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## **Spirulina platensis Provides a Small Advantage in Vertical Jump and Sprint Performance But Does Not Improve Elite Rugby Players' Body Composition**

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► **To cite this version:**

Mehdi Chaouachi, Sandrine Gautier, Yoann Carnot, Nicolas Bideau, Pierrick Guillemot, et al.. Spirulina platensis Provides a Small Advantage in Vertical Jump and Sprint Performance But Does Not Improve Elite Rugby Players' Body Composition. *Journal of Dietary Supplements*, 2021, 18 (6), pp.682-697. 10.1080/19390211.2020.1832639 . hal-04224873v1

**HAL Id: hal-04224873**

**<https://hal.science/hal-04224873v1>**

Submitted on 21 Jan 2021 (v1), last revised 2 Oct 2023 (v2)

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6 2 **Spirulina platensis provides a small advantage in vertical jump and sprint**  
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9 3 **performance but does not improve elite rugby players' body composition**  
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16 5 **RUNNING TITLE: Spirulina as an ergogenic nutrient in athletes?**  
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49 20 **CONFLICT OF INTEREST:** The authors declare no conflict of interest with the  
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52 21 information contained within this manuscript.  
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## 24 **ABSTRACT**

25 The present study aimed to examine the effects of Spirulina supplementation on  
26 anthropometrical measurements and physical performance in elite rugby players.

27 Twenty-two elite male Rugby Union players (21-36 years old) volunteered to participate in this  
28 study. They were randomly assigned to a Spirulina group (SPI: n = 11), or a placebo group  
29 (PLA: n = 11) in a double-blind design. Subjects were supplemented with Spirulina *platensis*  
30 (5.7g/d) or Placebo (iso-proteic and caloric) for seven weeks. At baseline ( $W_0$ ) and after 7 weeks  
31 of supplementation ( $W_7$ ), the same anthropometric measurements and physical performance  
32 test battery were performed. These tests included isokinetic leg strength and power, vertical  
33 jump, speed, and aerobic fitness assessment.

34 For anthropometric data, the fat mass (FM) percentage was significantly reduced in both groups  
35 without significant difference between groups. While both groups exhibited significant  
36 improvements for SJ, CMJ, 10 and 30-m sprints between  $W_0$  and  $W_7$ , higher percentage  
37 improvements with the SPI group did not reach significance. Neither training alone (PLA) nor  
38 training associated with spirulina supplementation affected leg maximal strength and power or  
39 aerobic fitness.

40 Seven weeks of spirulina supplementation in elite rugby players did not improve body  
41 composition nor substantially increase physical performance. We only observed a non-  
42 significant small advantage in vertical jump and sprint performance in the SPI group. Based on  
43 the data from this study, spirulina supplementation has modest effects in elite rugby players  
44 during the competitive phase. Further studies are required to verify spirulina supplementation  
45 effects among athletes of different sports, age, gender and athletic level with longer durations  
46 and higher dosages.

47 **KEY WORDS:** Arthrospira, body composition, elite athletes, performance,  
48 supplementation.

## 49 Introduction

50 *Spirulina* (*Arthrospira*) is a blue-green microalga belonging to the Cyanobacteria class with  
51 prokaryotic photosynthetic characteristics [1-4]. The most well-known species of spirulina safe  
52 for consumption are *Spirulina maxima*, *Arthrospira fusiformis*, and *platensis*, this last one being  
53 the most commonly used species and largely studied in the scientific literature [4, 5]. It's known  
54 for its complex chemical makeup including high protein content (50 to 70% of its dry weight),  
55 all the essential amino and fatty- acids, and most of the vitamins and minerals [6-8], which  
56 confers to spirulina numerous health benefits such as antioxidant, immunomodulatory, anti-  
57 inflammatory, anti-cancer and anti-viral activities [1, 8-10].

58 In recent years, spirulina has been widely used by athletes for these health benefit effects and  
59 most of them consume it in the belief it will improve body composition, physical performance  
60 and recovery. It was speculated that Chinese and Cuban Olympic teams have consumed  
61 spirulina daily for many years to improve performance [2]. Data in the literature is still rare and  
62 controversial about spirulina effects on anthropometric parameters and performances in  
63 athletes. Indeed, only a few authors investigated the effects of spirulina supplementation on  
64 these data in athletes. Concerning anthropometric parameters, in untrained subjects, Miczke et  
65 al. [11] and Zeinalian et al. [12] indicated a loss of body mass (BM: -6%) without changes in  
66 fat mass (FM). However, Lee et al. [13] and Mazokopakis et al. [14] reported no significant  
67 effects on these parameters. In athletes, Milasius et al. [15] reported no significant decrease in  
68 BM and FM after supplementation (2.25 g/d) which may suggest no change in lean body mass  
69 (LBM) or muscle mass contrary to spirulina assertions. Concerning spirulina effects on  
70 performance, Lu et al. [16] studied the effects of three weeks of *Arthrospira platensis*  
71 supplementation (7.5 g/d) in students and reported a significantly increased time to exhaustion  
72 during the Bruce protocol test only in the spirulina group. In moderately trained men, Kalafati  
73 et al. [17] showed that time to fatigue after a submaximal run was significantly higher after

