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Concurrent training followed by detraining: does the resistance training intensity matter?

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Running Head: Strength training intensity during concurrent training

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ABSTRACT

The aim of the present study was to analyze the training and detraining effects of concurrent aerobic training and resistance training against three different external loads on strength and aerobic variables. Thirty-two men were randomly assigned to four groups: low-load (LLG, n=9), moderate-load (MLG, n=9), high-load (HLG, n=8), and control group (CG, n=6). Resistance training consisted of FS with a low-load (40-55% 1RM), a moderate-load (55-70% 1RM) or a high-load (70-85% 1RM) combined with jump and sprint exercises. Aerobic training was performed at 75% of the maximal aerobic speed for 15-20 min. The training period lasted for 8-weeks, followed by 4-weeks detraining. Pre, post-training and post-detraining evaluations included 20m running sprints (0-10m: T10; 0-20m: T20), shuttle run test, countermovement vertical jump test (CMJ), and loading test (1RM) in full-squat (FS). All the experimental groups showed improvements ($p<0.05$) in all the parameters assessed, except the LLG for T10 and the HLG for T20. The LLG, MLG and HLG showed great changes in 1RM and VO_2max compared with the CG ($p<0.05$), whereas the HLG and MLG showed a greater percentage change than the CG in T10 ($p<0.001$) and CMJ ($p<0.05$). The 4-week detraining period resulted in detrimental effects in all variables analyzed for all three experimental groups. In conclusion, our results suggest that strength training programs with low, moderate, or high external loads combined with low-intensity aerobic training could be effective for producing significant gains in strength and aerobic capacities. Moreover, the higher loads used increased gains in explosive efforts.

KEYWORDS: Endurance training, weight training, load-magnitude, sprint performance, jump performance, full squat training

INTRODUCTION

Concurrent training (CT) has become a contemporary topic for coaches, strength and conditioning professionals and researchers because a large number of sports require both strength and aerobic capacities for maximize performance (30,41,51). However, resistance and endurance trainings produce divergent metabolic and morphological adaptations with little overlap between them (12,41). Therefore, it seems necessary to find optimal combinations of both types of training regimes to obtain maximum simultaneous development of strength and endurance capacities.

Studies analyzing the neuromuscular adaptations and performance improvements associated with CT have reported inconsistent results. While concurrent training does not alter the ability to positively adapt to endurance training (6,51), most studies have indicated that CT regimens appear to inhibit strength, hypertrophy and power development compared with resistance training alone (15,18,27). Nevertheless, some experiments have reported little or no negative effect on strength gains with the addition of aerobic training (1,35,48).

In addition to large influence of the interindividual variation in response to a training program (25,32), the effects of CT on strength gains may vary markedly due to a large number of design factors, including the mode, frequency, duration, type of exercises, volume and intensity used during both resistance and aerobic training, different sequences and recovery times between resistance and aerobic training sessions, training history of participants, and dependent variables selected (13,29,51). The effect of most of these variables has already received considerable attention in previous studies and reviews (41,51). However, to the best of our knowledge, a question that remains ignored in the literature is the possibility of manipulating the load magnitude during resistance training.

In addition, most of resistance exercises used in studies analyzing the effect of CT on physical performance (3,7,15,18,23,25,27) were open-chain, isolated, isotonic or machine-based exercises (i.e. leg extension and flexion, seated hamstring curl, leg curl, leg press, isometric plantar flexion, calf rise). It appears that resistance training programs which preferably include open-chain exercises may not provide adequate movement pattern specificity for optimal performance improvements in closed-chain sporting movements such as running (2). Therefore, it has been indicated that future investigations should include traditional multi-joint resistance exercises because are believed to be superior for eliciting optimal neuromuscular adaptations and increasing the force capabilities of the leg musculature (2). Since (i) the training load seems to be the most important variable to consider when designing a resistance training program (11), and (ii) the exercises selected in a resistance training programme can influence the magnitude of neuromuscular adaptations (2), gains in strength and endurance variables during CT may be directly influenced by the load magnitude and exercise used during resistance training. Thus, the first aim of the present study was to analyze the effect of three CT programs that only differed in the load magnitude used during the full squat training on performance in vertical jumping, sprint, leg strength and endurance capacity.

Additionally, interruptions in training sessions due to several factors are normal in any sport (26,38,40,42). For this reason, knowing the effects of a detraining period (DT) could be important for designing better training strategies. The detraining adaptations following strength or endurance training alone have been widely studied in different populations (8,9,26,31,36) Unfortunately, the effect of training cessation after CT has received less scientific attention (4,45,46,49). Moreover, although abrupt cessation of intense physical training is associated with a decline of physical performance (38-40), detraining-induced changes in performance after concurrent training are linked with multiple factors

(16,31,36,46,49,50) among which is included the relative intensity used during previous resistance program. Therefore, the second aim of the present study was to analyze the effects of 4-week DT following concurrent training programs differing in load magnitude used during resistance training on different strength and aerobic parameters.

