

or absence (NS; no straps) of lifting straps during execution of the deadlift. The participants performed specific 1RM tests for each condition (NS and WS) and, subsequently, executed 3 sets to failure at 90% 1RM based on the corresponding 1RM values, with 2 minutes of rest between them. The WS and NS conditions are interspaced by 48 hours, in a randomized counterbalanced design. The dependent variables included the 1RM deadlift values and the maximum number of repetitions, kinematic variables (power, force, amplitude, time, and speed) for concentric muscle actions, heart rate (HR) response, and rating of perceived exertion (RPE) for each set of deadlift trials.

Subjects

The study participants were physically active, apparently healthy men, (age: 25.0 ± 3.3 years; age range 20–30 years; body mass: 86.0 ± 7.6 kg; stature: 177.9 ± 4.7 cm; body fat percentage: 9.0 ± 3.1%) with 4.0 ± 2.6 years of resistance training experience and a weekly training frequency of 4.0 ± 0.8 days with a minimum of 3 consecutive months of resistance training experience. Subjects were excluded if any of the following criteria were identified: a history of injury or pain during this exercise within the last 3 months, use of controlled medications under medical supervision, or engagement in activities with a significant grip strength requirement, such as Brazilian jiu-jitsu, judo, and mountaineering (29).

Study Procedures

The study took place over 3 testing sessions, each separated by a 48-hour interval. The first consisted of the preliminary testing and familiarization with the instruments and procedures. During the second and third sessions, the experimental protocols were conducted in a randomized order.

Day 1—After signing the informed consent (approval number 037/2011 by the local ethical committee), the volunteers completed a medical history questionnaire. Skinfold thickness was measured with a skinfold caliper (CESCORF, Porto Alegre, Brazil; with accuracy of 0.1 mm) by a trained and experienced evaluator at the chest, abdomen, and thigh according to Jackson and Pollock protocol (14). From these data, body density (14) and body fat percentage (25) were calculated. In addition, subjects were familiarized with the deadlift exercise, as previously standardized (7), and the maximum load testing (1RM) protocol was performed as indicated by Ratamess et al. (20). During the 1RM testing procedures, subjects were also familiarized with the 0–10 RPE scale (24).

Days 2 and 3—After a 5-minute general warm-up on a cycle ergometer at a self-selected resistance and cadence, subjects executed the following procedures under both the WS and NS conditions: (a) evaluation of 1RM to identify the maximum load used in the subsequent training session and after a minimum rest interval of 3 minutes (9,20) and (b) the training session comprised 3 maximum number of repetition sets of the deadlift exercise, at 90% of 1RM while attempting to maximize speed of movement and range of

TABLE 1. Kinematic responses according to the presence or absence of straps and comparison of 3 successive deadlifting sets.*†

	WS			NS			Condition			Sets			Interaction			
	First set	Second set	Third set	First set	Second set	Third set	F	p	F	p	F	p	F	p	F	p
Maximum no. repetitions	5 ± 2	4 ± 2	3 ± 2	5 ± 1	4 ± 1	3 ± 1	0.3	0.58	13.1	<0.001‡	0.96	0.39				
Average power (W)	598 ± 140	528 ± 109	509 ± 115	669 ± 98	543 ± 179	455 ± 169	0.1	0.83	14.6	<0.001‡§	2.33	0.12				
Average speed (m·s ⁻¹)	0.4 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	5.8	0.03	17.1	<0.001‡	3.46	0.05				
Peak speed (m·s ⁻¹)	0.6 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.9 ± 0.1	0.7 ± 0.2	0.6 ± 0.2	7.6	0.02	14.5	<0.001‡	3.91	0.03				
Average force (N)	1,822 ± 479	1,725 ± 338	1,835 ± 631	1,321 ± 156	1,320 ± 83	1,463 ± 428	11.4	0.007	0.9	0.4	0.24	0.78				
Peak force (N)	2,279 ± 573	2,135 ± 438	2,305 ± 730	1,632 ± 161	1,616 ± 107	1,759 ± 469	14.9	0.003	0.8	0.43	0.18	0.83				
Average amplitude (mm)	506 ± 79	458 ± 126	462 ± 89	583 ± 83	480 ± 187	430 ± 164	0.5	0.5	5.8	0.01‡	2.05	0.15				
Average duration (ms)	1,424 ± 262	1,517 ± 631	1,682 ± 634	1,133 ± 141	1,115 ± 246	1,316 ± 422	12.6	0.005	1.9	0.16	0.31	0.73				