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2  
3 74 spirulina supplementation (6 g/d). Concerning the effects of spirulina consumption on muscular  
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5 75 strength, Sandhu et al. [18] examined the effects of eight weeks of spirulina supplementation  
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7 76 (2 g/d) in trained and untrained subjects. They reported significant improvements in isometric  
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9  
10 77 peak force, average force, and fatigue index due to the use of spirulina for both groups.  
11  
12 78 Therefore, they recommend the use of spirulina as a nutritional supplement by athletes and non-  
13  
14 79 athletes for improving isometric strength and muscle endurance. Recently and contrary to these  
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16  
17 80 conclusions, Juskiewicz et al. [19] showed that spirulina supplementation (1.5 g/d) was not  
18  
19 81 able to enhance the mean power output nor total run time during a 2000-m test on a rowing  
20  
21 82 ergometer with a Polish rowing team. Among the four studies which evaluated the effects of  
22  
23 83 spirulina on physical performance, only one examined elite athletes [19] and they only tested  
24  
25 84 the effect of spirulina on muscle power and not on various physical qualities. In addition to the  
26  
27 85 low level of evidence and the heterogeneity of previous studies concerning the types of the sport  
28  
29 86 involved, the duration and dose of supplementation, to our knowledge, no studies have  
30  
31 87 examined the effects of spirulina supplementation in team-sport athletes although they are  
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33 88 known for their widespread use of ergogenic aids [20, 21].  
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37 89 Thus, the aim of the present study was to examine the effects of spirulina supplementation on  
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39 90 anthropometric measurements and physical performance in elite rugby players. Physical  
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41 91 performance evaluation included a complete set of measurements such as leg strength and  
42  
43 92 power, vertical jump, speed, and aerobic fitness. We hypothesized that its high nutritional  
44  
45 93 quality protein content could reduce FM and possibly increase lean body mass (LBM), leading  
46  
47 94 to a greater improvement in performance.  
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## 52 **Materials and methods**

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55 96 The experimental protocol was approved by a local ethics committee (NOD0172, Tours, France  
56  
57 97 - protocol number 2016-A00233-48). The protocol was conducted in compliance with both  
58  
59 98 Good Clinical Practices and the Declaration of Helsinki. Tests were realized at M2S lab (FINES  
60

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3 99 of 31/05/17; EJ: 350051454; ET: 350051462). After being informed of the objectives, the  
4  
5 100 possible risks, discomforts and benefits, written and informed consent was obtained from all  
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7 101 participants prior to inclusion.  
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### 13 103 *Participants*

16 104 Thirty elite male rugby union players belonging to the same French first federal division rugby  
17  
18 105 club (Rennes Étudiants Club « REC ») volunteered to participate in this study. After having  
19  
20 106 completed a clinical examination and medical interview to determine eligibility, only twenty-  
21  
22 107 two participants (21-36 years old) satisfied the following inclusion criteria (being considered  
23  
24 108 healthy in clinical examination, not having any history of surgery and not taking any kind of  
25  
26 109 dietary supplement for the past 3 months). Exclusion criteria included tobacco use, current  
27  
28 110 intake of spirulina, supplements or anti-inflammatory drugs, known chronic diseases and  
29  
30 111 allergy to spirulina or any of its components.  
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### 37 113 *Study design*

40 114 A randomized, double-blind, placebo-controlled design was used. Sealed opaque envelopes  
41  
42 115 numbered in the order of inclusions, with the allocated treatment listed in the envelope, were  
43  
44 116 constructed from the established randomization list. The draw was conducted by a third party  
45  
46 117 who held the codes assigned to the subjects and used for data collection. Participants were  
47  
48 118 assigned to a spirulina group (SPI: n = 11), or a placebo group PLA: n = 11). Participant  
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50 119 characteristics are reported in **Table 1**.  
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<< Please insert table 1 here >>

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3 123 The study consisted of a daily supplementation period during 7 weeks in which the SPI group  
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5 124 received capsules with *Arthrospira platensis*, manufactured by Algae Green Value (AGV,  
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7 125 Vannes, France). This spirulina is certified as safe and its composition is reported in **Table 2**.

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12 127 << Please insert table 2 here >>  
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17 129 Each subject was asked to take three capsules before the three daily meals. Based on the doses  
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19 130 used in the previous human studies and taking into account the comfort of participants, the daily  
20  
21 131 dosage was 5.7g, below the 10g safety dosage recommended by Fox [22]. The placebo group  
22  
23 132 was given visually identical capsules with isocaloric and isoproteic content composed of 70.3  
24  
25 133 % egg proteins and 29.7 % carbohydrates.

26  
27  
28 134 Rugby players visited the laboratory five times during the study. The same anthropometric  
29  
30 135 measurements and physical performance test battery were performed at baseline (W0) and after  
31  
32 136 seven weeks of supplementation (W7). These tests included leg strength and power, vertical  
33  
34 137 jump, speed, and aerobic intermittent fitness test (yo-yo IRT-1). At W0 and W7, all subjects  
35  
36 138 were asked to record dietary intake for three days including one weekend day. Diet records were  
37  
38 139 analyzed using the Nutrilog software (Nutrilog® SAS, France). Players were invited to make  
39  
40 140 no modifications to their diet and to not use any other dietary supplements during the study or  
41  
42 141 risk being excluded.

