Original Investigation

Variations in power performance and perceptual responses to training in Olympic boxers over a seven-month training period

Running head: Performance and training loads in Olympic boxers

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Abstract

Purpose: To assess the variations in power performance and perceptual training responses and compare the physical performance of national boxing athletes qualified or not qualified for the Tokyo Olympic Games over a 7-month training period. **Methods:** Twelve amateur boxers from the Brazilian national team were tested 6 times across 7 months. In the first assessment, boxers performed squat and countermovement jumps (CMJ); and bench-press (BP), prone bench-pull, half-squat, and jump squat power tests. In the following testing sessions, only CMJ and BP power were assessed. In addition, the rating of perceived exertion (RPE) and total quality recovery (TQR) status were assessed in 106 training sessions across the study. Independent t-test and repeated measures analysis of variance were used for data analysis purposes. **Results:** No significant differences ($P > 0.05$) were observed between Olympic and non-Olympic groups for any test variables (ES [95% CI] ranging from 0.01 [-1.13; 1.13] to 0.69 [-0.53; 1.79]). No significant changes ($P > 0.05$) were detected throughout the study for CMJ height and BP-power in either group (ES [95% CI] ranging from 0.01 [-1.13; 1.13] to 1.03 [-0.25; 2.14]). Overall, both groups exhibited similar variations in both RPE and TQR over the 7-month period. **Conclusions:** Within the same national team, power-related performance was similar between Olympic and non-Olympic boxers. The maintenance of power abilities along with the optimization of technical and tactical skills seem to be key issues to consider during the final stages of preparation for international boxing competitions.

Keywords: athletic performance; athletes; resistance training; combat sports; martial arts; training load.

Introduction

Amateur boxing is an Olympic sport characterized by intermittent powerful actions in which athletes must perform effective punching techniques against the opponent to score points or achieve a knockout.[1,2] To properly execute these actions and increase the chances of a knockout, athletes rely on the development of high levels of relative strength and power.[1-3] Previous studies involving national-level team boxers showed that the punching impact force was closely associated with different measures of upper- and lower-body power ($r = 0.6$-0.8).[3,4] Power-related variables assessed in vertical jumps were also highly correlated with specific combat activities (e.g., total number of punches thrown and punch effectiveness) performed during actual boxing matches ($r \approx 0.75$).[5] As such, the regular assessment of power output is of fundamental importance for monitoring the variations and progression in performance of boxers across the different phases of the competitive season.

In this regard, a case report revealed that a male Olympic champion could generate (on average) 49% and 15% more power in the jump squat (JS) and bench press (BP) exercises, respectively, than his national team peers.[6] Another case study with combat sport athletes indicated that a double world karate champion produced 45% and 7% more power in the JS and BP, respectively, compared to his counterparts.[7] Furthermore, it is important to highlight that upper- and lower-body power outputs have been shown to properly discriminate between national team members and reserves and to be good predictors of punching acceleration in karate athletes,[8,9] which reinforces the importance of these physical parameters to punching performance. From these findings, it can be inferred that more powerful athletes may have some physical and technical advantages in striking combat sports. Thus, achieving and maintaining high levels of upper- and lower-body power seem to be key objectives for combat athletes.

Another important aspect to consider during the preparation of elite boxers (and athletes in many other sports) is their "internal" responses (e.g., subjective measures of effort or recovery) to different training loads.[10-13] For example, the readiness to train can be easily assessed using practical and simple methods such as perceptual responses of perceived exertion and recovery quality status.[10,14,15] Specifically, rating of perceived exertion has been recommended as a valid tool to monitor combat sport athletes training[16] and has been shown to be significantly related with physical performance variables ($r \approx 0.75$).[17] Previous studies with team-sports players (i.e., soccer and futsal) revealed that the athletes' responses to perceived training loads were highly influenced by their levels of muscle power.[13,18] Furthermore, it has already been shown that, in general, in periods when high internal training loads were accumulated, athletes exhibited lower levels of perceived recovery, being more susceptible to impairments in neuromuscular performance.[13,14] For these reasons, examining the perceptual responses of athletes along with more traditional physical measurements (e.g., jump and power tests) may be an effective strategy for implementation in high-performance training settings.

