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Original Research

Chronic Effects of Heavy Load Activity Performed Before Resistance Training Sessions on the Physical Performance of Youth Soccer Players

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ABSTRACT

International Journal of Exercise Science 14(6): 1421-1434, 2021. The adoption of resistance training (RT) programs has been shown to positively influence sports performance-related parameters. However, the chronic effects of maximal strength protocols on the performance of soccer players are not completely investigated. The aim of this study was to evaluate the effects of performing two repetition maximum (2RM) before a resistance training session on the physical performance of youth soccer players. Seventeen players (under-20 category) were allocated in one of the following groups: 2RM + resistance training group (2RM + RT, n = 8) and resistance training group (RTG, n = 9). Both groups performed the same RT protocol during experimental weeks. However, the 2RM + RT performed 1 set of 2RM for 4 exercises, previously to RT protocol. Pre and post intervention period, one repetition maximum of the back squat exercise ($1RM_{SQUAT}$), sprint time (15m-sprint test), countermovement jump (CMJ), repeated sprint ability (RSA_{BEST} and RSA_{MEAN}), and yo-yo intermittent recovery test level- 2 (YYIRT2) were assessed. Total load lifted (TLL) during the experimental weeks was also collected. Significant increases in $1RM_{SQUAT}$ (2RM + RT: +45.1%, d = 4.40; RTG: +32.3%, d = 1.84), 15m sprint (2RM + RT: -9.0%, d = 7.9; RTG: -8.8%%, d = 3.2), CMJ (2RM + RT: +2.3%, d = 0.17; RTG: +0.8%, d = 0.07), RSA_{BEST} (2RM + RT: -2.4%, d = 0.6; RTG: -2.3%, d = 1.04), RSA_{MEAN} (2RM + RT: -2.9%, d = 1.33; RTG: -3.4%, d = 1.78), YYIRT2 (2RM + RT: +12.0%, d = 0.82; RTG: +12.1%, d = 0.63) (all p < 0,05) were observed for both groups on pre to post-intervention periods, with no significant difference between groups. Therefore, the 2RM + RT protocol did not promote additional increase on performance of young soccer players.

KEY WORDS: Maximal strength, soccer, jumping, sprint

INTRODUCTION

Soccer is a high-intensity intermittent exercise, which involves movements such as kicking, jumping and running, which is based on explosive actions (4, 36). High-level soccer players share importance between strength, power and endurance (4, 18, 39). In addition to technical and tactical training skills, soccer players normally need to develop a higher level of athleticism, compromising strength, power and speed, in order to reach an optimal performance during a match (20). In this sense, the adoption of strength and conditioning activities has gained an increased attention to professionals engaged in this sport modality (39).

Previous studies have described that a structured resistance training program (RT) is able to induce a significant improvement in physical capabilities that positively influence the performance of soccer, especially regarding modality-specific actions (35). Indeed, a strong correlation between maximal strength of lower limbs, sprint (r = 0.94) and jumping (r = 0.78) performance in soccer players has been previously reported (41). Additionally, endurance performance also seems to be positively influenced by the adoption of regular RT with improved running economy (17). Then, through inductive reasoning, it can be suggested that increased strength levels induced by a RT schedule could represent relevant advantages for soccer players involved in a competitive context.

Despite the evidence supporting the acute effects of heavy resistance exercises on improving subsequent neuromuscular performance (e.g. explosive tasks and sprinting) (25, 43), there is limited research investigating its eventual chronic effects. In addition, competitive soccer teams usually dispose of short time available to physical training sessions, in this case, only 5 weeks of pre-season training camp. Thus, the aim of the present study was to evaluate the effects of adding a maximal strength protocol to a strength-endurance regular training session in strength, power and sprint performance of junior soccer players for 5 weeks. The hypothesis was that a significant higher adaptation would be observed in the group performing the additional maximal strength protocol (37).

METHODS

Participants

Seventeen male soccer players (sub-20 category) volunteered to participate in this study. We used the difference in total load lifted (TLL [2RM + RT vs. RTG]) of one pilot session as the main outcome for the sample size calculation. To achieve an effect size of 0.90, an alpha of 0.05, and a power of 0.95 the minimum sample required was 16 subjects (8 subjects/group). All participants were engaged in a regular specific modality-training (physical/technical/tactical) for more than 2 years and presented a minimal 1-year experience with RT. Moreover, participants were free from any existing musculoskeletal disorders; history of injury with residual symptoms in the trunk, upper and lower limbs within the last year and stated they had not taken any ergogenic aid for a minimum period of 12 months. Out of 20 male soccer players, 17 completed the study: 2 subjects in the 2RM + RT group and 1 in the RTG group discontinued the study (Table 1). The reasons for discontinuation were the development of respiratory tract infection (1 reported case) and incomplete data collection (2 reported cases). All procedures were in accordance with the Declaration of Helsinki and were carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (27). This study was approved by the university research ethics committee (protocol 80/12). All participants or their parents/guardians (for under-age athletes) read and signed an informed consent document.