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46 142 Supplementation compliance was assessed by counting the remaining capsules in the provided  
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48 143 bottles at the end of the study. Gastrointestinal symptoms were monitored using a questionnaire  
49  
50 144 as described by Bovenschen et al. [23]. The study design is illustrated in **Figure 1**.

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56 146 << Please insert Figure 1 here >>  
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## 148 ***Procedures***

149 All procedures were conducted during the competitive phase of the season (October-December  
150 2018). All participants actively participated daily in the rugby-specific training sessions. They  
151 were fully accustomed to the testing procedures used in this research as they routinely  
152 performed these tests in the club as part of their medical/training follow-up.

## 154 ***Anthropometric data and body composition***

155 Each participant's height, BM and FM were collected. Height and BM were collected using a  
156 wall-mounted stadiometer (Seca 206, Hamburg, Germany) and electronic scale (Terrillon,  
157 Paris, France), respectively. FM percentage was estimated from the sum of skinfolds (biceps  
158 brachii, triceps brachii, subscapular, and supra-iliac) monitored with Harpenden skinfold  
159 calipers (Baty International, West Sussex, England) according to Siri [24]. All anthropometric  
160 measurements were taken at W0 and W7 by the same experienced sports scientist.

## 162 ***Training load***

163 Throughout the experiment, the internal training load of all players was monitored using the  
164 session Rate of Perceived Exertion (Session-RPE) method as described by Comyns and  
165 Flanagan [25] expressed in arbitrary units (AU). About 30-minutes (min) after training sessions,  
166 participants were asked to rate the global intensity of the entire workout session using the  
167 French version CR-10 RPE scale [26]. The daily training load was evaluated by multiplying the  
168 training duration (min) by the session RPE score and the weekly training load was determined  
169 by summing the daily training loads each week for each rugby player.

## 171 ***Physical fitness tests***

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3 172 Prior to each testing session, participants completed a 15-min standardized warm-up that  
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5 173 included riding a cycle ergometer (Excalibur, Lode, Groningen, Netherlands) and dynamic  
6  
7 174 stretching. All testing sessions were completed at the same moment of the day for both W0  
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10 175 and W7, at the same turf pitch, with the same sports clothes, in the same order (**Fig. 1**) and by  
11  
12 176 the same investigators.

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### 178 *Isokinetic leg strength and power*

179 Subjects were comfortably seated on the dynamometer chair, with the hip joint at a standardized  
180 position of 85° hip flexion from the anatomical position. Straps were applied across the chest,  
181 pelvis, and mid-thigh to minimize extraneous body movements. The distal shin pad of the  
182 dynamometer was attached 2–3 cm proximal to the lateral malleolus by using a strap. The axis  
183 of rotation of the dynamometer was aligned with the lateral femoral epicondyle of the knee.  
184 Gravity torque effects were recorded on each subject throughout the range of motion to correct  
185 torque measurements during testing. The participants were given standardized verbal  
186 encouragement and were asked to position their arms across the chest with each hand clasping  
187 the opposite shoulder during the testing procedure. The thigh muscles of the dominant limb  
188 were tested by using an isokinetic dynamometer (CON-TREX® MJ; CMV AG, Dübendorf,  
189 Switzerland) as described by Maffiuletti et al. [27]. Subjects were asked to complete three  
190 submaximal practice repetitions prior to each test series. Concentric measurements involved  
191 three continuous, maximal knee extensions and flexions, which were performed at two pre-set  
192 constant angular velocities, 60 and 240 °s<sup>-1</sup>. Eccentric measurements consisted of three maximal  
193 contractions at a single velocity of 30° s<sup>-1</sup>. Knee flexor and extensor trials were performed as  
194 movements in a single direction (i.e. non-reciprocal). Subjects recovered passively for 120s  
195 between series of measurements. The Con-Trex software calculated the peak torque and power  
196 for concentric and eccentric trials in knee extensors and flexors.

