetition maximum performance (−11.5%), after the lockdown; however, during the retraining phase, all measures returned to similar values found at baseline, demonstrating that although COVID-19 lockdown impaired performance on elite athletes, these detrimental effects might be avoided by short period of retraining both on performance, and as well as observed in our study on body composition.

Previous studies from our group have shown that although highly trained athletes accomplish the moderate-to-vigorous physical activity recommendations during the regular season, they increased sedentary time and decreased total physical activity, time in moderate-to-vigorous physical activity, and time in vigorous activities during the COVID-19 pandemic compared with the pre-COVID-19 period [5]. Furthermore, home confinement can result in dietary changes, such as excessive food intake and frequent consumption of ultra-processed foods, leading to the consumption of high caloric foods due to impulse or anxiety [16], which contribute to weight and fat mass gain. Roberts [33] demonstrated that rugby's athletes increased or maintained their food intake during the lockdown. In addition, the athletes reduced daily energy expenditure, contributing to decrease lean mass and strength, although these effects seem to be recovered after the retraining period [13, 14].

Longer periods of detraining (> 12 weeks) decreased mean muscle fiber areas of both fiber types, cross-sectional area and decreased voluntary capacity to generate forces, as well as prolonged exposure to mechanical unloading may also cause impairments in tendon structures and properties [34], in the same sense, short period of detraining decreased half-life of mitochondrial proteins (~ 1 week), which may reduce the mitochondrial's function and capacity [35], and only 2-week period of detraining decreased lipoprotein lipase (LPL) regulation in muscle of athletes and increased LPL activity in adipose tissue, which contributed to the adipose tissue storage [36]. These morphological and physiological remodeling adaptations underlines the importance of movement and exercise to preserve not only the integrity of the muscles, but also reduced-training stimuli and mechanical unloading, such as the COVID-19 home confinement [37].

On the other hand, trained high-nuclei muscles have a biological predisposition to hypertrophy in response to subsequent retraining after a long-intervening period [38]. The authors verified that the protein expression of various mitochondrial regulatory proteins, such as PGC-1 α and mitochondrial fusion/fission proteins (i.e. Mfn2, Fis1 and Drp1), was upregulated to a greater extent in retrained muscles compared to naive muscles. In addition, there was a tendency to express more oxidative fibre-like properties in the retrained muscles, which could explain the benefits on cardiorespiratory fitness observed in both groups.

In the current study, the athletes decreased sauces and spices, beverages, and fruit throughout the study without significant differences between groups. However, the ES was large for sauces and spices in the retrained group and trivial for the detrained, while for fruit and beverage, the ESs were large in the detrained and small for the retrained. Highly trained athletes' diets should include fruit as its high sugar content provides great energy and performance. In addition, it includes a lot of minerals and vitamins for proper cell and tissue development [39], since antioxidant, vitamin C, vitamin E and alpha-lipoic acid have proven effective in reducing plasma free radicals, restoring microvascular function after eccentric exercise [40], and it seems to be effective in improving athletic performance by increasing oxygen, glucose and other nutrients for better muscle fuel [41].

Although the badminton players evaluated did not have the resources or a dietician to provide one-on-one nutritional education or nutrition recommendations for each athlete, everyone lived with their families and did not have time for grocery shopping and food preparation. Furthermore, it is essential to indicate that at the baseline assessment, both athletes' groups were already living a short period of COVID-19 social restriction (3 months), on the other hand, 1 year later, despite the second wave of COVID-19 in Brazil in January 2021, the restrictions decreased, and athletes

could have returned to their social routine following the WHO health guidelines [42]. Therefore, highly trained athletes seem to improve their nutritional behavior after 1 year; therefore, sports activity could be a preventative approach to avoid the harmful effects of inactivity due to the pandemic.

The negative effects of the COVID-19 social restriction in athletes are not restricted to physiological systems, but are also reflected in psychological symptoms [15]. Recent studies show that the population of athletes suffer the most from mental issues (anxiety, obsessive–compulsive disorders and depression) during the COVID-19 pandemic, at equivalent or even higher rates than non-athletes [15]. Some factors that worsen the psychological symptoms in athletes include isolation from society, cancellation of training and competitions, loss of income and fear of becoming infected and/or infecting other people [43, 44]. In this regard, a study conducted by Di Fronso et al. [45] revealed that the pandemic had a detrimental impact on perceived stress and psychobiosocial states of Italian athletes and related such effects as likely caused by the characteristics and emergency period restrictions.