Protocol
The present study was a randomized clinical trial. Participants were pair-matched according to baseline maximal strength values of the parallel back squat exercise and then randomly assigned to 1 of the 2 experimental groups: Two Maximum-Repetitions + Resistance Training (2RM + RT, n = 8), or Resistance Training Group (RTG, n = 9). Both groups performed the same RT protocol during the experimental weeks. However, 4 exercises, with a 2RM corresponding load, were performed previously to the RT protocol in all training sessions (see training program) in the 2RM + RT group. The experimental period lasted 7 weeks and was performed during the pre-competition phase of the year: 1st week – familiarization period and pre-intervention measures (baseline); 2nd - 6th week –training intervention period; 7th week – post-intervention measures. Testing was carried out during pre- and post-intervention periods in the following order: maximal voluntary muscle strength (1 repetition maximum [RM] test for the parallel back squat exercise), 15 meters-sprint test, jump height (countermovement jump [CMJ]), repeated sprint ability (RSA) and yo-yo intermittent recovery test level 2 (YYIRT2). Each test was separated by a 24-hour period. The total load lifted (TLL) of all exercises was also collected through the following equation: number of sets x number of repetitions x external load (kg). Participants were submitted to a familiarization period (1st week) in order to calculate the absolute loads that would be adopted in each exercise during the training period. The values of the absolute load were initially estimated by the subjects according to previous experience and determined under observation by an experienced professional during familiarization. During the intervention period, adjustments of 5 - 10% were adopted whenever the participants failed to perform the target repetition number. In addition to the RT sessions, during the 5-week intervention period, participants from both groups also performed technical/tactical training and small-sided games sessions twice weekly (see table 1).

The 2RM + RT protocol consisted of 1 set of 4 exercises/session (back squat, leg press 45°, front lat pull down, barbell bench press), with a corresponding load of 2RM, calculated during the familiarization period (week 1). A 4 min-rest interval was adopted between sets and exercises (32). The RTG protocol consisted of 3 sets of 8 exercises/session (back squat, leg press 45°, front lat pull down, barbell bench press, lunge, shoulder press, stiff-leg deadlift and calf raise) with a corresponding load of 10RM. A 1 min-rest interval was adopted between sets and exercises (32). A 4 min-rest interval was adopted between the maximal strength (1 x 2RM) and strength-endurance (3 x 10RM) protocols. Participants were instructed to perform each exercise with a full range of motion and the cadence of repetitions should be conducted in a controlled fashion, with concentric and eccentric actions of approximately 1.5 seconds, for total repetition duration of approximately 3 seconds. All sets were carried out to the point of concentric muscular failure. All routines were directly supervised by the research assistants to ensure the correct performance of the respective routines. Training loads were adjusted after each set when necessary. All training sessions were performed during the morning period.

The participants performed small-sided games during the intervention period, with 6 games in the first two weeks lasting 4 minutes with 2 min of passive rest-interval between each game. In weeks 3 and 4, athletes played 8 games of 4 minutes and a 2 minutes' interval between games. Field measurements were 24x36m. Each team was composed of 5 players, which were not allowed to touch the ball more than twice each time. In addition, athletes received verbal encouragement from coaches in order to ensure an intensity of effort ranging from 6 – 8 arbitrary units (A.U.) according to a rate of perceived exertion (RPE) scale (9). All sessions were performed during the afternoon period.

The sessions consisted of attack vs. defense activities, simulations of offensive gameplay and defensive actions, and soccer specific technical/tactical training, with a total of 19 minutes per session. All sessions were performed during the morning period.

Table 1. Weekly distribution of training sessions for 2RM + Resistance training (2RM + RT) and Resistance training (RTG) groups.

