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Effects of Resistance Training with Different Nutrient Supplementation on Muscle Strength

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Abstract- A large body of scientific evidence holds that a combination of carbohydrates and protein/essential amino acids is more efficient than carbohydrates alone when in optimal muscle strength and size gains through resistance training is the goal. However, there is much less consensus on what the optimal timing of administration is, with conflicting reports regarding consumption of supplements before, during, and after training. To try and answer some of these questions, a study was conducted using 23 volunteers performing resistance training for 8 weeks, and consuming either a combination of carbohydrates and protein or carbohydrates alone. Measurements of body composition, limb circumference and strength were performed both before and after. No significant differences could were be found observed in any of the measurements between the two groups after 8 weeks of training. While this was unexpected, a closer look at the data, as well as an evaluation of the training methods and nutrient supplementation used in the study in comparison with by other studies in the field, revealed that issues such as nutrient composition, dosage and the training process (directly supervised or not) training may have a strong influence on the results of a training study. Thus, in order to conclusively answer the question of which training and nutritional strategy produces were the best results, first of all, a more standardized training methods are is required.

I. Introduction

Muscle strength is a topic of great interest for scientific research, whether the goal is to improve quality of life in the elderly or seriously ill, or to maximize athletic performance. It is widely accepted that the maximal force output of a muscle is dependent on several different factors, such as motor neuron activation and muscle size. A popular strategy to increase muscle strength is resistance training, which is known to act on both of these factors (Phillips et al, 2005; Weinert, 2009; Andersen et al, 2005; Aagaard, 2004), albeit non-linearly, with increases in actual protein content and cross-sectional area believed to occur later than neuronal adaptations (Fleck & Kraemer, 2004; McArdle et al, 2010). To strengthen the effects on muscle size, resistance training is often accompanied by supplementation of carbohydrates and/or proteins or amino acids (Andersen et al, 2005; Kerksick et al, 2008; Aagaard, 2004). Evidence has shown that a combination of resistance training and proper nutrient supplementation can provide superior results than either alone (Dreyer et al, 2008; Kerksick et al, 2008; Aagaard, 2004; Wolfe, 2000; Bird et al, 2006 a,b,c, Rennie & Tipton, 2000; Cribb & Hayes, 2006).

In light of this background, the present study was conducted as an attempt to evaluate the effectiveness of supplementing macro-nutrients during the training itself, i.e. between sets. The purpose was to assess whether an experimental combination of carbohydrates and proteins could prove more efficient than carbohydrates alone in the context of assisting strength and muscle size gains in conjunction with resistance training over a period of time. The nutritional solution was designed to be consumed during the individual training bouts, similar to the studies by Bird et al (2006 a,b,c), to provide subjects with a near-constant flow of nutrients during resistance training. This in turn would provide a scientific basis on which to evaluate whether supplementation of nutrients during resistance training is a valid strategy when pursuing maximal muscular strength. Previous research in the matter (Dreyer et al, 2008; Kerksick et al, 2008; Aagaard, 2004; Wolfe, 2000; Bird et al, 2006 a,b,c, Rennie & Tipton, 2000; Cribb & Hayes, 2006)indicates that a synergistic effect between carbohydrates and proteins on the processes regulating muscular strength and size ought to occur, leading to greater adaptations than supplementation of carbohydrates alone would provide. Thus, the hypothesis was that a combination of carbohydrates and proteins would prove superior to carbohydrates alone, and provide both greater gains in lean mass and muscle strength. The study was conducted using a randomized double-blind model on volunteering human subjects.