METHODS

Experimental Approach to the Problem

An experimental research design was used to compare the effects of three concurrent resistance and aerobic training programs only differing in load magnitude used during resistance training (40-55% 1RM vs. 55-70% 1RM vs. 70-85% 1RM) on physical performance, and the subsequence detraining adaptations. To address this, thirty-six male physically active men were randomly assigned to control group (CG) or resistance training group with low loads (LLG), moderate loads (MLG) or high load (HLG). The players assigned to experimental groups performed resistance training combined with endurance, while players assigned to CG merely undertook daily life activities. All the experimental groups trained twice a week for 8 weeks using a CT regimen. All subjects were evaluated using a battery of tests performed in two sessions separated by a 48 h rest interval. During the first testing session, the participants performed the 20 m running sprints and the 20 m shuttle run test. During the second testing session, subjects executed the countermovement vertical jump test (CMJ), and an isoinertial loading test in full squat exercise. During the 2 weeks preceding this study, four preliminary familiarization sessions were undertaken to ensure a proper execution technique in both full squat and CMJ exercises. To evaluate the DT effects, the strength and aerobic parameters were tested after four weeks of training cessation. Throughout this period, the participants were asked refrain from participating in regular exercise programs aimed at developing or maintaining strength and aerobic capacity.

Subjects

Thirty-six male physically active men volunteered to participate in this study. After an initial evaluation, the participants were matched according to their estimated one-repetition maximum ($1RM_{est}$) in full-squat exercises (FS) and then randomly assigned to four groups depending on the loading magnitude used during resistance training, as follows: i) a low-load group (LLG, 40-55% 1RM), a moderate-load group (MLG, 55-70% 1RM), a high-load group (HLG, 70-85% 1RM), and a control group (CG). Due to injury or illness, four participant (one from the HLG and three from the CG) were absent from the post-testing sessions. Thus, of the 36 initially enrolled participants, only 32 successfully completed the entire study. Player characteristics are displayed in **Table 1.** Participants in the CG were asked not to perform any type of resistance or aerobic training during the experimental period. All the participants provided written informed consent to the experimental procedures after the possible benefits and risks of participation were explained to them. The investigation was conducted in accordance with the Declaration of Helsinki and was approved by the local Research Ethics Committee.

Please insert Table 1 near here

Procedures

Neuromuscular performance was assessed before (Pre), after the 8-week training period (Post 1), and after the 4-week detraining period (Post 2) using a battery of tests performed in two sessions separated by a 48h rest interval. Testing sessions were performed at the same time of day for each participant under the same environmental conditions (~20°C and

~60% humidity). Body mass and height (Seca Instruments, Ltd., Hamburg, Germany) were measured prior to the warm-up protocol in the first testing session. Strong verbal encouragement was provided during all tests to motivate participants to give a maximal effort.

Running sprints: Each participant performed three 20m sprints separated by a 3min rest. Photocell timing gates (Brower photocells, Wireless Sprint System, USA) were placed at 0, 10 and 20m so that the times needed to cover 0-10m (T10) and 0-20m (T20) could be determined. A standing start with the lead-off foot placed 1 m behind the first timing gate was used. The average of the best two sprints was used for the analysis. Warm-up consisted of 5 minutes of running at a self-selected intensity, 5 minutes of joint mobilization exercises, followed by several sets of progressively faster 30-m running accelerations. Reliability for T20 as measured by the coefficient of variation (CV) was 3.8%, while the intra-class correlation coefficient (ICC) was 0.94.

Shuttle run test: The 20m multistage shuttle run test was administered according to the original version described by Léger (28). The initial running velocity was set at 8.5 $km \cdot h^{-1}$ and was gradually increased in 0.5 $km \cdot h^{-1}$ each minute (14). The test was terminated when a participant failed to reach the appropriate marker in the allotted time twice or could no longer maintain the pace. The number of laps completed was recorded. Estimated maximum oxygen consumption (VO_{2max}, $ml \cdot kg^{-1} \cdot min^{-1}$) was calculated based on the maximal speed (MAS) reached before participants were unable to keep up with the audio recording, as follows: $-27.4 + 6 \cdot MAS$ (28).

Vertical jump test: The jump height was determined using a contact mat connected to an electronic power timer, control box and handset (Globus Ergojump, Italy). Each participant performed three maximal CMJs with their hands on their hips, separated by 1min rests. The highest value was recorded for the subsequent analysis. The ICC was 0.96, and the CV was 3.2%.

Isoinertial squat loading test: A Smith machine (Multipower Fitness Line, Peroga, Murcia, Spain) was used for this test. A detailed description of the testing procedures used in this study was recently reported elsewhere (14). The initial load was set at 17 kg and progressively increased in 10 kg increments until the attained mean propulsive velocity (MPV) was ~1.00 $m \cdot s^{-1}$ (range 0.95-1.05$m \cdot s^{-1}$) (14). The participants performed 3 repetitions with each load, with 3min recovery. A linear velocity transducer (T-Force System, Ergotech, Murcia, Spain) was used to register bar velocity. The $1RM_{est}$ was calculated based on the MPV attained against the heaviest load lifted, as follows: $(100 \cdot \text{load})/(-5.961 \cdot MPV^2) - (50.71 \cdot MPV) + 117$ (44).

