

# Effects of COVID-19 Lockdown on Body Composition and Fitness Performance among Football Players in Negro African Environment

Moulongo Jean Georges André<sup>1</sup>, Makosso Vheiye Georges<sup>1</sup>, Loubelo Prosper<sup>2</sup>,  
Mouanda Konde Dorel<sup>1</sup>, Massamba Miabaou Didace<sup>3</sup>, Mabilia Babela Jean Robert<sup>4</sup>,  
Massamba Alphonse<sup>1\*</sup> 

<sup>1</sup>Sport Biosciences Laboratory, Higher Institute of Physical and Sports Education, Marien Ngouabi University, Brazzaville, Congo

<sup>2</sup>Nutrition and Motor Performance Laboratory, Faculty of Sports Sciences and Physical Education, Lille 2 University, Lille, France

<sup>3</sup>Department of Digestive Surgery, University Hospital Center, Faculty of Health Sciences, Marien Ngouabi University, Brazzaville, Congo

<sup>4</sup>Department of Pediatrics, University Hospital Center, Faculty of Health Sciences, Marien Ngouabi University, Brazzaville, Congo

Email: \*mboya53@gmail.com

**How to cite this paper:** André, M.J.G., Georges, M.V., Prosper, L., Dorel, M.K., Didace, M.M., Robert, M.B.J. and Alphonse, M. (2022) Effects of COVID-19 Lockdown on Body Composition and Fitness Performance among Football Players in Negro African Environment. *Health*, 14, 456-475. <https://doi.org/10.4236/health.2022.144036>

**Received:** February 12, 2022

**Accepted:** April 26, 2022

**Published:** April 29, 2022

Copyright © 2022 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

---

## Abstract

**Context and Objective:** The nutritional and sports dimension of the lockdown implemented during the COVID-19 pandemic is unexplored in the African environment. The purpose of this study was to assess the effects of COVID-19 lockdown on body composition and fitness performance in Congolese football players. **Methods:** This was an observational study carried out in Brazzaville between February 9 and October 30, 2020. It included 16 male players among Congolese senior national team and 11 male football players of first division Brazzaville clubs. Two types of measurements were carried out: anthropometric measures (height, body mass, total fat percent, lean body mass); physical capacities [30 m sprint, repeated sprint, aerobic endurance (Yo-Yo Intermittent Recovery test), vertical jump (Squat Jump test, Countermovement test)]. The measurements were realized at 4 times: before lockdown (month of february, T0), 1<sup>st</sup> week of june (T1), 1<sup>st</sup> week of september (T2), 1<sup>st</sup> week of october (T3). Data were compared using Student t test, Sokal S test, Anova, Newman-Keuls test (multiple contrasts) and correlation analysis. **Results:** A significant increase in body mass ( $p < 0.05$ ), body mass index ( $p < 0.02$ ) was observed in all subjects, compared to a less marked increase in muscle mass. Significant reductions in performance in the 30 m sprint, the 6-sprint series, the endurance event and the vertical jumps were noted. However, a significant effect of “practice level” on the changes in performance on Squat Jump and Countermovement Jump was only found, the maximum dif-

---

---

ferences throughout experimental period being found among senior football players of Congolese national team. **Conclusion:** The present data suggest that COVID-19 lockdown promotes weight gain and decreased physical ability in football players.

### Keywords

COVID-19 Lockdown, Football, Body Composition, Physical Capacities, Congo-Brazzaville

---

## 1. Introduction

The COVID-19 pandemic that is hitting planet Earth is an event in the full sense of the term, an unforeseen upsurge that upsets our daily lives, even in our sports practices and therefore our motor performance. The Severe Acute Respiratory Syndrom Coronavirus-2 (SARS-CoV-2) or Corona virus Disease (COVID-19) pandemic began in December 2019 in the city of Wuhan, China [1], then reached the African continent, including the Republic Congo in early March 2020. In Congo-Brazzaville, 4642 cases of COVID-19 have been confirmed with 120 deaths from March 19, 2020 to March 1, 2021 [2]. Among the health restriction measures taken by the government to stem the spread of the pandemic are physical distancing and the closure of sports practice spaces (public and private gymnasiums, and playgrounds). However, these strategies can have unintended consequences for the health and fitness of athletes.

Indeed, studies carried out around the worldwide show that the COVID-19 pandemic and the health measures to contain it are accompanied in individuals by a radical change in daily activities and life routines, with numerous consequences. These include the significant disruption of biological rhythms [3]. Indeed, sleep-wake rhythms depend on a number of environmental parameters (“Zeitgeber” or time givers) to be able to function well, including: exposure to daylight [4], by far the most important synchronizer; but also the daily physical activity (PA) and especially in the morning; eating meals at regular times, and social interactions [5]. In a situation of lockdown, the majority of these synchronizers (light, physical activity, food, social interactions) are greatly modified or even suppressed—as a result, sleep disorders and sleep-wake rhythms may appear. In addition, the exposure of these Zeitgeber can also be done at the wrong time of the day (for example, exposure to television screens and microcomputers late at night and in particular to blue light). It is in this context that some recent studies report an impact of COVID-19 reduction strategies on the eating behavior and fitness of subjects [6] [7]. As far as athletes are concerned, the data relating thereto is fragmentary.

Indeed, football, which is banned in the public environment during lockdown, is an intermittent and high-intensity sports activity that requires excellent fitness to perform in its competitive practice. High-level football players cover a dis-

tance of  $587 \pm 333$  meters on the pitch at a fast speed  $v$  of running (19.8 - 25.2 km/h) and  $184 \pm 87$  meters of sprinting ( $v > 25.2$  km/h) [8]. The total distance covered at high intensity during a match depends on the position occupied by the player, the stake of the match and the rank occupied by the team during the championship (or competition) [9]. Thus, fitness is an important factor in getting a victory for a football team. Several studies have shown that intense training improves the fitness performance of players, through the development of abilities such as sprinting, strength and endurance [10] [11]. The organization of the physical preparation schedule for football varies according to the periodization of training, variations in volume and intensity of work load. These variations help to optimize the physical condition of the players and to minimize injuries [12]. Thus, the physical preparation takes place 4 - 5 months before the start of the competition. Therefore, a prolonged rest period for football players such as that relating to COVID-19 lockdown has an impact on their physical condition. Indeed, it emerges from the review of the literature that a long period of rest after the end of a sports season leads to the partial or complete loss of physiological adaptations and performance induced by training, which is called “detraining” in the specialized literature [13]. The magnitude of this loss depends on the fitness level of the subjects and the duration of cessation of training [14]. Regarding COVID-19 lockdown-induced detraining, a few Western studies report a significant loss in motor performance [4] [15]. However, these effects of detraining are not well documented and in sub-Saharan Africa no data have been identified in the literature. Hence the aim of this study was to determine and analyze the impact of COVID-19 lockdown on body composition and fitness performance in Congolese football players. The interest of this study is to raise awareness among athletes and sports actors in black African communities on the health of the athlete during the COVID-19 pandemic and its consequences on the determinants of performance.

## 2. Methods

### 2.1. Type, Period and Setting of the Study

The observational and longitudinal study was carried out from February 9 to October 30, 2020, *i.e.* 8 months 9 days, in Brazzaville, Republic of Congo. It concerned football players pre-selected to participate in the African Nations Championship (CHAN) in Cameroon in January 2021 and other football players playing in the first division teams of the Brazzaville league during the 2019-2020 sports season.

### 2.2. Participants

The target population was made up of 22 senior male football players at the continental level of practice (total squad for CHAN) and football players playing in the senior men’s teams of the Brazzaville first division, an estimated number of 253 players according to data from the technical staff of the Brazzaville football

league during the 2019-2020 sporting season.

The inclusion criteria were: 1) having at least 2 years of competitive football practice in top division football competitions and tournaments for players not selected for CHAN 2021; 2) be regular in training and competitions before lockdown for all players; 3) be shortlisted to participate in the African Nations Championship in Yaoundé in January 2021; 4) having a health status deemed normal before each physical test event after a sports medical examination.

