PHYSICAL EDUCATION OF STUDENTS

Effects of plyometric and pull training on performance and selected strength characteristics of junior male weightlifter

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Abstract

Purpose: The aim of this study was to investigate the effect of plyometric and pull training added an Olympic weightlifting training program (twice a week for 8 wk) on performance and selected strength characteristics in junior male weightlifter.

Material: The participants [n = 34; age: 16.03 ± 0.9 y; mass: 74.78 ± 14.86 kg; height: 170.53 ± 6.81 cm] were randomized into a pull (n = 11), a plyometric (n = 12), and a control (n= 11) groups. The groups trained 6 days a week during the 8-week study period. The pull group performed four pull exercises and the plyometric group performed four plyometric exercises added to Olympic weightlifting program for 2 days a week, and the control group performed an Olympic weightlifting program alone. Analysis of variance and Magnitude-based inferences used to determine whether a significant difference existed among groups on snatch clean and jerk total (SCT), squat (SQ), back strength (BS), countermovement jump (CMJ), 30 sec. repeated jump height (RJ_H) and peak barbell velocity (PV).

Results: The ANOVA showed a time × group interaction for SCT, BS and RJH. The MBI indicated positive changes for SCT in control group, for BS in pull group and for RJH in plyometric group. The results for the PV decrease in plyometric and pull group indicated no significant time × group interaction, but there was a significant main effects.

Conclusions: The results of this study showed that the addition of pull or plyometric training to an Olympic weightlifting program interfered with weightlifting performances.

Keywords: weightlifting derivatives, olympic weightlifting, clean and jerk, snatch and clean variations.

Introduction

Plyometric training is one of the best methods of developing explosive power in sports. Many coaches and athletes consider plyometrics a bridge between strength and power [1]. The meta-analysis by Saez-Saez de Villarreal et al., [2] reported that plyometric training very effective for lower-body muscle strength. These strength gains are of explosive nature and reinforced by the integration of strength exercises. Weightlifters must use Olympic weightlifting (OWL) techniques quickly and explosively to ensure successful lifts. Thus, plyometric training may improve OWL performance. There is a limited number of studies have compared the efficacy of plyometric exercises combined with OWL training on some strength tests. Arabatzi et al., [3] reported improvements in vertical jumps height via changes in power and technique. In a study, conducted with male youth, the authors reported 12 weeks of OWL or plyometric training were generally equal to or more effective for enhancing performance than traditional resistance training [4]. However, the training protocols in those study different from the traditional OWL training protocols and no study involved weightlifter.

In OWL, pull performances require very strong muscle activity to ensure the extension of the knee and hip joints. Pull exercises are frequently included in training programs for weightlifters at all levels to maximize the pull power and ability to produce high speeds and vertical bar height. Studies have analyzed the effects of pull exercises on some sports performance parameters, (5-7) but their specific effects on OWL performance have not been studied. However, OWL and its derivatives have been included in strength and fitness programs in many sports fields and are subject to scientific research [5, 8-10]. It is clear that the results of these studies cannot be generalized to specific OWL performance. Thus, it can be said that no evidence shows whether plyometric training or pull training added or combined with traditional OWL training improves specific OWL performance. The single training method approach may not be as effective as the combined training method to increase overall training adaptation [3]. Although some long-term research of strength-power athletes are available, such studies are limited, specifically for Olympic weightlifters [11].

Hypothesis: This study set out to test the hypothesis that plyometrics or pull training combined with OWL training could improve performance and selected strength characteristics.

Purpose: This study aimed to investigate the effects of plyometric and pull training added traditional OWL training on the performance and selected strength characteristics of junior weightlifters.

Material and methods

Participants

Thirty-four young weightlifters aged 15–17 years

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with at least 2 years of OWL experience voluntarily participated in the study. The participants' descriptive statistics are presented in Table 1. Two of the athletes had earned gold medals in international tournaments, while two others had earned silver medals. Four had earned gold medals in national championships, while four others had earned silver medals and two others had earned bronze medals. The participants and their coaches were warned that prohibited or non-prohibited nutritional supplements should not be taken during the study period. Written informed consent was obtained from the parents of the participants after a thorough explanation of the possible risks and discomforts associated with the experimental procedures was provided. The Central University Ethics Committee approved the study protocol.

