

COMPARISON OF DELORME WITH OXFORD RESISTANCE TRAINING TECHNIQUES: EFFECTS OF TRAINING ON MUSCLE DAMAGE MARKERS

■ Accepted
for publication
15.12.2009

AUTHORS: da Silva D.P.¹, Curty V.M.¹, Areas J.M.², Souza S.C.³, Hackney A.C.⁴, Machado M.¹

¹Laboratory of Physiology and Biokinetics (UNIG – Campus V)

²Pharmacy Basic of Muniz Freire (ES)

³Faculties of Philosophy, Sciences and Languages of Alegre (ES)

⁴Applied Physiology Laboratory, University of North Carolina at Chapel Hill (USA)

Reprint request to:

Marco Machado

Laboratório de Fisiologia e Biocinética
(UNIG – Campus V)

Coordenação de Educação Física

Universidade Iguazu (UNIG)

BR 356 - Km 02 Itaperuna, RJ, Brazil

CEP 28.300-000

Email: marcomachado1@gmail.com

ABSTRACT: Aim: The purpose of this study was comparing DeLorme with Oxford methods through ten repetition maximum (10 RM) performance and serum creatine kinase (CK) and lactate dehydrogenase (LDH) activity. Methods: Before and after four weeks of training with the DEL (n=16) or OXF (n=16) resistance training (RT) methods, rest and post exercise serum CK activity, serum LDH activity and 10 RM performance were measured and compared. Results: Both methods provide higher 10 RM results after training without significant differences between groups ($p < 0.05$). Rest and post exercise CK and LDH activity was less after training with DeLorme (DEL) and Oxford (OXF), but the magnitude of the relative peak response (48-hr our 72-hr post exercise, respectively) was higher after each training protocol. Comparisons of CK activity between groups display non-significant differences. Conclusion: DEL or OXF training methods cause the same improvement on muscle performance and both alters CK activity without differences between methods in a 4-week RT program.

KEY WORDS: creatine kinase, resistance training, micro-damage

INTRODUCTION

Resistance Training (RT) is indicated for muscle hypertrophy, strength gain, sport performance and physical rehabilitation, but in the last few years it has been promoted as a means for health promotion and disease prevention [1,9]. The design of an effective RT program is a complex process of applying with synergism established scientific principles, progressive research findings, veteran and modern practices, and professional knowledge to accommodate individual situations, needs, and goals. Differing from a professional athletes training, the recreational consumer exercise program should focus on improvements in muscular health and fitness [14]. Historically, a quantifiable relationship between the volume, intensity, and/or frequency of training, and muscular strength improvements, has been elusive and controversial in RT. For many years, personal opinion and the accounts of several unscientific literature reviews were the primary sources of evidence to support a variety of RT philosophies [3,14].

The American College of Sports Medicine position stand entitled "Progression Models in Resistance Training for Healthy Adults" [1] provides a framework for training prescription guidelines relative

to the need for progression in healthy novice, intermediate, and advanced trainees. This position stand recommends for novice and intermediate's gain strength then intensity between 60-70% of 1 repetitions maximum (1RM) for 8-12 repetitions is necessary. Regrettably, however, the certain aspects of the methods of RT were poorly commented on in the ACSM's position stand.

Thomas DeLorme's work in the 1940 s proposes a progressive resistance exercise (PRE) program based on 10 repetitions maximum (10RM) where subject begins sets of training by performing the first set of 10 at 50% 10RM, the second at 75% 10RM and the third (final) at the 10RM. This same author suggested that PRE overloaded a muscle by increasing the magnitude of the weight against which the muscle developed tension. In opposite was created the 'Oxford Technique' in which the full 10RM was the first set and subsequent two sets were reduced to 75% and to 50% of the 10RM. Apparently, a sparse number of research studies have directly compared these two RT methods. Interestingly in one such comparison, Fish et al. [7] reported no significant differences between both RT methods on strength gains.