Training program

The descriptive characteristics of the training programs completed by each group are presented in **Table 2**. The resistance training session comprised full squat, vertical jump and sprint exercises. Approximately 2-3min rest periods were allowed between each set and exercise. The participants were instructed to perform all exercises at maximal intended velocity to obtain the highest possible gains (43). The loads used by each participant in the full squat exercise were assigned according to $1RM_{est}$ obtained in the initial isoinertial squat loading test. Thus, the relative intensity of the full squat exercise progressively increased from 40% to 55% 1RM, 55% to 70% 1RM, and 70% to 85% 1RM for LLG, MLG and HLG, respectively. Because strength was expected to increase with training, an intermediate isoinertial squat loading test was carried out after 4 weeks of training in order to perform the necessary load adjustments for each training group. Aerobic training was performed 20 min after the participants completed the resistance training. All the experimental groups completed the same aerobic training regimen, which consisted of 15-20 min performing the 20 m shuttle run exercise at 75% of the maximal individual speed reached during the 20 m multistage shuttle run test. As for strength training, participants were assessed in the 20 m shuttle run test after 4 weeks of training in order to perform the necessary adjustments for each training group. At least 2 trained researchers supervised each workout session and recorded the compliance and individual workout data during each training session. All participants were instructed to maintain their normal daily activities throughout the study. The participants did not undertake any additional strength or aerobic training activities during the testing, training, and detraining periods.

Please insert Table 2 near here

Statistical analysis

The values of each variable are presented as mean ± standard deviation (SD). Homogeneity of variance across groups (LLG vs. MLG vs. HLG vs. CG) was verified using the Levene test, whereas the normality of distribution of the data was examined with the Shapiro-Wilk test. A 4 (group: LLG, MLG, HLG, CG) x 3 (time: Pre, Post 1, Post 2) repeated measures analysis of variances (ANOVA) was calculated for each variable. Sphericity was checked using *Mauchly's* test. Percentage of change for each variable was calculated [(post – pre/pre) × 100] and a one-way ANOVA was conducted to examine between-group differences with *tukey* post-hoc comparisons (LLG vs. MLG vs. HLG vs. CG) to clarify the interaction. In addition to this null hypothesis testing, the data were assessed for clinical significance using an approach based on the magnitudes of change (20). The effect sizes (ES) were calculated using Cohen's *d* (9) to estimate the magnitude of the training effect on the selected neuromuscular variables within each group. The threshold values for assessing the magnitudes of the standardized effects were 0.20, 0.60, 1.20 and 2.00 for small, moderate, large and very large magnitudes, respectively. Probabilities were also calculated to establish whether the true (unknown) differences were lower than, similar to, or higher than the smallest worthwhile difference or change (0.2 multiplied by the between-subject SD) (20). The quantitative chances of obtaining higher or lower differences were evaluated as follows: 1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; 99%, almost certain. If the chances of having higher or lower values than the smallest worthwhile difference were both >5%, the true difference was assessed as unclear. Inferential statistics based on the interpretation of the magnitude of effects were calculated using a purpose-built spreadsheet for the analysis of controlled trials (19). The statistical analyses were performed using SPSS software version 18.0 (SPSS, Inc., Chicago, IL, USA). Statistical significance was established at the $p \leq 0.05$ level.

RESULTS

Data for all variables analyzed were homogeneous and normally distributed ($p > 0.05$). There were no significant differences between groups at baseline for any analyzed variable. The mean values, percentage of change and intra-group ES for all variables analyzed during Pre, Post 1 and Post 2 are reported in **Table 3** (LLG), **Table 4** (MLG), and **Table 5** (HLG).

Please insert Table 3 near here

Please insert Table 4 near here

Please insert Table 5 near here

All the experimental groups showed improvements ($p<0.05$ - 0.001) in all the variables assessed except the LLG in T10 and the HLG in T20 (**Tables 3, 4 and 5**). No changes took place in the CG. The magnitude of change for LLG was from *small* (T10, T20, $1RM_{est}$ and VO2max) to *moderate* (CMJ). For MLG, the standardized effects were *small* (T10, T20 and $1RM_{est}$) and *moderate* (CMJ and VO2max), whereas for HLG, the qualitative outcome relative to ES was *small* (T20 and $1RM_{est}$), moderate (T10 and VO2max) or large (CMJ), depending to the assessed variable.

After the training period, significant "time × group" interactions were observed for T10 ($p < 0.001$), CMJ ($p < 0.01$), $1RM_{est}$ ($p < 0.01$) and VO2max ($p < 0.001$), whereas there was no "time × group" interaction in T20 ($p = 0.349$). The one-way ANOVA indicated that all the experimental groups showed significantly greater percent changes from Pre to Post 1 for $1RM_{est}$ ($p < 0.05$ - 0.01) and VO2max ($p < 0.05$ - 0.05) compared to CG, whereas the HLG and MLG also showed greater percentage of change than CG in T10 ($p < 0.001$) and CMJ ($p < 0.05$), respectively (**Table 6**; **Figure 1**).

The 4-week DT period produced an important detriment effect on all the variables analyzed for all the experimental groups. Most of these variables returned to initial values or lower after the rest period (Tables 3, 4 and 5). In fact, no differences were found between Pre and Post 2 in any studied variable for any experimental group. In addition, no significant differences were found between the three-trained groups and the CG at Post 2 for any variable.

