Reducing Resistance Training Volume during Ramadan Improves Muscle Strength and Power in Football Players

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Abstract ▼
We aimed to examine the effect of maintaining or reducing resistance training volume during Ramadan-intermittent-fasting (RIF) on short-term maximal performances. 20 footballers (age: 18.4 ± 0.8 years; body-mass: 72.4 ± 4.1 kg; height: 183.4 ± 4.6 cm) were matched and randomly assigned to a normal-training-group (G1) or a tapering-group (G2). They were tested for muscular strength (maximal-voluntary-contraction) and power (squat-jump and counter-movement-jump) 1 month before RIF (T0), 1 week before RIF (T1), after 2 weeks of fasting (T2) and at the end of RIF (T3). From T1 to T2, subjects performed a whole-body resistance training program (8-repetitions×4-sets with 4-min recovery in-between). During RIF, G1 maintained the same training program, while G2 performed a period of reduced training volume (3 sets/exercise: −22 %). Muscle strength and power increased significantly from T0 to T1, from T0 to T2 and from T0 to T3 in G1 and G2 and from T1 to T2 and from T1 to T3 only in G2 (p < 0.05). Performance was higher in G2 than G1 during T2 (p < 0.01). Moreover, the Δ-change of performance between T0 and T2 and T3 was significantly higher in G2 than G1 (p < 0.05). For young soccer players, a tapering period characterized by a reduced training volume during RIF may lead to significant improvement in muscle strength and power.

Introduction ▼
During the month of Ramadan, healthy able-bodied Muslims abstained from food and fluid intake, smoking and having sexual relations from sunrise to sunset daily. As the sporting calendar is not modified for religious observances and international sporting competitions occur throughout the year (i.e., the 2012 Olympics Games), Muslim athletes continue to train during Ramadan intermittent fasting (RIF) to be well-prepared for competitions scheduled during or after this fasting period. As RIF may induce specific physiological adaptations [30], athletes and coaches need to choose between (i) stopping training, with the inherent risk of inducing detraining effects, (ii) reducing the training-load in order to cope with the absence of nutrient and fluid intake during daylight (iii) or maintaining usual training loads to avoid any detraining effect [30]. Based on the data of current literature [1,2,6,8,16], RIF is often associated with a reduced performance, even though the effect of RIF has been the subject of several investigation and conclusions about this topic are still inconsistent. Indeed, recent studies demonstrated that RIF negatively affect a number of physical outcomes including high-intensity maximal exercise [15,16,31], repeated sprint performance [16,25], muscular strength and endurance [6,7], and long-duration aerobic tasks [16,25]. Chaouachi et al. [7] showed that RIF has little effect on physical performances (i.e., squat jump (SJ), counter-movement jump (CMJ), 30-m sprint, and the multistage fitness test) in elite judokas who maintain normal training loads. However, the authors suggested that Muslim judokas may be at risk of losing body mass and experiencing increased sensations of fatigue during RIF. Likewise, Aziz et al. [4] showed that aerobic and anaerobic adaptations to a high intensity-training program were not adversely affected as a result of RIF when the training intensity was maintained. To the authors’ knowledge, there are no studies examining the effect of resistance training volume on short-term maximal performances during RIF. The reduced training volume is considered to be a tapering phase aimed...
at reducing accumulated fatigue after a training period and improving performances [23]. Although most experimental research and observation research on tapering in the scientific literature has been conducted in individual (i.e., predominantly endurance) sports and events, Chtourou et al. [7], Gibala et al. [14], and Izquierdo et al. [20] showed that this phase (i.e., characterized by a reduction in the training volume) may increase muscle strength and power following a resistance training program. These beneficial effects of the tapering period could be explained by various physiological responses associated with the cardiorespiratory (e.g., increase in maximal oxygen uptake, etc.), metabolic (e.g., increased peak blood lactate concentration; and decreased blood lactate at submaximal intensities, increase in muscle glycogen concentration, reduction in blood creatine kinase, etc.), and hormonal (i.e., changes in testosterone and cortisol concentrations, etc.) systems [30]. Thus, the aim of the present study was to examine the influence of maintaining or reducing resistance training volume during RIF on muscular strength and power.