Protocols	Days	Week 1	Week 2	Week 3	Week 4	Week 5
2RM + RT *n* = 8	Mon	Resistance Training (2RM + 3 x 10RM)	Resistance Training (2RM + 3 x 10RM)	Resistance Training (2RM + 3 x 10RM)	Resistance Training (2RM + 3 x 10RM)	Resistance Training (2RM + 3 x 10RM)
	Tue	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (8 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (8 x 4′ rest:2′) (RPE: 6-8 a.u.)
	Wed	Resistance Training (2RM + 3 x 10RM)	Resistance Training (2RM + 3 x 10RM)	Resistance Training (2RM + 3 x 10RM)	-	Resistance Training (2RM + 3 x 10RM)
	Thu	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (8 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (8 x 4′ rest:2′) (RPE: 6-8 a.u.)
	Fri	Resistance Training (2RM + 3 x 10RM)	Resistance Training (2RM + 3 x 10RM)	Resistance Training (2RM + 3 x 10RM)	Resistance Training (2RM + 3 x 10RM)	-
RTG *n* = 9	Mon	Resistance Training (3 x 10RM)	Resistance Training (3 x 10RM)	Resistance Training (3 x 10RM)	Resistance Training (3 x 10RM)	Resistance Training (3 x 10RM)
	Tue	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (8 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (8 x 4′ rest:2′) (RPE: 6-8 a.u.)
	Wed	Resistance Training (3 x 10RM)	Resistance Training (3 x 10RM)	Resistance Training (3 x 10RM)	-	Resistance Training (3 x 10RM)
	Thu	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (6 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (8 x 4′ rest:2′) (RPE: 6-8 a.u.)	TT (90 min.) SSG (8 x 4′ rest:2′) (RPE: 6-8 a.u.)
	Fri	Resistance Training (3 x 10RM)	Resistance Training (3 x 10RM)	Resistance Training (3 x 10RM)	Resistance Training (3 x 10RM)	-

Note: **2RM + RT** = two maximal repetitions + resistance training group**;** **RTG** = resistance training group **TT:** technical and tactical training; **SSG:** Small-Sided Games; **RPE** = rating of perceived exertion; **a.u.**= arbitrary units.

1 RM_{SQUAT}: Lower-body maximum strength was assessed through 1RM testing in the parallel back squat ($1RM_{SQUAT}$) exercise. Subjects reported to the laboratory having refrained from any exercise other than activities of daily living for at least 48 hours before baseline testing and at least 48 hours before testing at the conclusion of the study. Maximum strength testing was performed according to the recommendations of Brown and Weir (6). Prior to testing, subjects performed a general warm-up consisting of 5 minutes cycling (Schwinne. AC Sport) at 60-70 rpm and 50W. Then, a specific warm-up set of the given exercise of 5 repetitions was performed at ~50% 1RM followed by 1 to 2 sets of 2–3 repetitions at a load corresponding to ~60–80% 1RM. Subjects then performed sets of 1 repetition of increasing weight for 1RM determination. The external load was adjusted by ~5-10% in subsequent attempts until the subject was unable to complete 1 maximal concentric muscle action. The 1RM was considered the highest external load lifted. A 3- to 5-minute rest was afforded between each successive attempt. All 1RM determinations were made within 5 attempts. Participants were required to squat down so that the top of the thigh was parallel to the ground (~90 degrees of knee joint flexion) for the attempt to be considered successful. A manual goniometer was used (Carci ind.; Sao Paulo; Brazil). Verbal encouragement was provided by the researchers. The data were expressed as kilograms (kg). The CV and TEM for $1RM_{SQUAT}$ were 0.9% and 2.10 kg, respectively.

15-m sprint: On a grass field, athletes performed a 15-m sprint. Participants began the test in a static position 0.5 m behind an automatic starting gate of photoelectric cells (photocells CEFISE® Standard, Nova Odessa, São Paulo, Brazil) and the finishing time was recorded by the split gate placed 15 m after the starting gate. Each athlete performed 3 attempts with a rest interval of 1 min. The best time (lowest value) was used for statistical analysis. Verbal encouragement was provided for each attempt. The data were expressed in seconds (s). The Coefficient of Variation (CV) and the typical error of measurement (TEM) for the 15m-Sprint test were 3.0% and 0.08 s, respectively.

Countermovement jump (CMJ): In order to measure the power of lower limbs, athletes performed a CMJ with arm swing on a force plate (CEFISE®, Ergojump Jump Pro 2.0; CEFISE, Nova Odessa, São Paulo, Brasil). All participants performed 3 attempts (interspaced by 1 min each) and the jump height was determined. The highest value was considered for analysis. An initial stand-up/extended legs position was adopted and, after a verbal stimulus, the participants performed the jump. The data were expressed in centimeters (cm). The CV and TEM for the CMJ were 5.0% and 0.6 cm, respectively.

Repeated sprint ability (RSA): The protocol previously described by Rampinini et al (29), consisted of 6 sprints of 40m (20 x 20) with a 20 second interval between sprints. The time of each sprint was recorded by a pair of photocells devices (CEFISE® Standard Photocells, Brazil). The tests were performed in an official soccer field. Athletes wore standard training clothes and cleats. The average (RSA_{MEAN}) and best (RSA_{BEST}) values of the 6 sprints were consider for statistical analysis. The data were expressed in seconds (s). The CV and TEM for RSA_{MEAN} and RSA_{BEST} were 2.9% / 0.06s and 3.5% / 0.08s, respectively.