Nutritional supplementation protocol

Using a double blind protocol all subjects were randomly assigned into two groups: CHO group and CHO+PRO group. In the CHO group, thirteen subjects (25 ± 3 yr; 79 ± 7 kg; 182 ± 7 cm) consumed a carbohydrate solution at 0.6667g cho/kg of body weight whereas in the CHO+PRO group, 10 subjects consumed a carbohydrate and protein solution at 0,1667g pro/kg and 0,5g cho/kg of body weight (25 ± 3 yr; 79 ± 8 kg; 181 ± 6 cm). The beverage was consumed during training sessions for both groups. Additionally, all subjects were fed a commercially available recovery drink (Gainomax) at 0.5g of cho/kg and 0.25g of pro/kg of body weight twenty-five minutes after a completed session. Subjects were instructed to avoid all other commercial and non-commercial supplements during the course of the study. A scheme of the CHO and CHO +PRO groups pre-training statistics is given.

Training protocols

Over the course of eight weeks, the subjects were given a choice of three different resistance training programs based on predilection and available time. The programs varied in training days per week (2,3 or 4), sets and reps in order to periodize training loads, in general, all programs offered a blend of guided-motion machines and free weights, and targeted all major muscle groups in the body, with a certain emphasis of the legs, particularly the quadriceps. Both the 2 and 3 sessions/week programs re-used the training schedule of weeks 1 through 4 with increased loads for weeks 5 through 8. The 4 sessions/week program, however, featured a different set of exercises for weeks 5 through 8. Each session lasted approximately 60 minutes, with an additional 10 minutes of standardized warmup before, and 25 minutes of rest after each session. A scheme of a typical resistance training session is given as figure 1. All participants were instructed to avoid excessive endurance training during the duration of the study, to avoid a potential negative effect on adaptations to resistance training (Fleck & Kraemer, 2004). All training schedules, as well as a more detailed explanation of each of the 3 programs.

Warmup (stationary bike)	First training period		Second training period		Third training period		Fourth training period		Recovery
	¼ of beverage	Resistance training	¼ of beverage	Resistance training	¼ of beverage	Resistance training	¼ of beverage	Resistance training	25 min rest, recovery drink
10 min, 50 rpm, 1,5 kpa		2 exercises, 2-4 sets		2 exercises, 2-4 sets		2 exercises, 2-4 sets		2 exercises, 2-4 sets	

Figure 1. Typical resistance training protocol for this study. Depending on which program subjects chose, the precise number of exercises could vary. Nevertheless, the basic schedule of warmup – ingestion of beverage – resistance training – ingestion of beverage was the same for all three programs, and recovery drinks were provided to all participants regardless of group assignement (i.e. CHO or CHO+PRO)

II. Results:

Body composition

After the 8 weeks training, both groups showed significant (P<0.05) increase in overall weight and whole body lean mass (Table 1a).

Table 1a. Body composition statistics for the CHO and CHO+PRO groups before and after exercise as well as P-values for both within group- and between group analyses. All data are presented ± SD. An indicates that P<0,05.

	CHO		CHO+PRO		P-values			
	PRE	POST	PRE	POST	Within groups		Between groups	
					CHO	CHO+PRO	PRE	POST
Weight (kg)	78,67 ± 8,44	80,8 ± 8,86	78,87 ± 6,87	81,24 ± 6,95	0,0004*	0,0005*	0,9518	0,8984
Whole body lean mass (kg)	61,02 ± 6,96	63,06 ± 6,91	59,72 ± 5,44	61,92 ± 5,16	0,0001*	<0,0001*	0,6323	0,6655
Whole body fat mass (kg)	14,37 ± 3,45	14,45 ± 3,93	15,83 ± 3,61	15,98 ± 4,05	0,7710	0,6475	0,3378	0,3701
Whole body fat %	19 ± 3,91	18,51 ± 4,17	20,88 ± 4,22	20,4 ± 4,47	0,1064	0,1475	0,2832	0,3075
Fat mass torso (kg)	6,98 ± 1,91	7,15 ± 2,32	7,41 ± 1,94	7,56 ± 2,24	0,4079	0,5031	0,6016	0,6739
Lean mass torso (kg)	27,92 ± 3,26	28,4 ± 3,11	26,86 ± 2,6	27,38 ± 2,31	0,0660	0,0438*	0,4114	0,3977
Fat mass legs (kg)	5,02 ± 1,29	4,93 ± 1,28	5,92 ± 1,38	5,91 ± 1,51	0,2830	0,9374	0,1217	0,1085
Lean mass legs (kg)	21,39 ± 2,67	22,52 ± 2,84	21,46 ± 1,72	22,62 ± 1,8	0,0001*	<0,0001*	0,9425	0,9252
Fat mass arms (kg)	1,5 ± 0,51	1,5 ± 0,49	1,57 ± 0,4	1,6 ± 0,46	0,9671	0,4742	0,6998	0,6082
Lean mass arms (kg)	8,34 ± 1,27	8,8 ± 1,27	7,84 ± 1,14	8,41 ± 1,12	0,0006*	<0,0001*	0,3412	0,4547

