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Effects of mental training on muscular force generation, hormonal alterations and physiological adaptations in kickboxers

Running head: Hormonal and physiological adaptations to mental training.

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Conflicts of interest

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Abstract

BACKGROUND: The aim of the present study was to examine the effects of mental training on muscular force generation, hormonal alterations, and physiological adaptations in male trained kickboxers. **METHODS:** Fifty-three male trained kickboxers (24.2 ± 4.4 yrs, 1.75 ± 0.08 m and 70.4 ± 10.2 kg) were randomly assigned to a physical-training group (PG; $n=20$), physical and mental training group [PMG: $n=18$, mental-training package (MTP) plus physical training] or control group (CG: $n=15$). Physical fitness tests: countermovement jump (CMJ), medicine ball throw (MBT), bench press, and half-squat tests; hormones: resting cortisol (C) blood sample, plasma testosterone (T) concentration, and T/C ratio; and physiological variables: resting heart rate (HR), and blood pressure (BP) were assessed before training commenced (baseline) and at week 6 and 12 of training. **RESULTS:** PMG and PG improved performance in CMJ height (16.2%, 8.4%), MBT (27.9%, 14.2%), bench press (26.5%, 15.7%), half-squat (27.2%, 16.3%), T concentration (35.2%, 22.4%), and T/C ratio (60%, 0%, for PMG only), respectively. In contrast, the C concentration decreased for the PMG (16.3%) and increased for the PG (22%) after 12 weeks. The PMG and PG had significant decrease from pre- to post-training for the resting HR (9.1%, 3%, respectively) and BP (8.5%, 5.3%, respectively). Furthermore, there was a significant increase in MBT (9.3%) after 6 weeks in PMG. Outlined improvements (PMG and PG) were favorable compared to CG ($p < 0.05$) in all instances. **CONCLUSION:** The greater muscular force generation in PMG than PG seem to be explained by the reduction of hormonal and physiological stress after 12 weeks.

Key words: Mental training, muscular power, strength performance, hormonal alterations, physiological adaptations.

Introduction

Muscular strength and power are important to reduce morbidity across the life span, and are key to successful execution of many sport specific skills. For example, amateur and elite sports people attempt to optimize sports performance via augmenting strength and power indices, whilst interventions within an increasingly elderly population also seek to enhance these fitness components.^{1,2}

It is acknowledged that successful muscular force generation is optimized by appropriate mental focus.² Specific to kickboxing, mental resilience, motivation and self-confidence are the psychological determinants/predictors of favorable performance and training outcomes.¹⁻⁴ Consequently, augmentation and maintenance of these psychophysical attributes are key to successful training and competition in kickboxing, with many germane training interventions aligned to these specific attributes.¹⁻⁴ Surprisingly however, only one study has provided evidence of the beneficial effects of mental training in healthy striking combat sport practitioners, including kickboxers.¹ Theoretically, the integration of mental training within kickboxing training and competition phases may help ensure quality practice, improve performance and facilitate the effective transfer of mental skills into competition.^{1,3}

Optimal performance is reliant upon appropriate mental training and competition preparation ('psyching-up', mental rehearsal, etc) to translate prior physical preparation and technical skill practice/execution to successful competition outcome.¹⁻⁴ Mental training strategies, such as self-talk or imagery, have been shown to improve sport performance.^{1,5-7} Multi-faceted mental training package (e.g., combination of mental imagery and self-talk, etc) have greater effect ($d = 0.98$) than those implementing single strategy (e.g., an approach such as self-talk in isolation) interventions ($d = 0.48$).⁶ Recent review⁸ and meta-analyses⁵ revealed a small effect ($d = 0.20$) for mental training on strength tasks, though other germane experimental data revealed no such effect (likely attributable to insufficient sample sizes).^{9,10} Despite promise that mental training could offer promising opportunities for the enhancement of muscular force generation in untrained athletes,^{5,7} there is no conclusive result regarding the effects of mental training on muscular force generation in trained combat sport athletes, despite the theoretical rationale outlined above.