Combat sports scoring actions strongly rely on power production, and a previous study with Paralympic judo athletes revealed that power-related measures varied across the season, with evident peaks close to competitions.[19] In striking combat sports (e.g., karate), variations in jump height may be used to monitor training responses in the last phases of preparation for main competitions (e.g., the Pan-American Games).[20] Although the importance of power-related capacities for boxing performance is well-established, it remains unclear whether the individual levels of upper- and lower-body power vary significantly over time, during different periods of preparation. Moreover, although outstanding combat athletes usually exhibit higher levels of muscle power,[6,7] it is not clear whether these differences can be extrapolated to specific contexts (e.g., Olympic and non-Olympic athletes). This information could help coaches and sport scientists to better select elite boxing athletes and create more effective training strategies to improve their competitive levels. Therefore, the aims of this study were to: 1) test and compare the physical performance of Brazilian national boxing athletes qualified or not qualified for the Tokyo Olympic Games; and 2) analyze the variations in jumping ability, power output, and perceptual training responses of these combat athletes over a 7-month training period.

Methods

Subjects

Twelve amateur boxers from the Brazilian national team (8 men: 2 welterweight, ≤63 kg; 2 middleweight, ≤75 kg; 2 light heavyweight, ≤81 kg; 2 heavyweight, ≤91 kg and 4 women: 2 featherweight, ≤57 kg; 2 lightweight, ≤60 kg) participated in this study. Athletes were divided into two distinct groups, as follows: (1) the Olympic group (OG) - 6 athletes (age: 22.3 ± 1.4 years; height: 1.79 ± 0.12 m; body mass [BM]: 73.8 ± 15.3 kg) qualified for the Tokyo Olympic Games, and (2) non-Olympic group (NOG) - 6 athletes (age: 22.8 ± 2.9 years; height: 1.74 ± 0.13 m; body mass [BM]: 74.5 ± 16.3 kg) from the national team and of the same weight category, not qualified for the Olympic Games. The sample comprised 1 Olympic gold, 1 silver, and 1 bronze medalist (Tokyo-2020), 1 World Champion, 5 Pan-American Games medalists, and 1 Youth Olympic Games gold medalist, thus attesting to their high level of competitiveness. The study was approved by the local Ethics Committee and all athletes signed an informed consent form before participating in the study.

Study Design

This longitudinal comparative study analyzed the variations in neuromuscular performance and in perceptual training responses in national team boxing athletes over a 7-month training period. Athletes were assessed on 6 occasions: in August (after the Pan-American Games – Lima, Peru), October, November, and December 2019; and in January and February 2020 (national qualifying tournament for Tokyo 2020), as part of their regular testing routine, as planned by their coaching staff. During this period, boxers participated in 6 international competitions, involving 4 top-level tournaments in Europe (including the Boxing World Championship), 1 pre-Olympic event in Tokyo, Japan, and 1 competition in the Dominican Republic, Central America. The typical weekly training schedule followed by the boxers during the period of the study is presented in table 1. The training content was constantly readjusted throughout the 7-month period, based on athletes' responses, in an attempt to maintain high levels of competitiveness during the entire competitive season, according to their fluctuations in performance, and not following a fixed periodization (i.e., without specific training phases such as maximal strength, and/or power training phases). In the first testing session, athletes performed squat and countermovement jumps (SJ and CMJ) and were assessed for bar-power output in the bench press (BP), prone bench-pull (PBP), half-squat (HS), and jump squat (JS) exercises. In the following five assessments, only CMJ and BP bar-power were recorded to analyze the training effects across the season. These two tests were selected for the longitudinal follow-up due to their strong relationships with punching force impact[4] ($r \geq 0.70$), and their time-saving and user-friendly characteristics, which facilitated the regular and constant monitoring of these athletes during the final phases of the Olympic cycle. Before performing the tests, athletes completed a 10-min standardized warm-up, comprising 5-min of running at a moderate pace followed by 5-min of active stretching, for both upper- and lower-limbs. Prior to the actual measurements, athletes performed 5 submaximal trials of each specific test with a 30-s interval between each trial. Throughout the study, the nutritional and sleep habits of the athletes were controlled by the technical staff of the Brazilian national team. In addition, the rating of perceived exertion (RPE) and total quality recovery (TQR) status were continuously recorded in 106 training sessions over the 7-month period. When two distinct training sessions were performed on the same day, average values of RPE and TQR scales were considered.