Please insert Table 6 near here

Please insert Figure 1 near here

DISCUSSION

To the best of our knowledge, this was the first study focused on analyzing the training and detraining effects after concurrent training programs differing in the relative intensity (%1RM) used during resistance training regime on strength and aerobic performance in physical active men. The main finding of the present study was that the all three experimental groups showed significant and practical improvements in different performance variables including jump, running sprint, maximal strength and VO_2max. Thus, it appears that resistance training programs consisting in full squat exercise with low (40 - 55% 1RM), moderate (55 - 70% 1RM), or high (70 - 85% 1RM) loads combined with the same low-intensity aerobic training (75% VO_2max) could be equally effective for producing significant gains in strength and endurance capacities. In addition, the DT period resulted in significant performance decrements in all variables assessed for all experimental groups. These results could be of great interest for coaches and strength and conditioning professionals to optimize training programs in those sports modalities to require combinations of both components of strength and endurance training for maximize performance.

Strength performance

All three experimental groups showed significant ($p < 0.05 - 0.01$) improvements in $1RM_{est}$ after training period. However, changes reported in LLG (13.9%; ES: 0.57), MLG (9.9%; ES: 0.40) and HLG (11.4%; ES: 0.47) were lower than those reported in previous studies (~20%) (15,23,35) and meta-analyses (ES:1.30) (51) that assessed the effects of CT on strength development in untrained male participants. Although have been described that continuous aerobic training would be predicted to have minimal interference on strength gains using either high load or moderate load resistance training protocols (6,13), it is possible that the short rest period between resistance and aerobic training in the present study (~20 min) may have induced a greater degree of interference than previous studies (51). Thus, our results confirmed the need to separate resistance and aerobic training sessions to optimize strength gains (13). In addition, the use of only one resistance exercise (full squat) has also been able to influence in the lower gains found in the present study compared to other studies (7,15,23,35) in which several resistance exercises were used (e.g., knee flexion and extension, leg curl, leg press, calf raise). Comparison between experimental groups showed no significant differences in strength gains between LLG, MLG and HLG. However, the analysis of practical inferences resulted in a *possible* better effect on $1RM_{est}$ for LLG compared to MLG and HLG. These results are in agreement with previous studies indicating that resistance training programs that include training with moderate to high loads and repetitions at or near the point of muscle failure lead to lower strength gains compared with the use of a moderate number of repetitions for not training to repetition failure (6,13,22,37).

Sprint and Vertical Jump Performance

Only few studies (5,21,34) have analyzed the effect of CT on jump performance, while, to the best of our knowledge, no studies have examined the influence of CT on running sprints in adult individuals. In the present study, all three combinations resulted in low-moderate improvements in CMJ (11.6 - 13.9%; ES: 0.61 - 1.27) and sprint times (1.0 - 3.5%; ES: 0.20 - 0.63). These improvements in CMJ were greater than previous studies conducted with untrained individuals (9.0 - 3.3%). Thus, although aerobic training (continuous and high-intensity run training) has been reported to cause deterioration in the capacity of the neuromuscular system to rapidly generate force (17), it appears that adding explosive exercises (jumps and accelerations) along with the full-squat exercise executing each repetition at maximal intended velocity could attenuate the interference on adaptations to short and high intensity efforts.

Regarding the load magnitude used during resistance training, the present study showed no significant differences for Pre-Post changes in jump and sprint variables between experimental groups. However, there was a slight trend toward greater intra-group ES for HLG compared with LLG and MLG in T10 and CMJ. In addition, HLG showed a *likely* greater effect than LLG and MLG in T10, while practically worthwhile difference was *possibly* more beneficial in favour of MLG compared to LLG. For the rest of comparisons, the differences between LLG, MLG and HLG were *unclear*. These results appear to be in contrast with a recent meta-analysis (47) which indicated that high-load resistance training alone resulted in lesser sprint ES (ES = 0.52) compared with lower loads (ES = 0.97). However, our results seem to indicate that, when resistance training is combined with continuous aerobic training, using moderate to high loads is more effective for improving jump and sprint performance than those with low loads.

Aerobic Performance

The training period resulted in similar improvements in VO_2max for all three experimental groups. These changes (~12 - 15%) were comparable to those reported in previous studies (~7 - 18%) performing CT or aerobic regimens alone (3,15,18,21,34). Therefore, although the present study did not include a group that underwent aerobic training alone, our results appear to be in line with previous reports, suggesting that CT does not affect the development of VO_2max in untrained or resistance-trained individuals. In addition, as a remarkable contribution of the present study, our results suggest that load magnitude used during resistance training do not effect on changes in aerobic performance, as no significant differences were found in VO_2max gains between LLG, MLG and HLG.

Detraining Effect

The DT period resulted in a marked and similar reduction in physical performance for all three experimental groups, with a partial (CMJ and $1RM_{est}$) or complete (T10, T20 and VO_2max) reversals of the adaptations obtained during 8-week training period. This is in accordance with previous studies that have shown important VO_2max declines (4-14%) with short-term training cessation in trained and untrained individuals (38). However, studies conducted with elementary school students using CT have shown both significant loss (45) and no changes (46) in this variable. In relation to sprint performance, several studies using a CT training period (36,45,46) have shown that the sprint time in 10, 20 and 30 m remained unchanged or only decreases slightly during the DT period. Discrepancies with our results could be due to differences in the age of the participants and the training program configurations (36,45,46).