Table 1b. Delta values in body composition for the CHO and CHO+PRO group after 8 weeks of training. A double asterisk indicates a non significant advantage for one group over the other.

	CHO Delta ± SD	CHO+PRO Delta ± SD
Weight (kg)	2,13 ± 1,6	2,37 ± 1,41**
Whole body lean mass (kg)	2,05 ± 1,25	2,2 ± 0,65**
Whole body fat mass (kg)	0,08 ± 0,92	0,16 ± 1,05**
Whole body fat %	-0,5 ± 1,03	-0,48 ± 0,96
Fat mass torso (kg)	0,17 ± 0,71**	0,15 ± 0,68
Lean mass torso (kg)	0,48 ± 0,85	0,52 ± 0,7**
Fat mass legs (kg)	-0,08 ± 0,26**	-0,01 ± 0,33
Lean mass legs (kg)	1,13 ± 0,75	1,16 ± 0,2**
Fat mass arms (kg)	0 ± 0,12	0,03 ± 0,13**
Lean mass arms (kg)	0,46 ± 0,36	0,57 ± 0,18**

Strength

As seen in table 2a, no significant differences were observed in any of the strength parameters between the two groups either before or after the 8 weeks of training.

*Table 2a. Strength results for the CHO and CHO+PRO groups before and after exercise, as well as P-values for both within group- and between group analyses. All data are presented ± SD. The CHO group had 11 subjects complete measurements for peak torque values, and 12 subjects complete the bench press 3 RM test. For the CHO+PRO group, one subject failed to complete measurements on his left leg post-exercise, thus bringing the number of completed measurements for peak torque in the left leg to 9. An * indicates that P<0,05.*

	CHO		CHO+PRO		P-values			
	PRE	POST	PRE	POST	Within groups		Between groups	
					CHO	CHO+PRO	PRE	POST
Peak torque extension R (Nm)	241,36 ± 48,16	257,75 ± 54,63	246,03 ± 29,84	263,55 ± 39,87	0,0672	0,0248*	0,7950	0,7862
Peak torque extension L (Nm)	242,58 ± 37,28	259,66 ± 42,23	231,82 ± 30,58	245,12 ± 34,88	0,0606	0,0425*	0,5046	0,4192
Peak torque flexion R (Nm)	122,95 ± 21,97	129,79 ± 24,79	129,53 ± 14,91	133,54 ± 11,84	0,1307	0,3247	0,4371	0,6688
Peak torque flexion L (Nm)	121,3 ± 21,01	124,96 ± 23,49	118,81 ± 10,69	125,84 ± 12,97	0,3074	0,0481*	0,7528	0,9212
Benchpress 3RM (kg)	79,17 ± 14,16	84,38 ± 14,15	75,25 ± 17,26	79,75 ± 19,16	0,0411*	0,0642	0,5649	0,5225

Table 2b. Delta values in strength for the CHO and CHO+PRO group after 8 weeks of training. A double asterisk indicates a non significant advantage for one group over the other.