Methods

Subjects
20 male soccer players (age: 18.4±0.8 years; body mass: 72.4±4.1 kg; height: 183.4±4.6 cm) from Tunisian junior football squads affiliated with a professional club participated in this study. The club was belonged to League 1 of the Tunisian National Senior League. Participants were informed of the possible risk and discomfort associated with the experimental procedures, and written informed consent was obtained from each athlete or from their parents prior to participation. The study was conducted in accordance with the Declaration of Helsinki as well as the ethical standards of the IJSM [26]. The experimental design of the study was approved by a local research ethics committee and was done in accordance with the Declaration of Helsinki. The study was carried out in Tunisia during Ramadan 2011 when the length of each fasting day was approximately 15–16 h.

Experimental procedure
The subjects were familiarized with the experimental testing procedures before the commencement of the study [10]. During this session, anthropometrical measurements and resistance load verifications for the training exercises were also determined [12, 17]. Thereafter, subjects underwent the same test battery (SJ, CMJ, and MVC, with a recovery period of at least 5 min in-between) in randomized order at 4 different times; 1 month before RIF (T0), 1 week before RIF (T1), after 2 weeks of fasting during RIF (T2) and at the end of RIF (T3). Test sessions were performed during the off-season period. Therefore, the subjects participated only in the resistance training programs (i.e., no soccer-specific training).

Resistance training and tapering programs
1 month before Ramadan (from T0 to T1), the subjects participated in a 4-week preparatory period. Thereafter, the participants were randomly assigned either to a normal-training group (G1: 18.3±0.7 years, 182.3±4.1 cm, and 72.3±3.5 kg; n=10) or a tapering group (G2: 18.5±0.9 years, 184.5±5.1 cm and 72.5±4.7 kg; n=10) for 4 weeks during Ramadan (from T1 to T3). Both the preparatory and the Ramadan training periods were planned as periodized programs with the main focus on the knee extensor muscles. Half squats (~90° knee angle), leg press, leg curl and leg extension were the primary exercises. Before Ramadan (from T0 to T1), the training program was similar for G1 and G2 (e.g., involving the same exercises, repetitions, number of sets). Subsequently, subjects of G2 participated in a 4-week period of tapering (from T1 to T3). However, the training program of G1 was similar during the 2 training periods (from T0 to T3). During the first period (from T0 to T1), training sessions were standardized to consist of 4 sets of 8 repetitions maximum (8-RM) with a recovery period of 4 min in-between (8-RM: Load was assessed as that which could just be lifted only 8 times. This test was performed before the 4 weeks of tapering period) and adjusted as muscle strength increased to stay within the desired RM training zone. During all training sessions, if the load happened to become slightly too heavy, as it did in some cases, the subject was assisted slightly during the last l-3 repetitions of the set. The training volumes, calculated by the multiplication of load, sets and repetitions (sets×repetitions×load), were: 3297.92±811.5 (i.e., over one training session) and 9893.75 kg±1384.3 (i.e., over one week: 3 sessions per week). After the first period (i.e., before Ramadan: from T0 to T1), subjects of G2 were assigned to 4 weeks of tapering period. Tapering consisted of a period of reducing the training volume (i.e., decreased the number of sets to 3, corresponding to a reduction of ~22% and ~48%, respectively). The training intensity (i.e., 8-RM) and exercises remained constant. During this tapering phase, the training volumes were 2655.62±567.4 (i.e., over one training session) and 5230.61±1111.7 kg (i.e., over one week).

Each training session was preceded by 10 min of warm-up/stretching (i.e., dynamic stretching) and concluded with 10 min of cool-down. Warm-up included 8–10 repetitions using light weights for all exercises.

Squat jump (SJ) and Countermovement jump (CMJ) tests
Jump height was calculated from the flight time using an infrared jump system (Optojump, Microgate, Bolzano, Italy) interfaced with a microcomputer. In the SJ, subjects lowered themselves into a squat position (90°) and after a brief pause, jumped upwards as quickly and as high as possible. No downward motion was allowed immediately prior to jumping upward. In contrast, in the CMJ subjects initiated the jump from an extended leg position, squatting down to a self-selected depth, and immediately performed an explosive concentric action for maximal height. They performed 3 maximal trials of each jump test with their hands on the hips interspersed with 15-s of rest, with the higher value being used for further analysis.