According to several studies and review analyzing the effect of detraining period after CT training or resistance training alone (26,38), the loss of maximal strength (4 - 7%) and CMJ height (5 - 9%) in the present study were lower compared aerobic performance. Since CMJ performance depends largely on the maximal strength of the leg extensors (10,52), it is possible that the lower reduction in CMJ performance was associated with the maintenance of $1RM_{est}$. In accordance with our results, other studies have shown no significant changes in CMJ performance after 4-6 weeks of cessation of resistance training (24,26,33). However, it appears that when resistance training is combined with aerobic training, both maximal strength and CMJ height trend to descend to a greater extent after DT period (45,46).

The present study has some limitations need to be addressed. Obviously, one of the main limitations of the present study is the low number of subjects in each group. Thus, some effects are associated with large confidence limits for the intra- and between-group change differences. Therefore, we can not be sure whether differences within and between groups would have been clearer with a greater number of subjects in each experimental group. In addition, the present study evaluated the efficacy of aerobic training and a specific resistance training regimen consisting in full squat exercise alone. It is possible that the use of only one resistance exercise may have been a limitation for strength gains during CT. In addition, this type of resistance training has also been able to influence the degree of loss of physical performance during the DT period. However, since the main aim of the present study was to analyze the training and detraining effects of combined resistance training programs against three different external loads with the same aerobic training on strength and aerobic variables, we consider it appropriate not to include additional resistance exercises to avoid increasing the number of confounding factors such as number of exercises, rest time between exercises, type of exercises (e.g., multi-join vs. isolated, closed- vs. open-chain, isoinertial vs. isotonic), or fatigue accumulated. However, a comparison of the relative efficacy of different resistance training regimens combined with different aerobic training seems to be an interesting topic for future research. Finally, we should acknowledge that different participants, for instance, experienced ones could lead to other results and further investigation should also be developed in this regard.

CONCLUSIONS

In brief, the results of the present study indicated that 8-weeks of resistance training programs with different loads combined with low-intensity aerobic training improved strength and aerobic capacities, regardless of training intensity used during resistance training. Despite the similar improvements, resistance trainings with loads higher than 55%

of $1RM_{est}$ are suggested to increase changes in explosive efforts, such as short runs (T10 m) and CMJ. In addition, 4-weeks of DT compromised previous gains, mainly in VO_2max and sprint time variables.

PRACTICAL APPLICATIONS

The results seems to suggest that performing strength training with low, moderate, or high external loads combined with low-intensity aerobic training regimen is beneficial for strength and aerobic development in healthy adult men. Furthermore, choosing higher loads during strength training can lead to increased gains in explosive efforts. Despite our data highlight that 8-weeks of training are sufficient to verify enhancements, it takes only 4-weeks without training to return to the initial values. This should be considered when designing concurrent training in sports clubs to improve its efficiency. Thereupon, this experiment provides a new path in order to integrate both strength and aerobic regimens in the same session.

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FIGURE LEGENDS

Figure 1. Relative changes in performance variables (**A**: T10; **B**: T20; **C**: CMJ; **D**: $1RM_{est}$; **E**: VO2max) from baseline in the low-load (LLG), moderate-load (MLG), high-load (HLG) and control group. Error bars represent 90% of confidence interval of changes from baseline to post-training and baseline to detraining. Statistically significant differences respect to CG: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 1. Subject characteristics.

Variable	Group LLG (n = 8)	MLG (n = 9)	HLG (n = 9)	CG (n = 6)
Age (years)	20.6 ± 0.9	20.6 ± 1.6	20.6 ± 1.9	20.7 ± 2.3
Height (m)	1.80 ± 0.1	1.80 ± 0.0	1.80 ± 0.1	1.80 ± 0.1
Body Mass (Kg)	71.8 ± 8.3	68.5 ± 10.4	67.8 ± 4.6	70.1 ± 4.8

Values are mean± SD.

LLG: Low-load group; MLG: Moderate-load group; HLG: High-load group; CG: Control group

Table 2. Characteristics of the training program performed by the LLG, MLG and HLG groups.

	Sessions														
Exercise	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Full Squat (% 1RM: SxR)															
LLG	40:3x8	40:3x8	40:3x8	45:3x8	45:3x8	45:3x8	50:3x6	50:3x6	50:3x6	55:3x6	55:3x6	55:3x6	50:3x6	50:3x6	40:3x6
MLG	55:3x8	55:3x8	55:3x8	60:3x6	60:3x6	60:3x6	65:3x6	65:3x6	65:3x6	70:3x6	70:3x6	70:3x6	65:3x6	65:3x6	60:3x6
HLG	70:3x8	70:3x8	70:3x8	75:3x8	75:3x8	75:3x6	80:3x5	80:3x5	80:3x5	85:3x5	85:3x5	85:3x5	80:3x5	80:3x5	75:3x8
CMJ (SxR)	2x5	2x5	2x5	2x5	2x5	2x5	2x5	3x5	3x5	3x5	3x5	3x5	3x5	3x5	2x5
Sprint (SxD)	2x30m	2x30m	2x30m	3x30m	3x30m	3x30m	3x20m	3x20m	3x20m	4x20m	4x20m	4x20m	3x20m	3x20m	2x20m
20m Shuttle Run (T x %MAS)	15 min x 75%	15 min x 75%	15 min x 75%	15 min x 75%	20 min x 75%	20 min x 75%	20 min x 75%	20 min x 75%	15 min x 75%	15 min x 75%	15 min x 75%	15 min x 75%	20 min x 75%	20 min x 75%	20 min x 75%

LLG: Low-load group; MLG: Moderate-load group; HLG: High-load group; 1RM: One-repetition maximum; SxR: sets x repetitions; SxD: Sets x distance; Tx%MAS: Time (min) x percentage of the maximal speed reached for each participant during the 20 m multistage shuttle run test.