	CHO Delta ± SD	CHO+PRO Delta ± SD
Peak torque extension R (Nm)	16,39 ± 26,48	17,52 ± 20,59**
Peak torque extension L (Nm)	17,08 ± 26,8**	13,3 ± 16,55
Peak torque flexion R (Nm)	6,84 ± 13,77**	4,01 ± 12,17
Peak torque flexion L (Nm)	3,66 ± 11,3	7,03 ± 9,05**
Benchpress 3RM (kg)	5,21 ± 7,8**	4,5 ± 6,75

Limb circumference

In both groups, overall limb circumference at all measuring points for both arm and leg increased following the training period (table 3a).

*Table 3a. Limb circumference results for the CHO and CHO+PRO groups before and after exercise, as well as P-values for both within group- and between group analyses. All data are presented ± SD. An * indicates that P<0,05.*

	CHO		CHO+PRO		P-values			
	PRE	POST	PRE	POST	Within groups		Between groups	
					CHO	CHO+PRO	PRE	POST
Arm 40 % (cm)	33 ± 2,18	33,79 ± 2,13	32,11 ± 1,9	32,87 ± 1,92	0,0654	0,1033	0,4254	0,3638
Arm 50 % (cm)	32,46 ± 2,51	33,15 ± 2,33	30,93 ± 1,71	31,82 ± 1,48	0,2283	0,0035*	0,2304	0,1759
Arm 60 % (cm)	31,16 ± 2,17	32,24 ± 2,49	30,01 ± 1,79	30,92 ± 1,61	0,0867	0,0014*	0,3438	0,2099
Leg 40% (cm)	57,64 ± 3,32	59,55 ± 3,21	58,47 ± 2,79	60,41 ± 3,04	0,0030*	0,0019*	0,5548	0,5781
Leg 50% (cm)	54,85 ± 2,79	56,58 ± 3,36	55,67 ± 3,31	57,94 ± 3,06	0,0094*	0,0094*	0,6361	0,3935
Leg 60% (cm)	50,88 ± 3,34	52,53 ± 2,7	51,54 ± 3,04	54,61 ± 3,6	0,0135*	0,0025*	0,6635	0,2011

*Table 3b. Delta values in limb circumference for the CHO and CHO+PRO group after 8 weeks of training. A double asterisk ** indicates a non significant advantage for one group over the other.*

	CHO Delta ± SD	CHO+PRO Delta ± SD
Arm 40 % (cm)	**0,79 ± 1,02****	**0,76 ± 1,23**
Arm 50 % (cm)	**0,69 ± 1,47**	**0,89 ± 0,65****
Arm 60 % (cm)	**1,08 ± 1,53****	**0,91 ± 0,58**
Leg 40% (cm)	**1,91 ± 1,22**	**1,94 ± 1,28****
Leg 50% (cm)	**1,73 ± 1,38**	**2,38 ± 2,1****
Leg 60% (cm)	**1,65 ± 1,42**	**3 ± 2,17****

III. Discussion

Overall, the results of this study showed that there are no statistically significant differences between the CHO and the CHO+PRO group after 8 weeks of training. Comparison within each of the two groups confirmed this result. However, a closer inspection of the data revealed that the CHO+PRO group exhibited slightly better, albeit not significantly so, results in body composition and limb circumference than the CHO group.

Body composition

As shown in table 1a, in the 10 parameters measured in the study, none of them showed significant difference between the two groups, indicating extra supplementation of protein in the CHO+PRO group did not bring more effectiveness in improving body composition compared to carbohydrates alone in the CHO group. This is confirmed by comparisons of the parameters within each group (shown in table 1a). The CHO+PRO group reached statistical significance in 5 parameters, whereas the CHO group reached significance in 4. Similar results were obtained when comparing the delta values of the two groups. As shown in table 1b, the CHO+PRO group obtained slightly better results in lean mass accretion, both at the whole body level and in individual segments, but this did not reach a significant level.