*WS = with straps; NS = no straps.
 †Condition: main effect for difference between WS and NS. Sets: main effect for differences between sets. Interaction: condition × set interaction.
 ‡Statistically different between first and third sets (p ≤ 0.05).
 §Statistically different between first and second sets (p ≤ 0.05).

motion (9,26,27), separated by 2-minute rest intervals. Subjects completed the procedures in a randomized counter-balanced order with respect to either the WS or NS conditions.

During execution of the deadlift, subjects used a HR monitor (Polar, Model RS800CX, Kempele, Finland) to identify the HR responses before and after each set. Immediately after execution of each maximum number of repetitions deadlift set, general (RPE-G) and muscle-specific (RPE-M) RPE scale ratings were recorded (19,24). Specifically for RPE-M, the subjects were asked to rate the perceived strain related to the exercising muscles (20).

Deadlift Methods

For both 1RM testing and training session, subjects gripped the barbell with a closed double pronated grip without chalk, using a 220-cm bar (Olympic-type; Physicus, São Paulo, Brazil). To normalize grip width for different sized individuals, the shoulder width was used to determine grip width. The deadlift technique was initiated with a shoulder width stance and flexed knees and hips although maintaining a flat back or slight lordotic arch and executed in manner outlined elsewhere (7) in which a single repetition was considered complete after full knee and hip extension were attained.

One Repetition Maximum Test

The 1RM test was preceded by general warm-up on a cycle ergometer for 5 minutes, at a self-selected resistance and cadence (16,24). Then, as specific warm-up, the subjects executed 5–10 deadlift repetitions at 40–60% of perceived 1RM. After a 1-minute rest interval, 2–3 additional repetitions were performed at 60–80% of perceived 1RM to complete the warm-up. During the testing trial, 3–4 maximum attempts (of a single repetition) separated by 2 minutes were conducted to determine the 1RM load (20).

Testing

Testing consisted of 3 successive sets of deadlifts performed until failure at 90% of 1RM, separated by 2-minute intervals. Subjects were oriented to lift at maximal speeds through the full range of motion (9,13). Only the repetitions that complied with previous standardization procedures regarding the execution and range of motion were deemed acceptable. The maximum number of repetitions for each set was recorded when a subject was unable to support the load or paused longer than 2 seconds (13,20) as analyzed by 2 independent assessors, with more than 5 years of experience in resistance training.

Measurement of Kinematic Variables

During the successive training sets, a linear potentiometer (Peak Power; CEFISE, Nova Odessa, Brazil) connected to the bar measured both displacement and time during the deadlift repetitions. After accounting for the specific load used, Peak Power software 4.0 (CEFISE) was used to calculate average and peak power (in watts), average and peak applied force (in newtons), amplitude (in millimeters), duration (in milliseconds), and speed (in meter per second) in the concentric and eccentric phases for each lift. Previous studies have shown this method to be both valid and reliable (17,22), with accuracy within 0.10–0.25% during the concentric phase, reliability error of 0.02%, and r values for test-retest reliability of 0.86–0.99 (11). In addition, data from our laboratory showed that the procedures have high test-retest reliability for the following variables: amplitude (Intraclass Correlation Coefficient [ICC] = 0.87), effort duration (ICC = 0.84), and power output (ICC = 0.82).

