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Research Article

Optimal Resistance Training
Comparison of DeLorme with Oxford Techniques

ABSTRACT

Fish DE, Krabak BJ, Johnson-Greene D, deLateur BJ: Optimal resistance training: Comparison of DeLorme with Oxford techniques. *Am J Phys Med Rehabil* 2003;82:903–909.

Objective: Progressive resistive exercises, such as the DeLorme or Oxford techniques, improve strength by adding weights to arrive at the ten-repetition maximum (10RM; DeLorme) or by starting at the 10RM and removing weight (Oxford). The goal of this study was to examine the efficacy of each training method.

Design: In this randomized, prospective, group design, evaluator-blind clinical trial, 50 subjects performed either the Oxford or DeLorme weight-training techniques. Three times a week for 9 wks, subjects completed three sets of ten-repetition knee extensions based on the 10RM measured weekly. Incremental or decremental changes in training weight were utilized in training sessions based on the protocol randomly assigned to each subject.

Results: The mean 10RM increase was 71.9 kg for the DeLorme group and 67.5 kg for the Oxford group, which was not significantly different. Examination with repeated measures multivariate analysis of variance revealed no significant difference between the two groups for 10RM increase, and no significant sex differences were found. Percentage change scores were not significantly different for 1RM and 10RM for both protocols and sexes.

Conclusion: Both protocol groups were able to complete their lifting assignments and progressed similarly in weekly 10RM weight lifted. It can be concluded that both the DeLorme and Oxford protocols improve strength with equivalent efficacy. Further studies involving a larger sample size are needed to address potential sex-specific changes in strength improvement in response to the protocols.

Key Words: Exercise, Conditioning, Rehabilitation

Despite the proven effectiveness of resistance training in building strength, uncertainty still exists as to the most efficient way to train. The work of DeLorme and Watkins[1–3] in the 1940s showed that with training, strength returns more quickly to atrophied muscles if relatively few repetitions are performed at high levels of resistance. They observed that the rate of muscle hypertrophy is proportional to the resistance overcome by the muscle;[1] thus, they prescribed a maximum of 20–30 repetitions, because performing >30 would require reducing the resistance and slow the rate of muscle hypertrophy.[2]

DeLorme defined the ten-repetition maximum (10RM) as the weight an individual could lift only ten times before temporary failure of the muscle occurred. One of DeLorme's hypotheses is that the muscle should be warmed up by the time 10RM is reached. Therefore, once the 10RM has been established during testing, the subject begins sets of training by performing the first set of ten at 50% 10RM, the second at 75% 10RM, and the third (final) at the 10RM. He suggested that progressive resistive exercises overloaded a muscle by increasing the magnitude of the weight against which the muscle developed tension. The goal was to lift the heaviest weight; thus, adjustment in the warm-up repetitions should be sought to enable the subject to complete the 10RM.

Factors impeding strength assessment include learning factors, such as an inability to exert maximal effort, fear of injury, or an unwillingness to endure the discomfort accompanying temporary muscle failure. For these reasons, DeLorme believed the initial 10RM was often an inaccurate reflection of a subject's strength. He noted that it was not unusual with training for strength to double within the first 1 or 2 mos and then to show a smaller increase during subsequent months.[1] Warm-up lifts were not intended to fatigue the muscle to the point that interfered with the subject's ability to complete the 10RM.[1] Instead, these initial lifts were thought to be important in preventing muscle soreness and in teaching the patient how to complete the exercises, thereby permitting maximal exertion by the final set.

In performing the DeLorme technique, Zinovieff[4] had consistent difficulties due to fatigue of the quadriceps muscle during the last quarter of the session.[5] Temporary failure of the muscle prevented the participant from completing the 10 repetitions at the 10RM. As the quality of performance fell, the full range of motion of the joint was compromised. Only the very athletic or determined individuals could carry out the technique as described by DeLorme. Zinovieff identified another method to strengthen muscle, the Oxford technique, in which heavy resistance and low repetition was maintained as per DeLorme, but the full 10RM was the first set and was subsequently reduced to 75% and to 50% of the 10RM in the remaining two sets. It was thought that this decrement in resistance would mimic the progressive increase in muscle fatigue. Each set of repetitions would continue to exercise the muscle to its maximum capacity, thus preserving the overload principle.