Whilst strength and power training can augment muscular force development,¹¹ whether the addition of mental training to such paradigms can enhance physiological adaptations is not currently known. Characterising the physiological responses (muscular force development, hormonal, etc) to such a training regime, with and without concurrent mental training would answer not only this additive effect question, but also potentially provide mechanistic evidence relative to previous equivocal data⁷ relative to the mental training muscular force development nexus. For example, the underlying physiological mechanisms facilitating mental imagery mediated enhanced muscular force generation are not clearly identified, although neural factors can account for some (not all) of improved performance with imagery.^{5,13} Additionally, a hormonal mechanistic rationale for such mental training derived muscular force generation augmentation is not clear. For example, positive psychological constructs, such as high self-confidence and low somatic and cognitive anxiety can be correlated with low cortisol concentrations.¹⁸ However, short-term mental training interventions (1 - 5 days) including psyching up, increased cortisol concentrations without changes in strength performance.^{7,14}

Currently there is a lack of well controlled data relative to the medium (weeks) and long term (months or years) additive influence of mental training upon standardized physical training within well-trained populations, relative to muscular force generation.^{5,7} Furthermore, appropriate characterization of hormonal and generic physiological responses (blood pressure, resting heart rate, etc) has not been conducted within a paradigm specifically designed to assess the additive influence of mental training. Therefore, the purpose of the present study was to examine the effects of mental training on muscular force, hormonal alterations and physiological adaptations in male trained kickboxers across a 12 week training programme. We hypothesized that mental training package would lead to increased maximal strength performance compared with a physical training alone. We also hypothesized that mental training package would result in a significant elevation in testosterone concentrations and testosterone/cortisol ratio, and reduction in cortisol concentrations, resting heart rate and blood pressure compared with the physical training alone.

Methods

Participants

Fifty-three male (24.2 ± 4.4 years, 1.75 ± 0.08 m and 70.4 ± 10.2 kg) trained (4 to 8 years; $n=9$ elite and 44 sub-elite) kickboxers (minimum of 4 national and/or international competitions per year) participated in the present study. Habitual discipline specific training for the prior 18 months comprised ~90-min per day 5 times a week. All participants had at least one year experience in resistance training. To be eligible to participate in the study, participants were required to meet the following criteria: (a) none of the participants had performed mental training with the aim of improving sport performance; (b) no consumption of any supplements or drugs; (c) no recent major injury history for the lower and upper-body; (d) no history of use of medications that could alter the hypothalamic-pituitary-gonadal (HPG) axis, such as anabolic steroids; (e) no history of chronic disease, including reproductive disorders; (f) regular eating patterns; (g) no history of depressive illness; (h) no severe cognitive impairment; and (i) subjected to a test on mental imagery [Sport Imagery Ability Measure (SIAM)]¹⁵ and having a moderate mental imagery ability. The participants were divided into (1) a physical and mental training group (PMG: $n=18$), (2) physical training only (PG: $n=20$) and (3) control group (CG: $n=15$) without any physical or mental training. Mental training was administered via a mental training package (MTP; subsequently described) (Figure 1).

The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Ethic Committee of the Unit of Research “Molecular Bases of Human Diseases”, Sfax Faculty of Medicine, Sfax, Tunisia. Written and verbal informed consent was obtained from each participant following verbal description all experimental details, with this obtained prior to any experimental data collection.

***** Figure 1 here*****

Procedures

Thirty-six training sessions occurred over 12 consecutive weeks, with a maximum of three training sessions per week, and a minimum of one days rest between training sessions. Details of the frequency and intensities (if relevant) of the physical and/or mental training program administered for PMG and PG, and the control procedures for CG, are detailed within Table 1. For each employed physical training exercise and mental training exercise, full standardized procedures are provided with the subsequent training program section.

The employed experimental design can be seen in Figure 1. In brief, the PMG and PG performed the same training exercises [bench press, half-squat, countermovement jump (CMJ) and medicine ball throw (MBT)] with the same rest period between sets (~80s). The difference between PMG and PG was in the activities performed during the rest periods immediately after training exercise completion (mental training package and neutral cognitive task, respectively, the neutral tasks being selected to never involve the abilities needed to form mental images – see Table 1). Furthermore, the other regular training sessions for both mental and physical groups consisted of 2 kickboxing sessions lasting 90 min, focusing not only on physical conditioning, but on technical and tactical aspects of the sport.

