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Does Short-Term Near-Maximal Intensity Machine Resistance Training Induce Overtraining?

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Reference Data

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ABSTRACT

To examine the efficacy of a 3-week, high-intensity, resistance exercise protocol for inducing overtraining, 9 subjects trained their lower body on a squat-simulating resistance exercise machine. Five subjects performed a training (Trn) protocol 5 days a week to elicit an overtraining response. Four subjects performed a control (Con) protocol 2 days a week. Test batteries of sprints, jumps, and strength tests were performed four times during the study at 1-week intervals (T1, T2, T3, T4). One-RM performances increased for the Trn group by T2 and remained augmented through T4. Overtraining did not occur, but other performances were attenuated for the Trn group. Increased sprint times for 9.1 m and 36.6 m were evident by T2 for the Trn group and remained slower through T4. Leg extension torque decreased for the Trn group by T4. Future attempts to induce intensity-dependent overtraining for study should use greater training intensities or different training modalities and should monitor physiological factors that may contribute to this phenomenon.

Key Words: weight training, isokinetic strength, isometric strength, high intensity

Introduction

The phenomenon of overtraining involves either a short- or long-term imbalance between exercise and recovery, resulting in prolonged fatigue and performance decrements (10). Overtraining can result from an increase in training volume or intensity, leading to decreased performance (10, 19). A short-term condition, sometimes referred to as overreaching (10, 19), leads to milder overtraining symptoms that can be easily overcome with short periods of rest or modified training.

It is thought that aerobic and anaerobic athletes may respond differently to overtraining, depending on the stresses incurred (2, 10, 21). Most of the research on overtraining has monitored aerobic activities. Related research has often focused on increased volumes of exercise (2, 3, 5). Short-term anaerobic protocols (e.g., resistance exercise) have not been extensively examined and we know of no resistance exercise study that has studied the effects of increased training intensity while maintaining volume. The endocrine and neuromuscular responses to overtraining appear to be dependent on the total training volume (5, 6, 7) and training intensity (6, 9). How these physiological systems respond to overtraining would shed light on the mechanisms responsible for it and may provide markers for its occurrence.

Therefore the purpose of the present investigation was to evaluate a short-term, high-intensity, resistance exercise protocol that was intended to cause performance decrements and symptoms of overtraining. Overtraining will be operationally defined as an increase in volume and/or intensity of exercise training that results in performance decrements (1) specific to the training modality.

Materials and Methods

Nine males served as subjects for this study ($M \pm SE$: age 22.9 ± 1.3 yrs, height 176.8 ± 1.8 cm, weight 81.3 ± 2.6 kg, fat-free mass 73.8 ± 2.4 kg, relative fat 9.2 ± 1.0%). All were currently weight trained and were capable of at least a 1.2 × body weight one-repetition maximum (1-RM) for the parallel barbell back squat. Each subject signed an informed consent prior to participating in the study and was screened for inappropriate knee joint laxity by a physician (13).

Lower body training was performed on a squat resistance exercise machine (Southern Xercise, Inc., Cleveland, TN) (see Figure 1). Body and foot stance positions were constant throughout the investigation and permitted each subject to attain a parallel position whereby the greater trochanter was level with the knee joint center.

All subjects participated in a 2-week familiarization phase (Weeks F1 and F2, see Figure 2) that included a self-tested 1-RM on the squat machine to