The informed consent, written or oral, of the subjects was required and constituted a prerequisite, as well as the authorization of the technical direction of the senior national football team. Ultimately, after approval of the study by the Ethics Committee for Research in Health Sciences, General Delegation for Scientific and Technical Research of the Republic of Congo, 16 senior male football players selected to participate at CHAN 2021 (group 1) and 11 senior male football players not selected (group 2) participated in the experiment.

### 2.3. Experimental Procedures

During the study period, all assessments were conducted between 8:00 a.m. and 10:00 a.m., three hours before breakfast. Four (04) evaluation moments were selected for carrying out the tests: one month before lockdown [Pre-lockdown (T0)]; first week of June [lockdown (T1)]; first week of September [lockdown (T2)]; first week of October and resumption of training [Post-lockdown (T3)].

The experiment was carried out in the following order: 1) anthropometric measurements (height, weight, fat percent, lean body mass); 2) blood pressure [systolic blood pressure (SBP), diastolic blood pressure (DBP)]; 3) motor performance (30 m sprint test, RSSA test, Yo-Yo IR1 test, Squat jump test, Counter-movement test).

During the study period, the subjects restricted the practice of exercises at home to games of skill and ball control, muscle flexibility exercises due to health measures related to the COVID-19 pandemic and the smallness of the accommodation (sharing of the courtyard with other tenants in the plot).

### 2.4. Anthropometric and Blood Pressure Measurements

All protocols for measuring height and body mass were based on the recommendations issued by the French Society of Sports Medicine on fitness performance [16]. Body mass and total fat percent (PCTG) were measured by impedance, using a scale fitted with an OMRON brand body composition monitor, type BF511 on renewable batteries (manufacturer: OMRON HEALTH CARE Co Ltd, Kyoto, Japan). The body mass index (BMI) reported in the tables of the National Institute of Health and Medical Research (INSERM) of France was calculated from the formula:

$$\text{BMI}(\text{kg}/\text{m}^2) = \text{Weight}(\text{kg}) / [\text{Height}(\text{m})]^2$$

The nutritional status of the subject was assessed using the BMI assessment scale of the World Health Organization [17]. Lean body mass (LBM) was calcu-

lated using the Forsyth and Sinning equation [18]:

$$\text{LBM (kg)} = \text{body mass} - \left[ \text{PCTG (\%)} \frac{\text{Body mass}}{100} \right]$$

Blood pressure was measured on the left arm of each subject using an Auto-Tensio<sup>®</sup> brand electronic blood pressure monitor (SPENGLER, Issoudun, France).

## 2.5. Fitness Performance Testing

Field tests used in this study are those likely to be implemented easily and not requiring too elaborate and expensive materials.

**Sprint ability.** The test consisted of 30 m sprint run on a 250 m long tartan athletic track. It is a running event on  $2 \times 30$  m with a 2 min rest between each sprint. The running time at the end of each 30 meters was recorded using a 1/100<sup>th</sup> stopwatch, and the best time taken by the subject was retained for data analysis.

**Repeated-sprint ability.** The ability to repeat sprints was determined using the repeated sprint running test (RSSA). This ability is a physical quality that takes on its full meaning in team sports, especially in football where players may be required to repeat movements at maximum speed, very intense game actions with short recovery periods between two actions. This is how the RSSA test is used to assess this ability in football players. This test includes rapid changes of direction, which represent a series of football-specific movements. After a 15-minute warm-up, each subject performed 6 sprints over a distance of 40 m each, spaced out by 20 s of passive rest. The race times were recorded using a stopwatch to 1/100<sup>th</sup> and the best time ( $T_{best}$ ) is retained. The average time taken during the 6 sprints is:

$$T_{mean} = (\sum t_i) / 6 \text{ where } \sum t_i = t_1 + t_2 + \dots + t_6$$

The decrease in race times, from the first to the sixth series, is described by the performance decrement [19]:

$$T_{dec} (\text{in \%}) = \left[ (T_{mean} / T_{best}) \times 100 \right] - 100$$

**Specific aerobic fitness.** The Yo-Yo Intermittent Recovery Level 1 (Yo-YoIR1) test, which took place on a tartan handball court, was used to assess high endurance performance [20]. Cones were placed on two horizontal lines 20 m apart and 5 m behind the starting line. Players completed a  $2 \times 20$  m run at the beep, with the two runs separated by a 10 s active recovery time of running across a  $2 \times 5$  m course. The duration of the beeps was shorter and shorter with each step and the subjects continued to run at increasing speed until they were no longer able to maintain the required pace between two beeps. Players had to place 1 foot on or behind the 20 m line at the end of each shuttle. If a player did not reach the line in time, they were asked to do so in the next round. The final stage (km/h) reached and the total distances traveled (m) were recorded.

**Vertical jump abilities.** The squat Jump (SJ) test was performed by the sub-

ject starting from the static semi-squat position, with the two segments (legs-thighs) of the pelvic limb forming an angle of approximately 90°. After a short rest (~1 s), the subject executed a vertical jump with the highest possible maximal effort.

Regarding the Countermovement Jump (CMJ), the subject, starting from a standing position, performed an explosive vertical relaxation according to a slow cycle of muscle shortening-stretching-relaxation for a 90% inclination with respect to the knee. All subjects performed on the same handball court the two vertical jump tests in the same order, *i.e.* SJ followed by the CMJ test with akimbo hands. Each subject performed 3 jumps for each test, with an interval of 60 s between each jump. The mean of the two best performances was retained for the data analysis [21].

## 2.6. Course of the Tests

The subjects performed the tests in the following order: 30 m sprint, Yo-Yo IR1 test, RSSA test, Squat Jump, Countermovement Jump. These tests were carried out after 2 days for each group of players: first day, Sprint on 30 m, Yo-Yo intermittent Recovery 1; second day, RSSA test, Squat Jump, Countermovement Jump. The consumption of alcohol or caffeine was prohibited 24 hours before the tests. One hour before the first series of tests, the subjects arrived at the experimental site for the anthropometric measurements.

## 2.7. Operational Definitions

The COVID-19 pre-lockdown period has been defined as the period prior to the date of declaration of containment for the populations of Brazzaville and Pointe-Noire, March 24, 2020. The COVID-19 lockdown period has been defined as that from March 24 to September 18, 2020, and characterized by two extensions. The date of January 17, 2021, following the declaration of the President of the Republic of Congo on the post-lockdown, was retained as that of the real start of training for the national football team.

## 2.8. Variables of the Study

These were: 1) body mass; 2) body mass index; 3) fat percent; 4) lean body mass; 5) time spent in the 30 meter running test; 6) the performance achieved (in meters) in the Yo-YoIR1 event; 7) the performance achieved (in seconds) in the RSSA running event; 8) the performance achieved (in cm) in the Squat Jump event; 9) the performance achieved (in cm) in the CMJ test.

## 2.9. Statistical Analysis

Results are expressed as mean  $\pm$  standard deviation. All statistical tests were implemented using Sigma Stat 3.5 software (Systat Inc, USA). The normal distribution of the data was checked from the Kolmogorov-Smirnov test and was confirmed. Student's paired t test was used to compare all the parameters measured

before lockdown and when training resumed for each group of players. This was the unpaired t test for comparing the values deduced from the measurements taken at a given time t between the football players of groups 1 and 2. The use of a one-way, 4-factor analysis of variance (ANOVA) made it possible to detect the differences observed between the values measured at times T(0), T(1), T(2) and T(3) at the level of each group of players. In case of statistical significance, the determination of the level at which these differences are located used the post-hoc test of multiple contrasts of Newman-Keuls. The relationships between some parameters of body composition and those associated with physical condition were also investigated using the correlation coefficients r of Pearson moment products. The level of correlation was defined according to the Hopkins scale [22]: trivial if  $r < 0.1$ ; low if r is between 0.1 and 0.3; moderate if  $r > 0.5 - 0.7$ ; narrow if  $r > 0.7 - 0.9$ ; very narrow if  $r > 0.9$ ; almost perfect if  $r > 0.9 - 1$ ; and perfect if  $r = 1$ . Finally, the “group” effects were evaluated from the values of the “square partial eta” coefficient,  $\eta_p^2$ , which is defined as: trivial if  $\eta_p^2 < 0.1$ , low for  $\eta_p^2$  between 0.1 and 0.3, moderate for 0.3 - 0.5 and broad if  $\eta_p^2 > 0.5$  [22]. Statistical significance threshold was set at 5% for all tests.