The training exercises (physical tests) were utilised to monitor baseline performance (immediately before 12 week training programme progressed, post familiarisation), after 6 weeks of the training programme and finally after 12 weeks of the training programme. Additionally, a blood sample was attained at the same three time points across the training to assess hormonal perturbations in tandem with generic physiological assessments of heart rate and blood pressure. In order to minimize the effect of any potential diurnal fluctuation, hormonal, physiological measurements (7-8 a.m.) and physical tests (5:30-7 p.m.) were scheduled at the same time of day (± 30 -min) at the three indicated periods of time. The intra-class correlation coefficient (ICC) for intra-observer reliability were 0.92 [countermovement jump (CMJ)], 0.87 [medicine ball throw (MBT)], 0.89 [one repetition max (1RM) bench press] and 0.80 (1RM back-squat) across the physical tests employed.

One week prior to baseline physical tests, participants were familiarized with the physical tests in order to control for any learning effect.

Training program

Physical training protocol and general experimental controls

***** Table 1 here*****

The physical tests employed (PMG, PG and CG) at baseline, and subsequently at 6 and 12 weeks of the training program, in addition to within each of the training sessions (PMG and PG only) are subsequently described in Figure 1 and Table 1.

CMJ: Participants were instructed to keep their hands on his hips while performing a downward movement followed by an immediate maximal effort vertical jump. All

participants were instructed to land in an upright position and bend the knees following landing. The CMJ test was performed using an infrared jump system (Optojump, Microgate, Bolzano, Italy) which was interfaced with a microcomputer and the results are expressed in centimetres (cm). During each test, three trials were completed with 1-min seated rest between each jump, and the best performance trial was used for the subsequent statistical analyses.¹⁶

MBT: Participants were seated on the bench with their legs fully extended and back against the wall. The medicine ball (5 kg) was held with both hands against the centre of the chest and the forearms positioned at 45° to the ground.¹ Participants were instructed to throw the medicine ball as far horizontally forward as they could, while maintaining contact between their back and the wall. The distance (m) thrown was measured between the base of the wall and the first point of contact between the thrown ball and floor. The best of the three trials was recorded and used for the subsequent statistical analyses, with 1 min seated rest between throws.

1RM: 1RM bench press and half-squat exercise tests were performed to measure upper and lower body strength. The 1RM tests were conducted as described by Hoffman.¹⁷ Participants warmed up with a light resistance (40 to 60% of 1RM) and then achieved a 1RM effort within 3 to 5 attempts. No bouncing was permitted, as this would artificially boost strength results. Bench press testing was performed in the standard supine position: the subject lowered an Olympic weightlifting bar to mid-chest and then pressed the weight until his arms were fully extended. The half-squat exercise required the participant to rest an Olympic weightlifting bar across the trapezius at a self-chosen location (which was recorded and standardized across all further movement executions across the experimental design). The half-squat was performed to the parallel position, which was achieved when the greater trochanter of the femur was lowered to the same level as the knee. The participant then lifted the weight until his knees were extended.

Heart rate (HR): HR was monitored at 5s intervals throughout the experiment and all training sessions using a wireless chest HR transmitter and a wrist monitor recorder (Polar Electro, Finland). Resting HR (HR_{rest}) was measured at 07:30 a.m. following 10 min supine rest, in a quite, cool and darkened room. The resting HR value corresponded to the minimal HR observed during this 10min period.¹⁸

Blood pressure (BP): The resting blood pressure (BP) was measured by the same trained experimenter after 10 min rest in a sitting position at ~07:40 a.m.,¹⁹ under the direct supervision of a doctor. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were registered as the mean of two consecutive BP measurements. Mean arterial blood pressure (MABP) was defined as $DBP + 1/3 (SBP - DBP)$.