Table 3. Changes in selected neuromuscular performance variables from pre-training to post-training and detraining period for LLG.

Variable	Pre	Post 1	Post 2	Post 1 *vs.* Post 2			Post 1 *vs.* Post 3			Post 2 *vs.* Post 3		
				p-value	Δ (±90% CI)	ES (±90% CI)	*p*-value	Δ (±90% CI)	ES (±90% CI)	*p*-value	Δ (±90% CI)	ES (±90% CI)
T10 (s)	1.87 ± 0.11	1.84 ± 0.09	1.90 ± 0.10	0.148	-1.3 ± 1.0	0.20 ± 0.15	0.573	1.6 ± 2.0	-0.24 ± 0.31	0.129	2.9 ± 2.3	-0.44 ± 0.34
T20 (s)	3.21 ± 0.15	3.16 ± 0.16	3.22 ± 0.15	0.007	-1.5 ± 0.6	0.29 ± 0.12	1.000	0.5 ± 0.6	-0.09 ± 0.18	0.042	2.0 ± 1.2	-0.38 ± 0.22
CMJ (cm)	33.8 ± 5.1	37.7 ± 5.3	34.2 ± 5.1	0.002	11.6 ± 3.9	0.61 ± 0.19	1.000	1.3 ± 6.6	0.07 ± 0.36	0.077	-9.3 ± 6.4	-0.54 ± 0.33
$1RM_{est}$ (kg)	81.9 ± 17.0	92.4 ± 18.5	85.5 ± 16.0	0.004	13.9 ± 5.6	0.57 ± 0.22	0.058	5.8 ± 3.8	0.25 ± 0.16	0.018	-7.1 ± 3.4	-0.33 ± 0.16
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	41.0 ± 8.5	46.7 ± 7.2	42.2 ± 5.0	0.000	15.2 ± 5.0	0.56 ± 0.17	1.000	4.3 ± 9.6	0.17 ± 0.36	0.089	-9.5 ± 5.7	-0.40 ± 0.25

Data are mean ± SD

LLG: Low-load group; Pre: initial evaluation; Post 1: Evaluation after training period; Post 2: evaluation after detraining period; Δ: percentage of change; ES: intragroup effect size; CI: confidence interval; T10: 10-m sprint time; T20: 20-m sprint time; CMJ: countermovement jump; $1RM_{est}$: estimated one-repetition maximum; VO_2max: estimated maximal oxygen uptake.

Table 4. Changes in selected neuromuscular performance variables from pre-training to post-training and detraining period for MLG.

Variable	Pre	Post 1	Post 2	Post 1 *vs.* Post 2			Post 1 *vs.* Post 3			Post 2 *vs.* Post 3		
				p-value	Δ (±90% CI)	ES (±90% CI)	*p*-value	Δ (±90% CI)	ES (±90% CI)	*p*-value	Δ (±90% CI)	ES (±90% CI)
T10 (s)	1.83 ± 0.06	1.81 ± 0.07	1.87 ± 0.09	0.034	-1.0 ± 0.6	0.27 ± 0.15	0.174	2.0 ± 1.7	-0.51 ± 0.47	0.015	1.8 ± 0.9	-0.77 ± 0.33
T20 (s)	3.12 ± 0.12	3.05 ± 0.13	3.17 ± 0.11	0.003	-2.3 ± 0.8	0.56 ± 0.20	0.214	1.6 ± 1.4	-0.37 ± 0.33	0.009	4.0 ± 1.8	-0.92 ± 0.41
CMJ (cm)	34.2 ± 4.9	38.8 ± 3.8	36.6 ± 5.0	0.005	13.9 ± 6.4	0.85 ± 0.37	0.164	7.2 ± 6.6	0.46 ± 0.40	0.115	-5.9 ± 4.1	-0.40 ± 0.29
$1RM_{est}$ (kg)	84.2 ± 16.7	92.6 ± 18.6	89.5 ± 16.9	0.022	9.9 ± 4.7	0.40 ± 0.18	0.165	5.5 ± 4.6	0.23 ± 0.19	0.267	-4.0 ± 3.8	-0.17 ± 0.17
$VO_2max(ml·kg^{-1}·min^{-1})$	43.9 ± 6.8	49.0 ± 5.7	41.9 ± 6.7	0.001	12.1 ± 4.7	0.64 ± 0.23	0.591	-4.7 ± 5.4	-0.27 ± 0.31	0.001	-15.0 ± 4.8	-0.91 ± 0.31

Data are mean ± SD

MLG: Moderate-load group; Pre: initial evaluation; Post 1: Evaluation after training period; Post 2: evaluation after detraining period; Δ: percentage of change; ES: intragroup effect size; CI: confidence interval; T10: 10-m sprint time; T20: 20-m sprint time; CMJ: countermovement jump; $1RM_{est}$: estimated one-repetition maximum; VO_2max: estimated maximal oxygen uptake.