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3 197 *Vertical jump*  
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5 198 Players performed the vertical jumps: squat jump (SJ) and countermovement jump (CMJ),  
6  
7 199 using an Optojump next photocell system (Microgate, Bolzano, Italy), which are valid and  
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9  
10 200 reliable tools for the assessment of vertical jump height [28, 29]. Participants were instructed  
11  
12 201 to place their hands on the hips to minimize lateral and horizontal displacement during the  
13  
14 202 performance and to prevent any influence of arm movements on the vertical jumps. Participants  
15  
16 203 also had to leave the ground with the knees and ankles extended and land in the same position  
17  
18 204 and location to minimize horizontal displacement and influence on flight time. For SJ, the  
19  
20 205 participant started from a stationary semi-squat position (knee angle  $\sim 90^\circ$ ), held a three-second  
21  
22 206 count and jumped vertically as high as possible. For CMJ, the participant started from an upright  
23  
24 207 standing position, performed a very fast preliminary downward movement, flexing and then  
25  
26 208 extended his knees and hip to jump vertically as high as possible off the ground. Three trials  
27  
28 209 per test were performed with approximately 2-min recovery and the best result was used for  
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31 210 analysis.  
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38 212 *Speed*  
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40 213 Running speed was evaluated using a stationary 10-m and 30-m sprint test as described by  
41  
42 214 Chaouachi et al. [30]. Players were located 20-cm behind the start line position and were  
43  
44 215 instructed to run as quickly as possible along the 30-m distance. Time was automatically  
45  
46 216 recorded using photocell gates (Witty system, Microgate, Italy, accuracy of 0.01 s) placed 0.4-m  
47  
48 217 above the ground. Participants performed two trials with at least 2-min rest between trials. The  
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50 218 run with the lowest 30-m time was selected for analysis.  
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56 220 *Aerobic fitness*  
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3 221 Players performed the Yoyo Intermittent Recovery Test Level 1 (Yoyo IRT-1) as described by  
4  
5 222 Krstrup et al. [31]. This test focuses on the capacity to carry out intermittent exercise leading  
6  
7 223 to maximal activation of the aerobic system [32]. It consists of 2 x 20-m runs back and forth  
8  
9  
10 224 between starting, turning, and finishing at the start line at a progressively increased speed  
11  
12 225 controlled by audio bleeps on a tape recorder. Between each shuttle, the subjects had 10-s  
13  
14 226 recovery time, consisting of 2 x 5-m of slowly jogging, but had to be stationary on the start line  
15  
16  
17 227 ready for the next shuttle. The test protocol started with four running bouts at 10–13 km/h and  
18  
19 228 another seven runs at 13.5–14 km/h, thereafter it continues with stepwise 0.5 km/h speed  
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21 229 increments after every eight running bouts until exhaustion. When the subjects failed twice to  
22  
23  
24 230 reach the finishing line in time, the distance covered was recorded and represents the test result.  
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26 231

### 28 232 *Statistical analyses*

30 233 Data are presented as group mean values and standard deviations (mean  $\pm$  SD). After normal  
31  
32 234 distribution was examined using the Shapiro-Wilk-Test, an independent samples t-test was  
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34  
35 235 calculated to determine significant differences between-group baseline values (W0).

37 236 All parameters were compared using 2 repeated measures analysis of variance (2-RM-  
38  
39 237 ANOVA), Group (SPI or PLA)  $\times$  Time (W0 or W7), respectively. The significance level was  
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41  
42 238 set at  $p < 0.05$ . Relative reliability was assessed using the intraclass correlation coefficient (ICC)  
43  
44 239 between the test and retest (2 trials performed for vertical jump and sprint measures at W0)  
45  
46 240 [33]. An ICC  $< 0.40$  was considered low; between 0.40 and 0.70 acceptable; between 0.70 and  
47  
48  
49 241 0.90 good and  $> 0.90$  excellent [34]. All analyses were performed using Statistical Package for  
50  
51 242 Social Sciences (SPSS) version 20.

54 243

57 244

## 245 **Results**

### 246 *Compliance, diet, internal training load and test-retest reliability*

247 SPI and PLA supplementation compliance was 98.3% and 92.3%, respectively. No adverse  
248 effects were reported during or after spirulina supplementation. Neither internal training load  
249 nor dietary intake showed differences between groups at W0 and W7 (**Table 3**).

250

251 << Please insert table 3 here >>

252

253 **Table 4** illustrates the ICC of vertical jump and speed measures. Excellent relative reliability  
254 was observed for these measures.

255

256 << Please insert table 4 here >>

257

### 258 *Anthropometric data and body composition*

259 At W0, all anthropometric measurements and body composition did not differ between groups.  
260 For anthropometric data, a significant main effect of “Time” was observed only for FM  
261 ( $p < 0.01$ ). The FM percentage was significantly reduced in both groups (-5%,  $p < 0.05$ ). No  
262 significant main effect of “Group” or “Group  $\times$  Time” interaction was observed for all  
263 anthropometric parameters. Thus, spirulina supplementation did not potentiate the loss of FM  
264 induced by training.

265

### 266 *Physical Fitness*

267 At W0, physical fitness measurements did not differ between groups.

268

### 269 *Isokinetic Leg strength and power*

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3 270 No significant main effect of “Time” or “Group” and no significant “Group × Time” interaction  
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5 271 were detected for the concentric and eccentric peak torque and power in knee extensors and  
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7 272 flexors meaning that, neither training alone (PLA) nor training associated with spirulina  
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9 273 supplementation affects leg maximal strength and power. Data are presented in **Table 5**.

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15 275 << Please insert table 5 here >>16  
17 27618  
19 277 *Vertical jump*

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21 278 A significant “Time” main effect was observed for SJ ( $p<0.01$ ) and CMJ ( $F=13.03$ ,  $p<0.01$ ).  
22  
23 279 Within-groups analysis showed significant improvements in SJ only for the SPI group ( $p<0.05$ )  
24  
25 280 and for both groups in CMJ ( $p<0.05$ ) (**Fig. 2A and 2B**). Moreover, the percentage change in  
26  
27 281 vertical jump parameters was always higher in SPI group compared to the PLA group (SJ: 3.4  
28  
29 282 vs 2.3 %; CMJ: 4.4 vs 3.6 %, respectively). Despite this, no significant “Group × Time”  
30  
31 283 interaction or main effect of “Group” was observed for vertical jump measurements.