Mental training protocol

Following familiarization, the participants in PMG received three ~90 min training sessions during one week, in which they received standardized verbal instructions and training on how to perform MTP (this training was delivered by the same certified sport psychologist for all participants). Specifically, the MTP involved the combination of motivational self-talk (M-ST) and mental imagery (MI); combined MI and self-talk (M-ST) elicit better information-processing models in the motor domain, than their singular discrete implementation.^{20,21}

Mental imagery (MI) training: During each training session, participants were instructed to imagine 4 sets for each plyometric and strength training exercise (see Table 1), after physical training. For instance, the athletes used internal MI (i.e., looking out through his own eyes while performing the action) and their imagination, performing maximal effort with their eyes closed. It should be noted that this mental exercise was not simply a visualization of oneself performing the task; rather, the performers were instructed to adopt a kinesthetic imagery approach. In this approach, they urged the muscle to contract maximally, which is usually accompanied by significantly elevated physiological responses.¹³

Motivational self-talk (M-ST) training: Self-talk refers to verbalization or a statement addressed to the self, with these incorporated before, during and after the imagined and actual trials actions (see Table 1 for order). Each session of M-ST training program was composed of two steps: the athletes had to seek (a) to identify and write negative self-talk statements that occurred before, during and after the training sessions and (b) to change them into positive and motivational statements. For instance, the participants were asked not to talk to their teammates during task performance but rather to repeat, either vocally or subvocally, the specified self-talk sentence during the actual and imagined movements. For example: “I can jump high”, “I can throw as far as possible”, “I can lift more weight” during jumping,

throwing, and strength (bench press and half-squat) tasks, respectively (not some language nuances may be lost due to Arabic and/or French to English translation). The athletes were also asked to change their statements each time they occurred according to this procedure. In line with self-determination theory,²² participants selected their own M-ST' sentences in order to preserve their perceived autonomy.

Control group

Control participants engaged in no mental or physical training between baseline testing, and peri- and post-training physical training programme athletic performance characterisation.

Blood collection

Three resting blood samples were drawn 48-72 hours after the last training session [at baseline, and peri (6 weeks) and post (12weeks) of the physical training programme]. All participants reported to the laboratory at the same time of the day (7-8 a.m.) after an overnight fast, with abstinence of alcohol, caffeine and exercise for at least 24 hours prior to this blood collection. Participants rested in the supine position for at least 10-min before blood collection via standard venipuncture technique, performed by a qualified phlebotomist. Plasma was separated by centrifugation within 15-min of collection and divided into two aliquots and subsequently, frozen and stored at -80°C for subsequent analysis. The plasma concentrations of testosterone (T) and cortisol (C) were measured by immunochemical methods using Chemiluminescent Microparticle Immunoassay (CMIA), in line with manufacturers instructions. Testosterone was determined with a sensitivity of 0.022ng/ml and an intra essay coefficient of variance (CV) of 2.5%. Cortisol was determined with a sensitivity of 8ng/ml and an intra essay CV 4.8%. The results of plasma concentrations of testosterone and cortisol are expressed in ng/ml. Testosterone to cortisol ratio (T/C) was also calculated.

Statistical analysis

Data are presented as mean $\pm$ standard deviation (SD). Two-way repeated measures ANOVA [3 (group) $\times$ 3 (time)] was applied to test the main effects between baseline, after six weeks and post-intervention (time) testing and between the three groups (PMG vs. PG vs. CG). Bonferroni test was used as post-hoc. To allow a better interpretation of the results, the effect sizes were calculated (eta squared η^2). Comparisons between elite and subelite groups before and after training programmes used non-paired Student's t-tests. The percentage changes were calculated as $[(\text{post-training value} - \text{pre-training value}) / \text{pre-training value}] / 100$. A

significance level of $p \leq 0.05$ was used for all analyses. All statistical analyses were carried out using the statistics package for social science (SPSS Inc., Chicago, IL, USA, version. 16.0).

Results

There were no significant differences in physical fitness, hormonal and physiological parameters at baseline and after training program between elite and subelite athletes ($p > 0.05$, all variables).

Performance

Mean $\pm$ SD values for muscular power and strength performance are presented in Table 2.

