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Dissimilar Effects of One- and Three-Set Strength Training on Strength and Muscle Mass Gains in Upper and Lower Body in Untrained Subjects

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Abstract. Rønnestad, B.R., W. Egeland, N.H. Kvamme, P.E. Refsnes, F. Kadi, and T. Raastad. Dissimilar effects of one- and three-set strength training on strength and muscle mass gains in upper and lower body in untrained subjects. *J. Strength Cond. Res. 21(1):157–163. 2007.*—The purpose of this study was to compare the effects of single- and multiple-set strength training on hypertrophy and strength gains in untrained men. Twenty-one young men were randomly assigned to either the 3L-1UB group (trained 3 sets in leg exercises and 1 set in upper-body exercises; $n = 11$), or the 1L-3UB (trained 1 set in leg exercises and 3 sets in upper-body exercises; $n = 10$). Subjects trained 3 days per week for 11 weeks and each workout consisted of 3 leg exercises and 5 upper-body exercises. Training intensity varied between 10 repetition maximum (RM) and 7RM. Strength (1RM) was tested in all leg and upper-body exercises and in 2 isokinetic tests before training, and after 3, 6, 9, and 11 weeks of training. Cross sectional area (CSA) of thigh muscles and the trapezius muscle and body composition measures were performed before training, and after 5 and 11 weeks of training. The increase in 1RM from week 0 to 11 in the lower-body exercises was significantly higher in the 3L-1UB group than in the 1L-3UB group (41 vs. 21%; $p < 0.001$), while no difference existed between groups in upper-body exercises. Peak torque in maximal isokinetic knee-extension and thigh CSA increased more in the 3L-1UB group than in the 1L-3UB group (16 vs. 8%; $p = 0.03$ and 11 vs. 7%; $p = 0.01$, respectively), while there was no significant difference between groups in upper trapezius muscle CSA. The results demonstrate that 3-set strength training is superior to 1-set strength training with regard to strength and muscle mass gains in the leg muscles, while no difference exists between 1- and 3-set training in upper-body muscles in untrained men.

Key Words. single set, multiple sets, leg muscles, upper-body muscles, training volume

Introduction

A strength-training program mainly consists of 3 different variables: volume, intensity, and frequency. In addition, the order of exercises, rest period between sets and exercise, contraction type, contraction velocity (15, 23), and nutrition (8) may affect the adaptations to strength training. These variables can be manipulated in numerous ways, resulting in an almost endless continuum of different strength training programs. However, of the various training variables, volume has received the most attention in the past 7 years, with focus mainly on the debate concerning single-set vs. multiple-set strength training programs (5, 6, 10).

The question of single- vs. triple-set strength training has been thoroughly reviewed with some discrepancies among the reviewers on the effect on strength improvement (4–6, 10, 24, 26, 27). Results in the literature range from no differences in strength gain between single and multiple sets (33) to a significant superiority of multiple sets (29). There seem to be several methodological explanations to this discrepancy. The pretest strength measures were sometimes performed only once (12, 18, 20, 28, 32), thus saying nothing about the reliability of the baseline data. In several single- vs. triple-set studies there is a difference in training intensity (17, 18, 20, 28) and type of exercises (18, 20) between training groups. When the goal is to examine the effects of different training volumes on strength increases, all other training variables should be held constant to attribute any differences in strength increase to the training volume.

Other studies are missing data on the amount of rest between sets given to the subjects who performed 3 sets (1, 28) and the subjects' strength training experience (36). There are numerous reports on strength-trained subjects gaining more from a larger training volume compared with untrained subjects (15, 24, 26, 27). Therefore, multiple sets seem to be superior to single-set training in strength trained subjects. Thus, it is essential to know the training experience of the subjects when comparing the strength-enhancing effects of single- and triple-set strength training.