Maximal voluntary contraction (MVC)
MVC was measured as previously described by Chtourou et al. [11]. Briefly, subjects performed three 5s MVC of the knee extensors (110° knee flexion) of the dominant leg in a knee extension device (leg extension machine, PANATTA SPORT®, Italy). All subjects were given standard verbal encouragement during each MVC and visual feedback of the produced force was provided. The torso was fixed with 2 horizontal safety belts in the chest and waist area, and the upper extremities were placed next to the body holding handgrips. Moreover, both thighs were strapped. The force generated during the muscle contraction was measured by a strain gauge (Globus Italia, Codogne, Italy) properly mounted on the leg extension machine with chains attached to the sliding axis of the seat. The signal from the load cell was amplified using a Globus amplifier (Tesys 400, Globus,
Moreover, repeated measures was used to determine the di
(2 [groups] × 4 [periods]) analysis of variance (ANOVA) with
G1 and G2.

\[ p < 0.05. \]

All statistical tests were processed using STATISTICA Software
(StatSoft, France). Mean and SD (standard deviation) values were
sected by 2 min rest, and the highest values were retained for
subsequent analyses.

Statistical analyses
All statistical tests were processed using STATISTICA Software
(StatSoft, France). Mean and SD (standard deviation) values were
calculated for each variable. Once the assumption of normality
by the Shapiro-Wilk W-test was confirmed, a Fisher’s two-way
(2 [groups] × 3 [periods]) ANOVA with repeated-

The main effects of groups (F = 4.47, p < 0.05) and periods (F = 14.42,
p < 0.001) were significant. Sj was higher in G2 than G1 (p < 0.05)
and in T2 than the other periods (p < 0.05). Likewise, the groups × periods interaction was significant (F = 3.14, p < 0.05).
Sj increased significantly from T0 to T1, T2 and T3 in G1 (p < 0.01 and p < 0.05, respectively) and G2 (p < 0.05, p < 0.001 and p < 0.001, respectively). However, Sj increased significantly from T1 to T2 and T3 only in G2 (p < 0.001 and p < 0.05, respectively).

Moreover, Sj was significantly higher in G2 than G1 only during
T2 (p < 0.01). The Δ-change of Sj between T0 and T2, between T0 and T3 and
between T1 and T2 were significantly higher (p < 0.05) in G2 in comparison with G1 (Table 1).

Table 1

The post-hoc test revealed that CMJ was significantly higher at
T1, T2 and T3 in comparison with T0 in both groups (p < 0.05
T0 and T3 for G1 and p < 0.001 for the other comparisons). Moreover,
CMJ was higher in T2 and T3 in comparison with T1 in G2
(p < 0.001) and p < 0.01, respectively) and lower in T3 in compar-
son with T1 in G1 (p < 0.05). Concerning the difference between
groups, CMJ was significantly higher in G2 than G1 at T2 and T3
(p < 0.001).

Table 1 – Change of muscle power and strength (means ± SD)

The Δ-change of CMJ between T0 and T2, between T0 and T3,
and between T1 and T2 were significantly higher (p < 0.001 and
p < 0.01, respectively) in G2 than G1 (Table 1).

The Δ-change of MVC between T0 and T2, between T0 and T3,
between T1 and T2, and between T2 and T3 were significantly higher (p < 0.05) in G2 than G1 (Table 1).

Maximal voluntary contraction (MVC)

The main effects of groups (F = 16.51, p < 0.001), periods
(F = 24.91, p < 0.001) and the interaction groups × periods
(F = 4.51, p < 0.001) were significant. MVC was higher in G2 than
G1 (p < 0.05) and in T2 than the other periods (p < 0.05).

The post-hoc test revealed that MVC values increased signifi-
cantly from T0 to T1 (p < 0.01), T2 (p < 0.001) and T3 (p < 0.001) in
G2 and from T0 to T1 (p < 0.01) and T2 (p < 0.001) in G1. However,
no significant difference was found between T0 and T3 in G1. In
comparison with T1, MVC increased significantly at T2 (p < 0.001)
and T3 (p < 0.05) only for G2. Moreover, MVC was significantly
higher in G2 than G1 (p < 0.001) at T2. The Δ-change of MVC between T0 and T2, between T0 and T3,
between T1 and T2, and between T2 and T3 were significantly higher (p < 0.05) in G2 than G1 (Table 1).