32 284

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35 285 *Speed*

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37 286 The statistical analysis indicated a significant main effect of “Time” for 10-m ( $p<0.05$ ) and 30-  
38  
39 287 m ( $p<0.05$ ) sprint measurements. Within-groups analysis showed significant improvements in  
40  
41 288 10- and 30-m sprint time only for the SPI group ( $p<0.05$ ) (**Fig. 2C and 2D**). Moreover, the  
42  
43 289 percentage change in both sprint measurements was higher for SPI compared to the PLA group  
44  
45 290 (10-m: -2.2 vs -0.8 %; 30-m: -1.1 vs -0.5 %, in SPI and PLA, respectively). However, no main  
46  
47 291 significant effect of “Group” and “Group × Time” interaction was detected for speed  
48  
49 292 measurements.

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55 294 << Please insert Figure 2 here >>

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5 296 *Aerobic fitness*

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7 297 No significant main effect of “Time” or “Group” and no significant “Group × Time” interaction  
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9  
10 298 was detected for the total distance covered in the yoyo IRT-1 meaning that neither training  
11  
12 299 alone (PLA) nor training associated with spirulina supplementation affect aerobic fitness  
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14 300 (1871.1-1993.3 vs 1940-1947.5 m at W0-W7 for SPI and PLA, respectively).  
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For Peer Review Only

## 301 Discussion

302 To our knowledge, this is the first study to examine the effects of *Arthrospira platensis*  
303 supplementation on anthropometric measurements as well as on physical performance using a  
304 battery of tests (leg strength, vertical jump, speed, and yoyo IRT-1 performances) in elite rugby  
305 players. Our hypothesis is partially verified since spirulina had no effect on anthropometric  
306 parameters and had only modest effects on performance (increase in vertical jump and sprint  
307 performance only for the SPI group without significant differences between groups).

308 Intense training has been shown to decrease the availability of essential amino acids, which  
309 may slow the rate of tissue repair and growth [35]. Athletes need to ingest enough high-quality  
310 protein in their diet to maintain essential amino acid availability during training and competition  
311 [36] and to generate a greater stimulus for muscle growth and enhanced recovery, potentially  
312 resulting in greater strength gains [37, 38]. The supposed effects of spirulina on muscle  
313 development are based on its high protein content, especially in essential amino acids such as  
314 leucine, valine, isoleucine. For these reasons, athletes use spirulina to improve body  
315 composition (especially LBM) and physical performance.

316 Few studies have documented the effects of spirulina supplementation on anthropometric  
317 measurements and physical performance in athletes. To our knowledge, only one study [15]  
318 examined the effects of 2-weeks of spirulina *platensis* supplementation on anthropometric  
319 parameters and body composition in athletes and reported no significant effect. Our results  
320 confirm the latter, because even with a longer time supplementation (7-weeks), we did not  
321 report any additive effect of spirulina supplementation to the training program since rugby  
322 players had similar FM loss (-5%) in both groups. The general consensus is that FM decreases  
323 with higher levels of play [39]. Moreover, the intensive training program of elite rugby players  
324 induces a significant decrease in FM, which makes it difficult to highlight the synergistic effect  
325 of spirulina. In pathological subjects, literature reported a decrease in BM and FM [40] after

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3 326 spirulina *platensis* supplementation. The underlying mechanism of the anti-obesity effects of  
4  
5 327 spirulina have been rarely discussed, but it seems that spirulina may be effective in lowering  
6  
7 328 BM and FM by reducing appetite [14]. These discrepancies between elite and pathological  
8  
9 329 subjects are not so paradoxical because it is more difficult to highlight anthropometric effects  
10  
11 330 of spirulina in elite athletes compared to obese or diabetic subjects who exhibit deleterious body  
12  
13 331 composition before supplementation.  
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19 333 Concerning spirulina effects on performance, due to its high protein content and nutritional  
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21 334 quality compared to animal and vegetable proteins [41, 42], spirulina could be of interest to  
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23 335 improve the LBM of athletes and consequently to increase strength, power and also field  
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25 336 performances requiring elevated muscle mass such as vertical jump, sprint performance and  
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27 337 distance covered during the Yo-Yo IRT-1. We showed no significant effects of spirulina on  
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29 338 concentric and eccentric peak torques and power of the quadriceps and hamstring muscles.  
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31 339 Contrary to our results, Sandhu et al. [18] reported significant improvements in isometric peak  
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33 340 force, average force, and fatigue index after eight weeks of spirulina supplementation (2g/day)  
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35 341 in trained and untrained subjects. These apparent contradictory results could be explained by  
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37 342 differences in assessment method (isokinetic dynamometer vs the HUR1\* 5340 Leg  
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39 343 Extension/Curl), the type of contraction (concentric and eccentric vs isometric) and subject's  
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41 344 training level (elite vs. university competitive level). No other study examined the effects of  
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43 345 spirulina supplementation on muscular strength.  
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49 346 With regards to power proxies, Juskiewicz et al. [19] recently showed that spirulina *platensis*  
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51 347 supplementation (1.5g/d for 6 weeks) was not able to enhance the mean power output during a  
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53 348 2000-m test on a rowing ergometer with a Polish rowing team. These findings are in accordance  
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55 349 with our results showing no effects of SPI on knee extensors and flexors isokinetic power.  
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3 350 Concerning vertical jump and sprint performance, to our knowledge, no study has examined  
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5 351 the effects of spirulina supplementation. Our results did not demonstrate any significant  
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7 352 difference between groups but showed a significant increase in vertical jump performance with  
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10 353 greater percentage changes in the SPI group for SJ (3.4 vs 2.3 %) and CMJ (4.4 vs 3.6 %)  
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12 354 compared to PLA. Concerning sprint performance, only significant improvements were found  
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14 355 for both 10-m and 30-m sprint but within-groups effects were significant only in the SPI group.  
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16 356 Similarly, to vertical jump performance, better improvement magnitudes were found in the SPI  
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18 357 compared to PLA group for 10-m (-2.7 vs -0.8 %) and 30-m sprint time (-1.6 vs -0.5 %). As  
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20 358 previously reported, it is more difficult to highlight the synergistic effects of spirulina on  
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22 359 performance in this elite population since physical qualities involved in sprint and vertical jump  
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24 360 were already reinforced in their training program.