Statistical Analyses

The Shapiro-Wilk test was used for data normality verification. The descriptive data are presented as mean and SD . For 1RM comparisons between the NS and WS conditions, a 1-way analysis of variance was used, with Greenhouse-Geisser correction when Mauchly's test of sphericity indicated a violation of this assumption. For comparisons between conditions (NS and WS) and deadlift sets (1, 2, and 3), 2-way repeated-measures analysis of variance was conducted with post hoc testing. Dependent sample t -tests were used to compare Pre/Post-HR, RPE-General, and RPE-M between conditions. Cohen's d values were calculated to evaluate effect size (ES) and interpreted as follows: 0.2 = small, 0.5 = moderate, and 0.8 = large

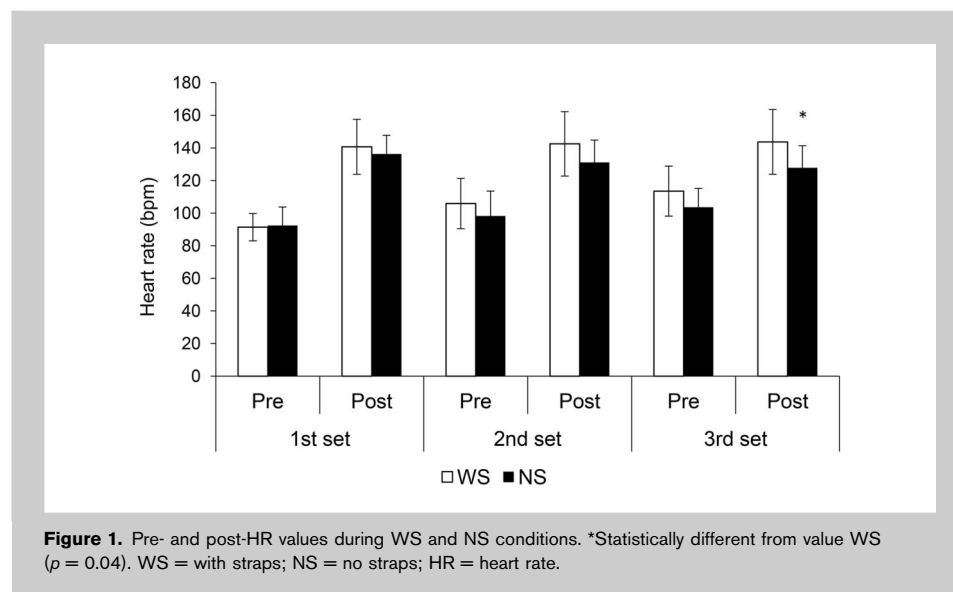


TABLE 2. Pre/post-HR and general/muscle-specific RPE.*

	WS		NS		<i>p</i>
	Mean	SD	Mean	SD	
Pre-HR (b·min ⁻¹)	103.6	10.4	98.1	9.7	0.2
Post-HR (b·min ⁻¹)	142.3	18.3	131.7	11.1	0.1
RPE-General	9.4	0.5	8.5	1.0	0.01
RPE-M					
Lumbar spine	9.7	0.4	8.1	1.9	0.002
Back of thigh	6.7	1.5	5.8	2.1	0.4
Trapezius	6.6	1.5	6.6	2.0	0.9
Forearm	4.6	2.0	8.5	1.5	0.03

*HR = heart rate; WS = with straps; NS = no straps; M = muscle specific.

(6). A significance level of 5% was assumed. Data were analyzed with SPSS 17.0 for Windows.

RESULTS

Eleven subjects completed the study. The load from the WS 1RM test (180.0 ± 14.8 kg) was statistically different ($p < 0.001$; ES = 1.3) than the load from the NS condition (151.0 ± 23.0 kg). The mean difference in 1RM between conditions (WS and NS) was 28.3 ± 13.2 kg with a range of 10–50 kg.