Each human muscle seems to be unique on the basis of its muscle fiber composition, fiber diameter, and function (34). Fleck and Kraemer (9) report that strength gains with different strength training regimens can vary dramatically from one muscle group to another. Therefore, the response to single- vs. multiple-set strength training could possibly be different in diverse muscle groups. This is supported by Paulsen et al. (22) who observed that leg muscles responded to a greater extent to 3-set strength training when compared with single-set strength training, while there were no differences in upper-body muscle response between the 2 training regimens in untrained men. This indicates a lower threshold of training volume in upper-body muscles compared with lower-body muscles. In the study of Paulsen et al. (22) the subjects trained the same exercises with the same intensity and two pre- and posttests were conducted. The study lasted only 6 weeks, and no measurement of changes in muscle mass or nutrition control was carried out.

Therefore, the purpose of this study was to further

Table 1. Subjects' characteristics at baseline in group 1L-3UB (1 set in leg exercises and 3 sets in upper-body exercises) and 3L-1UB (3 sets in leg exercises and 1 set in upper-body exercises). Values are mean ± *SE*.*

Variable	1L-3UB	3L-1UB
Age (y)	26.6 ± 1.6	26.5 ± 1.3
Height (cm)	181.8 ± 3.0	181.8 ± 2.2
Weight (kg)	82.6 ± 3.4	80.4 ± 4.2
Fat percentage	24.1 ± 1.9	22.1 ± 3.0
$1RM_{upper\text{-}body}$ (kg)	69 ± 1.9	69 ± 2.1
$1RM_{leg}$ (kg)	118 ± 13.2	107 ± 11.5
Knee flexion (N·m)†	128 ± 5.4	125 ± 7.3
Knee extension (N·m)†	228 ± 9.5	217 ± 14.4
$CSA_{quadriceps}$ (cm^2)	71.4 ± 3.2	73.2 ± 3.8
$CSA_{hamstrings}$ (cm^2)	61.9 ± 4.4	62.6 ± 3.4
$CSA_{upper\ trapezius}$ (cm^2)	10.5 ± 0.7	13.2 ± 1.4
Lean body $mass_{upper\text{-}body}$ (kg)	33.1 ± 1.6	35.5 ± 3
Lean body $mass_{lower\text{-}body}$ (kg)	19.9 ± 1.4	20.0 ± 1.5

* CSA = cross sectional area; 1RM = 1 repetition maximum.
† Peak torque at $60°\cdot s^{-1}$.

investigate the differences in adaptation between upper- and lower-body muscles to 1- and 3-set strength training protocols. In this study we have added measures of change in muscle mass as a possible mechanism behind the different strength gains and extended the training period to 11 weeks.

Methods

Experimental Approach to the Problem

The current study was conducted to compare the effect of single- and triple-set strength training on strength gains and changes in muscle mass during the first 11 weeks of training in untrained men. In an effort to reduce any possible effects of differences in total training volume, 1 group performed 3 sets in leg exercises and 1 set in upper-body exercises, while the other group performed 1 set in leg exercises and 3 sets in upper-body exercises. Effects on strength gains were tested in 1 repetition maximum (1RM) tests in 3 leg exercises and 5 upper-body exercises and in 2 isokinetic tests before training, and after 3, 6, 9, and 11 weeks of training. Cross sectional area of thigh muscles and trapezius muscle and body composition measures were performed before training, and after 5 and 11 weeks of training. Dietary intake was assessed before training, and after 5 and 10 weeks of strength training. Training intensity was equated and physical activity outside the training program, as well as diet and protein consumption, was controlled.

Subjects

Twenty-four healthy men (see Table 1 for descriptive data) with no regular strength training (<3 times per month) during the last year volunteered to participate in this study. Three subjects withdrew before completion of the study for reasons unrelated to the study. The study was approved by the Regional Ethics Committee of Norway.

Subjects were randomly divided into 2 groups. Group 1L-3UB ($n = 10$) trained 1 set in leg exercises and 3 sets in upper-body exercises. Group 3L-1UB ($n = 11$) trained 3 sets in leg exercises and 1 set in upper-body exercises. There were no differences between groups in anthropometric parameters, 1RM, peak isokinetic strength, or measures of muscle mass before the training period (Table 1).

Procedures

During 2 familiarization sessions, subjects were instructed in proper lifting technique and testing procedures. Thereafter, subjects completed 2 testing sessions before the start of the training period on separate days, each separated by approximately 72 hours.