Yo-yo intermittent recovery test level 2 (YYIRT2): The participants were instructed to perform interval sprints (20 x 20m) with a cadence set by an audio metronome, with standard rest interval between sprints (10s rest). The speed was increased progressively and the test was finished when the athlete was unable to maintain the required cadence. The maximum distance reached by each participant was recorded for analysis (3). The data were expressed in meters (m). The CV and TEM for *Yo-Yo* IR2 were 4.2% and 51m, respectively.

TLL: The external training loads of each training session (sets x repetitions x external load (12) were calculated from training logs filled out by research assistants in each one of the 8 exercises performed during the experimental protocol. The data were expressed in kilograms (kg).

Statistical Analysis
The normality and homogeneity of the variances were verified using the Shapiro-Wilk. The mean, standard deviation (SD) and 95% confidence intervals (CI) were used after data normality was assumed. To compare two means values of the descriptive variables (TLL) between-groups (2RM + RT vs. RTG) a paired *t*-test was used. A repeated measures analysis of variance (ANOVA) was used to compare Sprint 15m, CMJ, $1RM_{SQUAT}$, RSA_{MEAN}, RSA_{BEST} and YYIRT2 time effect (pre vs post week 5) x two groups (2RM + RT vs RTG). Post hoc comparisons were performed with the Bonferroni correction. Assumptions of sphericity were evaluated using Mauchly's test. Where sphericity was violated ($p < 0.05$), the Greenhouse–Geisser correction factor was applied (40).

Effect sizes in absolute differences (pre vs post 5 week) in raw values of the variables using the standardized difference based on Cohen's *d* units by means (*d* value) (11). The *d* results were qualitatively interpreted using the following thresholds: < 0.2, trivial; 0.2 - 0.6, small; 0.6 - 1.2, moderate; 1.2 - 2.0, large; 2.0 - 4.0, very large and; > 4.0, extremely large (19). To assess whether the observed differences could be considered real, changes were compared to their calculated smallest worthwhile chance (SWC) for all dependent variables (38). SWC was calculated by the formula (SWC = typical error measurement x 2). We defined an individual as "responding" positively to training with a response greater than +1SWC from zero for increases in dependent variables; if not, he was considered as non-responded. Percentage of subjects exceeding the SWC were calculated for all dependent-variables (24). SWC values were Sprint 15m = 0.16 s, CMJ = 1.2 cm, $1RM_{SQUAT}$ = 4.2 kg, RSA_{MEAN} = 0.12 s, RSA_{BEST} = 0.16 s and YYIRT2 = 102 m. SWC area (gray bar) was used in Forest Plot Graph. Absolute change analyses (Δ = post – pre) between groups for dependent-variables were performed employing unpaired *t* tests and ES in this case was calculated using the standardized difference, based on Cohen's *d* units by means (*d* value) (11). All analyses were conducted in SPSS-22.0 software (IBM Corp., Armonk, NY, USA). The adopted significance was $P \leq 0.05$. The figures were formatted in GraphPad Prism version 6.0 software (La Jolla, CA, USA) following the assumptions for continuous data.

RESULTS

No significant difference was observed for any baseline measurements between both groups ($p > 0.05$) (Table 2). In addition, both groups presented a similar number of athletes from each position (1 and 1 full back, 1 and 1 center back, 2 and 3 midfielders, 2 and 2 wide midfielder, 2 and 2 strikers, for 2RM+RT and RTG, respectively). All participants completed the whole intervention period, with relative training adherence of 98.2% and 99.1% for 2RM+RT and RT groups, respectively.

Table 2: Baseline descriptive statistics (mean ±SD).

Variables	2RM + RT (*n* = 8)	RTG (*n* = 9)	*p* value
Age (years)	18.1 ± 0.6	18.2 ± 0.5	0.341
Total Body Mass (kg)	72.3 ± 8.1	72.1 ± 8.0	0.458
Fat Mass (%)	6.6 ± 2.9	6.4 ± 2.8	0.367
Height (cm)	175 ± 4	177 ± 5	0.273
Training Experience (years)	5.0 ± 2.2	4.8 ± 2.6	0.322
Training Frequency (sessions $\cdot wk^{-1}$)	4.1 ± 0.6	4.2 ± 0.6	0.584
$1RM_{SQUAT}$ relative ($BM \cdot kg^{-1}$)	1.42 ± 0.3	1.39 ± 0.2	0.283

Legend: 2RM + RT = two maximal repetitions + resistance training group; RTG = resistance training group, $1RM_{SQUAT}$ relative = 1 repetition maximum in squat exercise relative to body mass.