The potential mechanism of social restriction to disturbing psychobiosocial symptoms in athletes can be explained by the physical effects of exercise and via neurobiological mechanisms. Additionally, exercise is a vehicle for cultivating behavioral mechanisms of change (e.g., self-regulatory skills and self-efficacy) [46]. It is well-known the potential effects of exercise to reduce depression and anxiety symptoms, mainly by activating adult neurogenesis in the dentate gyrus of the hippocampus [47]. Besides the molecular aspect, social restriction for the athlete is more than the need to stay at home but an obligation of social isolation, career interruption, the uncertainty of the qualification process, and unconventional and limited access to adequate training environments and training partners for example. The postponement of the Olympic Games (or the main competition of athletes in general) represents a significant career break involving loss of identity, motivation, and meaning [48]. However, it is essential to highlight that even knowing that the competition was postponed, lack of training can impact their subjective perception of mental health [49]. To understand the complexity of the pandemic experience for the athlete, comparing it to an injury or severe illness is perhaps a way of giving meaning to the fact. An injury or severe illness presents itself unexpectedly and forces sports practitioners to considerably change their engagement in sport [50], considering career interruption and training partners, for example.

Furthermore, according to coach information, some athletes who stopped their training routine during their 1-year COVID-19 social restriction became demotivated and abandoned the sport. On the other hand, sports have long been viewed as an opportunity in terms of physical performance and can make socially vulnerable youth less vulnerable

[51]. Therefore, providing such sporting opportunities for youth during the pandemic can be a necessary strategy to prevent mental health and minimize the chance of social exclusion outcomes during adulthood [52]. Furthermore, the same study demonstrated that a more structured leisure time spending (including sports) correlates with less social exclusionary outcomes on later periods of human life [52].

It is worth noting that the current study has some limitations. First, the small total sample size and disproportionate subject distribution among groups, mainly only three men athletes in the detrained group, impaired the comparison between sexes. Second, this study includes both adults and adolescents (> 15 years of age). Third, we not realized that sport performance analyses and subjective measurement of food intake and mood state response profile presented some limitations based on recall bias and the detraining period was not equivalent in the two groups (8 months in the retraining group versus 12 months in the detraining group) and the baseline assessment was taken after 3 months of detraining, since there are good chances of detraining to happen. However, it is necessary to highlight the long-term follow-up (1 year) and athletes were evaluated personally at the same period at baseline during COVID-19 pandemic, as well as after 1 year, since most studies in the literature evaluated high trained athletes only during the short time (< 4 months) and used an online survey.

Conclusions

In conclusion, young badminton athletes who stopped daily training routine during 8 months due to COVID-19 social restriction but returned to regular daily training 4 months earlier than athletes who stopped daily training routine during 1 year due to COVID-19 social restriction decreased fat mass and increased fat-free mass. There were no significant differences between groups for cardiorespiratory fitness, nutritional behavior, and profile of mood state response. However, the ES was medium for cardiorespiratory fitness, sauces, and spices in the retrained and trivial for the detrained group. For depression, fruit, and beverage intake, detrained athletes showed a medium to large effect, and the retrained athletes trivial effect. Thus, long-term COVID-19 social restriction seems to impact mainly body composition in young badminton athletes.

Therefore, the results of this study may be applied by coaches, trainers and sport nutritionist looking to improve body composition after long-term training restriction and retraining period in highly trained badminton players when making decisions concerning initial load and progressions during the return to training and matches. Also, safe and healthy strategies can be developed to mitigate physiological

and psychological responses for athletes to return to competition-level readiness.

Funding The authors would like to thank FAPEPI for their support (FAPEPI/MCT/CNPq N° 007/2018).

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval All procedures performed were developed according to the Declaration of Helsinki and approved by the Research Ethics Committee at the Federal University of Piauí (protocol: 2.552.506).

Informed consent Informed consent was obtained from all individual participants included in the study.