Before the testing, subjects conducted a 10-minute warm-up on a cycle at a workload of 60–70 W. The isokinetic knee-extension and knee-flexion was performed in a REV9000 dynamometer (Technogym, Gambettola, Italy). The range of motion was set from a knee angle of 90° to 20° from full extension. Subjects performed 4 warm-up contractions followed by 3 maximal contractions at a speed of $60°\cdot s^{-1}$. Peak torque was used in the data treatment. Coefficients of variation were 6.2 and 5.5% for the knee-extension and -flexion, respectively. Only the right leg was tested. Immediately following the isokinetic tests, the subjects continued with the 1RM tests.

The 1RM testing was performed in leg press, leg extension, leg curl, seated chest press, seated rowing, latissimus pull-down, biceps curl, and shoulder press. In all exercises, the subjects performed a standardized warm-up consisting of 3 sets with gradually increasing load (40, 75, and 85% of expected 1RM) and decreasing number of repetitions, 12, 7, and 3. The first attempt in all 1RM tests was performed with a load approximately 5% below the expected 1RM. After each successful attempt, the load was increased by 2–5% until failure of lifting the load in 2–3 following attempts. The rest period between each attempt was 4 minutes. The order of tests was similar in all testing sessions. All 1RM testing was overseen by the same investigator and conducted on the same equipment with identical subject/equipment positioning. The coefficient of variation was <5.4% in all 1RM tests. The highest value from the 2 pre- and posttests was used in statistical analysis. Only one 1RM test was conducted after 3, 6, and 9 training weeks. All tests were accomplished at the same time of day and in the same order.

Muscle Cross Sectional Area. Cross sectional area (CSA) of the thigh muscles and trapezius muscle was measured using magnetic resonance imaging technique (MRI; GE Signa 1.5 Tesla EchoSpeed, GE Medical Systems, Milwaukee, WI). Scans of the thigh muscles were taken while the subjects were relaxed in a supine position. Axial transverse images were obtained through the thigh at ¼, ½, and ¾ of the length of the femur from the condyle. After an axial localization scan in parallel with both acromioclavicular joints, 9 sagittal images of the upper trapezius muscle were taken from acromioclavicular articulation with an 8-mm space between each image. Due to methodical errors, the CSA of the upper trapezius muscle was measured in only 5 subjects from each group. The identities of the scans were blinded and analyzed by the same person. The thigh muscles were divided into extensors (quadriceps muscles) together with the sartorius muscle, and flexors/adductors compartments using a tracer function in the software. Using similar methods, coefficient of variation has been calculated to 2% from repeated examinations in 8 subjects (21).

Dual Energy X-Ray Absorptiometry. Lean body mass and fat mass were determined by dual energy x-ray absorptiometry (DXA) using a Lunar Prodigy densiometer (GE Medical Systems, Madison, WI). Prior to the DXA scan, subjects were requested to avoid training for 24 hours and to avoid any ingestion of liquids 2 hours before the scan. Subjects were lying in a standardized position in the machine.

Dietary Intake. The subjects recorded their daily dietary intake for a 4-day period (Wednesday to Saturday) using a weighted food intake method. When subjects are not supervised 24 hours a day, the weighted food intake method is recognized as a valid method (2, 3). The subjects were given food record journals and digital food weighing scales (Vera 67002; Soehnle-Waagen GmbH & Co, Murrhardt, Germany; precision 1 g). They were also given detailed oral and written guidelines about how to carry out this method. Dietary assessment data were analyzed using a nutrient analysis program (Mat på data 4.1; LKH, Oslo, Norway).

Training. The 11-week training period consisted of 3 workouts per week. Each workout consisted of leg press, leg extension, leg curl, seated chest press, seated rowing, latissimus pull-down, biceps curl, and shoulder press for all subjects and in the same order. After a 10-minute warm-up with light jogging or cycling, subjects performed 2 warm-up sets before the leg exercises and another 2 warm-up sets before the upper body exercises. All subjects were supervised by one of the investigators on all workouts during the first 3 weeks, and thereafter at least once a week during the entire training period.