A significant main effect of time ($F_{1,7}$ = 456.077, p = 0.001, η^2_p = 0.985), but not group x time interaction ($F_{1,7}$ = 0.012, p = 0.915, η^2_p = 0.002), was observed for Sprint 15m. There was no significant difference in time ($F_{1,7}$ = 0.574, p = 0.473, η^2_p = 0.076), and group x time interaction ($F_{1,7}$ = 0.553, p = 0.481, η^2_p = 0.073) for CMJ. A significant main effect of time ($F_{1,7}$ = 72.210, p = 0.001, η^2_p = 0.912), but not group x time interaction ($F_{1,7}$ = 2.044, p = 0.196, η^2_p = 0.226), was observed for $1RM_{SQUAT}$.

There was a significant main effect of time ($F_{1,7}$ = 29.826, p = 0.001, η^2_p = 0.810), but not group x time interaction ($F_{1,7}$ = 0.211, p = 0.660, η^2_p = 0.029) for RSA_{MEAN}. A significant main effect of time ($F_{1,7}$ = 7.231, p = 0.031, η^2_p = 0.508), but not group x time interaction ($F_{1,7}$ = 0.007, p = 0.935, η^2_p = 0.001), was observed for RSA_{BEST}. There was a significant main effect of time ($F_{1,7}$ = 51.800, p = 0.001, η^2_p = 0.881), but not group x time interaction ($F_{1,7}$ = 0.0001, p = 0.994, η^2_p = 0.001) for YYIRT2 (Table 3).

A large percentage of subjects responding positively to training was observed in $1RM_{SQUAT}$ (2RM + RT = 100.0%; RTG = 88.89%), RSA_{MEAN} (2RM + RT = 75.0%; RTG = 88,89%) and YYIRT2 (2RM + RT = 75.0%; RTG = 77.78%). In RTG, 15m- Sprint and RSA_{BEST} responded with identical values (RTG = 55.56% both); however, 2RM + RT responded more positively in 15m-Sprint (2RM + RT = 87.50%) and RSA_{BEST} (2RM + RT = 50%). A low percentage of subjects displayed a change in CMJ (2RM + RT = 37.5%; RTG = 22.22%) (Figure 1). In this case, the mean difference observed for CMJ cannot be considered relevant (figure 1, RTG = 0.4 cm and 2RM + RT = 1.2 cm), as this change was not greater than the SWC (1.2 cm).

Table 3. Pre and post – 5 week measures (mean ±SD).

Variables	Pre	Post 5 weeks	Δ%	ES (*d*)	MD (CI95%)
Sprint 15m (s)					
2RM+RT	2.13 ± 0.03	1.94 ± 0.02ᴬ	-8.9	7.45***	-0.19 (-0.12 to -0.26)
RTG	2.15 ± 0.05	1.96 ± 0.07ᴬ	-8.8	3.12***	-0.19 (-0.05 to -0.33)
CMJ (cm)					
2RM+RT	54.8 ± 8.1	56.0 ± 6.8ᴬ	2.2	0.16	1.2 (0.8 to 1.6)
RTG	49.4 ± 4.8#	49.8 ± 6.8ᴬ	0.8	0.07	0.4 (0.1 to 0.7)
$1RM_{SQUAT}$ (kg)					
2RM+RT	113 ± 10	163 ± 13ᴬ	44.2	4.31***	51 (38 to 64)
RTG	112 ± 14	148 ± 24ᴬ	32.1	1.83**	36 (6 to 56)
RSA_{MEAN} (s)					
2RM+RT	7.63 ± 0.17	7.41 ± 0.16ᴬ	-2.9	1.33**	-0.22 (-0.14 to -0.30)
RTG	7.77 ± 0.17	7.50 ± 0.12ᴬ	-3.5	1.83**	-0.26 (-0.20 to -0.32)
RSA_{BEST} (s)					
2RM+RT	7.17 ± 0.25	7.00 ± 0.31ᴬ	-2.4	0.60*	-0.17 (-0.11 to -0.23)
RTG	7.25 ± 0.14	7.08 ± 0.18ᴬ	-2.3	1.05*	-0.17 (-0.13 to -0.21)
YYIRT2 (m)					
2RM+RT	1500 ± 186	1680 ± 249ᴬ	12.0	0.82*	180 (121 to 239)
RTG	1503 ± 267	1684 ± 306ᴬ	12.0	0.63*	181 (116 to 246)

CMJ = countermovement jump; $1RM_{SQUAT}$ = one maximal repetition test in parallel back squat exercise; RSA_{MEAN} = mean sprint time; RSA_{BEST} = best sprint time; YYIRT2 = yo-yo intermittent recovery test level 2; 2RM + RT = two maximal repetitions + resistance training group; RTG = resistance training group; ES = effect size moderate*, large**, very large***; MD (IC95%) = mean difference (confidence interval 95%).
ᴬ Significantly different than the corresponding pre-intervention value ($p < 0.05$).
# $p < 0.05$ vs 2RM + RT pre value.