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28 361 Regarding aerobic performance, our results showed no significant effects of SPI (“Time” and  
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30 362 “Group” main effects or “Group × Time” interaction) on the total distance covered in the yoyo  
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32 363 IRT-1. Our hypothesis was not confirmed. This is not so surprising because spirulina had no  
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34 364 synergistic effect with training on BM and FM. In literature, spirulina supplementation effect  
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36 365 on aerobic fitness was documented by only a few studies. Lu et al. [16] reported in untrained  
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38 366 men a within-group increase in all-out treadmill time to exhaustion after 3-weeks of spirulina  
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40 367 *platensis* supplementation without significant “Group × Time” interaction. Similarly, Kalafati  
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42 368 et al. [17] also reported in moderately trained men a significant higher time to fatigue at 95%  
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44 369  $VO_{2max}$  after spirulina *platensis* supplementation. Perhaps, these conflicting findings may be  
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46 370 due to the intermittent character of the test and the different training status of our subjects (elite  
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48 371 vs. untrained and moderate trained).

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54 373 To summarize, the effects of spirulina on body composition and performance using a battery of  
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56 374 tests are modest in elite rugby players. The limited beneficial effects only concern vertical jump  
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3 375 and sprint performance. We cannot consider spirulina as a nutritional ergogenic aid in this  
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5 376 population. Our study does not confirm the assertions mentioned by the various commercial  
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7 377 sites, in particular, those specialized for elite athletes. With speculation, it is possible that the  
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9 378 results could be different with a longer duration (> 7 weeks) and a higher dose (> 5.7g/day).  
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11 379 Indeed, to our knowledge, no study has investigated the spirulina dose-response relationship in  
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13 380 athletes taking into account their training load. Since the optimal dose for such a population  
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15 381 with high training loads remains unclear, the dose used in this study might have influenced the  
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17 382 results. Further studies are required to verify spirulina consumption effects among athletes of  
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19 383 different sports, age, sex, and athletic level with longer durations and higher dosages taking into  
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21 384 account the relationship between the training load and the selected supplementation dose.  
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## 28 386 **Conclusion**

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31 387 Seven weeks of spirulina supplementation in elite athletes did not improve body composition  
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33 388 nor substantially increase physical performance evaluated by a battery of tests (muscle strength,  
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35 389 power, speed, and aerobic fitness). We only observed a small advantage in vertical jump and  
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37 390 sprint performance in the SPI group. The assertions mentioned by commercial sales sites are  
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39 391 far from scientific reality. It is preferable to await further studies before recommending spirulina  
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41 392 supplementation to high-level athletes in order to improve body composition and physical  
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43 393 performance.  
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## 49 395 **Acknowledgments and funding statement**

50  
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53 396 This study (SUPERF study - FANTASIO project) was supported by the Brittany Region and  
54  
55 397 the competitiveness pole “Valorial, osons l’aliment plus intelligent”. Spirulina was provided by  
56  
57 398 the society “Algae Green Value”. There is no conflict of interests for the authors of this paper.  
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3 399 We acknowledge the medical staff (Dr Pierrick Guillemot, Violaine Hamon, Dr Patrice  
4  
5 400 N’Gassa), the technical staff (Yann Moison, Yoann Carnot) and all the rugby players for their  
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7 401 involvement in the study.  
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10 402 The authors would like to thank the Professor David G. Behm for his perusal of our manuscript.  
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### 16 404 **Authors’ contribution**