Study Design

We used a pre-test–post-test design. Thirty-four young weightlifters were randomly allocated to pull (PG), plyometric (PLG), and control groups (CG). Randomization was done with a draw. Each participant was asked to draw from two separate papers with pre-prepared and folded group names written in the same size. The groups trained 6 days a week during the 8-week study period. The PG performed four pull exercises, the PLG performed four plyometric exercises added to the OWL program for 2 days a week, and the CG performed OWL program alone. Two-way analysis of variance and Magnitude-based inferences were used to analyze the likelihood of a standardized effect size (Cohen's > 0.35) in dependent variables, SCT, PV, SQ, BS, CMJ, and RJH.

Test procedures

Participants were not performed any familiarization session since they performed these tests at regular intervals within a National project (at least twice). All tests were performed using a device controlled by only one researcher and in two sessions at 1-day interval. The tests were conducted in the same order and in the same environment during the daytime training hours. The first day tests included body composition and vertical jumps, while the second day tests included PV and BS.

Anthropometrics

The height of each athlete was measured with a stadiometer using standard procedures (Holtain Ltd., Crymych, Dyfed, UK). Body composition was analyzed using a Bioelectrical Impedance Analyzer (BC-310, Tanita Corp., Tokyo, Japan).

Olympic Weightlifting Performance and Front Squat

For testing snatch, clean and jerk, squat previously established methods by González-Badillo et al. [12] were applied. Participants warmed up 40-50% of the estimated 1RM by using 3 to 5 repetitive warm-up sets, followed by 5 to 7 separate attempts from 60-100% of 1RM. The test was terminated after 3 losses of the same weight. The best good lift was recorded as the result of the test. The Squat test protocol was the same as snatch, clean and jerk, but only 2 failed attempts were allowed.

Vertical Jumps

The subjects warmed up before measurements by doing stretching exercises and free jumps and measurements were taken after a 3-min rest. Vertical jumps were obtained with Optojump Next® (Microgate, Bolzano, Italy). For the CMJ test, the participants were requested to squat and jump vertically as quickly as possible with their hands on their waists, knees at full extension, and bodies upright. In the RJH test, the participant was positioned in Optojump Next® and requested to jump vertically at the highest possible speed to the highest possible height with his hands on the waist for 30 seconds just as the "start" command was given. Pulling off the knees in the flight phase, pauses during movements, staying out of the Optojump Next® and the parallel bar range, or stepping on the parallel bars were considered failures and the test was repeated. Two trials were performed RJH a 5,6 -min rest in between and for CMJ with a 2,3-min rest in between, and the best result was used in the analysis.

Peak Barbell Velocity

Kipp et al., [13] suggested that the use of the traditional work-energy method to make inferences about power outputs during the clean at loads of 85% of 1-repetition maximum. In addition, Szabo and Aspects [14] suggested that the ideal weight for technique improvement should be on the range of 80-85%. Therefore, 85% load was

Table 1. Some physical anthropometrical and performance characteristics of subjects

Variable	Total (n=34) (± S)	PG (n=11) (± S)	PLG (n=12) (± S)	CG (n=11) (± S)
Age	16.03 ±0.87	15.91± 1.14	16.08 ± 1.14	16.10 ± 0.74
Height (cm)	170.53 ±6.81	168.81± 7.6	170.41±6.8	171.07±6.07
Body Weight (kg)	74.78 ±14.86	73.74±15.58	74.08±17.16	75.79±12.88
T Experience	3.18±1.14	3±1.18	3.02±1.04	3.54±1.21
BMI	25.66±4.46	25.83±4.65	25.44±5.26	25.66±3.83
Fat %	18.70 ±7.53	19.04±6.33	18.03±9.07	19.09±7.84
MS	86.56±16.06	86.09±16.36	81.58±18.23	90±9.62
MC&J	105.65±21.29	106.09±20.63	98.42±23.34	110±17.06
Total	192.26 ±37.08	192.18±36.86	180. ±41.14	200±26.05
SQ	131.37±27.19	132.±27.19	128±23.74	133±16.66