TABLE I. PARTICIPANTS CHARACTERISTICS (MEAN \pm SE)

	DEL Group (n = 16)	OXF Group (n = 16)
Age (years)	22.5 \pm 6.9	23.4 \pm 4.7
Height (cm)	173.1 \pm 6.7	175.5 \pm 7.9
Weight (Kg)	71.4 \pm 9.4	71.9 \pm 8.5
10RM (Kg)	88.6 \pm 11.4	93.4 \pm 11.6
Erythrocytes ($\times 10^6/l$)	5.3 \pm 4.3	5.2 \pm 3.2
Haemoglobin (g/dl)	14.4 \pm 1.4	15.3 \pm 1.2
Hematocrit (%)	46.5 \pm 4.2	44.5 \pm 7.0
Leucocytes ($\times 10^9/l$)	6.4 \pm 1.8	6.2 \pm 1.3
Basophils (/mm ³)	0.0 \pm 0.0	0.0 \pm 0.0
Eosinophils (/mm ³)	244.6 \pm 105.9	304.4 \pm 171.5
Myelocytes (/mm ³)	0.0	0.0
Bands (/mm ³)	180.6 \pm 98.7	173.1 \pm 76.3
Segmented (/mm ³)	3813.4 \pm 1542.0	3545.8 \pm 836.6
Lymphocytes (/mm ³)	1932.8 \pm 349.9	1911.0 \pm 434.4
Monocytes (/mm ³)	191.2 \pm 69.1	153.3 \pm 62.9

It has been suggested that RT may cause muscle cell membrane disruption. This may be a consequence of both metabolic and mechanical causes. Indeed, exhausted muscle fibers exhibit increased membrane permeability following an increase in internal free calcium ions, which promotes the opening of potassium channels and activation of proteolytic enzymes such as calpains and caspases [2,6,12]. Exercise induced muscle micro-injury leads to cellular damage with membrane disruption and leakage into the extracellular fluid and plasma. Creatine kinase (CK), lactate dehydrogenase (LDH), myoglobine have been used extensively as markers for skeletal muscle micro-injury [5,11,15]. These enzymes have also been proposed as scientific parameters for gauging muscle training adaptation efficacy in athletes [2,11].

Because of the limited amount of research available, this study was conducted to examine the effectiveness of the DeLorme's versus Oxford methods of RT training on strength performance and muscle adaptations. To this end, muscle strength gains and the activity of CK response were examined before and after four weeks of each method of RT program in young men.

MATERIALS AND METHODS

The subjects were men free from physical disease and were excluded from consideration if they were not currently lifting weights, had knee contractures, a prior history of knee surgery, and/or chronic

knee and/or low back pain. Subjects were divided according to a computer generated randomization list into the DeLorme (DEL; n=16) or Oxford (OXF; n=16) RT protocols. Comparisons of both protocol groups in terms of age, height, and body weight was done prior to initial strength testing and were found to be equivalent ($p > 0.05$; see Table 1). Pre- and Post-training strength of both lower limbs was determined by ten repetitions maximal (10 RM) for the Half Squat exercise. The experimental conditions were in accordance with federal and institutional guidelines for human subject's research.

To minimize possible errors in the 10 RM testing, the following strategies were employed: (a) all subjects received standard instructions on exercise technique, (c) exercise technique was monitored and corrected as needed, and (d) all subjects received verbal encouragement.

A rest interval of seven days after the 10RM testing was provided to the subjects (Fig. 1), all subjects were instructed to not perform exercises of any kind during this period. On the 8th day (PRE Test Day) they return to the laboratory and peripheral blood samples were obtained (see below). After a warm up (jogging and stretching) they performed 3 sets of 10 repetitions of the Half Squat exercise. In accordance with previous randomized process, DEL group started their 1st set of 10 repetitions at 50% of 10 RM, the 2nd set of 10 at 75% of 10 RM, and the 3rd set of 10 at 10 RM. The OXF group performed their sets in the reverse order of 10 RM, 75% of 10RM and 50% of 10 RM [7]. The repetition cadence was controlled with a digital sound signal (Beat Test & Training, CEFISE, Brazil) that was adjusted so that each repetition was completed in 3 seconds (one second concentric phase, two seconds eccentric phase).