*****INSERT TABLE 1 HERE*****

Methodology

Vertical jumping tests

Vertical jump height was assessed using the SJ and CMJ. In the SJ, athletes were required to remain in a static position with a 90° knee flexion angle for ~2-s before jumping, without any preparatory movement. In the CMJ, athletes were instructed to execute a downward movement followed by complete extension of the legs and were free to determine the countermovement amplitude to avoid changes in jumping coordination. All jumps were executed with the hands on the hips and the athletes were instructed to jump as high as possible. The jumps were performed on a contact platform (Elite Jump®, S2 Sports, São Paulo, Brazil) and jump height was automatically calculated based on the flight-time method. A total of five attempts were allowed for each jump, interspersed by 15-s intervals. The best attempts for the SJ and CMJ were used for subsequent analyses.

Maximum bar-power assessments

Maximum mean propulsive power (MPP) was assessed in BP, PBP, HS, and JS exercises, all performed on a Smith-machine device (Hammer Strength Equipment, Rosemont, IL, USA). Participants were instructed to execute 3 repetitions at maximal velocity for each load, starting at 40% of their BM in the PBP, HS, and JS and at 30% of their BM in the BP.[21] In the JS, participants executed a knee flexion until the thigh was parallel to the ground and, after the command to start, jumped as fast as possible without their shoulder losing contact with the bar. The HS was executed in a similar fashion to the JS, except that the subjects were instructed to move the bar as fast as possible without losing foot contact with the ground. During the BP, athletes were instructed to lower the bar in a controlled manner until the bar lightly touched the chest and, after the command to start, move the bar as fast as possible. In the PBP, athletes were required to assume a standing position, maintain the trunk parallel to the ground and the knees slightly flexed, while pulling the bar against the chest after holding the bar with the arms extended (i.e., initial position). A load of 10% of BM for HS, JS, and PBP and 5% of BM for BP was progressively added in each set until a decrease in MPP was observed. A 5-minute interval was provided between sets. To determine MPP, a linear transducer (T-Force, Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was attached to the Smith machine bar. We considered the maximum MPP value obtained in each exercise for data analysis purposes. The maximum MPP values were normalized by dividing the absolute power value by the athletes' BM (i.e., relative power = $W \cdot kg^{-1}$).

Rating of perceived exertion

Rating of perceived exertion was assessed 30-min after the completion of each of the 106 training sessions over the period of the study. Athletes were required to report the intensity of the entire session by means of a 10-point rating of perceived exertion scale.[15]

Total quality recovery scale

The general perceived recovery was obtained in the morning before each training session analyzed, using the TQR scale.[10] Athletes were asked to report how they felt about their general recovery in relation to the last 24-h (including night sleep). The TQR scores vary between 6 and 20, with the lowest values representing poorer recovery and the highest scores representing a better recovery state.