Abbreviations: T. Experience: Training Experience, BMI: Body Mass Index, MS: Maksimal Snatch: MC&J: Maksimal Clean&Jerk, Total: Snatch and Clean&Jerk Total, SQ: Squat.

preferred for PV measurements. Subjects performed their routine warm-up before the PV measurements were taken using a Tendo Weightlifting Analyzer (Tendo Sports, Trencin, Slovak Republic). After the warm-up, the athletes performed the snatch on their own platform, gradually moving up to 80% 1RM. On a different platform, the Tendo Weightlifting Analyzer's rope was fixed to the barbell and the athletes performed a 85% 1RM snatch. PV data were obtained in two trials for the snatch lift at 85% of 1RM and the best result was used in the analysis. Participants were encouraged to perform the second pull phase of the snatch as quickly as possible to maximize barbell velocity.

Back Strength

The relevant dynamometers were used to determine the trunk strength (Fabrication Enterprises, Inc., New York, USA). For the back strength test, the athletes were asked to place their foots on the dynamometer stand, to keep the knees and arms in full extension, the back in straight position, body in light forward inclined position and to pull the dynamometer bar vertically upwards with the hands. In both tests, two trials were performed and the high result was accepted valid.

Training Protocols

An 8-week training program was maintained for all groups specially designed for them. All participants took part in National Championships using the same training programs, so no adjustment program was required before the study. A progressive loading and the last two weeks of tapering were applied. All groups supervised by at least one coach registered with the National Weightlifting Federation. Exercise volume (set/repeat) and intensity rates included in the all groups training program are shown in Table 2.

OWL training programs were limited to the snatch, clean and jerk, power snatch, power clean and jerk, front squat, and back squat as basic exercises, and each athlete applied one repetition of all lifts that exceeded approximately 70% 1RM loads in each training session. This method of training is often referred to in the literature as the Bulgarian training approach [15, 16].

PG added four pull exercises to the traditional training program on Tuesdays and Thursdays. The training intensity was determined according to the 1RM full snatch and clean and jerk of the athletes for the snatch and clean pulls. Exercise 1, Full Snatch and Full Clean Pulls: Full snatch and full clean pulls included the stage at which the bar was pulled from the floor to the waist level with a continuous movement. The bar was pulled with a wide grip on the cleaning pull and the movement was applied with a narrow grip during the clean. The snatch pull was applied on Tuesdays and the clean pull was performed on Thursdays under the weekly training program. Exercise 2, Block Snatch Pull and Block Clean Pull: The block snatch pull and block clean pull include the part from the knee to nearly waist level in the snatch and clean and jerk movements. The bar was pulled from a stand at the athlete's knee level rather than from the ground. The block snatch pull was performed on Tuesdays, while the block clean pull was performed on Thursdays. Exercise 3, Hang High Pull: The difference in the hang pull, similar to the block snatch pull and the block clean pull, is that the bar is constantly raised and lowered from the knee level repeatedly in suspension without placement on the floor or a block. On the weekly training schedule, the hang high pull was performed on Tuesdays and the second clean pull was performed on Thursdays. Exercise 4, Jump Shrug: The jump shrug involves jumping continuously while the bar, kept at waist level, is released toward the knee and then pulled up back to the waist position. A more detailed description of the pull exercises performed can be found elsewhere [17].