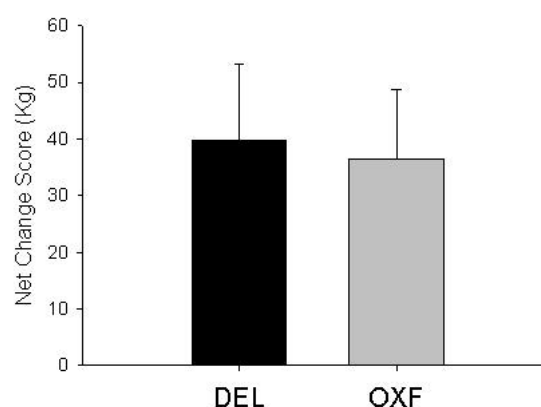


FIG. 2. Net change score in muscle strength. No significant difference between RT method groups was observed (Net Change Score was obtained by subtracting the initial 10RM scores from the final 10RM scores).

Day 1	Day 2-7	Day 8		Day 9	Day 10	Day 11	Day 12-14	Day 15-38	Day 39-42	Day 43	Day 43-48	Day 49		Day 50	Day 51	Day 52
10RM	REST	Blood Sample	PRE Test (DeLorme or Oxford)	Blood Sample	Blood Sample	Blood Sample	REST	TRAINING (DeLORME or OXFORD) 2 x WEEK	REST	10RM	REST	Blood Sample	POST Test (DeLorme or Oxford)	Blood Sample	Blood Sample	Blood Sample

FIG. 1. Time line of the study

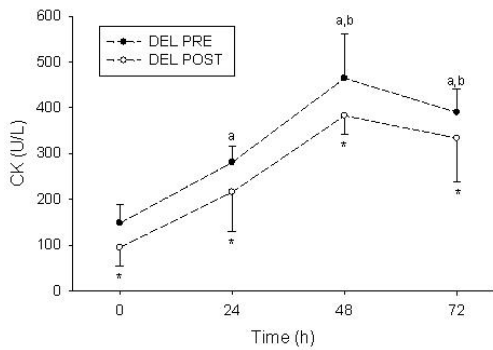


FIG. 3. Serum CK activity (mean±SD) in DEL group. (*) differences between PRE and POST ($p < 0.05$); (a) Different from 0h ($p < 0.05$); (b) Different from 24h ($p < 0.05$)

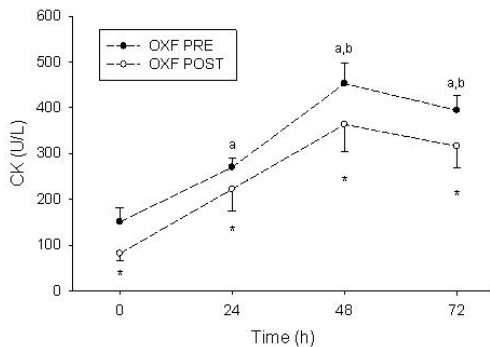


FIG. 4. Serum CK activity (mean±SD) in OXF group. (*) differences between PRE and POST ($p < 0.05$); (a) Different from 0h ($p < 0.05$); (b) Different from 24h ($p < 0.05$)

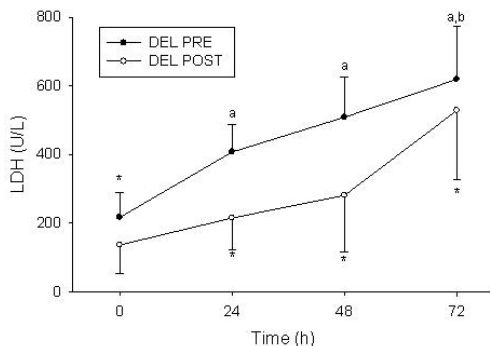


FIG. 5. Serum LDH activity (mean±SD) in DEL group. (*) differences between PRE and POST ($p < 0.05$); (a) Different from 0h ($p < 0.05$); (b) Different from 24h ($p < 0.05$)

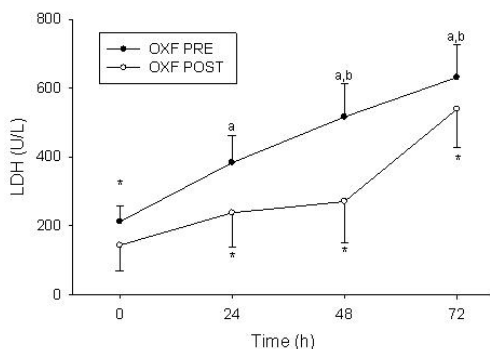


FIG. 6. Serum LDH activity (mean±SD) in OXF group. (*) differences between PRE and POST ($p < 0.05$); (a) Different from 0h ($p < 0.05$); (b) Different from 24h ($p < 0.05$)

There was a two-minute rest between each set. Subsequently, blood samples were collected again at 24, 48 and 72 hours after the first blood sample collection.