Many authors have suggested that the 10RM may not be the most important goal to reach in weight training.[6–9] Instead, the key to improving strength involves fatiguing the muscle.[9] Linnamo et al.[10] looked at fatigue and recovery of a muscle with explosive loading. He found that young women fatigued less than men. Chilibeck et al.[11] studied women for resistance training and noted that with a short training period, the amount of hypertrophy was less in women when compared with men. Charette et al.[12] proved that the muscles of elderly women are capable of hypertrophy and, therefore, strength gains.

At present it is unclear which technique, DeLorme or Oxford, is more effective at developing strength. The goal of our study was to evaluate the efficacy of each model of progressive resistive training.

METHODS

Sixty subjects (40 women and 20 men) were recruited from an academic hospital staff after sanction and approval of the study by the human investigation review committee. Subjects were screened to ensure that they were free from physical disease and were excluded if they were currently lifting weights, had knee contractures, a history of knee surgery, or chronic knee pain. Subjects previously engaged in an aerobic exercise routine were asked not to change their exercise routine during the study period. A consent form was signed and each volunteer was compensated for participating. The subjects were given a monetary reimbursement for participating in the study. The funding was given in increments as the testing unfolded. Each participant was given $50 for the initial testing, $75 for completion of the ninth week of training, and finally, $50 for the final day of testing.

Subjects were prospectively randomized into the DeLorme or Oxford weight-training protocols, 30 subjects in each protocol with 20 women and ten men comprising each group. Comparisons of both protocol groups in terms of age, height, and body weight was done before initial strength testing, and they were found to be equivalent.

Pretraining and posttraining strength of both lower limbs was determined by two methods: isokinetic torque-velocity curve and both a one (1RM) and ten (10RM) isotonic dynamic effort with a free weight attached to the foot by the DeLorme boot. Side of training was decided by a flip of a coin.

An isokinetic force *vs.* velocity curve was obtained using the Kin-Com dynamometer (Chattex, Chattanooga, TN). For testing on the Kin-Com, subjects were placed in the sitting position, hips flexed to 90 degrees to facilitate testing of the quadriceps muscle. Range of motion for testing was from 90 degrees of knee flexion to 0 degrees (full knee extension), with the force applied to knee extension using the dynamometer in the isokinetic mode and concentric/eccentric setting. To prevent hip flexion with training and testing, a Velcro belt was used to stabilize the knee.

Velocity variables of 30, 60, and 90 degrees/sec served as indices to estimate the starting 1RM and 10RM quadriceps muscle testing and training with the DeLorme boot. Each subject had three attempts at the 1RM for each speed of the Kin-Com selected. Two minutes of rest were used to prevent fatigue between each speed and 1 min of rest between each attempt at the 1RM.[13]

The torque *vs.* velocity curve was used to predict a 1RM with free weights. Using 60 degrees/sec, the free weight 1RM was approximated by using 90% of the generated peak torque. The participant had no more than three attempts to confirm the free weight 1RM so that fatigue was prevented.

The individual's isotonic dynamic initial testing 10RM was extrapolated from the testing of quadriceps strength by using 80% of the free weight 1RM.[14–17] After a 5-min rest, the participant performed a 10RM to clarify the projected 10RM. If the subject found this weight too difficult, by not completing the ten repetitions, or too easy, by performing more than ten repetitions, the weight was adjusted to a "true" 10RM by the examiner. Two minutes of rest was given to each subject during this phase of testing. No participant required more than three attempts in deriving the true 10RM. The derived true 10RM was used as the maximum resistance weight for the first day of training.