Both groups trained 3 times per week on nonconsecutive days. Training intensity (number of RM) was altered similarly for the 2 groups. During the first 2 weeks both groups trained with 10RM sets in all exercises; during the third and fourth training weeks they increased the intensity to 8RM sets, and during the final 6 weeks they trained with 7RM sets. Subjects were encouraged to continuously increase their RM loads during the intervention. Subjects were allowed assistance on the last repetition. However, to achieve a modified daily undulating periodization, the subjects were told to reduce their training load with ~10% in the second exercise bout in each week (this was coordinated between the 2 training groups).

In an effort to reduce any possible effects of differences in whole-body training volume, 1 group performed 3 sets in upper-body exercises and 1 set in leg exercises, whereas the other group performed 3 sets in leg exercises and 1 set in upper-body exercises. All exercises were performed in an explosive manner in the concentric phase, while the eccentric phase had a slower speed (approximately 2–3 seconds).

Subjects were allowed to complete no more than 1 bout of endurance training per week during the intervention. This was controlled with a training diary.

It has been indicated that protein administration before strength training may stimulate the protein synthesis and thus positively affect the strength and hypertrophy response to strength training (35). In an attempt to standardize the protein and energy consumption in the critical time around each bout of exercise, all subjects ate a protein chocolate bar before each bout of exercise, and consumed energy drinks during each bout of exercise throughout the intervention. All subjects completed at least 91% of the workouts.

Statistical Analyses

All values given in the text and figures are mean ± *SE*. Unpaired *t*-tests were used to compare the relative changes from before to after training between groups. Paired *t*-tests were used to test for significant changes within groups from before to after training. The level of significance was set at $p \leq 0.05$.

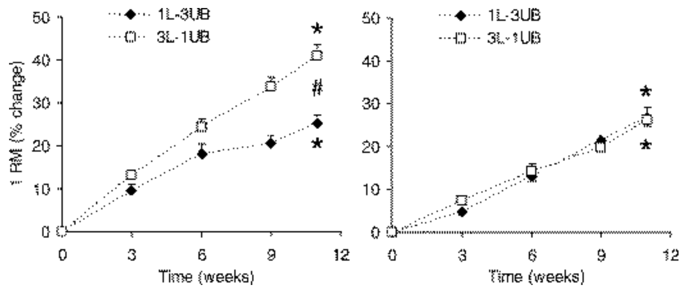

FIGURE 1. Relative changes in 1 repetition maximum (1RM) during the 11-week training intervention in the leg exercises (left) and upper-body exercises (right). 1L-3UB = 1 set in leg exercises and 3 sets in upper-body exercises; 3L-1UB = 3 sets in leg exercises and 1 set in upper-body exercises. * Significant difference from baseline ($p < 0.001$). # Significant differences between groups ($p < 0.001$).

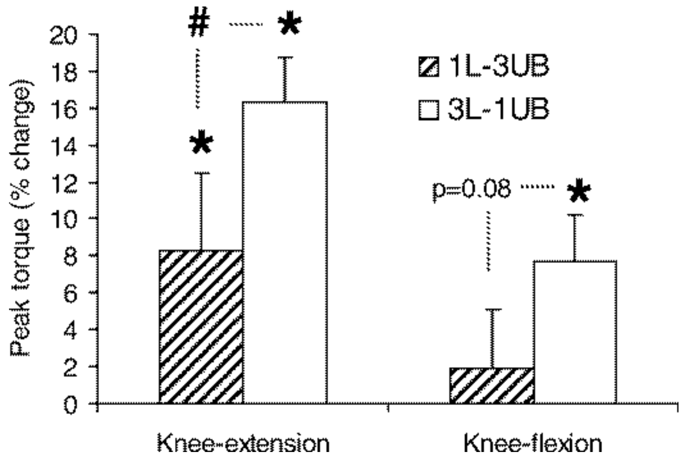

FIGURE 2. Percentage increase in peak isokinetic knee-extension and knee-flexion torque from pre- to posttest in the 1L-3UB (1 set in leg exercises and 3 sets in upper-body exercises) and 3L-1UB group (3 sets in leg exercises and 1 set in upper-body exercises). * Significant difference from baseline ($p < 0.05$). # Significant differences between groups ($p = 0.03$).