On the days of exercise training (days 15 to 38), always on Monday and Thursday of each week, the subjects performed some light stretching and warm-up exercises such as a mild walking for 10 to 15 minutes. Immediately after the warm-up, the DEL group realizes 3 sets of 10 repetitions of Half Squat in accordance with DeLorme protocol and the OXF group realize in accordance with Oxford protocol as described by Fish et al. [7]. All procedures were identical with PRE Test day. A spotter gave minimal assistance if necessary so that the ten repetitions were completed for all three sets of the exercise. Therefore, the volume of work ([load] x [sets] x [repetitions]) was equalized between the experimental sessions. As the subjects were of a moderate activity level (i.e., exercise training history), we choose the 2 sessions of training per week because research supports this is sufficient for strength gain [13,14,16,17].

At the end of four weeks of training, the same muscle performance tests for strength evaluation were employed. A post-training 10RM were done to determine if a gain in strength occurred. As a experimental control, the director of both the pre and post-strength testing was blinded as to the training assignment (Del vs. OXF) for each participant. One week later the procedures of PRE Test day were repeated and this test was named POST Test Day. Four blood samples were collected before the POST Test Day and 24, 48, and 72 hours afterwards as had been previously done.

All blood samples were venous and collected using veni-puncture from the forearm while the subjects were in a seated position. After collection, the blood samples were centrifuged for serum separation. Serum was quickly frozen and stored at -70°C . From serum samples activity of creatine kinase (CK) and lactate dehydrogenase (LDH) was determined. An enzymatic method at 37°C was used for enzymes activity analysis using high reliable, commercially available kits (BioTécnica - Brazil) in Cobas Mira Plus analyzer (Roche - Germany).

Statistically, we computed a net change score by subtracting the initial 10 RM (PRE Test Day) scores from the final 10 RM (POST Test Day) scores. Mean net change scores between protocol groups were then compared by using a student's t-test. The 2 (DEL vs OXF) x 2 (PRE vs POST) ANOVA was used to compare CK and LDH variations. For all parametric analysis an alpha of 0.05 was used.

RESULTS

The anthropometric, hematological and performance characteristics between groups is identical (Table 1). The hematocrit, erythrocytes and hemoglobin concentration remained stable and relatively homogeneous during the experimental protocol (data not show).

Fig. 3 shows the changes in CK after the DEL protocol (PRE vs POST training). Serum CK activity responses for the both testing times began to increase significantly from the baseline responses 24-hours after testing, reaching peak values at 48-hours

post-exercise testing ($p < 0.05$). All measurement time comparisons were significantly different between PRE and POST tests ($p < 0.05$).

Fig. 4 shows the changes in CK after the OXF protocol (PRE vs POST training). Serum CK activity responses increase significantly from the baseline responses 24-hours after testing, reaching peak values at 48-hours post-exercise testing ($p < 0.01$). All measurement time comparisons were significantly different between PRE and POST tests ($p < 0.05$).

Figs. 5 and 6 represent the results of serum LDH activity. All results were similar to those of serum CK activity displayed on Figs. 3 and 4, but different from CK the peak was found 72 hours after exercise in both methods.

Although the absolute CK and LDH activity was lower in POST testing measurements, the relative percentage of change were actually higher for each RT treatment group ($p < 0.05$). The greatest relative change was observed for peak responses. That is, the differences between peak and baseline serum enzymes activity were $\sim 50\%$ higher after each training protocol (Fig. 7a and 7b).

DISCUSSION

In accordance with Fish et al. [7], the results of present study displayed the same absolute strength gains independent of the DeLorme or Oxford method utilized. The strength gain is important for many protocols as athletic performance, disease prevention and rehabilitation exercises. The options of training method can attend the personal preference of athlete/patient because the strength gain is equivalent.