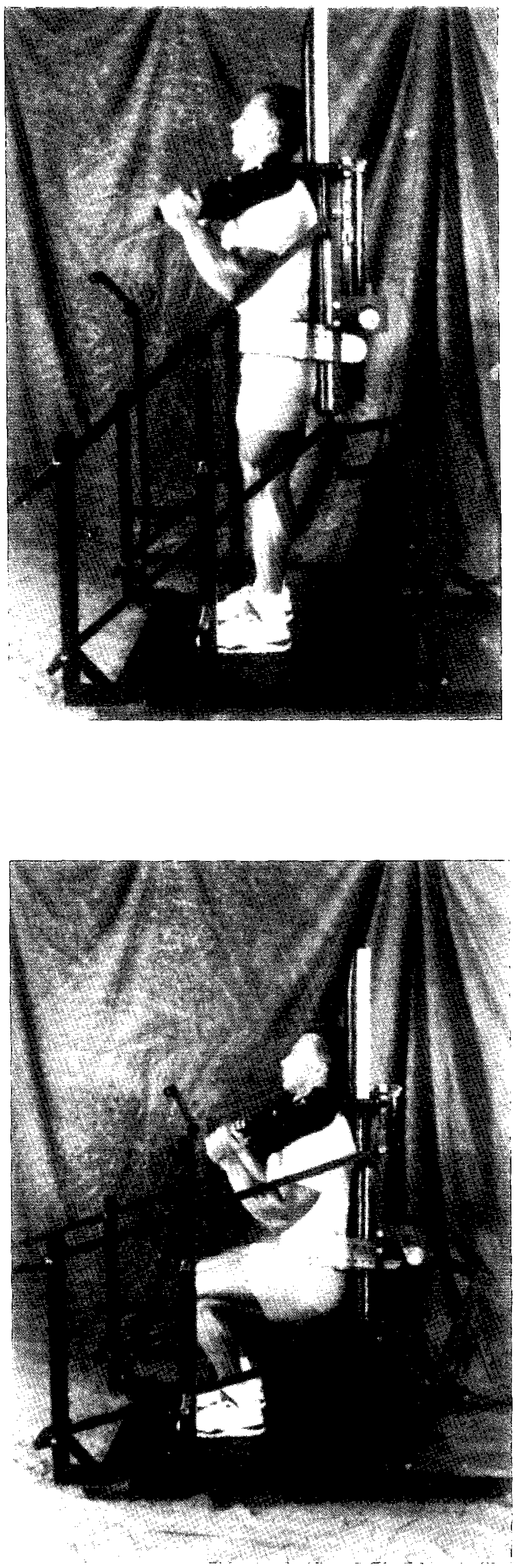

Figure 1. The Tru-Squat resistance exercise machine (photo courtesy of Southern Xercise, Inc., Cleveland, TN).

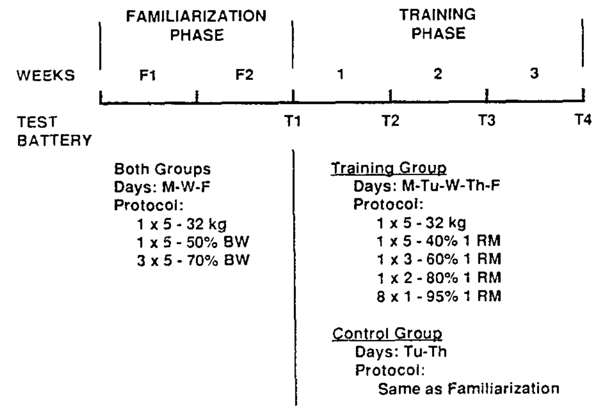

Figure 2. Testing timeline and training protocols for both groups.

acquaint them with heavy resistances on that machine. Beginning with Week 1 of the training phase, subjects were randomly divided into training (Trn, n = 5) and control (Con, n = 4) groups. The Trn group performed a low volume, high relative intensity (% 1-RM) training protocol on the squat machine while the controls performed a low volume, low relative intensity protocol. After a warm-up, Trn subjects performed 8 single repetitions with 2-min rest intervals at 95% of their most recent 1-RM on the squat machine.

Figure 2 describes the training protocols for both groups. If Trn subjects could not complete a certain lift, the training resistance for subsequent repetitions was decreased by 5% of their 1-RM. This was repeated for any additional missed repetitions in any training session. The completed training session for the Trn group consisted of the warm-up and 8 successful repetitions. This training program was intended to induce overtraining and was not intended to simulate typical training programs.