### 3. Results

#### 3.1. Sociodemographic and Clinical Characteristics

The sociodemographic and clinical characteristics of the subjects are recorded in **Table 1**.

**Table 1** shows that the age of the subjects in the two groups was comparable, with a mean age of 25 years (range: 19 - 27 years). If these football players did not smoke, all consumed alcohol. About 4/5 of the subjects had completed secondary education and none of them was illiterate. Overall, there were more single people (85.1%).

**Table 1.** Sociodemographic and clinical characteristics of the subjects

Characteristics	Group 1 (n = 16)	Group 2 (n = 11)	All group (N = 27)
<b>Age (years)</b>	24.5 ± 2.7	25.6 ± 2.2	25.0 ± 2.4
• Alcohol consumption (%)	16/16(100)	11/11	27/27 (100)
• Tobacco consumption (%)	---	---	---
<b>Level of studies</b>			
• Unschoolled (%)	---	---	---
• Primary (%)	2/16 (12.5)	3/13 (27.3)	5/27 (18.5)
• Secondary (%)	14/16 (87.5)	8/11 (72.7)	22/27 (81.5)
<b>Marital status</b>			
• Single without children (%)	3/16 (18.7)	10/11 (90.9)	13/27 (48.1)
• Single with child (%)	9/16 (56.3)	1/11 (9.1)	10/27 (37.0)
• Concubine (%)	4/16 (25)	---	4/27 (14.9)

### 3.2. Variations in Body Composition

The evolution of the players' body composition data during the experimental period and their changes is reported in **Table 2** and **Table 3**.

Before the start of lockdown and the start of the experiment, **Table 2** shows that no statistical difference was found between the football players of groups 1 and 2 in terms of body mass ( $\Delta = 0.4\%$ ), BMI ( $\Delta = 2.6\%$ ), total fat percent ( $\Delta = 1.1\%$ ) and lean body mass ( $\Delta = 0.3\%$ ). However, the values showed a significant increase throughout the study period (**Table 2** and **Table 3**): the differences noted between the times T(0) and T(3) (Pre-lockdown versus Post-lockdown) were +5.3% in group 1 and +6.5% in group 2 for body mass, +5.1% in group 1 versus +6.5% in group 2 for BMI, +9.7% in group 1 against +12.1% in group 2 for total fat percent, and +4.2% in group 1 and +5.1% in the group 2 for mean body mass. The maximum differences between football players of two groups were found at the resumption of training.

### 3.3. Evolution of Specific Fitness Performance

The evolution of performance in fitness tests among football players in groups 1 and 2 is shown in **Figures 1-5**.

**Table 2.** Evolution of body mass, body mass index, total fat percent and lean body mass of football players in groups 1 and 2 before lockdown, at 3 and 6 months during lockdown, and at resumption of training.

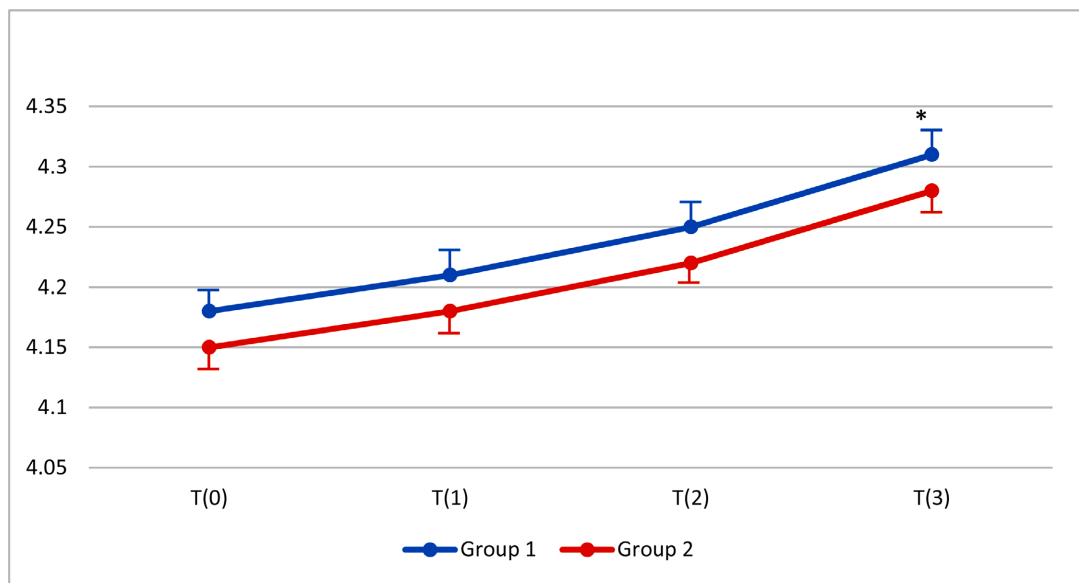
Anthropometric measures	Pre-lockdown (T0)	Lockdown (T1)	Lockdown (T2)	Post-lockdown (T3)	P	
<b>Height (m)</b>						
Group 1	1.74 ± 0.05	1.74 ± 0.05	1.74 ± 0.05	1.74 ± 0.05	---	
Group 2	1.72 ± 0.04	1.72 ± 0.06	1.72 ± 0.05	1.72 ± 0.05	---	
<b>Body mass (kg)</b>						
Group 1	67.5 ± 3.2	67.8 ± 3.7	68.6 ± 4.2	70.1 ± 3.1	71.3 ± 3.5	0.05
Group 2	67.8 ± 3.7	68.9 ± 4.1	70.6 ± 2.8	72.5 ± 3.2	72.5 ± 3.2	0.05
<b>BMI (kg/m<sup>2</sup>)</b>						
Group 1	22.3 ± 0.8	22.6 ± 0.5	23.1 ± 0.4	23.5 ± 0.7	23.5 ± 0.7	0.001
Group 2	22.9 ± 0.5	23.3 ± 0.3	23.9 ± 0.5	24.5 ± 0.5	24.5 ± 0.5	0.001
<b>% total fat</b>						
Group 1	9.4 ± 1.2	9.6 ± 0.8	10.1 ± 1.2	10.3 ± 1.4	10.3 ± 1.4	0.05
Group 2	9.4 ± 0.8	9.6 ± 0.5	10.4 ± 0.8	10.7 ± 0.6	10.7 ± 0.6	0.02
<b>LBM (kg)</b>						
Group 1	61.2 ± 3.1	62.0 ± 2.3	63.0 ± 2.7	63.9 ± 2.5	63.9 ± 2.5	0.05
Group 2	61.4 ± 2.6	62.3 ± 2.1	63.2 ± 2.4	64.7 ± 2.2	64.7 ± 2.2	0.05

BMI, body mass index; Pre-Lockdown (T0), pre-Lockdown at T0; Lockdown. (T1), Lockdown at T1; Lockdown. (T2), Lockdown at T2; Post-Lockdown, Post-lockdown and resumption of training.

**Table 3.** Variations observed in the body composition of football players in groups 1 and 2 between the start of lockdown and resumption of training.