Table 5. Changes in selected neuromuscular performance variables from pre-training to post-training and detraining period for HLG.

				Post 1 *vs.* Post 2			Post 1 *vs.* Post 3			Post 2 *vs.* Post 3		
Variable	Pre	Post 1	Post 2	*p*-value	Δ (±90% CI)	ES (±90% CI)	*p*-value	Δ (±90% CI)	ES (±90% CI)	*p*-value	Δ (±90% CI)	ES (±90% CI)
T10 (s)	1.87 ± 0.09	1.81 ± 0.09	1.87 ± 0.06	0.013	-3.6± 1.7	0.63± 0.31	1.000	0.1± 2.1	-0.01± 0.37	0.035	3.8 ± 2.2	-0.65± 0.37
T20 (s)	3.12 ± 0.12	3.07 ± 0.10	3.14 ± 0.07	0.153	-1.6 ± 1.3	0.37± 0.31	0.906	0.9 ± 1.4	-0.20± 0.33	0.037	2.5 ±1.5	-0.56± 0.34
CMJ (cm)	34.7 ± 3.0	39.0 ± 4.1	36.9 ± 4.5	0.002	12.3 ± 4.4	1.27 ± 0.43	0.259	5.9± 6.0	0.63± 0.62	0.300	-5.7± 5.5	-0.64 ± 0.64
$1RM_{est}$ (kg)	85.3 ± 17.3	94.6 ± 16.2	90.4 ± 17.2	0.003	11.4 ± 4.6	0.47 ± 0.18	0.071	6.2 ± 4.4	0.26± 0.44	0.085	-4.7 ± 3.5	-0.21± 0.16
$VO_2max(ml \cdot kg^{-1} \cdot min^{-1})$	43.6 ± 4.4	48.9 ± 4.5	44.5 ± 6.0	0.000	12.2 ± 2.8	1.00 ± 0.22	1.000	1.7 ± 5.2	0.15± 0.45	0.011	-9.4 ± 4.4	-0.86± 0.42