PG added four plyometric exercises to OW program. The progressive plyometric training program used in this study based on findings from previous investigations [18]. Exercise 1, Hurdle Hops: Simple jumps are made over hurdles created with weight plates. Hurdle heights and hop numbers were determined according to weekly training volume and intensity. Exercise 2, Box Jump: The feet are shoulder-width apart and the arms are used to jump over the weightlifting plates at a certain height. The height created with the plates is increased or decreased depending on the weekly training intensity, and hop numbers were also determined according to weekly training volume and intensity. Exercise 3, Depth Jump: The first 2 weeks were applied as a free fall and vertical jumps on a weight plate at 30 cm height, 3 and 4 weeks at 35 cm height, 5 and 6 weeks at 40 cm height, 7 and 8 weeks at 35 cm height. Exercise 4, Medicine Ball Back Throw: A 5-kg medicine ball is held with the knees and body bent together and immediately thrown at maximal effort. All phases of this movement are applied without hesitation. Among the sets, a 2-3min rest was given.

Statistical Analyses

Relative reliability between repetitions within each testing session was determined using a 2-way random effects model intra-class correlation coefficients and 95% confidence intervals. An ANOVA with repeated measures was used to examine the effects of training (PRE–POST) between the 3 groups on each variable. Post hoc Tukey tests were applied for comparisons between individual means when required. The alpha level was set at $p \leq 0.05$. In addition, pre to post difference was analyzed using the magnitude-based inference (MBI) [19]. The probability of a standardized magnitude (0.35) effect on the variables in the pre- and post-test was calculated by Cohen's *d*. The effect size classification of Rhea for strength training was used [20]. Based on this classification, <0.35 points indicate a trivial effect; 0.35–0.80, small effect; 0.80–1.50, medium effect; and >1.50 was evaluated as the major effect. The differences in the variables were characterized by probabilistic terms, and the following scale was used: 25%–75%, possibly; 75%–95%, likely; 95%–99.5%, very likely; and >99.5% most likely. The inference was categorized as uncertain that the 95% confidence limits (CL) overlapped with the threshold values for the smallest worthwhile positive and negative effects [19].

Table 2. Volume (Set / Repeat) and Intensity Rates of Training Programs

Exercise	Week 1			Week 2			Week 3			Week 4		
Control Group	S	R	%	S	R	%	S	R	%	S	R	%
Snatch	8	1	80	8	1	80	7	1	85	7	1	90
Clean&Jerk	8	1	80	8	1	80	7	1	85	7	1	90
Squat	8	1	80	8	1	80	7	1	85	6	1	90
Power Snatch and Clean&Jerk	8	1	80	8	1	80	7	1	85	7	1	90
Plyometric Group	S	R	-	S	R	-	S	R	-	S	R	-
Hurdle Hops	2	10	-	2	10	-	2	15	-	2	15	-
Box Jump	3	5	-	3	5	-	3	8	-	3	8	-
Depth Jump	3	5	-	3	5	-	3	8	-	3	8	-
Medicine Ball Back Throws	3	5	-	3	5	-	3	8	-	3	8	-
Pull Group	S	R	%	S	R	%	S	R	%	S	R	%
Clean Pull and Snatch Pull	3	5	80	3	5	80	3	5	90	3	4	100
Block Snatch Pull and Block Clean Pull	3	5	80	3	5	80	3	5	90	3	4	100
Hang High Pull	3	5	80	3	5	80	3	5	90	3	4	90
Jump Shrug	3	5	30	3	5	30	3	5	40	3	4	40
Exercise	**Week 5**			**Week 6**			**Week 7**			**Week 8**		
Control Group	S	R	%	S	R	%	S	R	%	S	R	%
Snatch	6	1	95	7	1	95	7	1	85	6	1	85
Clean&Jerk	6	1	95	7	1	95	7	1	85	6	1	85
Squat	6	1	95	7	1	95	7	1	85	6	1	85
Power Snatch and Clean&Jerk	8	1	95	7	1	95	7	1	85	8	1	85
Pliometric Group	S	R	-	S	R	-	S	R	-	S	R	-
Hurdle Hops	2	20	-	2	20	-	2	15	-	2	15	-
Box Jump	4	8	-	4	8	-	3	5	-	3	5	-
Depth Jump	4	8	-	4	8	-	3	5	-	3	5	-
Medicine Ball Back Throws	4	8	-	4	8	-	3	5	-	3	5	-
Pull Group	S	R	%	S	R	%	S	R	%	S	R	%
Clean Pull and Snatch Pull	3	3	100	3	3	100	3	4	90	3	3	90
Block Snatch Pull and Block Clean Pull	3	3	110	3	3	110	3	4	90	3	3	90
Hang High Pull	3	3	100	3	3	100	3	4	90	3	3	90
Jump Shrug	3	5	50	3	5	50	3	5	40	3	5	40

Results

Test Reliability

The ICC indicated that the variables were reliable (T; r=0.95, SQ; r=0.87, TS; r=0.88 CMJ; r=0.91 and PV; r=0.84).