A very important consideration when examining these results is the nature of the nutritional supplement that was provided. As was mentioned earlier, carbohydrates are capable of influencing protein accretion in the muscles, mainly through their effect on insulin, and the subsequent decrease in catabolism observed in the muscle cells (Bird et al, 2006 a,b; Aagaard, 2004, Lemon et al, 2002) Thus, it is not the increase in lean mass exhibited by the CHO group that is unexpected in itself, but rather the lack of significant difference with the CHO+PRO group, since combination of both carbohydrates and protein is widely considered to be more efficient than either nutrients alone (Volek, 2003; Dreyer et al, 2008; Kerksick et al, 2008; Aagaard, 2004; Wolfe, 2000; Bird et al, 2006 a,b,c, Rennie & Tipton, 2000; Cribb & Hayes, 2006).

Also of interest when analyzing these results is the actual dosage of nutritional supplementation that the subjects were given. The dosage of nutritional supplementation received by the test subjects were relatively modest, and, as described in the methods section, both groups received the same post-exercise supplement. This means that the difference between both groups was a small amount of mixed protein over each training session. While mixed protein is known to have an anabolic effect in combination with resistance training (Hulmi et al, 2010; Hulmi et al, 2009; Weinert, 2010; Andersen et al, 2005; Willoughby et al, 2006), it seems that essential amino acids, in particular leucine, have a similarly potent effect (Dreyer et al, 2008; Greiwe et al., 2001; Karlsson et al., 2004; Rennie, 2005; Smith et al., 2005; Bohé et al., 2003; Hara et al., 1998; Weinert, 2009). In particular, the studies published by Bird et al (2006 a,b,c) obtained hypertrophic responses from their subjects with dosages of 6g essential amino acids. Other studies report similar effects when essential amino acids are supplemented (Børsheim et al., 2002; Karlsson et al., 2004). Perhaps a higher concentration of these essential amino acids instead of mixed protein would have been more beneficial. Alternatively, a higher dosage of protein might also have led to more clearly defined results, such as those of Hulmi et al (2009) (30g), Hartman et al (2007) (35g) Willoughby et al (2006) (40g) and Andersen et al (2005) (50g). This is further supported by the lack of significant differences post-exercise between test subjects in a study by Rankin et al (2004), who used a low dosage of protein (0,21g/kg body weight).

Strength

Comparison in results of all parameters between groups showed no significant difference in results, suggesting no effect on muscle strength with extra protein supplementation during resistance training. However, within group analyses showed that the CHO+PRO group obtained slightly better results than the CHO group, with the former presenting 3 statistically significant changes and the latter only 1 statistically significant change (see table 2a). This result suggests that the extra protein supplementation during resistance training in this study is indeed more effective in improving muscle strength, albeit not significantly so. Further analysis of the delta values of both groups, as seen in table 2b, revealed no trend towards either group becoming better in results than the other, thus supporting our conclusion based on comparisons between groups.