Test batteries were administered following Weeks F2 (T1), 1 (T2), 2 (T3), and 3 (T4) of the study; they consisted of the following items:

- Sprints—9.1 m (10 yds) and 36.6 m (40 yds) (14);
- Agility—lateral running agility tests starting in both the right and left directions (4);
- Vertical Jumps—heights for counter-movement (CMVJ), non-counter-movement (from a squat position, SVJ), low depth (30.5 cm, LDJ), and high depth jumps (61.0 cm, HDJ), determined with a Vertec vertical jump tester (Sports Imports, Inc., Columbus, OH) (8);
- Muscular Strength—1-RM on the squat machine (20), and isometric (45° knee flexion) and isokinetic peak leg extension torque (N · m) of the dominant leg at angular limb velocities of 0, 1.05, 3.14, 4.19, and 5.24 rad · s^{-1} on a Cybex II dynamometer (Lumex, Inc., Ronkonkoma, NY); and
- Body Composition—body density, relative fat, and fat-free mass estimated anthropometrically (12, 17).

Statistical analyses ($p < 0.05$) were performed with 2 × 4 mixed model analyses of variance (Group × Time). When significant interactions were observed ($F \geq 5.59$; $df = 1, 7$), post hoc analyses were performed with a Fisher's least significant difference procedure to determine significant differences from the first test battery (T1) for each group.

Results

Physical performances for each test battery are listed in Table 1 for both groups. One-RM strength on the Tru-Squat machine significantly increased by T2 for the Trn group, and by T4 for the controls. Significant performance decrements were observed for the Trn group for leg extension torque at 1.05 rad · s^{-1} by T4, as well as both 9.1-m and 36.6-m sprint times by T2. Significantly improved agility runs to the left were observed for the Trn group by T2, and the controls by T4. No other changes were observed for either group, including body weight, fat-free mass, and relative fat.

Table 1
Performance Responses for the Four Test Batteries (T1–T4) for the Training (Trn, *n* = 5) and Control (Con, *n* = 4) Groups

		T1		T2		T3		T4	
Variable	Group	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
1-RM Tru-	Trn	109.8	9.8	115.2	10.9[a]	116.1	9.2[a]	117.0	10.1[a]
squat (kg)	Con	124.2	4.3	125.9	5.4	127.6	5.7	131.6	6.6[a]
Isokin. leg exten. torque (N · m)									
0 rad·s⁻¹	Trn	226.4	28.0	212.1	24.9	219.1	23.7	206.7	14.3
	Con	278.6	29.9	263.7	11.8	264.7	27.6	287.5	32.2
1.05 rad·s⁻¹	Trn	237.6	18.2	224.6	18.2	224.2	18.5	220.4	18.7[a]
	Con	254.9	25.5	266.1	17.7	248.5	23.1	272.5	17.3
3.14 rad·⁻¹	Trn	148.5	10.7	139.5	11.0	140.3	13.2	151.2	9.6
	Con	171.5	19.2	172.5	17.4	161.9	15.7	174.6	13.5
4.19 rad·s⁻¹	Trn	122.7	9.4	117.0	8.1	124.0	7.4	126.4	5.9
	Con	137.6	17.4	137.6	13.3	132.2	14.8	145.1	6.7
5.24 rad·s⁻¹	Trn	103.7	7.7	104.0	5.9	101.4	6.5	110.9	3.0
	Con	128.4	20.8	121.4	17.2	108.8	14.4	129.5	8.6
9.1-m Sprint	Trn	1.72	0.06	1.82	0.07[a]	1.80	0.06[a]	1.81	0.09[a]
(s)	Con	1.68	0.04	1.69	0.02	1.70	0.03	1.74	0.02
36.6-m Sprint	Trn	5.40	0.20	5.59	0.24[a]	5.63	0.21[a]	5.57	0.25[a]
(s)	Con	5.01	0.06	5.05	0.09	5.17	0.12	5.17	0.06
Agility run (s)									
Right	Trn	4.90	0.20	4.85	0.17	4.83	0.17	4.85	0.16
	Con	4.69	0.05	4.67	0.07	4.70	0.06	4.59	0.03
Left	Trn	4.95	0.13	4.82	0.13[a]	4.77	0.15[a]	4.71	0.16[a]
	Con	4.67	0.05	4.68	0.04	4.65	0.03	4.54	0.07[a]
Vertical jumps (cm)									
Counter-	Trn	50.1	4.0	49.8	4.0	51.6	4.3	51.3	4.1
mvmt.	Con	55.9	2.2	55.8	2.1	56.2	2.3	54.6	1.9
Non-cntr.	Trn	45.7	3.4	45.7	3.2	47.5	3.9	46.8	4.1
mvmt.	Con	53.7	2.4	54.0	3.3	51.8	2.7	51.5	2.0
Low depth	Trn	48.2	4.1	47.8	4.3	49.8	5.1	48.0	4.3
(30.5 cm)	Con	54.3	2.8	54.3	1.5	52.4	2.0	53.3	1.8
High depth	Trn	46.2	3.7	46.7	4.6	47.8	4.0	48.3	5.2
(61.0 cm)	Con	51.8	1.8	50.8	1.8	52.7	2.8	51.8	2.6