Analysis of variance

The analysis of variance indicated a significant main effect and time × group interaction on SCT ($p < 0.05$). Post hoc analysis showed that control group and plyometric group improved SCT, but this was not true for the pull group. SQ did not improve in the all groups ($p > 0.05$). There was a significant time × group interaction in BS ($p < 0.05$). The results indicated that gains for the pull group were greater than plyometric group and control group ($p < 0.05$). For RJH, the ANOVA indicated a significant time × group interaction effect on the variables ($p < 0.05$). Post hoc analysis showed that the plyometric group showed a significant increase. The results for the CMJ and PV indicated no significant group × training interaction, but there was a significant main effect for CMJ in PLG and for BS in PG. ($p < 0.05$).

Magnitude-based inferences

PG: Pull training elicited likely positive improvements in BS (65,4% possibly, “small” *d*=0,42). All other effects were possibly “trivial” (SCT, PV, RJH), likely “trivial”

Table 3. Pretesting and Posttesting Results of Pull Group

Pull Group					
Measure	**Pre**	**Post**	**Diff. %**	**Cohen’s *d***	**MBI**
SCT, kg	182.7±35.6	192.2±36.8	4.9[#*b]	0.26 trivial	28.7/71.1/0.1 possibly trivial
SQ, kg	132±27.19	132.9±23.74	0.68	-0.06 trivial	1.5/93.5-5 likely trivial
BS, kg	142.1±15.4	150.1±24.5	5.62[#*b,c]	0.42 small	65.4/34.5/0.1 possibly positive
CMJ, cm	36.8±7.9	37.3±6.82	1.35	0.03 trivial	2.9/96.6/0.6 very likely trivial
RJ_h, cm	26.4±5.2	25.03±4.98	-4.46[*b]	-0.26 trivial	0.4/66.4/33.2 possibly trivial
PV. m/s^{-1}	2.2 ± 0.2	2.15± 0.1	-2.27	-0.20 trivial	2.2/70.7/27.2 possibly trivial

Abbreviations: MBI: Magnitude-based Inference. SCT: Snatch clean and jerk total. SQ: Front Squat. BS: Back Strenght. CMJ: Counter Movement Jump. RJ_h: 30 sec Repeated Jump Height, PV: Peak Barbell Velocity

[#]is significant for time at $P < 0.05$. *is significant for time×group at $P < 0.05$. [a]Different from PG. [b]Different from PLG. [c]Different from CG.

Table 4. Pretesting and Posttesting Results of Plyometric Group

		Plyometric Group (n=12)			
Measure	**Pre**	**Post**	**Diff. %**	**Cohen’s *d***	**MBI**
SCT, kg	167±39.3	180±41.4	7.78[#*a.c]	0.32 small	35.3/64.7/0.0 possibly trivial
SQ, kg	128.1±23.74	130.9±24.7	2.18	0.22 trivial	8.2/91.8/00 likely trivial
BS, kg	149.5±28.1	154.1±22.9	3[*a]	0.17 trivial	10.9/89.2/0.2 likely trivial
CMJ, cm	34.88±7.54	36.25± 6.69	3.92[#]	0.38 small	51.7/35.4/12.9 possibly positive
RJH, cm	23.1 ± 5.1	26.5± 5.1	14.71[#*a,c]	0.69 trivial	93.9/6.1/0.0 likely positive
PV. m/s^{-1}	2.3± 0.2	2.2± 0.1	-4.34[#]	-1.001 moderate	1.9/21.0/77.1 likely negative

Abbreviations: MBI: Magnitude-based Inference. SCT: Snatch clean and jerk total. SQ: Front Squat. BS: Back Strenght. CMJ: Counter Movement Jump. RJ_h: 30 sec Repeated Jump Height, PV: Peak Barbell Velocity

[#]is significant for time at $P < 0.05$. *is significant for time×group at $P < 0.05$. aDifferent from PG. bDifferent from PLG. cDifferent from CG.