Subjects trained their quadriceps muscle with the aid of DeLorme boots while in a seated position. Training position was sitting on a plinth, which allowed participants to fully extend the knee and flex the knee to 90 degrees. There was no backrest, and subjects were constantly reminded not to lean backward when executing a lift. The weight was controlled throughout the upward and downward portion of the lift. A trainer ensured that the weight was not dropped, but slowly lowered and did not pass 90 degrees of knee flexion. A metronome was utilized to ensure a smooth and controlled lifting motion, which was set to the comfort of the individual subject.

On the days of exercise training (Monday, Wednesday, and Friday), the subjects performed some light stretching and warm-up exercises such as a mild walk for 10–15 mins. The DeLorme group started their first set of ten repetitions at 50% of 10RM, the second set of ten at 75% of 10RM, and the third set of ten at 10RM. The Oxford group performed their sets in the reverse order of 10RM, 75% of 10RM, and 50% of 10RM. The subject lifted a weight at a comfortable speed set to a metronome so that a constant lift pace was kept and each lift was smooth to avoid any ballistic and momentum-based efforts. Each lift was controlled in both concentric extension and eccentric flexion of the knee corresponding to the "tock" and "tick" of the metronome. There was a 1-min rest between each set.

At the beginning of the next week of training, a new 10RM was established by adding 2.75 kg to the 10RM.[4] A 10RM set was attempted to confirm the subject's ability to perform the new 10RM. If the subject was unable to perform at least eight repetitions of the new 10RM, the previous 10RM was utilized for the remainder of the week of training. If the subject was able to perform >12 repetitions of the new 10RM, another 2.75 kg was added, and an attempt at the new 10RM was made. If the subject easily lifted the new 10RM, a decision by the trainer to substantially increase the weight was made to ensure that a true 10RM was used. A rest of 3–5 mins was incorporated between lifts to prevent fatigue.[1] No more than three tests of the new 10RM were done to ensure that fatigue would not influence the subsequent training.

At the end of 9 wks of training, the same muscle performance tests of strength were employed to generate a posttraining torque *vs.* velocity curve. A posttraining 1RM and 10RM were done to determine a gain in strength. The director of both the prestrength and poststrength testing was blinded to the training group and side of training for each participant.

We computed a net change score by subtracting the initial 1RM and 10RM scores from the final 1RM and 10RM scores. Mean net change scores between protocol groups were then compared by using a Student's t test. The mean weekly 10RM was followed over 9 wks and evaluated by a repeated measures multivariate analysis of variance using protocol type (DeLorme and Oxford) and sex as the independent variables. Lastly, we computed percentage change scores for the 1RM and 10RM measures by dividing the initial and final scores. For all parametric analysis, we used an alpha of 0.05.

RESULTS

We recruited 60 subjects, and attrition was classified as follows: personal reasons unrelated to the study ($n = 5$), failure to complete the posttraining strength testing ($n = 4$), and onset of new physical symptoms pos-

TABLE 1

One-repetition maximum (1RM) and ten-repetition maximum (10RM) strength gains (in pounds) by sex for the DeLorme and Oxford protocols

	DeLorme		Oxford	
Protocol	Men (6)	Women (18)	Men (6)	Women (20)
Initial 1RM, kg	53.7 (SD = 11.2)	40.0 (SD = 7.7)[a]	56.2 (SD = 14.8)	48.8 (SD = 12.7)[a]
1RM change	71.0 (SD = 7.0)	24.0 (SD = 9.7)	65.0 (SD = 22.9)	23.7 (SD = 10.3)
Percentage change	133	60	115	48
Initial 10RM, kg	45.3 (SD = 8.1)	32.9 (SD = 5.1)[a]	48.7 (SD = 12.5)	43.1 (SD = 10.7)[a]
10RM change	59.9 (SD = 9.4)	26.0 (SD = 9.1)	52.0 (SD = 15.2)	24.3 (SD = 12.0)
Percentage change	132	79	107	56

[a] $P < 0.05$.

sibly related to the protocol ($n = 1$). Of the ten subjects who failed to complete the study, four were from the Oxford group and six were from the DeLorme group, suggesting that there was not a selective attrition between the two protocols. The final number of participants was 38 women and 12 men who performed either the Oxford ($n = 26$, six men) or DeLorme ($n = 24$, six men) techniques.