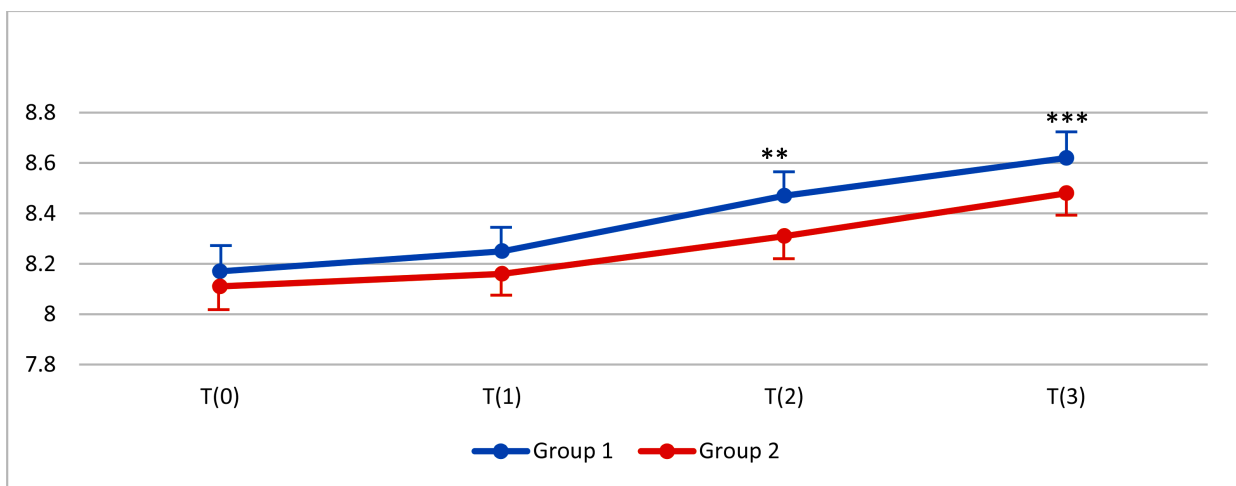
Parameter	% of deviation	$\eta_p^2$
Body mass	5.3 - 6.4	0.425
BMI	5.1 - 6.5	0.643
% total fat	9.7 - 12.1	0.861
LBM	4.2 - 5.1	0.382

BMI, body mass index; LBM, lean body mass.



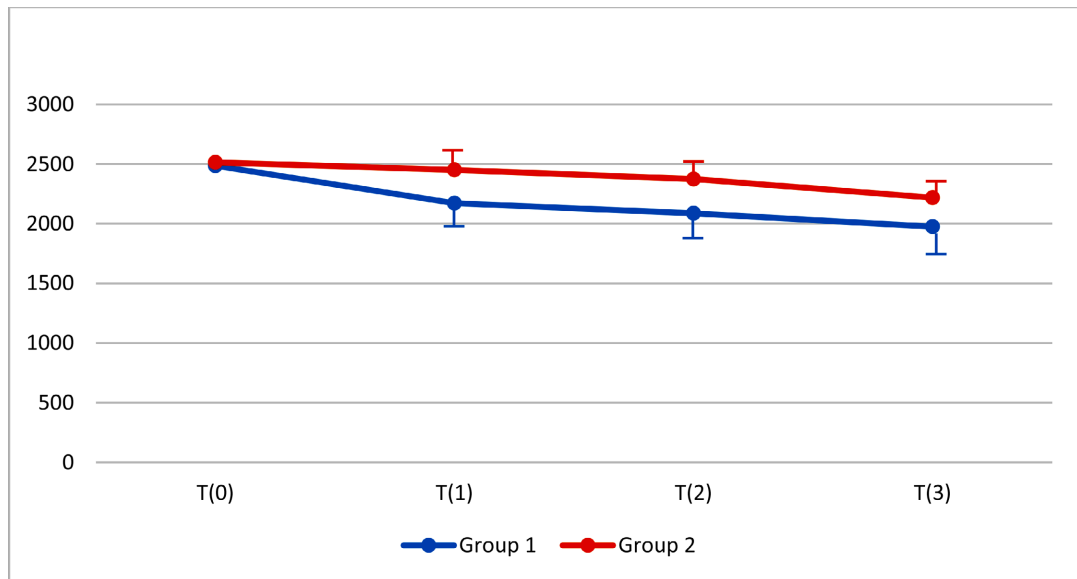
**Abbreviations:** \*p < 0.05, significant difference compared to the values noted in pre-lockdown.

**Figure 1.** Evolution of performance (in seconds) in the 30-meter sprint test among football players in groups 1 and 2 during the study period.

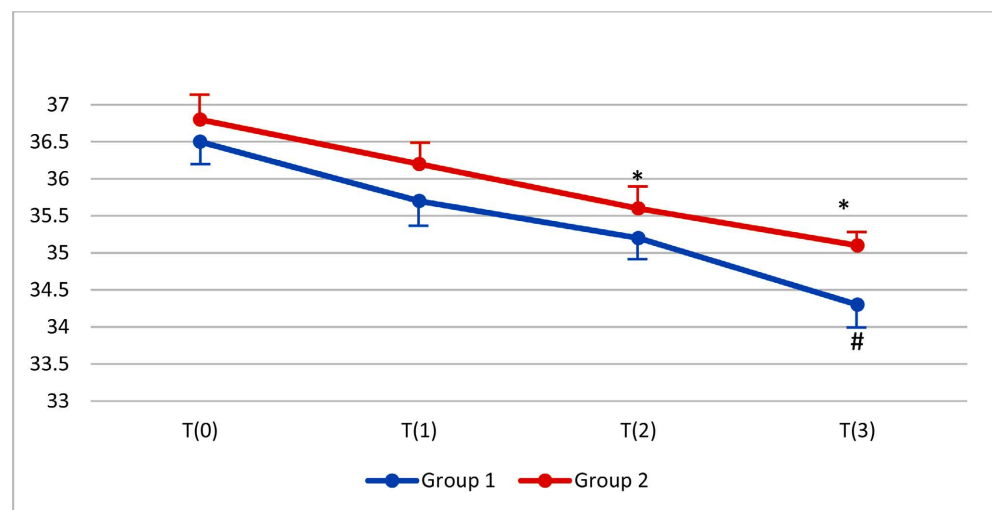


**Abbreviations:** \*\*p < 0.01, significant difference compared to the values noted in pre-lockdown; \*\*\*p < 0.001, significant difference compared to the values noted in pre-lockdown

**Figure 2.** Evolution of performance (in seconds) in the RSSA test in groups 1 and 2 during the study period.



**Figure 3.** Evolution of performance (in meters) in the Yo-Yo IR2 test among football players in groups 1 and 2 during the study period.

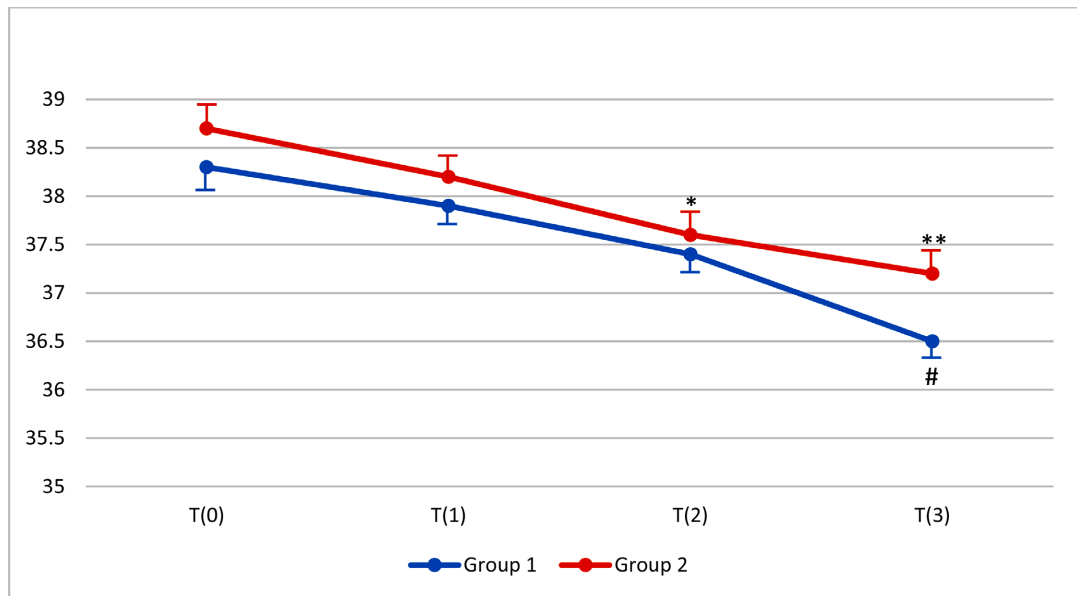


**Abbreviations:** \*\* $p < 0.05$ , significant difference compared to the values noted in pre-lockdown; #, significant intergroup difference at  $p < 0.05$ .