Table 1 exhibits the total number of repetitions performed in each set for each condition. A significant difference ($F = 13.12$; $p < 0.001$) was identified between the first and third sets in both conditions.

Also, Table 1 describes the kinematic values obtained from the comparison between conditions and between the 3 successive sets. A significant condition × set interaction ($F = 3.91$; $p = 0.03$) was shown for peak speed (PSpeed). Follow-up analyses revealed a significant difference between sets for the NS condition ($F = 3.6$; $p = 0.03$) with a decrease in PSpeed from the first to third set ($p = 0.036$). No between-set differences were found for the WS condition. Paired samples *t*-tests showed significantly greater PSpeed during the NS condition for the first ($p = 0.007$) and second ($p = 0.043$) sets when compared with WS, but no difference for the third set ($p = 0.269$). No significant interactions were identified for any of the other variables.

For the between-condition (WS and NS) comparison, the average mean speed (ASpeed; ES = 0.8) and average PSpeed (ES = 0.9) were different in across sets, with higher NS values and large effects for both variables. Average mean force (AForce; ES = 0.6) and average peak force (PForce; ES = 0.7) were different across sets with medium effects and the highest values in the WS condition. The average duration was greater in the WS condition across all sets with a large effect ($p < 0.02$; ES = 0.8), whereas no differences were found for the average amplitude.

For the between-set comparison, APower in S1 was significantly greater than S2 and S3 ($p < 0.001$; ES = 0.8) for both conditions with a large effect. ASpeed ($p = 0.001$; ES = 1.1), PSpeed ($p = 0.001$; ES = 0.8), and average amplitude were significantly different between S1 and S3 ($p = 0.01$; ES = 1.8) with large effects.

Figure 1 presents HR values before and immediately after each deadlift set for both the WS and NS conditions. All preset values were statistically lower than postset ($F = 208.9$; $p = 0.04$; ES = 2.3) with large

effects. The only statistical difference for HR between conditions was after S3, with the WS condition producing higher values than the NS condition ($F = 24.9$; $p = 0.04$; ES = 1.9) with a large effect.

Table 2 presents the general RPE values between conditions for each set and the muscle-specific RPE values between conditions. For RPE-G, values for WS were significantly greater than NS for both S1 and S2 ($p < 0.02$; ES = 0.6) with moderate effects, but not S3. For RPE-M, significant differences were noted in lumbar area and forearms. The values for the lumbar region were greater after the WS condition ($p = 0.002$; ES = 1.5), whereas the forearm values were greater under the NS condition ($p = 0.03$; ES = 1.9), both with large effects.

DISCUSSION

This study aimed to evaluate the effects of lifting straps use on different kinematic variables during 3 successive sets of deadlift exercise. Differences were found in the concentric phase of the following variables: load, speed, force, and duration. Regarding HR, a difference between conditions after the third set was shown, whereas for RPE-G, differences occurred after only the first and second sets.

The main muscles activated during deadlifts are lower limbs and back, but there are also significant action in the hips, arms, and shoulders (1). The current RPE-M results noted significant 16% higher values for WS on the lumbar region and 45% higher values for NS on forearms region between conditions. The higher HR values after the third deadlift set in the WS condition are likely related to increased cardiovascular demand as a result of the greater load applied compared with the NS condition (5). In addition, removing the limitation of grip strength likely allowed the ability to generate more work through larger muscles groups, subsequently increasing cardiac output (1,22).