18  
19 405 **Chaouachi Mehdi:** Data curation, Formal analysis, Investigation, Methodology, Software,  
20  
21 406 Validation, Roles/Writing - original draft - review & editing, Validation;  
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23 407 **Gautier Sandrine, Moison Yann, and Collin Tom:** Data curation, Investigation;  
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25 408 **Carnot Yoann:** Data curation, Investigation, Software;  
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28 409 **Bideau Nicolas:** Data curation, Investigation, Software, Methodology;  
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30 410 **Guillemot Pierrick:** Data curation, Investigation, Methodology;  
31

32 411 **Groussard Carole, and Vincent Sophie:** Conceptualization; Formal analysis, Funding  
33  
34 412 acquisition, Investigation, Methodology, Project administration, Supervision, Writing - review  
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36 413 & editing, Validation;  
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39 414 All authors have read and approved the final version of the manuscript, and agree with the order  
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41 415 of presentation of the authors.  
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### 44 416 **Conflict of interest**

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47 417 The authors declare no conflict of interests with the information contained within this  
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**Table 1. Participant anthropometric characteristics.**

	<b>SPI (n=11)</b>	<b>PLA (n=11)</b>
<b>Age (year)</b>	25.8 ± 3.4	26.3 ± 4.4
<b>BM (kg)</b>	100.0 ± 13.6	99.1 ± 19.9
<b>Height (cm)</b>	184.1 ± 7.7	182.4 ± 7.7
<b>FM (%)</b>	19.7 ± 4.6	19.3 ± 4.8
<b>FM (kg)</b>	20.2 ± 6.5	19.8 ± 8.0
<b>LBM (kg)</b>	79.8 ± 8.0	79.4 ± 12.7

Values are presented as mean ± standard deviation. BM, body mass; FM, Fat Mass; LBM, lean body mass.

**Table 2. Composition of *Arthrospira platensis* produced by AGV (100 g).**

	Unity	Amount		Unity	Amount
<b>Energy</b>			<b>Vitamins</b>		
	kJ	1530	Vitamin A	µg	<20
	kcal	363	β-carotene	mg	24,902
<b>Fat</b>			Vitamin C	mg	<2,5
Total fat	g	6,3	Vitamin B3	mg	8,5
Saturated fat	g	3,8	Vitamin B5	mg	0,05
Unsaturated fat	g	2,5	Vitamin B6	mg	0,09
Monounsaturated fat	g	0,4	Vitamin B9	µg	156
Polyunsaturated fat	g	2	Vitamin B12	µg	61,3
Omega 3	%	0,12	Vitamin E	mg	6,84
Omega 6	%	14,31	<b>Minerals</b>		
<b>Carbohydrates</b>			Sodium	mg	1338,2
Total Carbohydrates	g	16,5	Phosphorus	mg	1353,8
Dietary Fiber	g	7,4	Calcium	mg	310,4
<b>Proteins and amino acids</b>			Copper	mg	1,83
Proteins	g	63,7	Iron	mg	76,43
Leucine	g	5,56	Magnesium	mg	434,2
Isoleucine	g	3,47	Manganese	mg	7,06
Valine	g	4,02	Potassium	mg	1932
			Zinc	mg	7,43

**Table 3. Participant's dietary intake and internal training load.**

		SPI (n=11)	PLA (n=11)	<i>p</i> -value
<b>Caloric intake (kcal)</b>	W0	2680.8 ± 495.4	2844.8 ± 495.4	0.508
	W7	2788.3 ± 535.6	2646.8 ± 523.6	0.558
<b>Carbohydrates (g)</b>	W0	2.83 ± 0.91	2.85 ± 0.96	0.948
	W7	3.05 ± 0.99	2.64 ± 0.89	0.350
<b>Proteins (g)</b>	W0	1.37 ± 0.38	1.66 ± 0.66	0.243
	W7	1.43 ± 0.36	1.62 ± 0.64	0.416
<b>Fat (g)</b>	W0	1.15 ± 0.32	1.09 ± 0.37	0.718
	W7	1.16 ± 0.33	1.10 ± 0.45	0.735
<b>Internal training load (AU)</b>	W1	1408.1 ± 434.2	1258.9 ± 579.4	0.531
	W2	1317.4 ± 358.9	1218.2 ± 695.2	0.696
	W3	1192.0 ± 244.9	1206.5 ± 424.9	0.927
	W4	675.0 ± 200.1	809.5 ± 192.3	0.143
	W5	1296.4 ± 399.2	1562.6 ± 631.0	0.268
	W6	1592.6 ± 316.0	1740.8 ± 414.8	0.372

Values are presented as mean ± standard deviation.