Table 5. Pretesting and Posttesting Results of Control Group

Control Group (n=11)					
Measure	**Pre**	**Post**	**Diff. %**	**Cohen's *d***	**MBI**
SCT, kg	183.4±29.9	197.3±26.9	7.57$^{\#*b}$	0.49 small	82.7/17.3/0.0 likely positive
SQ, kg	133.16±23.7	134.18±14.2	0.76	-0.03 trivial	2.2/93.0/4.8 likely trivial
BS, kg	143.3 ± 18	145±55	1.5^{*a}	0.12 trivial	9.5/89.6/0.9 likely trivial
CMJ, cm	35.98±6.7	36.49± 73	1.4	0.06 trivial	0.3/99.6/0.1 most likely trivival
RJ_h, cm	25.94±6.72	24.58±6.82	-5.24^{*b}	-0.49 small	0.5/78.9/20.5 likely trivial
PV, m/s^{-1}	2.2±0.1	2.1±0.2	-4.54$^{\#}$	-0.48 small	0.4/31.5/68.1 most likely negative

Abbreviations: MBI: Magnitude-based Inference. SCT: Snatch clean and jerk total. SQ: Front Squat. BS: Back Strenght. CMJ: Counter Movement Jump. RJ_h: 30 sec Repeated Jump Height, PV: Peak Barbell Velocity

$^{\#}$is significant for time at P < 0.05. *is significant for time×group at P < 0.05. aDifferent from PG. bDifferent from PLG. cDifferent from CG.

(SQ) and very likely "trivial" (CMJ).

PLG: Plyometric training was likely (93,9%) to elicit positive improvements in RJH with effect size "small" (*d*=0,69) and CMJ (51,7% possibly, "small" *d*=0,38) while was likely (94,2%) negative in PV with effect size "moderate" (*d*=-1,001). Other effects were likely "trivial" (SQ, TS) and possibly "trivial" (SCT).

CG: Traditional training was 82,7% likely to elicit positive improvements in SCT with effect size "small" (*d*=0,49). Other effects were likely "trivial" (SQ, BS, RJH), most likely "trivial" (CMJ) and "most likely negative" (*d*=-0,48) in PV.

Discussion

In this study, we aimed to establish the training effects of additional plyometric and pull training when performed twice a week over a period of 8 weeks in junior male weightlifter. To our knowledge, this study was the first to investigate the effects of different training programs for junior weightlifters on specific OWL performance and selected strength characteristics. The most important finding of the study was that an 8-week pull or plyometric training added to a traditional OWL training program interfered with OWL performance. However, no significant improvement in the strength characteristics of the control group was seen. These results suggest that adaptations might be due to some deterioration in OWL techniques.

To ensure a successful lift in the snatch and clean attempts or the ability to catch the barbell after the second pull, it is necessary to gain enough height in the second pull phase. Therefore, in the study, the PG training involved various exercises with different loads for the muscle groups participating in the first pull phase, transition phase, and the second pull phase of the snatch and clean. However, the smallest effect on snatch and clean performance was seen in this group. Snatch and clean (traditional training) applied alone in a training program appears to provide a unique adaptation. This result can be explained via the training specificity principle.

The repeated jump test, considered a sensitive measure of anaerobic power and capacity changes, is an effective test for activities requiring repeated use of the stretch-shortening cycle in the jump movements of the lower extremity [21]. Markovic's [22] meta-analysis showed that plyometric training significantly increased the height of all four types of vertical jumps. The average effect observed at the jump height varies from 4.7% to 8.7%; at the same time, these results are considered practically significant. In another meta-analysis [23], plyometric training was highly effective (*d* = 0.84) for vertical jump skill. However, according to the findings of our research, the increase in PLG was likely "trivial." Therefore, an increase in RJH could not be transferred to the OWL performance. In addition, the increase or decrease in RJH as an indicator of anaerobic capacity in weightlifters does not directly affect OWL performance.