As seen in table 2a, both groups exhibit strong trends towards increases in the parameters where statistical significance was not reached, with the exception of flexion for both legs. It is possible this is a result of the training programs mainly focusing on exercises targeting the quadriceps, responsible for extending the knee joint, as well as the fact that the hamstring muscles, the main knee flexors, are generally smaller muscles when compared against the quadriceps (Tortora & Derrickson, 2006). However, the effect of directly supervised training could also be an important factor, as directly supervised resistance training has been shown to produce better effects than unsupervised training in moderately trained young men (Mazetti et al, 2000). In particular Mazetti et al. (2000), demonstrated that mean training loads, expressed in kg per set, as well as rates of increase and maximal 1 RM strength in the squat and bench press were significantly higher in a group training for 12 weeks under direct supervision, when compared to another unsupervised group. The difference in duration notwithstanding, the method used by Mazetti et al. (2000), is quite similar to the method in this study regarding the use of direct supervision. In that study, the author concluded that the reason direct supervision was more efficient than unsupervised was because of the increased training loads supervised subjects was exposed to, due to a faster weekly progression. This may have been caused by two separate factors working in a feed-forward fashion, with the presence of a personal trainer increasing motivation and competitiveness in the supervised subjects, thus enabling the use of higher loads, which in turn would have caused a higher recruitment of fast-twitch motor units. Over a period of 12 weeks, these factors working in tandem are a probable explanation to the results displayed, as the author his selve theorize (Mazetti et al, 2000). Working on this assumption, it is quite possible that the positive psychological, motivational, and logistical aspects, such as spotting, of the direct supervision that both the CHO and CHO+PRO groups were subject to may have had similar effects on the end results displayed. Thus, it is a possibility that this also could have acted in a manner that would have decreased differences between the two groups. This is not supported by the results of Hartman et al (2007), who reported significant differences between a group consuming fat-free milk and two other groups consuming soy or carbohydrate after 12 weeks of directly supervised training. However, as mentioned earlier, Hartman et al (2007) also used a relatively large dosage of protein (35g), which may partially account for the discrepancy with our results. In comparison, Bird et al (2006) also used direct supervision for 12 weeks, but reported few significant differences between treatment groups, likely because of low nutrient dosage. Similar results are exhibited by Rankin et al (2004), who report no significant differences between a group consuming fat-free milk and a group consuming carbohydrates only after 10 weeks of supervised training. Again, low dosage of nutrients appears to be a likely explanation, since Rankin et al (2004) used 0,21g of protein/ kg body weight. Thus, while supervision on its own is known to play an important role in increasing adaptation to resistance training, it seems that this effect is not as potent when combined with various supplementation regimes. However, to this authors knowledge, no study has examined this directly. Thus, more research is required in order to assess whether or not this is the case.

Limb circumference

Has been shown in this study, both the CHO+PRO group and the CHO group increased their lean mass almost equally. Consequently, there are no statistical differences between the two groups regarding limb circumference either. Since limb size is dependent on the accretion of protein in muscles, it is possible that many of the factors mentioned earlier as likely explanations for the lack of significance between the groups also apply here. Limb circumference is also not a very common indication of increased muscle size, however studies that have measured CSA through muscle biopsies tend to support this theory. For example, in a 12 week training study using an intense (5 sessions/week) protocol, subjects consuming a fat-free milk solution showed greater increase of CSA in both type I and II fibers. This study also used a large (35g of protein) dosage of nutrient supplementation (Hartman et al, 2007). In comparison, Bird et al (2006 c), who also used directly supervised training report a significant difference between their CHO+EAA and CHO only group only in type Iia fiber CSA. In that study, the nutritional dosage was low (6g of essential amino acids). Similar results are also reported by Rankin et al (2004), who used direct supervision and a low dosage of nutrient supplementation.

IV. Conclusion

In conclusion, no significant differences were observed in any of the measurements between the two groups after 8 weeks of training. a closer look at the data generated by this study shows that supplementation of protein and carbohydrates at a dosage of 1,667 and 0,5g/kg body weight during training bouts produces slightly better results than supplementation of carbohydrates at 0,667g/kg body weight, in young healthy men with resistance training experience. However, while within-group analyses show a trend for the CHO+PRO group to exhibit better results than the CHO group, between-group analyses show no significance. Examining the results shown by this study and those of others suggest several factors, like nutrient dosage and composition, as well as training duration, periodization and supervision, all influence the final results. Adaptation to training, although what, if any degree of synergy there is between these factors is hard to assess because of dissimilar methods and results. Thus, any future studies aim to examine nutritional supplementation during resistance training to improve muscle strength and size should take precautions to avoid such mitigating factors, in order to insure more clearly defined answers

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