RESULTS

The increase in 1RM from week 0 to 11 in the lower-body exercises was significantly higher in the 3L-1UB group than in the 1L-3UB group (41 vs. 21%; $p < 0.001$; Figure 1 left panel). There were no significant differences between groups in 1RM changes in upper-body exercises (Figure 1 right panel). Peak torque in maximal isokinetic knee extensions increased significantly more in the 3L-1UB group than in the 1L-3UB group (16 vs. 8%; $p = 0.03$), while the increase in knee-flexion peak torque was not statistically different between groups ($p = 0.08$; Figure 2).

There were no differences between groups in total training volume (kg × reps × set). During the first training week, both the 1L-3UB group and 3L-1UB group had the same total training volume (sum of all exercises), 9,201 ± 438 kg and 9,676 ± 532 kg, respectively. Due to reduction in repetitions and increase in load, the total training volume was the same in the last training week with no significant difference between groups (9,310 ± 346 kg and 10,174 ± 581 kg in the 1L-3UB group and 3L-1UB group, respectively). The 3L-1UB group increased their training load in the leg exercises to a greater extent than the 1L-3UB group in both absolute and relative terms ($p \leq 0.02$; Figure 3), while there was no difference between groups in upper-body exercises.

The CSA of the thigh muscles increased significantly more in the 3L-1UB group than in the 1L-3UB group (11 vs. 7%; $p = 0.01$). When the thigh was divided into knee-extensors and knee-flexors, the increase in CSA in the 3L-1UB group was still superior to the 1L-3UB group ($p \leq 0.05$; Figure 4). Independent of groups, the largest increase in CSA of the knee-extensors was observed in the distal region, and for the knee-flexors the largest increase in CSA was observed in the proximal region (data not shown). Regarding CSA changes in the trapezius muscle, there was no difference between the 1L-3UB group and the 3L-1UB group (13.9 ± 2.5% and 9.7 ± 1.4%, respectively).

There were no significant differences between groups regarding changes in lean body mass and fat mass, but it was only 5 subjects in each group (Figures 5 and 6). The 3L-1UB group increased their body weight to a greater extent than the 1L-3UB group ($p < 0.03$, Figure 7).

During the intervention there was no difference between groups in intake of energy, protein, carbohydrate, or fat (Table 2).

Discussion

Both the 1L-3UB and 3L-1UB groups significantly improved 1RM in all exercises during the training intervention. However, 3-set strength training was superior to 1-set regarding 1RM increase in leg exercises, whereas the increase in 1RM for the upper-body exercises was identical with 1- and 3-set training. The 1RM results are supported by the larger increase in peak isokinetic knee-extension and knee-flexion torque with 3-set training compared to 1-set training. In addition, the greater strength increase in leg exercises with 3 sets compared to 1 set was concomitant with a greater increase in leg muscle mass with 3 sets.

Our results show that leg muscles respond with a larger gain in 1RM and muscle mass when a moderate strength training volume (3 sets) is compared with a low training volume (1 set) in the early phase of adaptation to strength training. However, this difference in response to 1- and 3-set strength training was not evident in upper-body muscles. Because training variables such as intensity of training, repetition velocity, frequency of training, and strength test specificity were similar in the 2 training groups, the additional improvements in strength are likely the result of a more effective stimulus induced by multiple sets in the leg muscles. Although differences in adaptation between upper- and lower-body have not been subject to detailed examination in earlier studies, a closer examination reveals no differences between 1 and

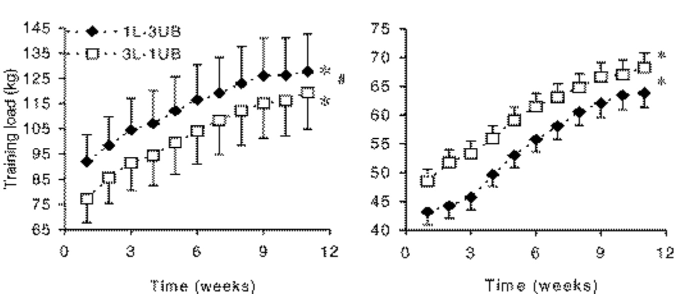

Figure 3. Mean training weight (kg) during the 11-week training intervention in the leg exercises (left) and upper-body exercises (right). 1L-3UB = 1 set in leg exercises and 3 sets in upper-body exercises; 3L-1UB = 3 sets in leg exercises and 1 set in upper-body exercises. * Significant difference from baseline ($p < 0.01$). # Significantly larger increase in 3L-1UB group compared with 1L-3UB group in both absolute and relative terms ($p \leq 0.02$).