The power analysis revealed that the standard deviation in the current study averaged 17 and 28 kg for the DeLorme and Oxford groups, respectively. An average standard deviation for the cells would be 22.5. Assuming a moderate effect size (0.25) and a power of 0.80, the study would need a cell size of $n = 65$ (total of 130 subjects) for primary data analysis comparing the two techniques with a repeated measures multivariate analysis of variance.

The average age, height, and weight of participants for the women in the Oxford group was 38.8 yrs (SD = 10.4), with a range of 24–55 yrs, 144.5 cm (SD = 6.8), and 90.4 kg (SD = 25). The DeLorme group was 42.9 yrs (SD = 10.1), with a range of 30–56 yrs, 140.8 cm (SD = 5.5), and 70.72 kg (SD = 16.0). The average age, height, and weight for the men in the Oxford group was 37 yrs (SD = 12), with a range of 22–51 yrs, 180.3 cm (SD = 3.0), and 82.6 kg (SD = 13.6), respectively, and for the DeLorme group, 35 yrs (SD = 8.5), with a range of 23–44, 175.3 cm (SD = 5.0), and 83.6 kg (SD = 10.3), respectively. The only significant difference was in the weight of the women ($P = 0.04$).

All of the participants increased the amount of weight lifted in both the 1RM and the 10RM testing after 9 wks of training. All subjects for both protocols were able to complete the lifting assignments during the training sessions, and the compliance for subject attendance was >95%. At each session of training, each participant always reached the 10RM calculated for that week. For the number of attempts to set the new 10RM, 50% of subjects required one attempt to reach the new 10RM, whereas 36% required two attempts and 14% required three attempts. Although participants progressed in 10RM lifted over the 9 wks, final testing of the 10RM was smaller in two individuals, one man and one woman. Final 10RM was taken as the higher of 10RM attained at week 9 of training or final 10RM testing.

Sex evaluation (Table 1) revealed that the initial 1RM and 10RM differences between the two protocols were mainly due to the female subjects. The mean initial 1RM for women in the DeLorme and Oxford groups was 88 kg (SD = 17) and 107 kg (SD = 28), respectively, which was significantly different ($t = 2.37$, $P = 0.05$). The mean initial female 10RM was significantly different ($P = 0.008$), with the DeLorme protocol starting at 72 kg (SD = 11) and the Oxford protocol at 95 kg (SD = 23). For men, the initial 1RM for the DeLorme and Oxford groups was 118 kg (SD = 25) and 124 kg (SD = 32), respectively, which was not significantly different ($t = 0.33$, $P = 0.78$). The initial male 10RM for the DeLorme and Oxford group was 100 kg (SD = 18) and 107 kg (SD = 28), respectively, which was not significantly different ($t = 0.55$, $P = 0.58$).

Although participants were randomly assigned to each of the two groups, analysis of the 1RM and 10RM scores revealed group differences. In Figure 1, the initial 1RM of the DeLorme group was 94 kg (SD = 23.3), and the Oxford group started at 111 kg (SD = 29.5), which was a significant difference ($t = 2.1$, $P < 0.05$). The mean 1RM increase in strength after 9 wks of training (Fig. 4) was 87 kg (SD = 50) for the DeLorme group and 74 kg (SD = 50) for the Oxford group, which was not significantly different ($t = 0.88$; $P < 0.4$). The overall percentage change scores of the 1RM for the DeLorme and Oxford groups were 92% and 66.5%, respectively.