References

- Phomsoupha M, Laffaye G (2015) The science of badminton: game characteristics, anthropometry, physiology, visual fitness and biomechanics. *Sports Med (Auckland, NZ)* 45(4):473–495
- Wackerhage H, Everett R, Krüger K, Murgia M, Simon P, Gehlert S, Neuberger E, Baumert P, Schönfelder M (2020) Sport, exercise and COVID-19, the disease caused by the SARS-CoV-2 coronavirus. *Dtsch Z Sportmed* 71(5):E1–E12
- Wiersinga WJ, Rhodes A, Cheng AC, Peacock SJ, Prescott HC (2020) Pathophysiology, transmission, diagnosis, and treatment of coronavirus disease 2019 (COVID-19): a review. *JAMA* 324(8):782–793
- Sachs JD, Karim SA, Akin L, Allen J, Brosbøl K, Barron GC, Daszak P, Espinosa MF, Gaspar V, Gavi A (2020) Lancet COVID-19 commission statement on the occasion of the 75th session of the UN General Assembly. *Lancet* 396(10257):1102–1124
- da Silva Santos AM, Rossi FE, Dos Santos NMH, de Sousa Junior AVM, Machado DC, Neves LM, Brito AS, Moura P, Monteiro PA, Freitas Junior IF, Dos Santos MAP, Ribeiro SLG (2021) COVID-19 pandemic impacts physical activity levels and sedentary time but not sleep quality in young badminton athletes. *Sport Sciences for Health*, 17(4):969–977.
- Henriksen K, Schinke R, Moesch K, McCann S, Parham WD, Larsen CH, Terry P (2020) Consensus statement on improving the mental health of high performance athletes. *Int J Sport Exerc Psychol* 18(5):553–560
- Huber BC, Steffen J (2021) Altered nutrition behavior during COVID-19 pandemic lockdown in young adults. *Eur J Nutr* 60(5):2593–2602
- Sarto F, Impellizzeri FM, Spörri J, Porcelli S, Olmo J, Requena B, Suarez-Arrones L, Arundale A, Bilsborough J, Buchheit M et al (2020) Impact of potential physiological changes due to COVID-19 home confinement on athlete health protection in elite sports: a call for awareness in sports programming. *Eur J Nutr* 50(8):1417–1419
- Fikenzer S, Fikenzer K, Laufs U, Falz R, Pietrek H, Hepp P (2021) Impact of COVID-19 lockdown on endurance capacity of elite handball players. *Sports Med (Auckland, NZ)* 61(7):977–982
- Grazioli R, Loturco I, Baroni BM, Oliveira GS, Saciura V, Vanoni E, Dias R, Veeck F, Pinto RS, Cadore EL (2020) Coronavirus disease-19 quarantine is more detrimental than traditional off-season on physical conditioning of professional soccer players. *J Strength Conditioning Res* 34(12):3316–3320
- Spyrou K, Alcaraz PE, Marín-Cascales E, Herrero-Carrasco R, Cohen DD, Calleja-Gonzalez J, Pereira LA, Loturco I, Freitas TT (2021) Effects of the COVID-19 lockdown on neuromuscular performance and body composition in elite futsal players. *J Strength Conditioning Res Natl Strength Conditioning Assoc* 35(8):2309–2315
- Csulak E (2021) The impact of COVID-19 on the preparation for the Tokyo Olympics: a comprehensive performance assessment of top swimmers. *Int J Environ Res Public Health* 18(18):9770
- Dauty M, Menu P, Fouasson-Chailloux A (2021) Effects of the COVID-19 confinement period on physical conditions in young elite soccer players. *J Sports Med Phys Fit* 61(9):1252–1257
- Valenzuela PL, Rivas F, Sánchez-Martínez G (2021) Effects of COVID-19 lockdown and a subsequent retraining period on elite athletes' workload, performance, and autonomic responses: a case series. *Int J Sports Physiol Perform* 16(11):1707–1711
- Chen P, Mao L, Nassis GP, Harmer P, Ainsworth BE, Li F (2020) Coronavirus disease (COVID-19): the need to maintain regular physical activity while taking precautions. *J Sport Health Sci* 9(2):103–104
- Andreato LV, Coimbra DR, Andrade A (2020) Challenges to athletes during the home confinement caused by the COVID-19 pandemic. *Strength Conditioning J* 42(3):1–5
- Muscogiuri G, Barrea L, Savastano S, Colao A (2020) Nutritional recommendations for CoVID-19 quarantine. *Eur J Clin Nutr* 74(6):850–851
- Bisciotti GN, Eirale C, Corsini A, Baudot C, Saillant G, Chalabi H (2020) Return to football training and competition after lockdown caused by the COVID-19 pandemic: medical recommendations. *Br J Sports Med* 37(3):313–319
- Stokes KA, Jones B, Bennett M, Close GL, Gill N, Hull JH, Kasper AM, Kemp SPT, Mellalieu SD, Peirce N et al (2020) Returning to play after prolonged training restrictions in professional collision sports. *Int J Sports Med* 41(13):895–911
- Wilson MG, Hull JH (2020) Cardiorespiratory considerations for return-to-play in elite athletes after COVID-19 infection: a practical guide for sport and exercise medicine physicians. *Br J Sports Med* 54(19):1157–1161
- Pelliccia A (2020) Return to play after the COVID-19 pandemic: a commentary by the Editor in Chief. *J Sports Med Phys Fit* 60(5):675–676
- Goodyear MD, Krljeza-Jeric K, Lemmens T (2007) The declaration of Helsinki. *Br Med J Publ Group* 335:624–625
- Fikenzer S, Fikenzer K, Laufs U, Falz R, Pietrek H, Hepp P (2020) Impact of COVID-19 lockdown on endurance capacity of elite handball players. *J Sports Med Phys Fit*, 61(7):977–982
- Mialich MS, Sicchieri JF, Junior AJ (2014) Analysis of body composition: a critical review of the use of bioelectrical impedance analysis. *Int J Clin Nutr* 2(1):1–10
- Campa F, Toselli S (2021) Assessment of body composition in athletes: a narrative review of available methods with special reference to quantitative and qualitative bioimpedance analysis. *Nutrients* 13(5):1620
- Willett W (2012) *Nutritional epidemiology*, vol 40. Oxford University Press, Oxford
- Fisberg RM, Colucci ACA, Morimoto JM, Marchioni DML (2008) Questionário de frequência alimentar para adultos com base em estudo populacional. *Rev Saude Publica* 42:550–554
- Selem SSADC, Carvalho AMD, Verly-Junior E, Carlos JV, Teixeira JA, Marchioni DML, Fisberg RM (2014) Validade e reprodutibilidade de um questionário de frequência alimentar para adultos de São Paulo, Brasil. *Rev Bras Epidemiol* 17:852–859