Between-group ES (2RM + RT vs RT): ES in absolute differences post 5 weeks – pre between 2RM + RT vs RTG was trivial for Sprint 15m (0.06, IC 90% = -0.14 to 0.26), RSA_{BEST} (0.01, IC 90% = -31 to 0.33) and YYIRT2 (-0.01, IC 90% = -0.29 to 0.28), small for CMJ (-0.24, IC 90% = -0.44 to 0.04) and RSA_{MEAN} (-0.29, IC 90% = -0.64 to 0.03) and moderate to $1RM_{SQUAT}$ (-0.77, IC 90% = -.07 to -.44). All $p > 0.05$ in absolute differences post 5 weeks – pre between groups.

Training Load: No significant between-group difference was noted in any TLL variables when excluded 2 RM exercises ($p = 0.120$) (Figure 2). The descriptive values in TLL Total 3 x 10RM were: 2RM + RT = 409629 ± 14546 kg vs RTG = 413690 ± 10211 kg (Δ = 1.0%) (Figure 2). In 5 weeks, group 2RM + RT lifted in 2RM squat 3354 ± 350 kg, 2RM bench press 1875 ± 132 kg, 2RM leg press 10710 ± 632 kg and 2RM pulldown 2041 ± 157 kg. When comparing the sum of 2RM with the other exercises (634400 ± 23202 kg) there was a significant difference between groups ($p = 0.001$; Δ = 63.6%) (Figure 2 – gray bar).