In Figure 2, the initial mean 10RM weight for the DeLorme and Oxford protocols (Fig. 2) was 79.2 kg

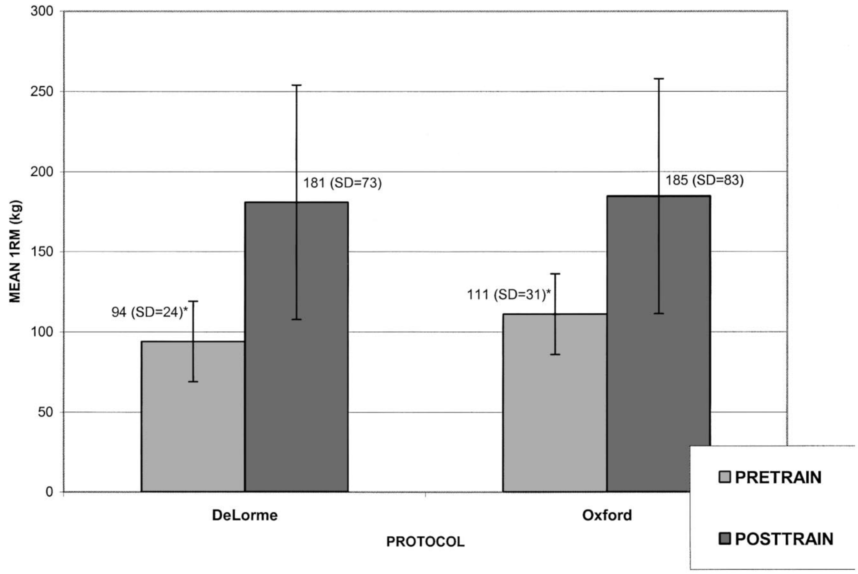

Figure 1: Comparison of DeLorme with Oxford one-repetition maximum (*1RM*) strength after 9 wks of training. There was a significant difference between pre-training mean 1RM for Delorme *vs.* Oxford. *$P < 0.05$.

(±17.3) and 98 kg (±25), respectively, which was significantly different ($P = 0.004$). The mean 10RM increase after 9 wks of training (Fig. 4) was 76 kg (±38.5) for the DeLorme group and 67.5 kg (±38) for the Oxford group, which was not significantly different ($t = 0.76$, $P < 0.65$). The overall percentage change scores of the 10RM for the DeLorme and Oxford groups were 96% and 69%, respectively.

Repeated measures examination using 1RM and 10RM (Fig. 3) data from each of the 9 wks of training showed no significant difference by protocol ($F = 1.828$, $P = 0.183$) with the DeLorme and Oxford groups gaining a mean of 127 and 139 kg, respectively.

DISCUSSION

Both the DeLorme and Oxford protocol subjects improved muscle strength, as demonstrated by the weekly 1RM and 10RM gains over 9 wks of training. Subjects from each protocol were able to maintain attendance and compliance with required lifting assignments.

The percentage change scores for the 1RM and 10RM show equivalent increases for both protocols. Although there was no significant difference between the two protocols, it should be noted that the DeLorme group started with significantly lower 1RM and 10RM scores. In addition, the DeLorme group had larger percentage change scores than scores from the Oxford protocol, but these were not significantly different. No significant sex differences were found for either protocol in regard to strength gains over the 9-wk training program.

The purpose of the present study was to determine the optimal method of developing muscle strength. Strength development is a goal of many exercise programs. For patients whose muscles have atrophied because of disuse associated with injury and in healthy individuals planning a lifelong exercise routine for themselves, building strength has been shown to give many important benefits. Poor muscular fitness can be associated with reduced muscle and connective tissue strength, reduced lean body mass, and reduced bone density. Together, these conditions increase the risk of falls, injuries, and low back pain. In the older population, age-related muscle atrophy is the main reason for impaired muscle function.[18,19] Therefore, determining the best method for building strength is relevant to individuals of all ages and health levels.