**Figure 4.** Evolution of performance (in centimeters) in the Squat Jump test among football players in groups 1 and 2 during the study period.

The sprinting times had lengthened throughout the experimental period (**Figure 1**), with respective differences between T0 and T3 of +5.3% ( $p < 0.05$ ) in the group 1 ( $4.1\% \pm 0.07$  s versus  $4.39 \pm 0.11$  s) and +2.6% ( $4.15 \pm 0.02$  s versus  $4.26 \pm 0.04$  s) in group 2. No difference between groups of players was observed ( $\eta^2_p = 0.177$ ;  $p = 0.157$ ).

During the RSSA event (**Figure 2**), there was a significant increase in repeating-sprint times throughout the COVID-19 lockdown; the maximum durations were found at the end of the experiment in comparison with the times noted at the start of the study:  $8.58 \pm 0.21$  s vs  $8.18 \pm 0.17$  s in group 1. In addition, there



**Abbreviations:** \* $p < 0.05$ , significant difference compared to the values noted in pre-lockdown; \*\* $p < 0.01$ , significant difference compared to the values noted in pre-lockdown; #, significant intergroup difference at  $p < 0.05$ .

**Figure 5.** Evolution of performance (in centimeters) in the Countermovement Jump test among football players in groups 1 and 2 during the study period.

was no significant difference in performance achieved between the two groups regardless of the moment of evaluation ( $\eta_p^2 = 0.144$ ;  $p = 0.203$ ), particularly at the third evaluation T(2):  $8.58 \pm 0.21$ s in group 1 versus  $8.43 \pm 0.12$  s in group 2 (t value of Student test = 0.83;  $p > 0.05$ ) and at T(3):  $8.42 \pm 0.09$  s for group 1 versus  $8.25 \pm 0.10$  s for group 2 (t value of Student test = 1.81;  $p > 0.05$ ). The average decrease in running times between the first and sixth series of running, before and after follow-up, was respectively:  $-6.3\%$  in group 1 versus  $-11.8\%$  in group 3 before follow-up,  $-4.7\%$  in group 1 vs  $-10.6\%$  in group 2 after follow-up.

With regard to the performances achieved in the Yo-Yo IR1 test (Figure 3), a regular drop in the established scores was noted between the start and the end of the experiment, but no significant difference:  $2503 \pm 182$  m versus  $221 \pm 154$  m for group 1;  $2498 \pm 203$  m against  $1812 \pm 195$  m for the group.

As for performance in the Squat Jump (Figure 4) and Countermovement (Figure), no-significant decreases were found until the 3rd evaluation T(2) compared to the values recorded at T(0): Squat Jump,  $36, 72 \pm 0.53$  cm at T(0) vs  $35.24 \pm 0.71$  cm at T(2) in group 1,  $36.46 \pm 0.31$  cm at T(0)  $35.18 \pm 0.62$  cm at T(2) in group 2; Countermovement Jump,  $38.62 \pm 0.45$  cm at T(0) vs  $37.61 \pm 0.32$  cm at T(2) in group 1,  $38.30 \pm 0.32$  cm at T(0) vs  $37.41 \pm 0.26$  cm at T(2) in group 2.

The differences were further increased from the T(2) to T(3) assessment and a significant difference between groups 1 and 2 was found in the two tests at T(3): Squat Jump,  $35.13 \pm 0, 52$  cm in group 1 against  $34.43 \pm 0.26$  cm in group 2; Countermovement Jump,  $37.25 \pm 0.34$  cm in group 1 against  $36.48 \text{ cm} \pm 0.31$  cm

in group 2.

### 3.4. Impact of Body Composition Changes on Fitness Performance

The values of the correlation coefficients  $r$  between the variations of some body composition parameters and the performances achieved in the physical fitness tests are recorded in **Table 4**.

**Table 4** shows that negative and significant correlations between the changes in body mass, BMI and total fat percent between T0 and T3 and those of performance in the Yo-Yo IR1 test and the SJ test were found.

However, these correlations were positive and no significant for in lean body mass changes. As regards the relationships between the RSSA test and the body composition parameters, they were positive and significant, except for  $\Delta$  (% total fat) where it was negative ( $r = -0.54$ ;  $p = 0.042$ ) and  $\Delta$  (muscle mass) where the relationship, although positive, was no significant ( $r = +0.33$ ;  $p = 0.075$ ).

## 4. Discussion

This study assessed the changes in body composition and fitness performance in Congolese football players during the COVID-19 lockdown. The main findings highlight: 1) a significant increase in body mass ( $p < 0.05$ ), body mass index ( $p < 0.001$ ), total fat percent ( $p < 0.02$ ), unlike lean body mass ( $p > 0.05$ ) in football players in groups 1 and 2; 2) a significant decrease of performance during the 30 m sprint, the series of 6 repeated sprints, the endurance Yo-Yo IR1 test and the vertical jumps (Squat Jump and Countermovement Jump); 3) a “level of practice” effect (intergroup difference) on the variations observed in the performances achieved during the final evaluations of the vertical jumps tests, the maximum differences between pre-lockdown and the resumption of training being found in the group 1.

The variations in body mass, BMI and fat mass throughout our study which are significant, reflected in a steady increase. This can be explained by the disruption of the food system as observed by Makosso Vheiye *et al.* [23] in their study on the dietary profile of Congolese adults in Brazzaville during the first 6 months of the COVID-19 lockdown. These authors noted lipid intakes of 43.27%

**Table 4.** Relations (Pearson correlation coefficients) between variations in body mass, body mass index, percentage of total fat, lean body mass and those of some fitness parameters.

	Yo-YoIR1 (m)	RSSA (s)	SJ (cm)
$\Delta$ Body mass (kg)	$r = -0.54$ ; $p = 0.042$	$r = +0.62$ ; $p = 0.039$	$r = -0.52$ ; $p = 0.042$
$\Delta$ BMI ( $\text{kg}/\text{m}^2$ )	$r = -0.63$ ; $p = 0.036$	$r = +0.70$ ; $p = 0.018$	$r = -0.65$ ; $p = 0.033$
$\Delta$ % total fat	$r = -0.52$ ; $p = 0.047$	$r = -0.54$ ; $p = 0.042$	$r = -0.57$ ; $p = 0.040$
$\Delta$ LBM (kg)	$r = +0.21$ ; $p = 0.081$	$r = +0.33$ ; $p = 0.075$	$r = +0.20$ ; $p = .079$

BMI, Body mass index; LBM, lean body mass;  $\Delta$ , deviation.

of daily caloric intake during the study, a higher percent than the recommended standards for a balanced diet: 30% of caloric intake. Even if we do not have data showing the absence of self-regulation between the ingestion of lipids and the oxidation of lipids in the compartment of energy reserve within the organism, these eating habits are found in the most average and low-income Brazzaville households, which constitute 94.7% of the social strata [24]. Therefore, the high lipid intake has undoubtedly induced an imbalance between ingestions and their oxidation; which is accompanied by net fat storage and an increase in body mass.

No pathological case of sleep disorder was found in our subjects during the study, other major factors are also thought to explain players' weight gain. First, it is the increased frequency of snacking during the COVID-19 lockdown and the reversal of the food rhythm, which clearly contributes to the increase in body mass and total fat [25]. Added to this is the time spent in front of television and computer screens, as reported in the study by the study of Dietz and Gortmaker carried out on football players during a 4-month period of detraining [26]: in subjects aged 20 to 27, body mass would increase by 1.5% for 30 hours spent in front of the small screen. In addition, the establishment of the curfew has led to the overconsumption of food taken outside the home in a limited time, a phenomenon comparable to food compulsion or "binge eating" of the Anglo-Saxons which often leads to weight gain [27].