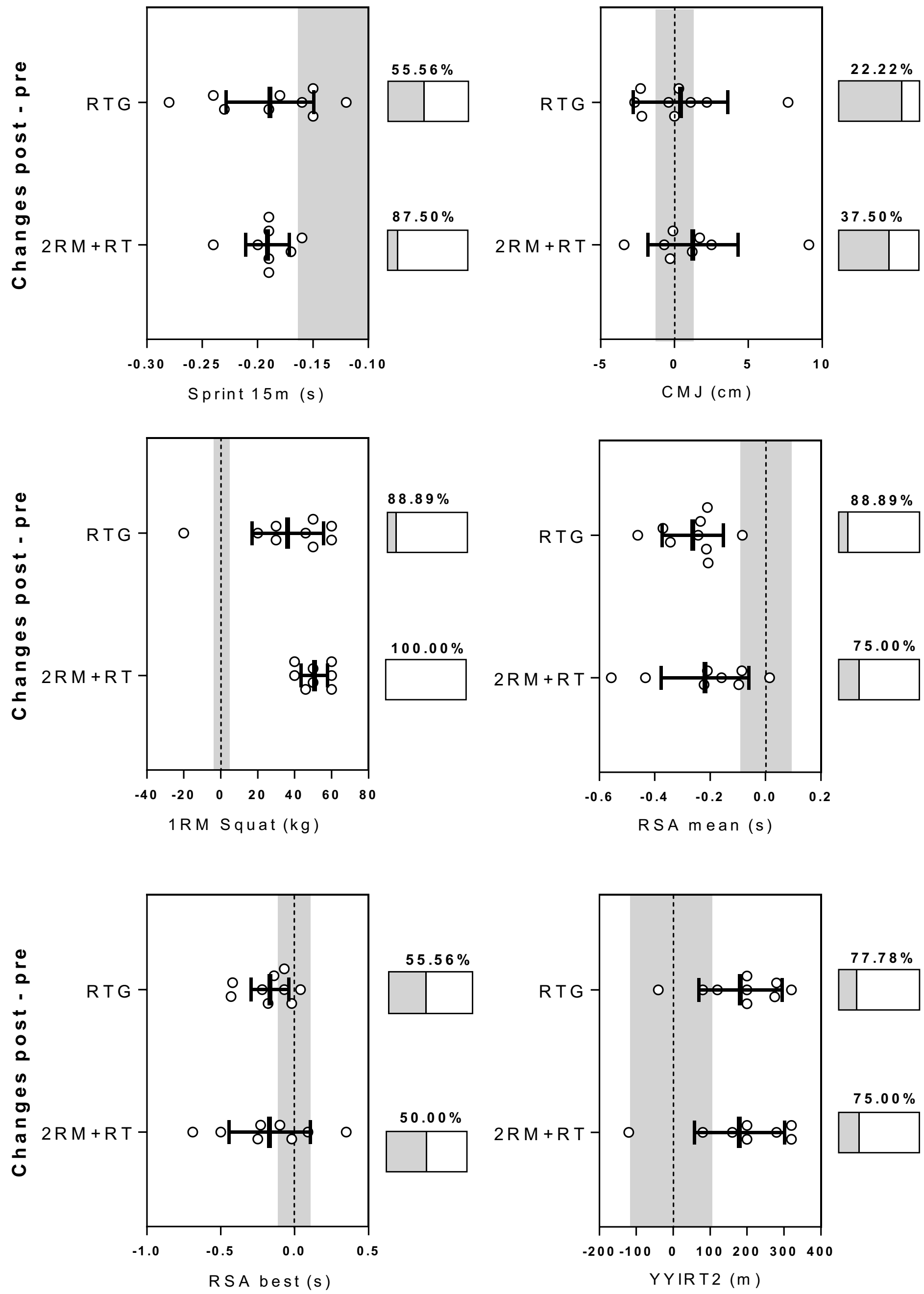

Figure 1. Mean with 95%CI (errors bars) of individual absolute changes in relation to pre values for variables Sprint 15 meters, Countermovement Jump (CMJ), one repetition maximum test in parallel back squat exercise ($1RM_{SQUAT}$), mean (RSA_{MEAN}) and best sprint time (RSA_{BEST}) and yo-yo intermittent recovery test level 2 (YYIRT2). Grey area indicates the SWC (see methods). Horizontals columns represent the percentage of subjects responding positively to training. Legend: 2RM + RT = two maximal repetitions + resistance training group; RTG = resistance training group; # = $p < 0.05$.

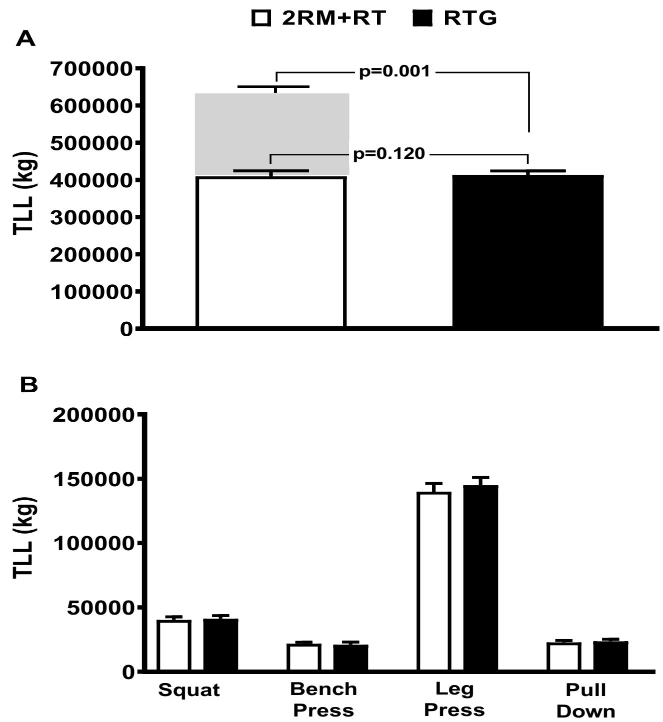

Figure 2. Total load lifted (TLL) during the 5-weeks of training intervention (A) and exercises squat, bench press, leg press and pull down (B) in groups 2RM + RT vs RTG. Gray bar represents additional 2RM in group 2RM + RT. Legend: 2RM + RT = two maximal repetitions + resistance training group; RTG = resistance training group.

DISCUSSION

The purpose of the present study was to evaluate the effects of performing a maximal strength protocol in addition to a regular RT protocol (strength-endurance type) in strength and power related-outcomes of junior soccer players. Different from the hypothesis, the main finding was that 5 weeks of maximal strength training (2RM + RT) did not enhance strength, power and sprint outcomes when preceding a traditional RT protocol (3 x 10RM).

A higher level of strength/power has been shown to substantially influence on-field performance in soccer (42). Indeed, the adoption of a heavy RT protocol may improve soccer-relevant actions, as the initial acceleration and change of direction (13). The 5-week intervention period adopted in the present study was sufficient to induce a significant increase in lower limbs maximal strength for both groups. Even though no significant difference was observed between experimental groups, a higher percentage increase was noted for the 2RM+RT in comparison with RTG (45.1% vs 32.3%, respectively). In addition, when comparing the ES between groups, a moderate effect was noted favoring the 2RM + RT group, which can be explained by the fact that the larger increase in muscle strength are directly influenced by the adoption of higher intensity training protocols (7, 22, 39). However, such result must be interpreted with some caution, since 1 participant from RTG presented reduction in $1RM_{SQUAT}$ value from pre- to post-intervention moments, influencing the mean values of the respective group. The absence of significant effect from the high intensity protocol (2RM + RT) adopted in maximal strength might be explained by the low volume (1 set per exercise) adopted during the intervention weeks. Training volume has been shown to influence RT-induced muscle strength increases (23, 33). In this sense, meta-analytic data previously reported a large effect of multiple sets compared to single ones in maximal strength of trained individuals (28). Moreover, it can be suggested that the 5-week intervention period was not sufficient to induce a significant difference between groups (2). Then, it could be expected that a larger difference would be induced by a higher number of sets and/or longer training periods.