29. McNair DM, Lorr M, Droppleman LF (1971) Manual profile of mood states. San Diego, CA: Educational and Industrial Testing Services
30. Rohlfs ICPDM, Rotta TM, Luft CDB, Andrade A, Krebs RJ, Carvalho TD (2008) Brunel Mood Scale (BRUMS): an instrument for early detection of overtraining syndrome. *Revista Brasileira de Medicina do Esporte* 14(3):176–181
31. Léger LA, Mercier D, Gadoury C, Lambert J (1988) The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci* 6(2):93–101
32. Morris SB (2008) Estimating effect sizes from pretest–posttest-control group designs. *Organ Res Methods* 11(2):364–386
33. Roberts C, Gill N, Sims S (2020) The influence of COVID-19 lockdown restrictions on perceived nutrition habits in rugby union players. *Front Nutr* 7:216
34. Frizziero A, Salamanna F, Della Bella E, Vittadini F, Gasparre G, Nicoli Aldini N, Masiero S, Fini M (2016) The role of detraining in tendon mechanobiology. *Front Aging Neurosci* 8:43
35. Hood DA (2001) Invited review: contractile activity-induced mitochondrial biogenesis in skeletal muscle. *J Appl Physiol* 90(3):1137–1157
36. Simsolo RB, Ong JM, Kern PA (1993) The regulation of adipose tissue and muscle lipoprotein lipase in runners by detraining. *J Clin Invest* 92(5):2124–2130
37. Girardi M, Casolo A, Nuccio S, Gattoni C, Capelli C (2020) Detraining effects prevention: a new rising challenge for athletes. *Front Physiol* 11:1234
38. Lee H, Kim K, Kim B, Shin J, Rajan S, Wu J, Chen X, Brown MD, Lee S, Park JY (2018) A cellular mechanism of muscle memory facilitates mitochondrial remodelling following resistance training. *J Physiol* 596(18):4413–4426
39. Ibrahim SA, Ayad AA, Williams LL, Ayivi RD, Gyawali R, Krastanov A, Aljaloud SO (2021) Date fruit: a review of the chemical and nutritional compounds, functional effects and food application in nutrition bars for athletes. *Int J Food Sci Technol* 56(4):1503–1513
40. Richardson RS, Donato AJ, Uberoi A, Wray DW, Lawrenson L, Nishiyama S, Bailey DM (2007) Exercise-induced brachial artery vasodilation: role of free radicals. *Am J Physiol Heart Circ Physiol* 292(3):H1516–H1522
41. Ormsbee MJ, Lox J, Arciero PJ (2013) Beetroot juice and exercise performance. *Nutr Diet Suppl* 5:27–35
42. WHO (2020) Lancet COVID-19 Commission Statement on the occasion of the 75th session of the UN General Assembly. *Lancet* (London, England) 396(10257):1102–1124
43. Reardon CL, Bindra A, Blauwet C, Budgett R, Campriani N, Currie A, Gouttebarga V, McDuff D, Mountjoy M, Purcell R (2021) Mental health management of elite athletes during COVID-19: a narrative review and recommendations. *Br J Sports Med* 55(11):608–615
44. Clemente-Suárez VJ, Fuentes-García JP, de la Vega MR, Martínez Patiño MJ (1985) Modulators of the personal and professional threat perception of olympic athletes in the actual COVID-19 crisis. *Front Psychol* 2020:11
45. Di Fronso S, Costa S, Montesano C, Di Gruttola F, Ciofi EG, Morgilli L, Robazza C, Bertollo M (2020) The effects of COVID-19 pandemic on perceived stress and psychobiosocial states in Italian athletes. *Int J Sport Exerc Psychol*, 20(1):79–91
46. Smith PJ, Merwin RM (2021) The role of exercise in management of mental health disorders: an integrative review. *Annu Rev Med* 72:45–62
47. Micheli L, Ceccarelli M, D’Andrea G, Tirone F (2018) Depression and adult neurogenesis: positive effects of the antidepressant fluoxetine and of physical exercise. *Brain Res Bull* 143:181–193
48. Henriksen K, Schinke RJ, Noce F, Poczwadowski A, Si G (2020) Working with athletes during a pandemic and social distancing. *Int Soc Sport Psychol Corona Chall Recomm*
49. Gupta S, McCarthy PJ (2021) Sporting resilience during COVID-19: what is the nature of this adversity and how are competitive elite athletes adapting? *Front Psychol* 12:374
50. Samuel RD, Tenenbaum G, Galily Y (2020) The 2020 coronavirus pandemic as a change-event in sport performers’ careers: conceptual and applied practice considerations. *Front Psychol* 11(2522)
51. Haudenhuyse RP, Theeboom M, Coalter F (2012) The potential of sports-based social interventions for vulnerable youth: Implications for sport coaches and youth workers. *J Youth Stud* 15(4):437–454
52. Feinstein L, Bynner J, Duckworth K (2006) Young people’s leisure contexts and their relation to adult outcomes. *J Youth Stud* 9(3):305–327