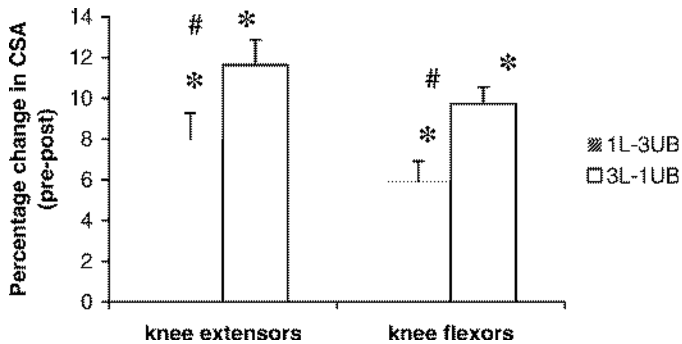

Figure 4. Percentage increase in cross sectional area (CSA) of knee-extensors and knee-flexors from pre- to posttest in the 1L-3UB (1 set in leg exercises and 3 sets in upper-body exercises) and 3L-1UB group (3 sets in leg exercises and 1 set in upper-body exercises). * Significant different from baseline ($p < 0.01$). # Significant differences between groups ($p \leq 0.05$).

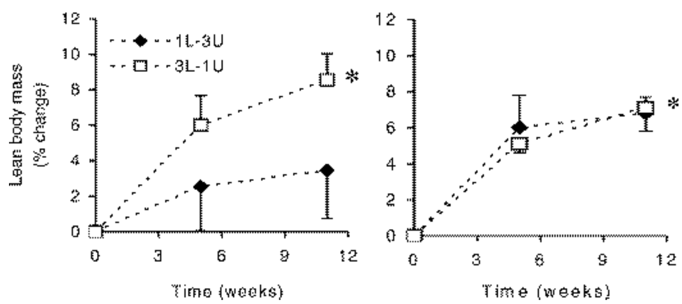

Figure 5. Relative changes in lean body mass after 5 and 11 weeks of strength training in the lower body (left) and upper body (right). 1L-3UB = 1 set in leg exercises and 3 sets in upper-body exercises ($n = 5$); 3L-1UB = 3 sets in leg exercises and 1 set in upper-body exercises ($n = 5$). * Significant difference from baseline ($p < 0.05$).

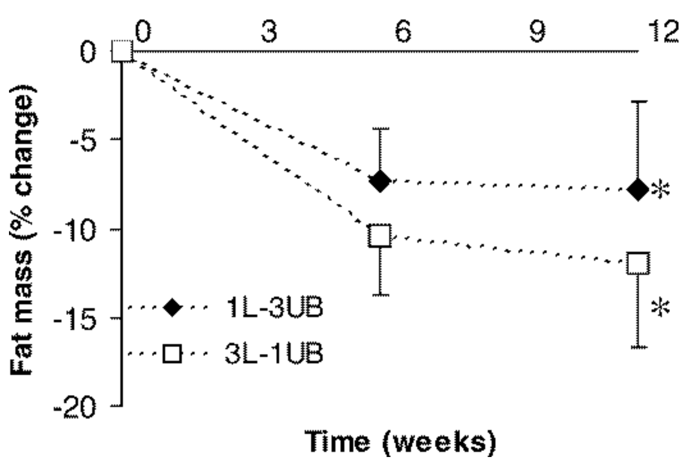

Figure 6. Relative changes in total fat mass after 5 and 11 weeks of strength training. 1L-3UB = 1 set in leg exercises and 3 sets in upper-body exercises ($n = 5$); 3L-1UB = 3 sets in leg exercises and 1 set in upper-body exercises ($n = 5$). * Significant difference from baseline ($p < 0.05$).