Third, the stress induced by the COVID-19 lockdown prolonged by the curfew until now may be incriminated in the weight gain in our subjects. This could lead to eating disorders (snacking, food compulsions) which pass through biological relays. Among these biological agents, we find monoamines (including catecholamines), peptides (including CRF) and other substrates at work in the central control of food intake [28] and through the effects of some of them. them on peripheral metabolism, although there are still uncertainties in the intricate nature of their various interactions. Finally, the weight gain observed in all our subjects can be explained by the decrease in daily physical activity. Indeed, lockdown and the curfew are accompanied by a reduction in daily activities, the adoption of several physically passive behaviors (watching television, playing on the console, working on the computer, telephoning while seated, etc.) and by movements or movements of low intensity; all of these are weight gain factors.

The significant decrease observed in BMI ( $p = 0.001$ ) during the 8 months of experimental study in both groups of football players, parallel to that of the percentage of total fat ( $p = 0.05$  in group 1 and  $p = 0.02$  in group 2) is found in the literature; it confirms the fact that the predominance of sedentary occupations promotes an increase in BMI or adiposity. In a longitudinal study by Gallagher *et al.* [29] relating to 286 adults aged 20 - 25 years at inclusion, the physical activity assessed is inversely associated with changes in BMI and body fat at the age of 25 - 30 years. The harmful effect of sedentary occupations is observed in adults who are less active or have a diet higher in fat; these observations agree with ours. Thus, the assertion that the time spent in front of the television re-

flects a lack of PA is consolidated; but other unfavorable factors such as nibbling behaviors also intervene. However, only the evaluation of plasma insulin levels, plasma concentrations of triglycerides (TG) and high density lipoproteins (HDL) can better objectify these assertions.

The results relating to the significant drop in physical performance are in agreement with numerous studies on populations of football players. This deterioration in the physical abilities of the players studied partly explains the defeat of the Congolese team during the quarter-finals at CHAN 2021, Yaoundé (Cameroon), insofar as our players from group 1 formed the backbone of the national selection during this African competition; this is in line with the observations of the technical staff at the end of this competition. With regard to the data from the Yo-Yo IR1 test (endurance test), a decrease in the distances traveled by the subjects was noted from the 3rd month of COVID-19 lockdown (Figure III.3). Our observations agree with those of Thomassen *et al.* [10], Christensen *et al.* [30] who also highlight, after 2 weeks of detraining, a drop in performance in this test in top football players. In addition, a study conducted in the laboratory reports that a prolonged period of detraining induces an 8% decline in maximal oxygen consumption [31], in close correlation with the distance traveled in the Yo-Yo IR1 test [32]. The degree of fitness deterioration during the detraining period after a competitive season is closely related to the fitness level of athletes prior to detraining [33]. Thus, in this work, the decrease in performance in the Yo-Yo IR1 test from the third month of COVID-19 lockdown can be explained. These decreases in performance may have a muscular origin. Indeed, it is known that several weeks of detraining lead to a return of muscle capillarization to the basic level in athletes (~3 weeks for elite footballers according to the literature [34], but not evaluated in our study) and to a 25% - 45% drop in enzymatic oxidative activities, a result of the reduced production of ATP mitochondria in skeletal muscle [35]. This decrease in fitness is for Noon *et al.* [36], Olivier *et al.* [37], in connection with a few factors of well-being and quality of life of the subjects such as motivation, appetite, fatigue and stress.

As for the performance achieved in the Squat Jump (Figure 4) and Counter-movement Jump (Figure 5) significant drops were observed throughout the COVID-19 lockdown (Figures 1-5). This decrease in anaerobic performance is reported in the literature in high-level soccer players, after a short period of detraining after a competitive season [38]. Thus, the cessation of training beyond 2 weeks could affect the expression of the Na<sup>+</sup>-K<sup>+</sup> pump, translated by: a reduction in the signal AB FXVD1 ser 68; a 17% decrease in the level of pyruvate dehydrogenase; 12% in the activity of citrate synthase and 18% in 3-hydroxyacyl CoA. In addition, the performances achieved during the SJ test and CMJ test also showed a respective drop of 5.95% and 6.4%. Kooundourakis *et al.* [39], examining the effect of detraining on exercise performance, noted that a 6-week period of detraining significantly decreased maximal oxygen consumption (VO<sub>2max</sub>) and performance achieved in sprint tests (10 m, 20 m), SJ and CMJ. These varia-

tions can be related to changes in skeletal muscle morphology, reflected in a reduction in mitochondrial enzymatic section [40].

Furthermore, following the COVID-19 lockdown measures characterized among other things by a notable increase in physical inactivity, the decrease in contractile activity of the muscle may explain this drop in performance in the Yo-Yo IR1, CMJ and Squat events. Jump. Indeed, significant muscle atrophy (1% - 4% decrease) has been reported after just 14 days of reduced physical activity in young and older adults [41]. According to Arc-Chagnaud *et al.* [42], skeletal muscle adapts to prolonged physical inactivity by decreasing not only muscle fiber size (atrophy) but also muscle function and quality. Additionally, mechanosensing proteins such as costamers, titin, filamin-C, and bag 3 are known to enable muscle fibers to transform electrical excitation into mechanical forces [43]. Their activation during muscle contraction regulates protein turnover through the interaction between the rapamycin 1 complex (mTORC1) and the main proteolytic pathways (autophagic systems of lysosomes and ubiquitous proteases) [44]. However, research on rats shows that the immobilization of muscle during a 2 - 3 weeks period of drastically reduces the quantity and quality of mitochondria due to the decrease in the regulation of mitochondrial biogenesis, the increase in the regulation of proteases ubiquities and increased expression of mitophagic genes [45] [46]. Indeed, mitochondria, conventionally considered as sources of muscular energy production, play an important role, not only by controlling the proliferation and production of new organelles (biogenesis of mitochondria) but also by regulating the elimination of the dysfunction of mitochondria via mitophagy and morphological dynamics through fusion and fission [45] [46]. This deterioration of mitochondrial homeostasis during the COVID-19 lockdown then undoubtedly leads to a decline in muscle function, and therefore in specific-fitness performance such as suggested in this study.

However, some precautions should be taken into consideration when interpreting the results presented. First, these are the small size of our sample of the subjects in group 2, 11 out of 253 first division football players; this does not authorize the generalization of the conclusions obtained to the entire population of football players. Second, the morbid antecedents and lifestyle of the subjects during the experimental period were based only on their declarations, without rigorous verification. Third, we should have strictly controlled the diet of our subjects and made it uniform in both groups. However, the socioeconomic crisis due to the COVID-19 pandemic has resulted in Brazzaville households losing purchasing power, and therefore the disruption of eating habits, as reported by Makosso Vheiyé *et al.* [23]. Fourth, the study would also have assessed the recovery process of players throughout the lockdown. Although a measure of recovery was planned, the large number of missing data did not allow these analyzes to be carried out. However, these limitations mentioned do not completely affect the power of the observations. This study nevertheless has the merit of having addressed the monitoring of body composition and physical condition parameters

in athletes during COVID-19 lockdown, a topic not yet addressed in recent African scientific literature. In addition, our experimental work followed protocols similar to other previous studies on detraining [47] [48] [49] [50]. In these studies, subjects like those in our series were assessed four times and considered as their own control. Another strength of our work lies in the simplicity and speed of the fitness tests used; these did not require any sustained learning, while guaranteeing the repeated follow-up of the subjects. They therefore remain particularly suitable for our study.

## 5. Conclusion

This study, while presenting certain limitations, made it possible to identify the interesting results of the impact of 8 months of prolonged COVID-19 lockdown on the body composition and some physical abilities in senior football players from Brazzaville. The body mass and fat percentage of the subjects are increased. The physical condition of the players is altered, reflected in a significant decrease in performance in sprint, endurance and relaxation. This is why, in the current socio-economic and health crisis, it is necessary to at least limit the damage by authorizing the controlled resumption of sports training. For this, it is desirable to improve the sports management of the current health crisis to meet the needs of the populations for the maintenance of physical condition and the maintenance of body shape.

## Author Contributions

Conceptualization: Massamba, A.

Formal analysis: Massamba, A., Makosso-Vheiye, G., Moulongo J.G.A.

Investigation: Makosso-Vheiye, G., Loubelo, P., Mouanda Konde, D.