[a]Different from T1, $p < 0.05$.

Discussion

The 1-RM performance on the Tru-Squat machine actually increased, showing that overtraining had not occurred for the Trn group. This was not expected, given that the design of the training protocol was intended to produce decreases in 1-RM leg strength. It appears that a learning effect was at least partially responsible for the 1-RM results, since the controls also demonstrated increased 1-RM strength by T4. Previous investigations on overtraining have noted that it is difficult to adversely affect sport-specific performance (2, 3), although weightlifters have demonstrated altered lifting technique (18) and decreased vertical jump performance (22) and endurance athletes have demonstrated decrements in running performance (11) with high volume training protocols.

The training-specific adaptation of 1-RM strength was used as the overtraining criterion in the present study to permit evaluation of the exact exercise stimulus used during training. Although performance tests not specific to the training protocol may provide important information for the coach or athlete, they might be indicative of different physiological demands and may be differently influenced by the various phases of the long-term training program. Therefore, for the purposes of this study, overtraining was determined by performance on a training-specific 1-RM lift.

Performance on the Tru-Sprint was not necessarily indicative of performance on other physical performance variables. Although most of the physical performances for the Trn group were not affected by the training protocol, several tests did exhibit significant changes (see Table 1). Specifically, sprint times and leg extension torque at 1.05 rad · s^{-1} demonstrated attenuated performance for the Trn group but not the controls. Leg extension torque decreased for only the angular limb velocity most like that used during the training lifts at 95% of 1-RM. It appears there was a learning effect for the agility run to the left, since both groups demonstrated improved performance.

Neurological alterations due to resistance exercise can be evident in fiber recruitment patterns (15) as well as in recruitment of synergistic muscles (16). It is speculated that altered neural recruitment patterns contributed to the enhanced 1-RM strength. In this manner, 1-RM performance could be enhanced despite decrements in other performance tasks. Future investigations should closely monitor neural input (e.g., EMG activity) and attempt to localize the site of the responsible mechanisms, that is, central versus peripheral. In addition, endocrine factors that may affect these possible mechanisms should also be investigated. Finally, the effect of different resistance exercise modalities (e.g., free weights) on physiological responses to overtraining must be studied. In summary, the high-intensity resistance training protocol using a controlled machine environment did not result in overtraining, as would be indicated by decreases in 1-RM performances.

Practical Applications

These results have important implications for the strength and conditioning professional. It should be noted that improvements in 1-RM performance on a machine may not reflect performance in other tasks, for example sprint times and leg extension torque. Training consistently with near-maximal relative intensities with a machine modality may produce detrimental results on other physical performance tasks. Proper exercise prescription and testing programs must be implemented to avoid this problem.

Several considerations for future study of a high-intensity resistance exercise overtraining model are evident. The model used in the present study was not adequate to induce overtraining. Future studies of the physiological characteristics of intensity-dependent resistance exercise overtraining may need to use a greater training intensity of perhaps up to 100% 1-RM. This would call for a shorter training program (e.g., 2 weeks) to permit constant training at these high intensities while keeping the risk of injury to a minimum.

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