The serum CK activity we observed can serve to verify if the training protocol is adequate. Higher serum CK activity associated with other clinical signals and symptoms suggest the excessive training regime and skeletal muscle lesion. Conversely, lower values can signify the training planning do not promote the adaptations [11]. Mougios [11] proposes values for serum CK activities for athletes with an aim for providing parameters for coaches, athletes and sport physicians. In the present study, the serum CK activities always were inside the values proposed for Mougios [11]. This finding suggests a safety in DeLorme and Oxford methods of RT when applied in the fashion used here within.

Serum LDH activity was higher after exercise as CK activity. The data of the variation in serum LDH activity confirm the data found in serum CK activity. The LDH also seen being used in several studies [4,5,15], but in smaller quantities that CK. Our results show the peak in LDH activity 72 hours after exercises, these data corroborate the data of Chen & Hsieh [4].

Tidball [19] describes the importance of the inflammatory process influencing the muscle hypertrophy, the principal stimulus for that is the micro-damage when induced by exercise. A practical method for micro-damage verification is the serum CK activity as measured in the blood [2]. Both, DeLorme and Oxford methods alters the serum CK activity, suggesting the micro-damage and the inflammatory process response to the training. In the present study the time of

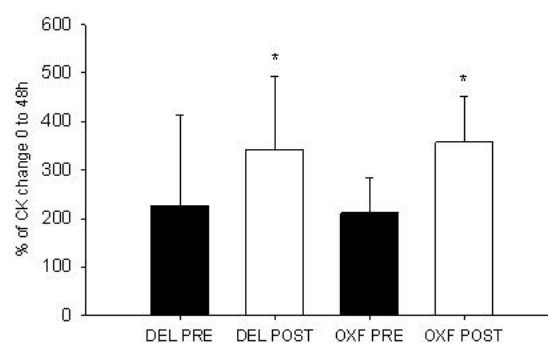


FIG. 7a. Changes in CK activity before and after training in groups DEL and OXF. (*) significant difference from PRE responses ($p < 0.05$)

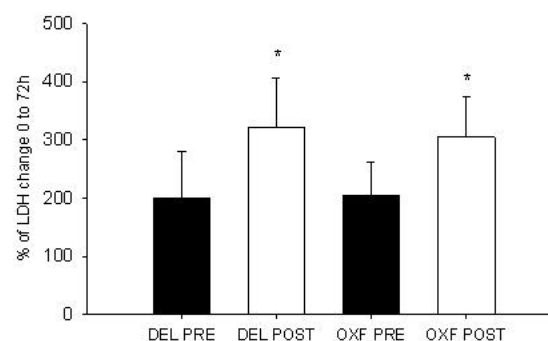


FIG. 7b. Changes in LDH activity before and after training in groups DEL and OXF. (*) significant difference from PRE responses ($p < 0.05$)

training was only four-weeks, consensual data [8] indicates this is an insufficient interval for hypertrophy adaptation within the muscle, and thus the strength gains would most likely provided from neural adjustments. The data from CK activity were totally in accordance with previous studies, with a serum CK peak elevation at 48h as has been observed in many others studies [2,6,11,12,18].

Two points concerning the study must be considered: the subjects were of a moderate activity level and the RT protocols were only four weeks in duration. Least one limitation of the study, the training status was choice in accordance with the prescription recommendation for the methods of training. That is, more complex methods, with higher intensity-volume demands should not be prescribed for novices [1,10].

Mougios [11] and Braccaccio et al. [2] propose higher values for CK activity on athletes during training period when compared with non-athletes individuals. The constant mechanical and metabolic stress of athletic training results in maintenance of higher CK levels. Our results demonstrate lower values post of the training regimes we examined. This result apparently is contradictory with previous reports (above), but we provided one week of rest to the subjects before the baseline post-training measurement. In fact, many studies [6,12,18] display reduction on CK level 5-7 days after exercise when a rest period is provided. Based on the findings of Chen and Hsien [4] and Saka et al. [18]

we postulated such an adjustment occurred in our subjects induced by the training-rest protocol.

Serum LDH activity confirms the data from CK activity, both enzymes display similar comportment (except peak hour) in PRE and POST training measures. The smaller activity before training corroborates the data from CK and can postulate the adjustment process induced by the two compared RT methods. In accordance with CK activity, despite find lower values in the enzyme activity, the change until the peak was higher after both RT methods.