*** Table 2 here***

For the CMJ height, there was an effect of groups was found ($F_{(2,50)}=8.13$; $p=0.001$; $\eta^2=0.32$). However, an effect of moment was observed ($F_{(1,50)}=564.56$; $p<0.001$; $\eta^2=0.91$), with higher values post-training compared to pre-training ($p < 0.001$). A group and moment interaction effect was also found ($F_{(2,50)} = 660.61$; $p < 0.001$; $\eta^2 = 0.96$), with lower values for the PG at pre-training compared to itself and the PMG at post-training ($p < 0.05$ for both comparisons) and lower values for the PMG at pre-training compared to itself ($p < 0.001$) and the PG at post-training ($p < 0.05$). Post-hoc comparisons revealed that, at the post-training period, CMJ height was higher in the PMG ($p < 0.001$), PG ($p= 0.03$) than in the CG, whereas no significant difference was noted between PMG and PG ($p > 0.05$).

For the MBT, an effect of groups ($F_{(2,50)} = 15.17$; $p < 0.001$; $\eta^2 = 0.37$) and moments ($F_{(1,50)} = 3725$; $p < 0.001$; $\eta^2 = 0.98$) were found, with lower values for the PG compared to the PMG ($p < 0.05$) and higher values after the training period compared to pre-training ($p < 0.001$). An interaction effect was also found ($F_{(2,50)} = 1500$; $p < 0.001$; $\eta^2 = 0.98$), with lower values for the PG at pre-training compared to itself and the PMG after training ($p < 0.001$) and higher values for the PMG at pre-training compared to itself and PG after training ($p < 0.05$). Moreover, post-hoc comparisons revealed that, at the post-training period, MBT was higher in the PMG ($p < 0.001$), PG ($p= 0.01$) than in the CG, and in the PMG than in the PG ($p = 0.01$).

Bench press test differ between groups ($F_{(2,50)} = 7.72$; $p = 0.001$; $\eta^2 = 0.23$) was found. However, an effect of moment was detected ($F_{(1,50)} = 441.36$; $p < 0.001$; $\eta^2 = 0.89$), with higher values post-training compared to pre-training ($p < 0.05$). A group and moment interaction effect was also observed ($F_{(2,50)} = 307.46$; $p < 0.001$; $\eta^2 = 0.92$), with lower values for the PG at pre-training compared to itself at post-training ($p < 0.05$) and lower values for the PMG at pre-training compared to itself and the PG after training ($p < 0.001$). Post-hoc comparisons revealed that, at the post-training period, relative bench press was higher in the PMG ($p = 0.001$), PG ($p = 0.02$) than in the CG.

For the squat test differ between groups ($F_{(2,50)} = 5.66$; $p = 0.006$; $\eta^2 = 0.18$). However, an effect of moment was detected ($F_{(1,50)} = 705.79$; $p < 0.001$; $\eta^2 = 0.93$), with higher values post-training compared to pre-training for the PMG and PG ($p < 0.001$). A group and moment interaction effect was also observed ($F_{(2,50)} = 430.49$; $p < 0.001$; $\eta^2 = 0.94$). Post-hoc comparisons revealed that, at the post-training period, relative squat was higher in the PMG ($p = 0.006$), PG ($p = 0.04$) than in the CG. No significant difference was found between the PG and CG at the post-training period ($p > 0.05$).

Hormonal alterations

Mean $\pm$ SD values for hormonal and physiological variables are presented in Table 3 and Figure 2.

***** Table 3 here*****

***** Figure 2 here*****

Basal T concentrations differ between groups ($F_{(2,50)} = 7.51$; $p = 0.001$; $\eta^2 = 0.23$) was found. However, an effect of moment was detected ($F_{(1,50)} = 52.33$; $p < 0.001$; $\eta^2 = 0.51$), with higher values post-training compared to pre-training for the PMG and PG ($p < 0.05$). A group and moment interaction effect was also observed ($F_{(2,50)} = 37.07$; $p < 0.001$; $\eta^2 = 0.59$). The post-hoc indicated higher values for the PMG and PG compared to the CG ($p = 0.001$, $p = 0.04$, respectively).

For the C concentrations an effects of groups ($F_{(2,50)} = 8.44$; $p = 0.001$; $\eta^2 = 0.25$) was found. However, an effect of moment was detected ($F_{(1,50)} = 49.87$; $p < 0.001$; $\eta^2 = 0.499$). The post-hoc indicated higher values of C concentrations at post-training for the PMG

compared to the PG ($p = 0.001$) and CG ($p = 0.04$), whereas a marginally significant difference between physical and control groups ($P \approx 0.05$). Additionally, a group and moment interaction was also observed ($F_{(2,50)} = 271.38$; $p < 0.001$; $\eta^2 = 0.91$).