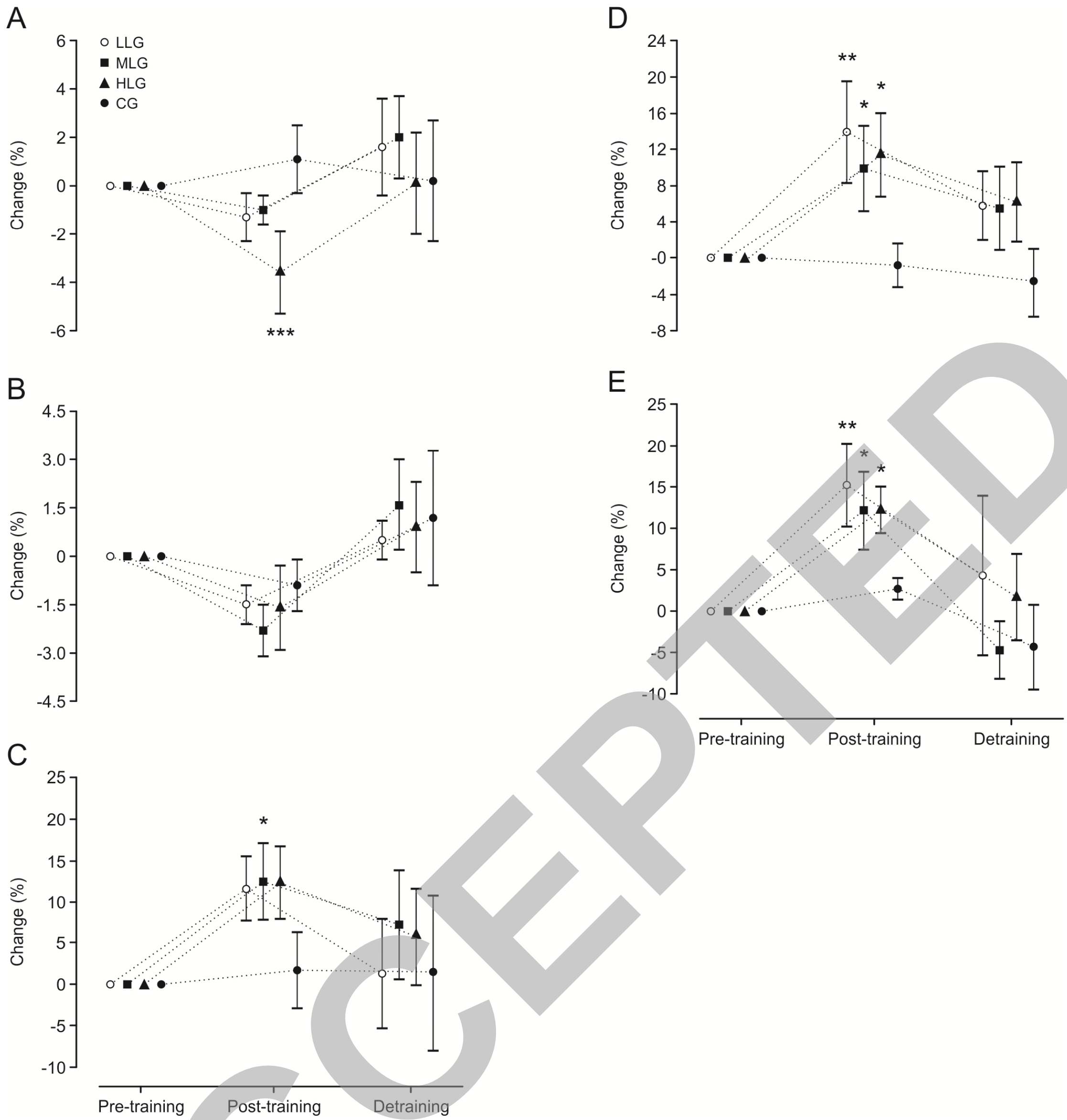
Data are mean ± SD

HLG: High-load group; Pre: initial evaluation; Post 1: Evaluation after training period; Post 2: evaluation after detraining period; Δ: percentage of change; ES: intragroup effect size; CI: confidence interval; T10: 10-m sprint time; T20: 20-m sprint time; CMJ: countermovement jump; $1RM_{est}$: estimated one-repetition maximum; VO_2max: estimated maximal oxygen uptake.

Table 6. Changes in selected neuromuscular performance variables from initial evaluation (pre) to final evaluation (post) between groups.

		Changes observed for post- vs. pre		
	P value between groups	Standarized differences (Cohen: 90% CI)	Percent changes of better/trivial/ worse effect	
T10				
LLG vs. CG	0.148	0.38 (0.13 to 0.63)	89/11/0	Likely
MLG vs. CG	0.254	0.43 (0.14 to 0.71)	91/9/0	Likely
HLG vs. CG	0.000	0.80(0.45 to 1.16)	99/1/0	Very Likely
LLG vs. MLG	1.000	0.05 (-0.16 to 0.25)	11/87/3	Likely Trivial
LLG vs. HLG	0.108	-0.40 (-0.72 to -0.07)	0/15/85	Likely harmful
HLG vs. MLG	0.057	0.52 (0.15 to 0.88)	93/7/0	Likely
T20				
LLG vs. CG	1.000	0.11 (-0.06 to 0.28)	18/81/0	Likely Trivial
MLG vs. CG	0.436	0.29 (0.08 to 0.49)	77/23/0	Likely
HLG vs. CG	1.000	0.14 (-0.14 to 0.42)	35/62/3	Unclear
LLG vs. MLG	1.000	-0.19 (-0.39 to 0.02)	0/54/46	Possibly harmful
LLG vs. HLG	1.000	-0.03 (-0.32 to 0.27)	10/75/15	Unclear
HLG vs. MLG	1.000	-0.18 (-0.54 to 0.17)	5/49/46	Unclear
CMJ				
LLG vs. CG	0.159	0.50 (0.22 to 0.78)	96/4/0	Very Likely
MLG vs. CG	0.031	0.67 (0.28 to 1.05)	97/3/0	Very Likely
HLG vs. CG	0.093	0.69 (0.31 to 1.08)	98/2/0	Very Likely
LLG vs. MLG	1.000	-0.13 (-0.52 to 0.26)	8/55/37	Unclear
LLG vs. HLG	1.000	-0.04 (-0.41 to 0.32)	13/64/23	Unclear
HLG vs. MLG	1.000	-0.12 (-0.65 to 0.41)	15/45/40	Unclear
$1RM_{est}$				
LLG vs. CG	0.004	0.48 (0.30 to 0.66)	99/1/0	Very Likely
MLG vs. CG	0.043	0.36 (0.20 to 0.53)	95/5/0	Likely
HLG vs. CG	0.016	0.41 (0.25 to 0.58)	98/2/0	Very Likely
LLG vs. MLG	1.000	0.16 (-0.11 to 0.43)	39/59/2	Possibly
LLG vs. HLG	1.000	0.10 (-0.17 to 0.37)	26/71/3	Possibly
HLG vs. MLG	1.000	0.06 (-0.19 to 0.31)	17/79/4	Likely Trivial
VO_2max				
LLG vs. CG	0.004	0.54 (0.33 to 0.74)	99/1/0	Very Likely
MLG vs. CG	0.035	0.54 (0.28 to 0.80)	98/2/0	Very Likely
HLG vs. CG	0.037	0.73 (0.51 to 0.95)	100/0/0	Most Likely
LLG vs. MLG	1.000	0.13 (-0.14 to 0.39)	32/66/2	Possibly
LLG vs. HLG	1.000	0.14 (-0.11 to 0.39)	34/64/2	Possibly
HLG vs. MLG	1.000	0.00 (-0.31 to 0.32)	15/71/14	Unclear

CI: confidence interval; LLG: Low-load group; MLG: Moderate-load group; HLG: High-load group; CG: Control group; T10: 10-m sprint time; T20: 20-m sprint time; CMJ: countermovement jump; $1RM_{est}$: estimated one-repetition maximum; VO_2max: estimated maximal oxygen uptake. *Note*: all differences are presented as improvements for the first group compared with the second group (i.e., LLG vs. CG), so that negative and positive differences are in the same direction.


A
B
C
D
E
LLG
MLG
HLG
CG
Change (%)
Pre-training
Post-training
Detraining