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Authors and Affiliations

Igor Almeida Silva¹  · Arilene Maria da Silva Santos¹  · Alberto Jimenez Maldonado²  · Helton Pereira dos Santos Nunes de Moura¹  · Priscila Almeida Queiroz Rossi³  · Lucas Melo Neves^{4,5}  · Marcos Antonio Pereira dos Santos⁶  · Dionis Castro Dutra Machado⁷  · Sergio Luiz Galan Ribeiro⁷  · Fabricio Eduardo Rossi^{8,9} 

¹ Postgraduate Student in Science and Health and Immunometabolism of Skeletal Muscle and Exercise Research Group, Department of Physical Education, Federal University of Piauí (UFPI), Teresina, PI, Brazil

² Facultad de Deportes Campus Ensenada, Universidad Autónoma de Baja California México, Ensenada, Mexico

³ Postgraduate Student in Science and Health and Nucleus of Study in Physiology Applied to Performance and Health (NEFADS), Department of Physical Education, Federal University of Piauí (UFPI), Teresina, PI, Brazil

⁴ Postgraduate Program in Health Sciences, Santo Amaro University, São Paulo, Brazil

⁵ Bipolar Disorder Program (PROMAN), Department of Psychiatry, University of São Paulo Medical School, São Paulo, Brazil

⁶ Nucleus of Study in Physiology Applied to Performance and Health (NEFADS), Department of Biophysics and Physiology, Federal University of Piauí, Campus Minister Petrônio Portela, Ininga, Teresina, Piauí, Brazil

⁷ Department of Physical Education, Federal University of Piauí (UFPI), Teresina, PI, Brazil

⁸ Immunometabolism of Skeletal Muscle and Exercise Research Group, Department of Physical Education and Professor at Graduate Program in Science and Health, Federal University of Piauí (UFPI), Teresina, PI, Brazil

⁹ Department of Physical Education, Federal University of Piauí (UFPI), “Ministro Petrônio Portella” Campus, Teresina, PI 64049-550, Brazil