Statistical Analysis

Data are presented as means ± standard deviation (SD). Data were analyzed by using the intention-to-treat approach, considering all data collected from the participants, according to their respective groups. The Shapiro-Wilk test was used to confirm the normality of the data. The differences in the BM and in physical tests performed in the first assessment, between OG and NOG were examined using an independent t-test. To analyze the differences in the CMJ and BP tests executed over the 7-month period between OG and NOG, a repeated measures analysis of variance was conducted followed by the Bonferroni's post-hoc. The statistical significance was set as $P < 0.05$. Finally, to determine the magnitude of differences, Cohen's *d*[22] effect sizes (ES) along with their 95% confidence intervals (CI) were calculated and interpreted using the thresholds proposed by Rhea[23] for highly trained individuals, as follows: <0.25, 0.25-0.50, 0.50-1.00, and >1.00 for trivial, small, moderate, and large, respectively. All measurements used here demonstrated small errors of measurement, as evidenced by their high levels of accuracy and reproducibility (i.e., coefficient of variation < 5% and intraclass correlation coefficient [using an alpha two-way mixed model] > 0.90) for all assessments.

Results

Figure 1 depicts the comparisons of the physical tests between OG and NOG in the first assessment performed. No significant differences (*P* > 0.05) were noted between groups for the variables analyzed (ES [95% CI] = 0.69 [-0.53; 1.79], 0.49 [-0.70; 1.59], 0.01 [-1.13; 1.13], 0.16 [–0.99; 1.28], 0.07 [-1.20; 1.06], and 0.04 [-1.10; 1.17] for SJ, CMJ, JS, BP, PBP, and HS, respectively).

*****INSERT FIGURE 1 HERE*****

Figure 2 shows the variations in the CMJ height and BP maximum bar-power across the 6 physical assessments for both OG and NOG. No significant changes (*P* > 0.05) were noticed over the 7-month period of assessments for both CMJ height and BP power in both OG (ES [95% CI] ranging from 0.01 [-1.13; 1.13] to 1.03 [-0.25; 2.14] for CMJ, and between 0.02 [-1.11; 1.15] and 0.48 [-0.70; 1.59] for BP) and NOG (ES [95% CI] ranging from 0.01 [-1.12; 1.14] to 0.76 [-0.47; 1.86] for CMJ, and between 0.01 [-1.13; 1.13] and 0.14 [-1.01; 1.26] for BP).

*****INSERT FIGURE 2 HERE*****

Figure 3 describes the variations in the RPE and TQR over the 7-month period of analysis. Although some differences occurred in specific training sessions, in general, both groups presented similar variations in both RPE and TQR throughout the analyzed time-points.

*****INSERT FIGURE 3 HERE*****

Discussion

After comparing the neuromuscular abilities of Olympic and non-Olympic boxing athletes and analyzing the variations in vertical jumping ability, BP power, and perceptual responses to training, we observed that: 1) Olympic and non-Olympic boxers presented similar performance in both loaded and unloaded power-related tests; and 2) the two groups exhibited similar variations in physical performance as well as in perceptual responses to training during the intervention period. Although power capacity is of great importance for boxing athletes,[1,4,5] at the group level, this variable was not capable of differentiating between national boxers qualified or not qualified for the Olympic Games. Moreover, the lack of meaningful changes in physical performance and perceptual responses across the 7-month training period suggests that, although not following a fixed periodization, the training content was properly planned and managed by the technical staff. This training organization was potentially able to prepare athletes to cope well with the variations in training loads, and with the high number of competitions, journeys, and training camps over this challenging and demanding training phase.

Olympic and non-Olympic boxers presented similar results in loaded and unloaded power-related tests. Several studies have highlighted the importance of developing high levels of relative power to be successful in different combat sports[1,4,5,8] as well as demonstrated the differences in power output between "outperformers" (i.e., Olympic and World boxing and karate champions) and their highly trained peers.[6,7] Nevertheless, it seems that at a group level, especially when athletes achieve a certain level of specialization (e.g., national team athletes), muscle power is not able to discriminate between less or more qualified subjects. In this sense, it is reasonable to infer that the qualification of boxing athletes for the Olympic Games relies on technical and tactical skills that cannot be assessed or ranked by using traditional physical testing batteries. Importantly, even considering that the NOG was composed of non-Olympic athletes, it is essential to highlight that these athletes had high levels of competitiveness, and regularly participated in (and won) relevant tournaments and competitions such as the Pan-American Games and World Championships. Added to this, we should emphasize that our sample was formed by athletes from the permanent national team, who followed the same training program for the duration of the cycle preparing to the Olympics, which certainly contributed to the lack of differences between groups.