The change in PV was possibly "trivial" in the PG, but it might be a significant result that the effect was unclear in CG and likely "negative" in PLG. To be able to successfully lift in the snatch and clean techniques or catch the barbell after the second pull, it is critical that the bar reaches a sufficient height in the second pull phase to provide a power output associated with sufficient speed to produce this height. A higher bar velocity is considered a distinctive feature of strong weightlifters [24-27], but previous studies showed that PV is not the only determining factor for successful versus unsuccessful weightlifting [26, 28]. A successful lift cannot be predicted over a single variable, and it has been reported that the barbell trajectory, barbell velocity, barbell displacement, and method through which the force is applied to the barbell are closely related to a successful lift [29]. As mentioned earlier, the increase in SCT in the CG is likely "positive," while that of PG and PLG is possibly "trivial." In this context, according to the results of these early investigations, PV is not a determining factor of successful versus unsuccessful lifts; in addition, our findings suggest that the decrease in PV alone as a result of a training program is not a factor affecting OWL performance.

Strength is the main factor of success in weightlifting and necessary for maintaining the static and dynamic balance of the body and the bar during erroneous lifts at a tolerable level. When the exercises practiced by the CG were compared to those of the other groups, we found that PV had not changed during the 8-week period. According to these results, an increase in TS alone cannot improve snatch and clean and jerk performance or improve PV during such motions. However, despite the improvement of these properties in the PG, the lowest increase in OWL performance was seen in this group. This result might be due to some deterioration in OWL techniques. Many studies emphasized that good technique is an invaluable factor that affects weightlifting performance [30].

The quadriceps are the most active muscle group in Olympic lifts. Thus, the greatest adaptation through intensive training occurs in this group of muscles [31]. In addition, in the OWL program, the squat is the most frequently used auxiliary exercise. However, in our study, there was a decrease in the trivial effect on pull group after 8 weeks of training. There was no difference in CG, and although there was an increase in PG, it did not reach significance. For well-trained quadriceps muscle groups, the load/intensity programmed in this study's 8-week training may be insufficient to enable the necessary adaptation.

Olympic-style lifts and some stages thereof have similarities between sports skills such as hip, knee, and ankle triple extensor velocity, motion patterns, and vertical jump [32-34]. In this study, although the CMJ increased by 3.92% (d = 0.38) in the PG, the treatment effects were "unclear." However, treatment effects on CMJ are most likely trivial" in CG and very likely "trivial" in PG. Many studies have shown that Olympic lifts effectively increase vertical jumping performance [4, 35, 36]. A strong association between CMJ by dynamic force movements was reported [37]. Similarly, there was a strong correlation between CMJ and weightlifting performance (r = 0.74). The results of our study do not overlap with the results of these studies. In contrast to the mentioned studies, Hakkinen and colleagues [38] reported no significant differences in relative loaded and unloaded CMJ during 1-year training in elite weightlifters. However, the elite weightlifters had different isometric power production curves than novice weightlifters in terms of maximal force, dynamic explosive power production, and elastic energy. Helland et al. [39] also compared OWL, motorized strength and power training, and free weight strength and power training in young athletes. They reported that OWL training resulted in smaller improvements in CMJ performances. Therefore, it may be said that similar studies are needed for more clear findings.

Conclusions

Pull exercises and plyometric exercises, added to an OWL training program interfered with OWL performances. The decrease in PV does not affect OWL performance and CMJ and RJH increases cannot be transferred to OWL performance. However, in spite of an improvement in these strength characteristics, failure to transfer to OWL performance may be caused by deterioration of lifting techniques.

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Conflict of interest

The authors wish to confirm that there is no conflict of interest associated with this publication and that there has been no financial support for this work that could have influenced its outcome.

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