Countermovement jump (CMJ)

The Δ-change of Sj between T0 and T2, between T0 and T3;
between T1 and T2 and between T2 and T3 were significantly higher (p < 0.05) in G2 in comparison with G1 (Table 1).

Fig. 1 presents the Sj results recorded at T0, T1, T2, and T3 in
G1 and G2.

Table 1

<table>
<thead>
<tr>
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<th>G1</th>
<th>G2</th>
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<tbody>
<tr>
<td>Sj (%)</td>
<td>8.41±6.03</td>
<td>7.52±6.62</td>
</tr>
<tr>
<td>CMJ (%)</td>
<td>8.00±7.33</td>
<td>7.50±7.24</td>
</tr>
<tr>
<td>MVC (%)</td>
<td>11.96±11.40</td>
<td>9.86±10.53</td>
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</tbody>
</table>

*: significant difference between G1 and G2; §: significant difference in comparison with T0; #: significant difference in comparison with T1: T0: 1 month before Ramadan; T1: 1 week before RIF; T2: after 2 weeks of fasting during RIF; T3: at the end of the fasting period; G1: normal-training group; G2: tapering group; Sj: squat jump; CMJ: countermovement jump; MVC: maximal voluntary contraction

**Table 1**: Δ-change of muscle power and strength (means ± SD) recorded between T0 (before the first resistance training period) and T1 (at the end of the first resistance training period), T2 (after 2 weeks of the second resistance training period) and T3 (at the end of the second resistance training period).
Chtourou et al. [11, 13] and Izquierdo et al. [27] showed an improvement in muscle power and strength during the SJ, the CMJ, the 30-s Wingate test, the MVC and the one-repetition maximum for lower-limbs exercises following 4–8 weeks of resistance training performed 2 or 3 times per week. Concerning the second training period, subjects who maintain the same training volume as before RIF experienced a stabilization or even a decreased (i.e., CMJ at T3) performances. This is consistent with the findings of Chaouachi et al. [7], who showed that elite judo athletes maintaining high training loads maintain their aerobic and anaerobic performance. Indeed, the authors observed that sprint performance (i.e., 5, 10 and 30 m sprint times), SJ, CMJ and the estimated values for maximal aerobic velocity during the Multistage Fitness Test were also relatively unchanged during RIF. However, they found a small reduction in the 30-s repeated jump test at the end of Ramadan. Likewise, Aziz et al. [3, 4] showed that aerobic (i.e., continuous progressive incremental-resistance cycling exercise) and anaerobic (i.e., Wingate test) performances were not compromised during RIF. The authors attribute this unchanged performance to the maintained training intensity and volume and nutrient intake during RIF. In addition, Güvenç [21] suggested that if regular training regime, body fluid balance, daily energy intake and sleep duration are maintained at the same level as before RIF, fasting does not have detrimental effects on aerobic exercise performance (i.e., 20-m shuttle run test) or body composition in young soccer players. However, Chennaoui et al. [9] showed that maximum aerobic velocity of middle-distance runners, as determined by the Montreal Track Test Velocity method, decreased by −3% and −4% on the 5th and 21st day of RIF, respectively when the training volume was unchanged. Therefore, it appears from the present study findings and those of the current literature that RIF has a relatively small effect (even if sometimes there is a significant reduction) on athletes who maintain their training volume during this month.