It is also interesting to note that the 2RM + RT protocol did not affect the performance in the exercises subsequently performed in the training sessions, since no difference was noted in TLL between experimental groups during the 5-week intervention period. Lastly, even when concomitantly performing soccer specific technical/tactical activities, a large percentage increase per training session (3.0%) in maximal strength was noted for the 2RM + RT group, confirming previous findings from Ronnestad et al. (30).

For muscle power, both training protocols were able to induce significant increases in CMJ. However, such increments must not be considered significant, since the mean differences (pre to post) for both groups were not higher than the SWC. In addition, no difference was noted between groups. Assessing such variable is justified by the fact that soccer performance seems to be positively correlated with measures of power generation (39). Moreover, there is strong evidence regarding the effects of RT in improving muscle power of adolescent athletes (16). It was initially expected that the adoption of a heavy RT protocol (2RM + RT) would induce a significant increase in muscle power when comparing to the exclusively strength-endurance one (10RM), since RT programs that involve high loads lead to a greater increase in muscle power compared with low loads ones (1). The present results differ from those reported by previous studies as Christou et al. (8) specially due to the short intervention period adopted (5 vs 16 weeks, respectively). Indeed, in the latter, an initial 8-weeks period of RT was not sufficient either to induce a significant increase in CMJ, stressing the need of longer periods of RT intervention. It is of great relevance to point that improving strength does not automatically result in more powerful movements and improved performance (21, 31). Indeed, it has been suggested that a proper development of specific jumping control (pattern of neuromechanical coordination) would be necessary to take full benefit from maximal strength increment (5). Another plausible explanation for the lacking difference in CMJ performance between groups is that the 2RM protocol did not enhance a change in the stretch reflex or increased capacity to store and reuse elastic energy.

Both training protocols induced a significant improvement in 15m sprint time (-9.0% and -8.8% for 2RM + RT and RTG, respectively) RSA_{MEAN} (-2.9% and -3.4% for 2RM + RT and RTG, respectively), RSA_{BEST} (-2.4% and -2.3% for 2RM + RT and RTG, respectively) and YYIRT2 (+12.0% and +12.1% for 2RM + RT and RTG, respectively). Although meta-analytic data pointed that the increase in lower body strength positively transfer to sprint related-outcomes (34) and 7 from the 8 participants allocated in the 2RM + RT group and only 5 from the 9 participants of RTG responded positively (above SWC) to each training intervention, no significant difference between groups was observed in the present study. These results corroborate findings from previous investigations in which no positive transference effect of RT-induced strength increase to sprint performance was noted (10, 26). Additionally, the magnitude of sprint performance does not seem to be affected by the RT methods adopted during a training intervention, load intensity (% of 1 RM) used during the RT sessions, training program duration, number of exercises per session, number of sets per exercise and number of repetitions per set (34). It is important to note that, in addition to strength level, sprint performance in soccer is influenced by other factors, as neuromuscular skill and coordination, postural control/stability, and mechanical/morphological characteristics of locomotor muscles (14). It also can be suggested that the lack of direct correspondence between the higher percentage increases in maximal strength induced by the 2RM protocol and the others dependent variables assessed (RSA_{MEAN}, RSA_{BEST} and YYIRT2) is partially due to a lag time effect, which has been described as the period of time in which an athlete learns to use his or her increased strength in several sport skills (12, 30). Then, one can assume that a larger intervention period would be able to induce a higher difference in the aforementioned variables between experimental groups.

The present study is not without limitations. Firstly, the short intervention period might not have been sufficient to reach significant statistical differences between the groups. However, it is important to highlight that the purpose was to reproduce the short available time that soccer teams usually have to implement proper physical training programs during both pre and competitive phases. Lastly, the current findings must not be extrapolated to professional-level soccer players. Then, future studies with different samples regarding training level must be addressed to better clarify these findings.

The findings of the present study suggest that junior soccer players can maximize strength, power and sprint performance as a result of a 5-week RT protocol. These data present a meaningful practical application to soccer coaches that dispose of a reduced available pre-competitive phase. However, when adopting a previous 2RM + RT protocol during each training session, there was no further improvement in physical performance. Therefore, the current data shows that junior soccer players aiming to increase their strength and power levels do not beneficiate from the adoption of a maximal strength protocol, considering a short-term period of 5 weeks.

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