In this study, the maximum number of repetitions was not found to be significantly different between conditions

($p = 0.5$). Conversely, Werneck et al. (29) reported differences between conditions using the cable pull-down exercise at 75% of 1RM NS (27.3 ± 3.2 reps in WS condition vs. 20.9 ± 2.4 repetitions NS, $p < 0.01$). This discrepancy may be explained by the fact that this study used the condition-specific (NS or WS) 1RM values, and there was a large difference between conditions (180.0 ± 14.8 kg for WS and 151.6 ± 23.0 kg for NS, $p < 0.001$) leading to greater total work for the WS condition. The inclusion of the 1RM before the deadlift training sessions could have had a confounding influence on deadlift performance, which may be supported by differences in speed and duration, whereas the lack of difference between the maximum number of repetitions does not support this assertion.

When comparing the successive sets, a statistically significant difference was shown in the number of complete cycles (maximum number of repetitions) between the first and third set in both conditions ($p < 0.001$), which is supported by previous findings that noted declines in power, strength, and speed with each repetition during power cleans (10). Forces (average and peak) were higher in the WS condition ($p < 0.01$), whereas speed was higher during NS ($p < 0.03$). This can be explained by the force-velocity relationship, which postulates that with low loads, it is possible to generate higher speeds (10,15). Conversely, as the load increases, the speed decreases progressively with a concomitant increase in force production (26). Considering the self-selected cadence used in this protocol, it is hypothesized that the greater initial speed (and subsequent decline) with NS may be indicative of subjects realizing that grip strength is a limiting factor leading to a more rapid completion of the deadlift sets faster to avoid fatigue. These alterations in force and velocity parameters caused by the lifting straps may be considered during training prescription because the parameters of strength and power are fundamental for human athletic performance (4), and differences in acute neuromuscular responses to how lift-specific training volume is implemented may also play an important role in chronic neuromuscular adaptations (28).

Neuromuscular fatigue is considered an important variable in the development of muscular strength and hypertrophic response (12) and may be elicited by an increased time under tension combined with heavy loads (28). Grip strength may be an important limiting factor during deadlift, leading to the premature interruption of the exercise and reducing training loads, which may compromise the stimuli imposed to the target muscles. Previous research has also shown that hand size and the use of bars with different thickness could affect deadlift's performance (20). To overcome these limitations, many strategies have been used, such as LS and an "alternate" or "inverted" grip (one hand supinated and the other pronated) (18). With the use of the former, the opposing rotational forces prevent the bar from rolling out of the hands of the lifter and, typically, increase the amount of weight that can be lifted. However, in competitive weightlifting, the inverted

grip may cause excessive tension on the tendon of the biceps brachii of the supinated arm and generate undue hip rotation (1,18), which would increase the risk of injuries and muscle imbalances. The double pronated grip used and the absence of chalk in our protocols may have resulted in the lower load of NS exercise and the subsequent differences in performance between conditions. Nonetheless, the use of lifting straps is considered suitable when the load is greater than or equal to 80% 1RM because it removes the limiting factor of grip strength during deadlift training and allows the utilization of greater workloads as demonstrated by both the 1RM testing and subsequent training data reported in this study. The results of this study indicate that the use of lifting straps directly influences the absolute load of the deadlift exercise and its kinematic variables. With the use of lifting straps, it is possible to provide higher workloads to the target muscles than performing the exercise without lifting straps. The current findings demonstrate that the increased maximal loads WS allow increases in workload and time under tension, both of which are relevant variables for power acquisition and muscle hypertrophy.

PRACTICAL APPLICATIONS

Considering that speed was lower, and that force and duration were greater in the WS condition, coaches may choose to use lifting straps to focus on developing specific physical attributes during strength training. The greater absolute load in the WS condition resulted in altered kinematic variables during deadlift training. These alterations were likely due to the direct transfer of force to the bar through the lifting straps rather than the forearm and hands/fingers (23), thereby allowing the individual to have greater control of the movement. Thus, the positive effect of lifting straps on performance may be dependent on the targeted kinematic variables, as the increase in training load and force would be offset by decreased power during the deadlift movement. Finally, the authors suggest that future investigations compare other ergogenic techniques, such as the use of chalk and an alternated grip, to the results of those obtained lifting straps.

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