CONCLUSIONS

The results of this study show that there were no significant differences between the DeLorme or Oxford methods of RT on muscle performance or on serum enzymes activity responses over a 4 week period. Each method of training resulted in significant, but comparable, muscle strength gains and a low risk of injury. Thus the choice of one or another of these RT methods is acceptable for moderately active men.

REFERENCES

1. ACSM American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med. Sci. Sports Exerc.* 2009;41:687-708.
2. Brancaccio P., Maffulli N., Limongelli F.M. Creatine kinase monitoring in sport medicine. *Br. Med. Bull.* 2007;81-82:209-230.
3. Carpinelli R.N., Otto R.M., Winett R.A. A critical analysis of the ACSM position stand on resistance training: insufficient evidence to support recommended training protocols. *J. Exerc. Physiol.* Online 2004;7(3):1-60.
4. Chen T.C., Hsieh S.S. Effects of a 7-day eccentric training period on muscle damage and inflammation. *Med. Sci. Sports Exerc.* 2001;33:1732-1738.
5. Chevion S., Moran D.S., Heled Y., Shani Y., Regev G., Abbou B., Berenshtein E., Stadtman E.R., Epstein Y. Plasma antioxidant status and cell injury after severe physical exercise. *Proc. Natl. Acad. Sci. USA* 2003;100:5119-5123.
6. Clarkson P.M., Hubal M.J. Exercise-induced muscle damage in humans. *Am. J. Phys. Med. Rehabil.* 2002;81: S52-S69.
7. Fish D.E., Krabak B.J., Johnson-Greene D., Delateur B.J. Optimal resistance training: comparison of DeLorme with Oxford techniques. *Am. J. Phys. Med. Rehabil.* 2003;82:903-909.
8. Kraemer W.J., Fleck S.J., Evans W.J. Strength and power training: physiological mechanisms of adaptation. *Exerc. Sport Sci. Rev.* 1996;24:363-398.
9. Kraemer W.J., Ratamess N.A. Fundamentals of resistance training: progression and exercise prescription. *Med. Sci. Sports Exerc.* 2004;36:674-688.
10. Mazzetti S.A., Kraemer W.J., Volek J.S., Duncan N.D., Ratamess N.A., Gómez A.L., Newton R.U., Häkkinen K., Fleck S.J. The influence of direct supervision of resistance training on strength performance. *Med. Sci. Sports Exerc.* 2000;32:1175-1184.
11. Mougios V. Reference intervals for serum creatine kinase in athletes. *Br. J. Sports Med.* 2007;41:674-678.
12. Nosaka K., Newton M., Sacco P. Muscle damage and soreness after endurance exercise of the elbow flexors. *Med. Sci. Sports Exerc.* 2002;34:920-927.
13. Peterson M.D., Rhea M.R., Alvar B.A. Maximizing strength development in athletes: A meta-analysis to determine the dose-response relationship. *J. Strength Cond. Res.* 2004;18:377-382.
14. Peterson M.D., Rhea M.R., Alvar B.A. Applications of the dose-response for muscular strength development: a review of meta-analytic efficacy and reliability for designing training prescription. *J. Strength Cond. Res.* 2005;19:950-958.
15. Pettersson J., Hindorf U., Persson P., Bengtsson T., Malmqvist U., Werkström V., Ekelund M. Muscular exercise can cause highly pathological liver function tests in healthy men. *Br. J. Clin. Pharmacol.* 2007;65:253-259.
16. Rhea M.R. Synthesizing strength and conditioning research: The meta-analysis. *J. Strength Cond. Res.* 2004;18:921-923.
17. Rhea M.R., Alvar B.A., Burkett L.N., Ball S.B. A meta-analysis to determine the dose-response for strength development. *Med. Sci. Sports Exerc.* 2003;35:456-464.
18. Saka T., Akova B., Yazici Z., Sekir U., Gür H., Ozarda Y. Difference in the magnitude of muscle damage between elbow flexors and knee extensors eccentric exercises. *J. Sports Sci. Med.* 2009;8:107-115.
19. Tidball J.G. Inflammatory processes in muscle injury and repair. *Am. J. Physiol.* 2005;288:R345-R353.