Methodology: Makosso Vheiye, G., Moulongo, J.G.A., Massamba Miabaou, D., Mabilia Babela, J.R.

Data processing: Massamba, A., Moulongo, J.G.A., Makosso-Vheiye, G.

Writing of the draft: Makosso-Vheiye, G.

Corrections and revision of the draft: Massamba, A, Moulongo, J.G.A., Massamba Miabaou, D., Mabilia Babela, J.R.

Analysis of the final text: All authors.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

- [1] Wu, Y., Ho, W., Huang, Y., Jin, D.Y., Li, S., Liu, S.L., *et al.* (2020) SARS-CoV-2 Is an Appropriate Name for the New Coronavirus. *Lancet*, **395**, 949-950. [https://doi.org/10.1016/s0140-6736\(20\)30557-2](https://doi.org/10.1016/s0140-6736(20)30557-2)
- [2] Ministère de la Santé et de la Population Du Congo (2021) Déclaration N°43 du

Gouvernement de la République du Congo Relative a la Pandémie du Coronavirus (COVID-19), Mars 2021. <http://www.primature.gouv.cg>

- [3] Wang, C., Pan, R., Wan, X., Tan, Y., Xu, L., Ho, S.C., *et al.* (2020) Immediate Psychological Responses and Associated Factors during the Initial Stage of the 2019 Coronavirus Disease (COVID-19) Epidemic among the General Population in China. *International Journal of Environmental Research and Public Health*, **17**, Article No. 1729. <https://doi.org/10.3390/ijerph17051729>
- [4] Stephenson, K.M., Schroder, C.M., Bertschy, G. and Bourgin, P. (2012) Complex Interaction of Circadian and Non-Circadian Effects of Light on Mood: Shedding New Light on an Old Story. *Sleep Medicine Reviews*, **16**, 455-454. <https://doi.org/10.1016/j.smrv.2011.09.002>
- [5] Potter, G.D., Skene, D.J., Arendt, J., Cade, J.E., Grant, P.J. and Hardie, L.J. (2016) Circadian Rhythm and Sleep Disruption: Causes, Metabolic Consequences, and Countermeasures. *Endocrine Reviews*, **37**, 584-608. <https://doi.org/10.1210/er.2016-1083>
- [6] Ammar, A., Brach, M., Trabelsi, K., Chtourou, H., Boukhris, O., Masmoudi, L., *et al.* (2020) Effects of COVID-19 Home Confinement on Eating Behavior and Physical Activity: Results of the ECLB-COVID19 International Online Survey. *Nutrients*, **12**, Article No. 1583. <https://doi.org/10.3390/nu12061583>
- [7] Lesser, I.A. and Nienhuis, C.P. (2020) The Impact of COVID-19 on Physical Activity Behavior and Well-Being of Canadians. *International Journal of Environmental Research and Public Health*, **17**, Article No. 3899. <https://doi.org/10.3390/ijerph17113899>
- [8] Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P. and Drust, B. (2009) Analysis of High Intensity in Premier League Soccer. *International Journal of Sports Medicine*, **30**, 205-212. <https://doi.org/10.1055/s-0028-1105950>
- [9] Kotzaminidis, C., Chatzopoulos, D., Michailidis, C., Papaiaikovou, G. and Patikas, D. (2005) The Effect of Combined High-Intensity Strength and Speed Training Program on the Running and Jump Ability of Soccer Players. *The Journal of Strength & Conditioning Research*, **19**, 369-375.
- [10] Thomassen, M., Christensen, P.M., Gunnarsson, T.P., Nybo, L. and Bangsbo, J. (2010) Effect of 2-wk Intensified Training and Inactivity on Muscle Na<sup>+</sup>-K<sup>+</sup> Pump Expression, Phospholemman (EXYD1) Phosphorylation and Performance in Soccer Players. *Journal of Applied Physiology*, **108**, 898-905. <https://doi.org/10.1152/jappphysiol.01015.2009>
- [11] Mara, J.K., Thompson, K.G., Pumpa, K.L. and Ba, N.B. (2015) Periodization and Physical Performance in Elite Female Soccer Players. *International Journal of Sports Physiology and Performance*, **10**, 664-669. <https://doi.org/10.1123/ijsp.2014-0345>
- [12] Jeng, T.S., Reilly Tn Morton, J., Bae, S.W. and Drust, B. (2011) Quantification of the Physiological Loading of “Pre-Season” and One Week of “In-Season” Training in Professional Soccer Players. *Journal of Sports Sciences*, **29**, 1161-1166. <https://doi.org/10.1080/02640414.2011.583671>
- [13] Chang, H.J. (2018) The Effects of Short-Term Detraining and Retraining on Physical Fitness in Elite Soccer Players. *PLoS ONE*, **13**, Article ID: e016212. <https://doi.org/10.1371/journal.pone.0196212>
- [14] Soares De Araújo, C.G. (2021) Physical Activity, Exercise and Sports and Covid-19: What Really Matters? *The International Journal of Cardiovascular Sciences*, **34**, 113-115.
- [15] Duncan, G.E., Avery, A.R., Seto, E. and Tsang, S. (2020) Perceived Change in Physical Activity Levels and Mental Health during COVID-19: Findings among Adult

- Twin Pairs. *PLoS ONE*, **15**, Article ID: e0237695.  
<https://doi.org/10.1371/journal.pone.0237695>
- [16] Harrichaux, P. and Medelli, J. (2002) Tests d'aptitude et tests d'effort en médecine du sport. Chiron, Paris.
- [17] World Health Organization (2007) Body Composition of Ethnic Groups in the African. Evaluation of Total and Regional Body Composition. Report of an Experts' Committee. World Health Organization, Geneva.
- [18] Forsyth, H.L. and Sinning, W.E. (1973) The Anthropometric Estimation of Body Density and Lean Body Weight of Male Athletes. *Medicine & Science in Sports*, **5**, 174-180.
- [19] Impellizzeri, F.M., Rampinini, E., Castagna, C., Bishop, D., Bravo, D.F., Tibaudi, A., *et al.* (2008) Validity of a Repeated-Sprint Test for Football. *International Journal of Sports Medicine*, **29**, 899-905. <https://doi.org/10.1055/s-2008-1038491>
- [20] Bangsbo, J., Iaia, F.M. and Krstrup, P. (2008) The Yo-Yo Intermittent Recovery Test: A Useful Tool for Evaluation of Physical Performance in Intermittent Sports. *Sports Medicine*, **38**, 37-51. <https://doi.org/10.2165/00007256-200838010-00004>
- [21] Claudino, J.G., Cronin, J., Mezêncio, B., Mc Master, D.T., Mc Guigan, M., Tricoli, V., *et al.* (2017) The Countermovement Jump to Monitor Neuromuscular Status: A Meta-Analysis. *Journal of Science and Medicine in Sport*, **20**, 397-402.  
<https://doi.org/10.1016/j.jsams.2016.08.011>
- [22] Hopkins, W.G., Marshall, S.W., Batterham, A.M. and Hanin, J. (2009) Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Medicine & Science in Sports & Exercise*, **41**, 3-12. <https://doi.org/10.1249/mss.0b013e31818cb278>
- [23] Makosso Vheiyé, G., Mananga, V., Bouhika, E.J., Mouanda Konde, D., Mouloungo, J.G.A., Packa Tchissambou, B. and Massamba, A. (2021) Effet du confinement de la pandémie a COVID-19 sur les besoins nutritionnels dans une population adulte active et Chez des Personnes en age de Retraite a Brazzaville, République Du Congo. *Annals of African Medicine*, **14**, e4183-e4195.
- [24] Ministère du plan (2020) La république du congo en Chiffres. Données Socioéconomiques de L'année 2020. Centre national de la statistique et des études économiques, Brazzaville.
- [25] Maillard, G., Charles, M.A., Lafay, L., Thibault, N., Vray, M. and Borys, J.M. (2000) Macronutrient Energy Intake and Adiposity in Non-Obese Adults Aged 19-30 Years (The Fleurbaix Lavantie Ville Sante Study). *International Journal of Obesity*, **24**, 1608-1617. <https://doi.org/10.1038/sj.ijo.0801446>
- [26] Diet, W.H. and Gortmaker, S.L. (2008) Do We Fatten Sportsmen during Long Term Detraining? Body Composition and Television Viewing in Sportsmen. *The Open Sports Sciences Journal*, **1**, 15-19.
- [27] Hawbins, R.C. and Clément, P.F. (2004) Binge Eating: Measurement Problems and a Conceptual Model. In: Hawkins, R.C. and Clément, P.F., Eds., *The Binge-Purge Syndrome*, Springer-Verlag, New-York.
- [28] Dadoun, F. (2002) Prise Alimentaire: Qui Contrôle Quoi? *Annales d'Endocrinologie*, **6**, 3S15-3S24.
- [29] Gallagher, D., Heo, M., Jebb, S., Foster, M.A., Cameron, G.G. and Foster, K.R. (2004) Assessment of Body Mass Index and Body Fat on 286 Men Aged 20 to 25 Years. *British Journal of Nutrition*, **62**, 598-608.
- [30] Christensen, P.M., Krstrup, P., Gunnarsson, T.P., Killerich, K., Nybo, L. and Bangsbo, J. (2011) VO<sub>2</sub> Kinetics and Performance in Soccer Players after Intense Training and Inactivity. *Medicine & Science in Sports & Exercise*, **43**, 1716-1724.