**Table 4: ICC of vertical jump and speed measurements**

Measures	ICC	Interpretation
<b>SJ</b>	0.958	Excellent
<b>CMJ</b>	0.980	Excellent
<b>10-m Sprint</b>	0.900	Excellent
<b>30-m Sprint</b>	0.937	Excellent

*ICC, intraclass correlation coefficient; SJ, squat jump; CMJ, countermovement jump.*

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**Table 5. Isokinetic leg strength and power before and after supplementation**

		Peak torque (Nm)		Maximal power (W)	
		W0	W7	W0	W7
<b>CON 60 E</b>	PLA	263.20 ± 22.72	273.82 ± 27.68	275.61 ± 23.80	286.75 ± 28.99
	SPI	278.42 ± 15.64	271.96 ± 26.97	291.57 ± 16.37	284.79 ± 28.24
<b>CON 60 F</b>	PLA	183.59 ± 30.18	192.37 ± 43.81	192.27 ± 31.60	201.46 ± 45.88
	SPI	190.32 ± 30.81	184.55 ± 30.29	199.31 ± 32.26	193.25 ± 31.71
<b>CON 240 E</b>	PLA	213.55 ± 24.41	213.21 ± 31.77	947.28 ± 162.39	906.83 ± 103.02
	SPI	226.15 ± 38.76	216.49 ± 24.59	849.51 ± 102.25	893.08 ± 133.07
<b>CON 240 F</b>	PLA	170.03 ± 34.97	179.25 ± 43.45	727.23 ± 141.31	724.69 ± 166.01
	SPI	173.61 ± 33.73	173.01 ± 39.63	712.22 ± 146.46	750.83 ± 181.99
<b>ECC 30 E</b>	PLA	287.28 ± 38.64	308.75 ± 29.95	111.82 ± 12.77	111.64 ± 16.63
	SPI	316.67 ± 16.53	319.83 ± 23.07	118.40 ± 20.28	113.36 ± 12.89
<b>ECC 30 F</b>	PLA	200.25 ± 37.18	186.38 ± 42.51	89.02 ± 18.31	93.85 ± 22.76
	SPI	195.58 ± 19.27	196.55 ± 25.39	90.90 ± 17.66	90.58 ± 20.75

*Nm*, Newton metre; *W*, Watt ; *CON*, Concentric; *ECC*, Eccentric; *E*, extensors; *F*, Flexors; 60, 60°/s; 240, 240°/s; 30, 30°/s.

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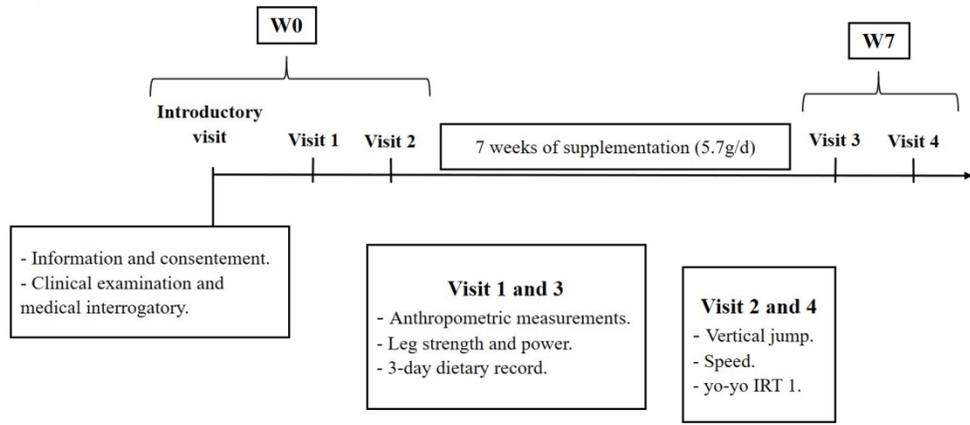


Figure 1. Study design

Figure 1. Study design

64x31mm (600 x 600 DPI)

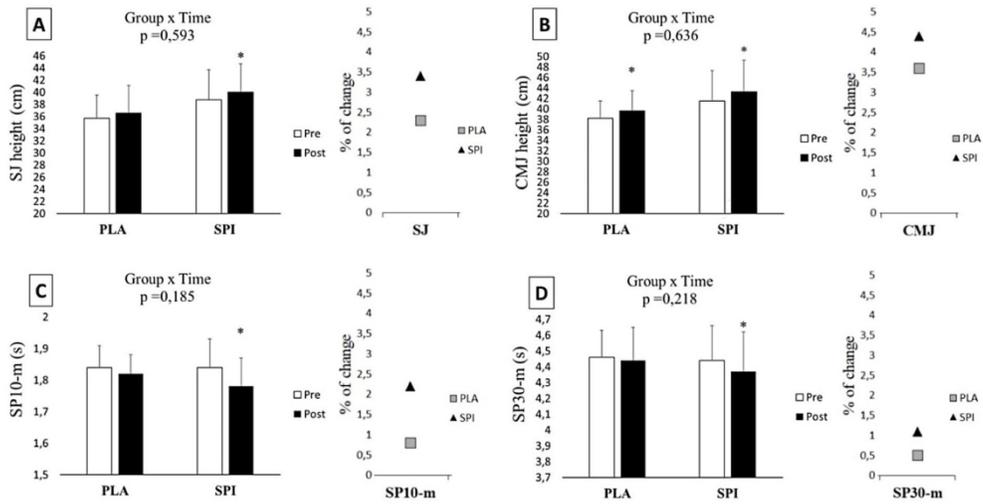


Figure 2. Effects of supplementation on Vertical jump and Speed measurements.

\*p<0.05

Figure 2. Effects of supplementation on Vertical jump and Speed measurements. \*p<0.05

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