From the results of the present study, it seems that both the DeLorme and Oxford protocols can develop strength in healthy men and women. Optimal strength development can occur when a muscle contracts against a degree of resistance high enough to reach maximal or

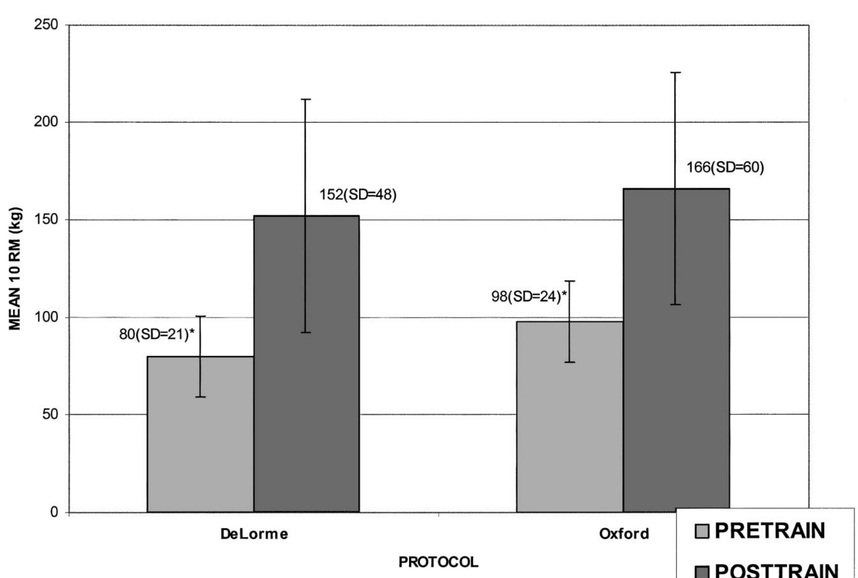

Figure 2: Comparison of DeLorme with Oxford mean strength gains after 9 wks of training ($P < 0.05$). *RM*, repetition maximum.

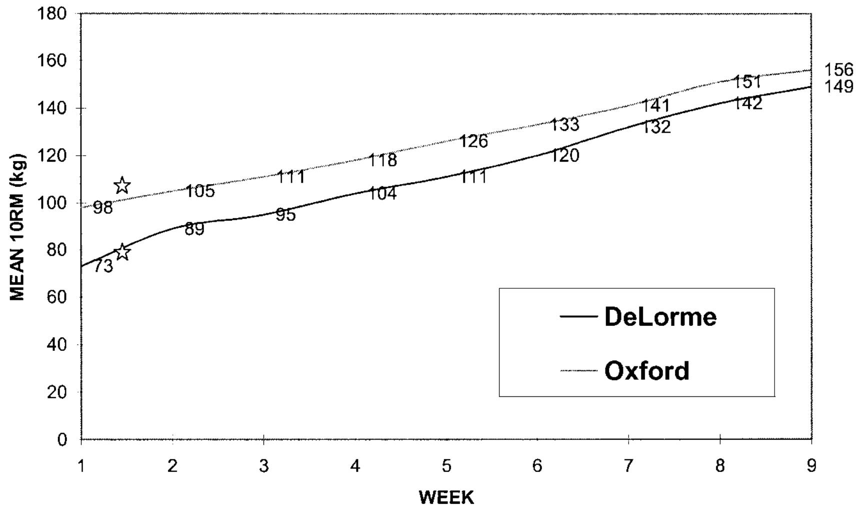

Figure 3: Comparison of DeLorme with Oxford mean ten-repetition maximum (*10RM*) strength after 9 wks of training. There was a significant difference between pretraining mean 10RM for Delorme *vs.* Oxford. ☆$P < 0.004$.