3 sets in the upper-body muscles (7, 22, 25, 31, 33) and superiority of 3 sets over 1 set in leg muscles (17, 22, 25, 28) regarding strength gains in relatively untrained subjects. Unfortunately, in other studies (18, 29) the results were not divided into upper- and lower-body muscles, making it impossible to determine whether there was a difference.

Based on the results of the present study, it is difficult to point out the reasons why upper-body muscles are not as responsive to differences in training volume as leg muscles. One possible explanation is that we use leg muscles in daily-life activities to a greater extent than our upper-body muscles. As a consequence, some of the growth potential in the leg muscles might already be reached through daily activities, meaning they are better trained than the upper-body muscles in subjects not committed to regular strength training. Furthermore, trained muscles seem to benefit more from a larger training volume than relatively untrained muscles (15, 24, 26, 27). This is in line with the way Paulsen et al. (22) explained similar findings. However, if the upper-body muscles are less trained than leg muscles, a greater increase in relative strength should be expected in upper-body muscles than in the leg muscles. This was, however, not the case since relative strength increased more in the leg muscles than in the upper-body muscles. Based on this finding the opposite conclusion may be drawn; the upper-body muscles need a higher training volume (>3 sets) than leg muscles to benefit from multiple-set strength training protocols. In support of this view, McBride et al. (19) found that 6 sets in biceps curl were superior to 1 set during 12 weeks of training in untrained subjects. However, the translation of these results into a normal strength training setting may be questioned because the subjects conducted only 2 exercises (leg press and biceps curl) per workout 2 times per week.

Greater increase in muscle mass seems to be the major explanation of superior strength gains in the 3-set group compared with the 1 set in the leg muscles. However, differences in neural adaptations have also been suggested as an explanation for the superiority of 3-set strength training compared with 1-set (12). We did not measure neural adaptations like changes in muscle activation, so we cannot exclude this as a possible explanation for the difference between groups. However, in a recent review, it was concluded that untrained subjects only have a minor activation deficit of their muscle in simple movements (30). Since all strength measurements were conducted in machines and the movements were in straight lines with small coordinative challenges, the exercises used in the present study can be defined as simple. Since the window of neural adaptations in simple movements seems to be relatively narrow, it is not likely that differences in neural adaptations explain the superiority of 3 sets in the leg exercises.

The 3L-1UB group increased their body weight significantly more than the 1L-3UB group. Since there were no differences between the groups in upper-body muscle hypertrophy, the superior hypertrophy of the lower-body muscles in the 3L-1UB group is likely to explain the difference in body weight gain between groups. The latter is supported by the tendency toward superior increase in lean body mass in the lower body in the 3L-1UB group compared with the 1L-3UB group, while no differences were found in the upper body. This is also reinforced by the fact that there is a greater part of total muscle mass

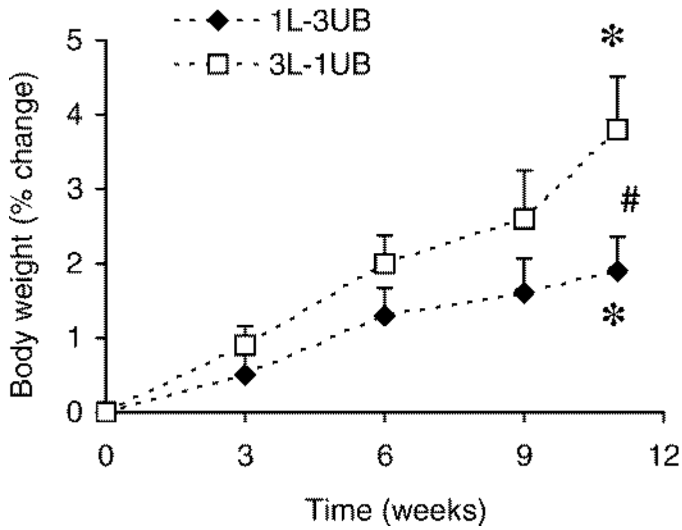

FIGURE 7. Percentage change in body weight during the strength training period in 1L-3UB (1 set in leg exercises and 3 sets in upper-body exercises) and 3L-1UB group (3 sets in leg exercises and 1 set in upper-body exercises). * Significant difference from baseline ($p < 0.01$) # Significant differences between groups ($p < 0.03$).

in the lower body (13) and that the percentage of fat decreased to a similar extent in both groups.