T/C ratio differed between groups ($F_{(2,50)} = 13.28$; $p < 0.001$; $\eta^2 = 0.34$). However, an effect of moment was detected ($F_{(1,50)} = 51.44$; $p < 0.001$; $\eta^2 = 0.50$). The post-hoc indicated higher values of T/C ratio at post-training for the PMG compared to the PG ($p = 0.001$) and CG ($p < 0.001$), with no significant difference between PG and CG ($p = 0.6$). A group and moment interaction effect was also observed ($F_{(2,50)} = 108.36$; $p < 0.001$; $\eta^2 = 0.81$).

Physiological adaptations

For the resting HR, there was an effects of groups ($F_{(2,50)} = 12.90$; $p < 0.001$; $\eta^2 = 0.34$) and moment ($F_{(1,50)} = 52.90$; $p < 0.001$; $\eta^2 = 0.51$) were found, with lower values post-training compared to pre-training for the PMG and PG ($p < 0.001$). Additionally, a group and moment interaction was also observed ($F_{(2,50)} = 263.91$; $p < 0.001$; $\eta^2 = 0.91$). The post-hoc indicated higher values at post-training of resting HR for the CG compared to the PG ($p = 0.028$) and PMG ($p < 0.001$).

The BP differed between groups ($F_{(2,50)} = 14.33$; $p < 0.001$; $\eta^2 = 0.36$) and moments ($F_{(1,50)} = 397.81$; $p < 0.001$; $\eta^2 = 0.88$) were found, with lower values post-training compared to pre-training for the PMG and PG ($p < 0.001$). An interaction effect was also found ($F_{(2,50)} = 314.42$; $p < 0.001$; $\eta^2 = 0.92$). The post-hoc indicated lower values for the PMG compared to the PG ($p = 0.022$) and CG ($p < 0.001$).

Discussion

The aim of the present study was to examine the effects of mental training package (combined motivational self-talk and internal mental imagery) on muscular power and strength performance, hormonal alterations and physiological adaptations in male trained kickboxers. The findings have shown that upper-body muscular power and strength performance increased significantly in mental training more than in physical training and control condition at the end of 12 weeks. These findings could be explained by the elevations of T

concentrations and T/C ratio and the reductions of C concentrations and resting HR and BP in mental training group than other conditions.

Performance

The obtained results have proven that the combination of MTP with physical training (PMG) was sufficient to elicit more significant changes in muscular power (CMJ, 16.2%, MBT, 27.9%) than physical training alone (CMJ height, 8.4%, MBT, 14.2%) and CG. The practice of MTP by trained kickboxers, such as M-ST and MI, is believed to be an excellent method to enhance physical performance.^{23,24} Indeed, the results of the current study highlights that the combination of MTP and physical training increases more strength performance (relative bench press, 26.5% and half-squat, 27.2%) than physical training alone (bench press, 15.7% and half-squat, 16.3%) and CG. Thus, it has been shown that physical training increase more muscular force than CG. In fact, several researchers have noted that most athletic interventions are multimodal and include mental along with physical trainings.^{8,25} Rozand et al.²⁶ has further explained this combination by the fact that did not induce additional muscle fatigue, it activated the corticospinal pathways and would improve intrinsic motivation and arousal level of the athletes without having negative effects on their future performances. What is worthwhile to mention is that few research works have investigated the effect of psyching-up on force production, especially during dynamic tasks in well trained athletes.^{5,7,12} Previous studies have suggested that neural factors, rather than changes at the muscular level, largely account for the mental training-induced strength gains.¹³ Accordingly, MacKay²⁷ showed that the mental training improves the appropriate coordination patterns by priming the corresponding motor neurons of the muscles necessary to perform the motor actions and optimizing physical performance. From an applied perspective, strength gains would be directly related not only to the neural adaptations and psychological effects (e.g., improve self-confidence and motivation) of mental practice,^{1,28} but also to pure hormonal and physiological adaptations.