Throughout the 7-month training period, neither vertical jumping ability nor BP power presented significant changes in the OG and NOG groups. Of note, these athletes were monitored during the competitive phase of the season, when coaches focused on developing technical and tactical skills, which can be confirmed by observing the high volume of training dedicated to this content during the typical training week (Table 1). Considering that the majority of training sessions (i.e., ~ 85% of the total weekly volume; Table 1) during this phase can be classified as "aerobic-based activities" (e.g., high-intensity interval training, continuous running, and technical training), the maintenance of power performance across this training period suggests that training content was properly designed and adjusted to avoid any concurrency of the potential adaptations. In fact, in other sports, it has been shown that high volumes of aerobic-based training may be detrimental to neuromuscular performance, due to the interference phenomenon induced by a concurrent training period, which can be even more pronounced in athletes with superior speed-power capacities.[13,18] Thus, it seems that, at least for national boxing athletes, when adequately planned and prescribed, concurrent training does not negatively impact power-related performance.

In general, both groups reported very similar perceptual responses to training intensity and to post-training recovery (i.e., RPE and TQR, respectively) throughout the training period (Figure 3). The lack of differences between Olympic and non-Olympic groups may be expected since, as previously mentioned, they had similar physical performances and were exposed to a similar training program across the entire phase analyzed. Based on these results, it is reasonable to assume that both groups exhibit not only power, but also similar endurance-related capacities. Even considering that cardiovascular performance was not tested in this research, previous studies conducted with athletes from other sports (i.e., basketball and futsal) reported negative associations between perceived training loads and endurance capacity,[11,12] which might help to support our argument. In addition, although in many training sessions the RPE was rated as “very hard” (i.e., rated with high scores), the recovery responses of athletes were described as (at least) “reasonable recovery”, for the majority of assessments (Figure 3). This reinforces the notions that these athletes were able to cope well with the total training load and that the training content was adequate to preserve their physical performance over the entire training period.

In summary, our findings revealed that both loaded and unloaded power-related capacities were not able to discriminate between Olympic and non-Olympic boxing athletes. Furthermore, the variations in physical performance and perceptual responses to training across a 7-month training period, within the Olympic training cycle, were similar between these respective groups. The main limitations of the study were the small sample size and the highly selected characteristic of the sample (i.e., national team boxing athletes), which precludes extrapolation of our results to larger or less specialized populations. Additionally, for reasons related to time-efficiency and practicality (which is essential during the latter phases of an Olympic training cycle), only one lower-limb test (i.e., CMJ) and one upper-limb test (i.e., bench press) were used to monitor the variations in power-related performance. In contrast, we worked with a highly specialized sample of national boxing athletes (i.e., three Olympic Medalists and one World Champion) across their final preparation to the Olympic Games, which reinforces the importance and applicability of our findings to high-level boxers.

Practical Applications

Power-related performance is not able to discriminate between Olympic and non-Olympic boxers, at least within the same national boxing team. At the elite level, when substantial levels of power are present, more successful boxers are likely to be distinguished by their superior technical and tactical skills. Therefore, especially during the last phases of preparation for international tournaments (e.g., Olympic Games), coaches are advised to focus their attention and training strategies on technical-tactical development. Nonetheless, the lack of variations in power performance across this crucial period also suggests that power maintenance is an important aspect to be considered. In this regard, the prescription of frequent and short resistance training sessions using light-to-moderate training loads (i.e., from the body-mass to the optimum power load)[6,24] can be strongly recommended. Additional studies are required to examine the technical and tactical differences between Olympic and non-Olympic boxing athletes, especially when approaching major competitions.