The mechanisms behind superior gains in muscle mass after 3-set strength training in the lower-body muscles, but not in the upper-body muscles, remain unclear. However, testosterone and growth hormone (GH) are known to be involved in the anabolic processes in the muscle cell, and hypertrophy may, therefore, be stimulated by changes in these hormones (16). In the present study we cannot exclude the possibility that increased serum concentrations of anabolic hormones elicited by 3 sets of the leg muscles, contributed to the strength increase in the upper-body muscles. It has been shown that acute GH and testosterone responses are larger in 3-set than in 1-set strength exercise protocols (11). However, because total training volume, intensity, and rest between sets were similar in both groups, differences in anabolic hormone secretion were probably negligible compared to traditional 3- vs. 1-set protocols.

Another possible explanation of the different responsiveness to training volume between upper- and lower-body muscles might be intrinsic differences. For example, the content of androgen receptors is higher in upper-body muscles (trapezius) than in leg muscles (vastus lateralis), and androgen receptors are less sensitive to strength training in the lower-body muscles compared with the upper-body muscles (14). It might, therefore, be hypothesized that muscles in the lower body to a greater extent are dependent on training volume due to the apparent lack of up-regulation of androgen receptors compared to upper-body muscles. Furthermore, it is possible that after the early phase of adaptation, training volume becomes more important also in upper-body muscles due to reduced changes in androgen receptors.

In conclusion, 3 sets of strength training on lower-body muscles is superior to 1 set during the first 11 weeks of strength training in untrained men. There seems to be no difference between 1 set and 3 sets in the upper-body muscles during this first phase of adaptation to strength training. The superiority of the 3-set protocol on the low-

TABLE 2. Energy, protein, carbohydrate, and fat intake before start of training and in training weeks 5 and 10. Values are means ± *SE*.*

Nutrient	1L-3UB			3L-1UB		
	Pre	5th week	10th week	Pre	5th week	10th week
Energy intake ($KJ \cdot d^{-1}$)	11,435 ± 704	12,114 ± 948	12,009 ± 878	11,783 ± 802	12,854 ± 768	11,983 ± 754
Protein ($g \cdot d^{-1}$)	106 ± 6.1	115 ± 8.1	119 ± 8.9	109 ± 6.3	136 ± 7.8	109 ± 6.2
Protein ($g \cdot kg^{-1} \cdot d^{-1}$)	1.3 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	1.7 ± 0.1	1.3 ± 0.1
Carbohydrate ($g \cdot d^{-1}$)	302 ± 18	360 ± 25	335 ± 24	307 ± 25	328 ± 20	356 ± 20
Carbohydrate ($g \cdot kg^{-1} \cdot d^{-1}$)	3.7 ± 0.3	4.3 ± 0.3	4.0 ± 0.4	3.9 ± 0.4	4.1 ± 0.4	4.4 ± 0.5
Fat ($g \cdot d^{-1}$)	94 ± 5.9	94 ± 11.3	96 ± 9.8	97 ± 9.9	111 ± 10.6	88 ± 11.3

* 1L-3UB = 1 set in leg exercises and 3 sets in upper-body exercises; 3L-1UB = 3 sets in leg exercises and 1 set in upper-body exercises.

er-body muscles to improve strength was mainly caused by a greater increase in muscle mass.

PRACTICAL APPLICATIONS

In the first 11 weeks of strength training there seems to be no difference between 1-set and 3-set protocols regarding strength gain and hypertrophy in the upper-body muscles. However, 3 sets seem to be superior to 1 set in the lower-body muscles regarding the same parameters. Therefore, if the aim is to get optimal strength and hypertrophy in previously untrained subjects, and the option is between 1 and 3 sets, we recommend 1 set on the upper-body muscles and 3 sets strength training on the lower-body muscles during the first 11 weeks of training. Based on the principle of overload and progression, it is likely that after the first period of adaptation, multiple sets will be superior also in the upper-body muscles. In addition, it might be that the upper-body muscles need more than 3 sets to benefit from multiple-set strength training programs.

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