Hormonal alterations

For the mental group, resting plasma T concentration increased, while, the C level decreased after 12-week concurrent mental package- and physical-training. Thus, the combination of MTP and physical training seems to be more effective to increasing anabolic hormone (T) than physical training only. Accordingly, mental training program several days a week was successful in changing the C level.^{29,30} Consequently, the present study have demonstrated

that T/C ratio in the mental training group increased significantly at post-training compared to pre-training. This ratio is influenced by training intensity and duration. When athletes are at great pressure, some hormonal changes occur with the most outstanding ones being anabolic and catabolic hormones.³¹ Given that T/C ratio is used as an indicator of training pressure, it can be concluded that mental along with physical trainings (during 12 weeks and with the training setting of the present study) favourably affect this ratio. These observations support the suggestion that the periodical adaptative responses in the endogenous hormone balance during mental training seem to have an increasing importance for changes in physical performance, especially in trained athletes.

Physiological adaptations

The findings have revealed a significant decrease in basal HR and BP after 12 weeks of mental training and physical training. Mental training program used in the present study is a combination of “internal imagery” and M-ST. Particularly, internal imagery significantly generates greater physiological responses such as blood pressure, heart rate, and respiration rate than external imagery, in which only an image of the motor task is generated in one’s mind, as if the person was viewing him/herself exercising on a television screen.^{13,32} Thus, many past studies have found the reductions in BP and HR after either physical exercise or internal mental training.^{30,33} Accordingly, we also found that the effect of mental training package combined with physical training on these measures seem to be affected. This agrees well with previous studies showing that a profound change in psychological states after mental practice is associated with a corresponding change in mental-emotional and physiological states and parasympathetic dominance, which decreased HR.^{29,34} In fact, mental training creates a bridge between mind and body, linking perception, emotion, and psychological, physiological, behavioral and hormonal adaptations. Consequently, training programs could be adjusted and adapted to include mental training in addition to physical practice, which may reduce the hormonal and physiological stress and overtraining, while still proving sufficient to stimulate muscular force increases.

The present study had some limitations. It is important to note that the results of the present study could have been influenced by the former experience of each study participant with regard to mental practices and their mental imagery ability. Indeed, each athlete could have developed his own mental practice abilities, which was not investigated by specific questionnaires/tools. Furthermore, this study improvements seem very high with respect to classical “physical training” programs. Therefore, it has to be noted that the literature reports

improvement of around 60% by mental training programs.⁷ The extent of these improvements should be considered with care in the future studies.

Conclusions

Concurrent MTP and physical training is very effective in producing gains in muscular power and strength performance in trained kickboxers. In addition, the practice of M-ST and MI over three months increased more muscular force than short duration training (6 weeks). These adaptations are associated most likely with physiological ones as well as with changes in the endocrine system in trained athletes. Furthermore, the strength gains in both mental and physical groups seem to be explained by reduced hormonal and physiological stress after 12-week training program. Future research studies relevant to elite strength males and females athletes are needed to support the findings presented in the current study.

Practical applications

The results of the present study have important implications for the fields of sport psychology and resistance training. Thus, combining mental training package with physical practice was the most effective intervention. Athletes may adapt their training to incorporate a mental training package component, possibly even replacing some actual power and strength training with mental training allowing potentially reducing the physical strain without losing training adaptations.

Conflicts of interest

None declared.

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Table 1: Training session for both physical and mental groups.

Table 2: Mean $\pm$ SD values for muscular power and strength performance during 12-week of mental training in male trained kickboxers.

Table 3: Mean $\pm$ SD values for physiological variables during 12-week of mental training in male trained kickboxers.

Figure 1: Schematic of experimental design. Mental and Physical Training Group (MPG); Physical Training Group (PG); Control Group (CG); *see physiological monitoring sections within methods for protocols and tests employed; #see table 1 for details for training programmes.

Figure 2: Mean $\pm$ SD values for resting testosterone (A), cortisol (B) concentrations and T/C ratio (C) during 12-week of mental training in male trained kickboxers. *: Significant difference at post-training compared with pre-training at $p < 0.05$; **: Significant difference at post-training compared with pre-training at $p < 0.001$; #: Higher values for the mental group at post-training compared to physical and control groups at $p < 0.05$; †: Higher values for the physical group at post-training compared to the control group at $p < 0.05$.

Figure 1.