near maximal effort, which is enough to fatigue the trained muscle.[4,6,7,9,20] The rate of this increase is proportional to the resistance relative to the muscle capacity (i.e., the percentage maximum of voluntary muscle contraction) and a patient's initial condition, which is an important factor to consider when devising rehabilitation programs for patients.[4,17,20] Strength benefits attributable to hypertrophy do not occur immediately on the initiation of a strength-training regimen. Rather, early gains in strength are attributed to nervous system adaptations.[21] The more complex the exercise, the more learning that must take place and the more important it is to train to task.[22]

The reason the Oxford technique was developed was that Zinovieff found that only healthy, well-developed, and motivated individuals could complete the final 10RM of the DeLorme technique. Our study did not find any individual having difficulty by the third set of lifts with the DeLorme method. The subjects were given ample time to recover so that fatigue would not be an inhibiting factor. The women who might be considered as weak or deconditioned by making small strength gains were able to lift the third set in the DeLorme techniques just as readily as did the Oxford subjects.

This study has several limitations: the small number of subjects, the small number of male subjects, and a randomization error in the inequality at the start of the study between the women in terms of body weight and initial mean 1RM and 10RM scores. Furthermore, the sedentary women that were chosen for this study would have been difficult to motivate if it were not for monetary reimbursement. This, however, did not guarantee that each individual would give his or her best efforts during either the training or testing phases. Many women involved with this study did not give an all out effort, and looking at the very low weight gains for the weekly 10RM could easily identify them. This could also account for the large standard deviations.

The inequality of the initial testing of the women may confuse the findings; because the Oxford group started at a higher 1RM and 10RM, one would expect that the DeLorme group would have more room to make gains. In our study, this finding turned out not to be true as the mean gains in strength (absolute values) in the 1RM and 10RM were statistically the same in both protocols.

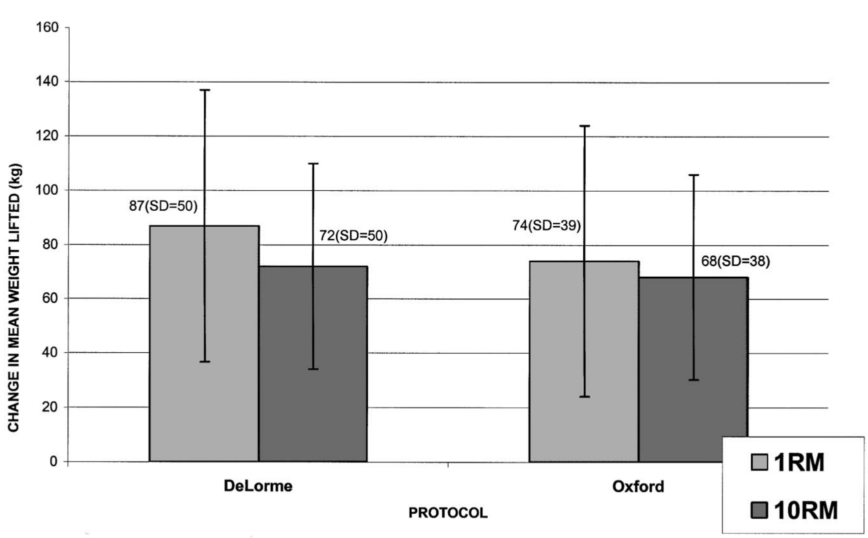

Figure 4: Comparison of DeLorme with Oxford mean ten-repetition maximum (*10RM*) per week during 9 wks of training ($P < 0.05$).

CONCLUSION

Both the DeLorme and Oxford protocols can improve muscle strength, as demonstrated by the weekly 10RM and net change in 1RM and 10RM gains over 9 wks of training. Because all subjects were able to complete their lifting assignments (finish the third set for each session) and all progressed in weight lifted at the end of 9 wks, it can be hypothesized that both the DeLorme and Oxford protocols can improve strength without over fatiguing the muscles. The inability to complete the 10RM, which led to the dissatisfaction with the DeLorme protocol by earlier studies, was not seen in the present study. Further research with larger sample sizes are needed to determine any sex-specific changes in strength improvement in response to these protocols.

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