Conclusions

Within the same national team, power performance is similar between Olympic and non-Olympic boxers. Maintenance of muscle power and optimization of technical-tactical skills seem to be key issues to consider during the final stages of preparation for top-level competitions.

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Figure Legends

Figure 1. Comparison of the physical performance of Olympic (OG) and non-Olympic (NOG) groups at the first assessment. Bars and error-bars represent means and standard deviations, circles and triangles represent individual values. SJ: squat jump; CMJ: countermovement jump; BP: bench press; PBP: prone bench-pull; HS: half-squat; JS: jump squat.

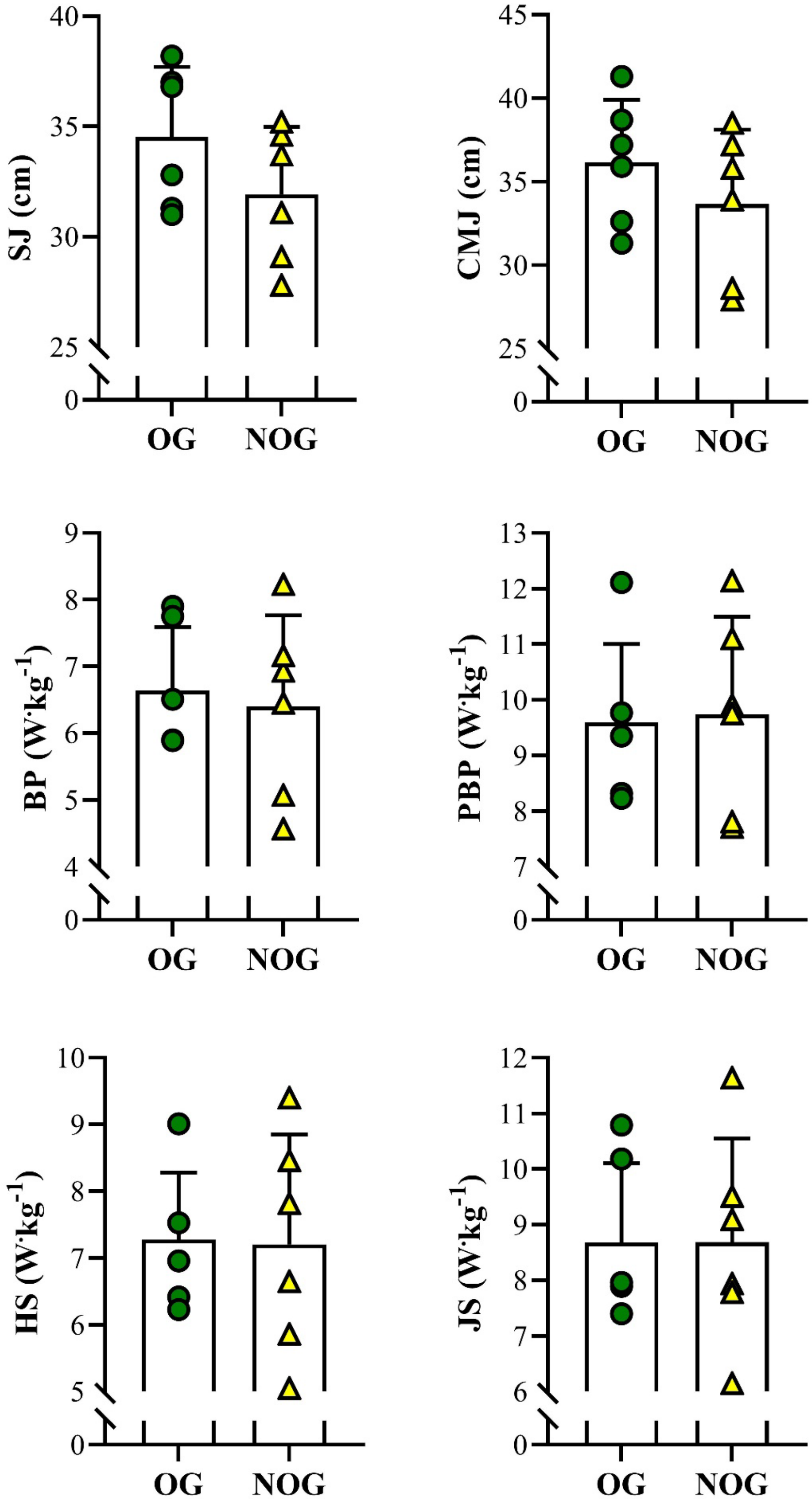
Figure 2. Variations in the countermovement jump (CMJ) height and bench press (BP) power among 6 successive testing sessions over the 7-month period for both Olympic (OG) and non-Olympic (NOG) groups. Bars and error-bars represent means and standard deviations; circles and triangles represent individual values.