When athletes maintain the same training intensity and reduce their training volume (i.e., tapering period), the present study findings indicate that resistance training during RIF induces a significant improvement of muscle power and strength assessed by the SJ, CMJ and MVC tests. In soccer training, Meckel et al. [29] suggested that the decrease in performance of their youth players during RIF was due to the significant decrease in the weekly volume of intense physical activity from 6.4 ± 0.2 h/wk before Ramadan to 4.5 ± 0.1 h/wk during Ramadan. It is not surprising that Meckel et al. [29] showed a significant reduction in performances during Ramadan after a reduced volume of training due to the decreased intensity of training that could lead to a detraining status [30]. Indeed, maintaining training intensity is an essential requirement for maintaining training-induced adaptations during periods of reduced training and tapering for athletes and less well-trained subjects [5]. Determining the optimal loading of training sessions during RIF is a challenging task for both athletes and coaches (i.e., Muslim athletes may need to train through the RIF month to be well-prepared for competitions which may fall during or immediately after this fasting period), and, to the authors’ knowledge, this is the first study that has investigated the effect of tapering after resistance training during RIF on muscle power and strength. For athletes in a non-fasting state, previous studies showed significant increases in isometric peak torque and low-velocity isokinetic strength performance of the elbow flexors [18] and on maximal strength [19, 20] and muscle power [27] after 3–16 weeks of resistance training. In addition, Chtourou et al. [5] recently showed that 2

**Discussion**

The result of the present study confirmed that during the first training period (i.e., before RIF) muscle strength and power increased significantly in both groups. During RIF, the major findings of the present study indicated that reducing training volume may have resulted in further muscle performance improvement especially during the first 2 training weeks. However, muscle strength and power were unchanged or even decreased (i.e., CMJ at T3) when maintaining a high training volume during RIF.

Concerning the first training period, the 2 groups improved their muscle performances after the 4 weeks of resistance training, which is consistent with the literature [11, 13, 27]. In fact, Chtourou et al. [11, 13] and Izquierdo et al. [27] showed an
weeks of tapering, characterized by a reduced volume, after 12 weeks of resistance training increases muscle strength (i.e., MVC: 8–10N) and power (i.e., SJ and CMJ: 2–8 and 5–6cm respectively) in physically active men. Although speculative, it is possible that the tapering phase used during RIF can reduce accumulated fatigue [14] after the first training period and improve performance. Moreover, during RIF, Mujika et al. [30] concluded that athletes and recreationally strength-trained subjects can readily maintain their lean body mass, oxidative enzyme activities and muscular strength with reduced training programs. We could also speculate that the tapering phase during RIF would result in reducing the dehydration induced by the training session (i.e., the reduction in the training volume may reduce the sweat losses), which could be used to relatively preserve the blood glucose concentrations. Although these mechanisms could explain, in part, the beneficial effect of reducing training volume during Ramadan, studies are also needed to identify the mechanisms by which taper may improve short-term performance during RIF. Furthermore, the present study results indicate that the improvement of performance in G2 was higher in T2 than T3. This reduction could be explained by the duration of taper (i.e., duration of the reduced training volume). Indeed, the timeframe that separates the benefits of a successful taper from the negative consequences of insufficient training has generally been reported to be 2 weeks. Likewise, recent reviews support this duration as an optimal period of tapering [5,30]. In this context, Kenitzer [28] concluded that a taper of approximately 2 weeks represented the limit of recovery and compensation time before detraining became evident. Therefore, a long period of tapering could result in a loss of the training-induced increases (i.e., detraining). Consistent with this, previous studies have reported a significant reduction in muscle strength (i.e., 7–12%) after short-term periods (4–8 weeks) of training cessation or periods of reduced training [22–24]. Therefore, the present study findings would suggest using only 2 weeks of tapering period at the beginning (i.e., normal-training volume, 2 weeks of reduced volume, and normal-training volume) or at the end (during the last 2 weeks) of RIF. However, as the subjects were tested during the off-season period in the present study, our results would have to be confirmed by investigating the effects of tapering period on physical performance when Ramadan occurs during the month of Ramadan.

In conclusion, the present study findings demonstrate that reducing training volume during RIF may improve muscle strength and power especially during the first 2 weeks of training. However, muscle strength and power were unchanged or even slightly decreased when a high training volume was maintained during RIF. Therefore, tapering (i.e., characterized by a reduction in the training volume) during RIF may lead to significant improvement in muscle strength and power. Coaches, sport scientists and athletes should be aware of the potential impact of high training volume during RIF (i.e., for young soccer players). Moreover, strength and power athletes required to compete during RIF may be advised to reduce their training volume for 2 weeks before a major competition.

Conflict of interest: The authors have no conflicts of interest that are directly relevant to the contents of this manuscript.

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