- <https://doi.org/10.1249/mss.0b013e318211c01a>
- [31] Godfrey, R.J., Ingham, S.A., Pedlar, C.R. and Whyte, G.P. (2005) The Detraining and Detraining of an Elite Rower: A Case Study. *Journal of Science and Medicine in Sport*, **8**, 314-320. [https://doi.org/10.1016/s1440-2440\(05\)80042-8](https://doi.org/10.1016/s1440-2440(05)80042-8)
- [32] Krstrup, P., Mohr, M., Nybo, L., Jensen, J.M., Nielsen, J.J. and Bangsbo, J. (2006) The Yo-Yo IR Test: Physiological Response, Reliability, and Application to Elite Soccer. *Medicine & Science in Sports & Exercise*, **38**, 1666-1673. <https://doi.org/10.1249/01.mss.0000227538.20799.08>
- [33] Nakamura, D., Suzuki, T., Yasumatsu, M. and Akimoto, T. (2021) Moderate Running and Plyometric Training during Off-Season Did Not Show a Significant Difference on Soccer-Related High-Intensity Performances Compared with No-Training Controls. *The Journal of Strength & Conditioning Research*, **26**, 3392-3397. <https://doi.org/10.1519/jsc.0b013e3182474356>
- [34] Impellizzeri, F.M., Marcora, S.M., Castagna, C., Reilly, T., Sassi, A., Iaia, F.M., *et al.* (2006) Physiological and Performance Effects of Generic versus Specific Aerobic Training in Soccer Players. *International Journal of Sports Medicine*, **27**, 483-492. <https://doi.org/10.1055/s-2005-865839>
- [35] Fitts, R.H. (1994) Cellular Mechanisms of Muscle Fatigue. *Physiological Reviews*, **74**, 49-94. <https://doi.org/10.1152/physrev.1994.74.1.49>
- [36] Noon, M.R., James, R.S., Clarke, N.D., Akubat, I. and Thake, C.D. (2015) Perceptions of Well-Being and Physical Performance in English Elite Youth Footballers Across a Season. *Journal of Sports Sciences*, **33**, 2106-2016. <https://doi.org/10.1080/02640414.2015.1081393>
- [37] Olivier, J.L., Llyod, R.S. and Whitney, A. (2015) Monitoring of In-Season Neuromuscular and Perceptual Fatigue in Youth Rugby Players. *European Journal of Sport Science*, **15**, 514-522. <https://doi.org/10.1080/17461391.2015.1063700>
- [38] Buchheit, M., Morgan, W., Wallace, J., Bode, M. and Poulos, N. (2015) Physiological, Psychometric, and Performance Effects of the Christmas Break in Australian Football. *International Journal of Sports Physiology and Performance*, **10**, 120-127. <https://doi.org/10.1123/ijspp.2014-0082>
- [39] Koundourakis, N.E., Androulakis, N.E., Malliaraki, N., Tsatsanis, C., Venihaki, M. and Margioris, A.N. (2014) Discrepancy between Exercise Performance, after a Six-Week Detraining Period in Professional Soccer Players. *PLoS ONE*, **9**, Article ID: e87803. <https://doi.org/10.1371/journal.pone.0087803>
- [40] Bangsbo, J. and Mizuno, M. (1988) Morphological and Metabolic Alterations in Soccer Players with Detraining and Retraining and Their Relation to Performance. *Proceedings of the first World Congress of Science and Football*, Liverpool, 13-17 April 1988, 107-116.
- [41] Bowden Davis, K.A., Pickles, S., Sprung, V.S., Kemp, G.J., Alam, U., Moore, D.R., *et al.* (2019) Reduced Physical Activity in Young and Older Adults: Metabolic and Musculoskeletal Implications. *Therapeutic Advances in Endocrinology and Metabolism*, **10**, 1-15. <https://doi.org/10.1177/2042018819888824>
- [42] Arc-Chagnaud, C., Py, G., Fovet, T., Roumanolle, R., Demangel, R., Pagano, A.F., *et al.* (2020) Evaluation of an Antioxidant and Anti-Inflammatory Cocktail against Human Hypoactivity-Induced Skeletal Muscle Deconditioning. *Frontiers in Physiology*, **11**, Article No. 71. <https://doi.org/10.3389/fphys.2020.00071>
- [43] Lutz, G.J. and Lieber, R.L. (1999) Skeletal Muscle Myosin II-Structure and Function. *Exercise and Sport Sciences Reviews*, **27**, 63-77.
- [44] Wackerhage, H., Schoenfeld, B.J., Hamilton, D.L., Lehti, M., Hulmi, J.J. (2019) Sti-

- multi and Sensors That Initiate Skeletal Muscle Hypertrophy Following Resistance Exercise. *Journal of Applied Physiology*, **126**, 30-43.  
<https://doi.org/10.1152/jappphysiol.00685.2018>
- [45] Woods, J.A., Hutchison, N.T., Powers, S.K., Roberts, W.O., Gomez-Cabrera, M.C., Radak, Z., *et al.* (2020) The COVID-19 Pandemic and Physical Activity. *Sports Medicine and Health Science*, **2**, 55-64. <https://doi.org/10.1016/j.smhs.2020.05.006>
- [46] Kang, C., Googman, C.A., Hornberger, T.A. and Ji, L.L. (2015) PGC-1 $\alpha$  Over-Expression by *in Vivo* Transfection Attenuates Mitochondrial Deterioration of Skeletal Muscle Caused by Immobilization. *The FASEB Journal*, **29**, 4092-4106.  
<https://doi.org/10.1096/fj.14-266619>
- [47] Joo, C.H. (2018) The Effects of Short Term Detraining and Retraining on Physical Fitness in Elite Soccer Players. *PLoS ONE*, **19**, Article ID: e0196212.  
<https://doi.org/10.1371/journal.pone.0196212>
- [48] Mujika, I. and Padilla, S. (2000) Detraining: Loss of Training Induced Physiological and Performance Adaptations. Part I: Short Term Insufficient Training Stimulus. *Sports Medicine*, **30**, 79-87. <https://doi.org/10.2165/00007256-200030020-00002>
- [49] Moore, R.L., Thecker, E.M., Kelly, G.A., Musch, T.I., Sino Way, L.I., Foster, V.L., *et al.* (1987) Effect of Training/Detraining on Submaximal Exercise Responses in Humans. *Journal of Applied Physiology*, **63**, 1719-1724.  
<https://doi.org/10.1152/jappphysiol.1987.63.5.1719>
- [50] Izquierdo, M., Ibanez, J., Gonzalez-Badillo, J.J., Ratamess, N.A., Kraemer, W.J., Hakkinen, K., *et al.* (2007) Detraining and Tapering Effects on Hormonal Responses and Strength Performance. *The Journal of Strength & Conditioning Research*, **21**, 768-775.