Figure 3. Variations in the rating of perceived exertion (RPE) and total quality of recovery (TQR) over the 7-month training period. OG: Olympic group; NOG: non-Olympic group.

Table 1. Typical weekly training program for the Brazilian national boxing team over the 7-month training period.

	Monday	Tuesday	Wednesday	Thursday	Friday
Morning	S/PT 40 min	Cond 60 min	S/PT 40 min	Cond 60 min	S/PT 40 min
Afternoon	TEC 120 min	TEC 90 min	TEC 120 min	TEC 90 min	TEC 120 min

Note: Cond = general conditioning training, involving circuit training, running workouts, and/or jump rope; S/PT = strength-power training, involving 4-6 series of 4-8 repetitions of upper- and lower-body traditional and ballistic exercises (half-squat, jump-squat, prone-row, bench-press, and bench-throw) executed mainly under light- to moderate-to-heavy loading conditions (30%-75% 1RM), with a trend towards lighter loads close to competitions; TEC = Technical training, involving boxing technique and sparring.


SJ (cm)
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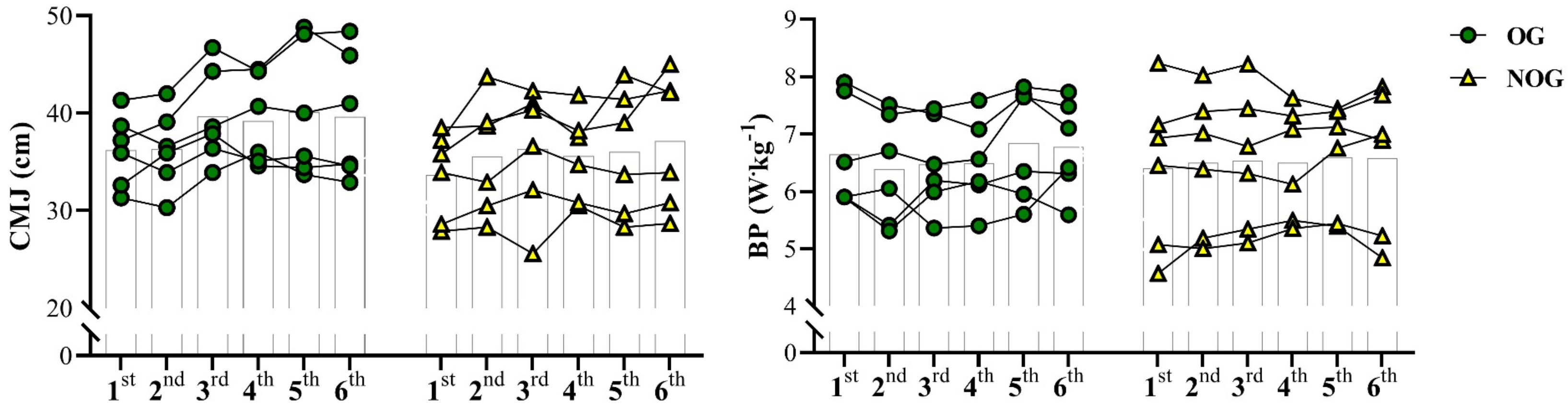
OG
NOG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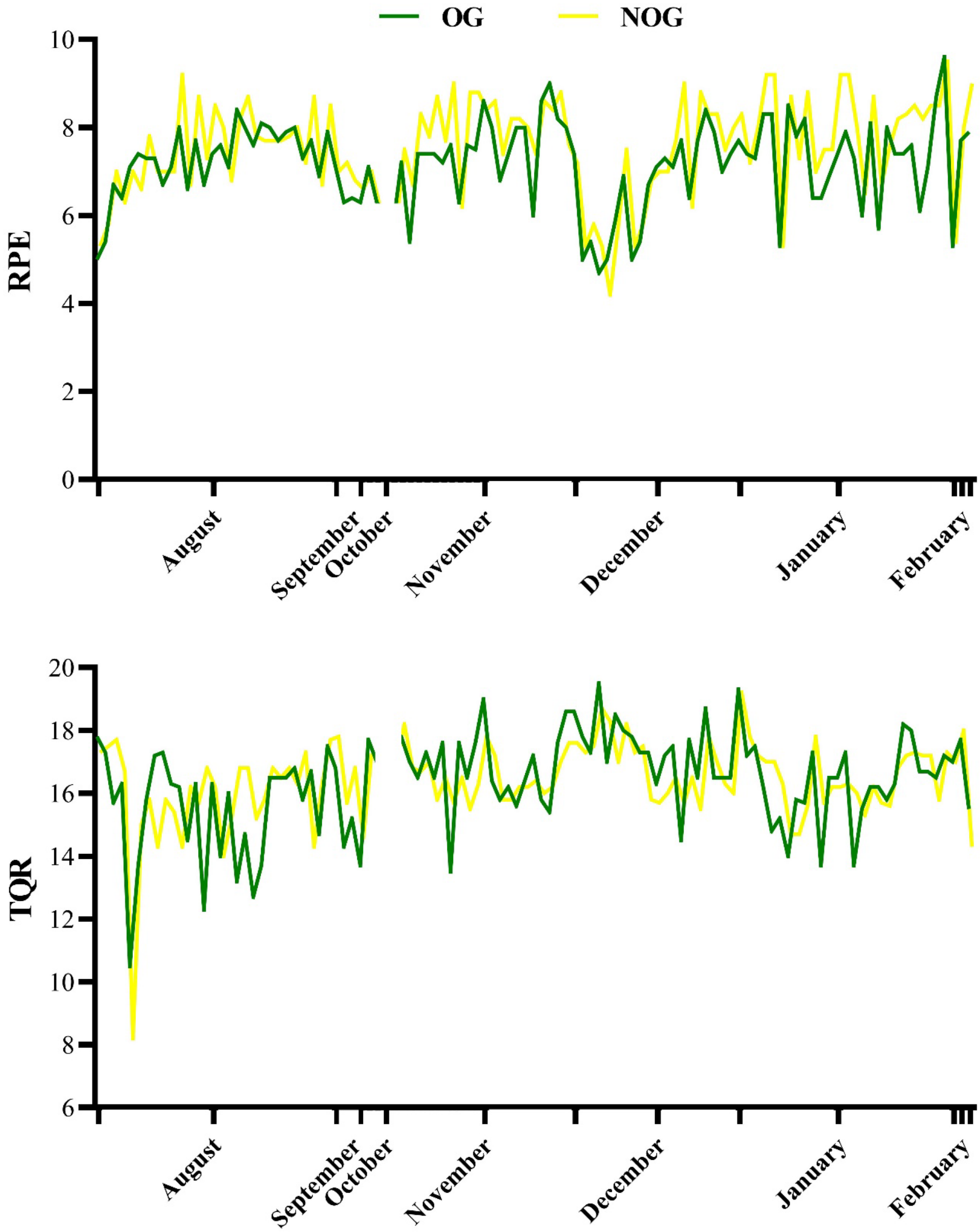
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