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CONVENTIONAL STRENGTH TRAINING AND MAXIMAL VOLUNTARY DYNAMIC FORCE TRAINING

COMPARISONS OF EFFECTS

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Abstract: One of the biggest obstacles to sport training and physical therapy is to transfer strength developed using exercise devices to real life situations. Although, numerous devices have been constructed to simulate practical activities to improve strength, these machines cannot completely simulate the countless specific human movements. Therefore, the possibility to transfer gained strength from the training session to real-life is not necessarily direct and/or immediate. This difficulty is well explained by the specificity principle. This principle, when applied in physical training is related not only to the muscle or muscle group being trained, but also to the velocity of movement, joint position, and metabolism. One way that athletes and ill persons try to solve this deficiency is by executing a specific desired movement without using any external load. This can be seen in most championships or trainings, especially at the moments before the matches. However, there is no clear evidence that such a technique improves either the quantity or quality of strength. The purpose of this study was to compare the effects of conventional strength training using hand-held weights with a training technique based on the repetition of a desired movement in which the "load" is the maximal voluntary force, without any external load, just developing muscle tension, and executing the desired movement. Five subjects undergone strength training of the biceps brachialis, one arm with hand-held weight, the other with maximal voluntary force, over a period of seven weeks. Measurements of upper arm girth, maximum elbow flexor strength, and EMG signals of the both arms were taken before, and at the end of the training period. The arm trained with maximal voluntary force showed similar gains in relations to the arm trained with hand-held weights, i.e., conventional strength training. The gains of both arms was especially expressed by the increase of maximal voluntary force.

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BACKGROUND AND PREVIOUS WORK

Although questions remain about the validity of the specificity principle, which states that "specific exercises elicit specific adaptations creating specific training effects" (1), numerous previous works have demonstrated that it frequently applies in exercise training. Pollock (2), citing Sale and McDougall, presents two conflicting theories regarding training. One theory states that training should simulate the sport movement as closely as possible relative to the anatomical movement pattern, velocity, contraction type, and contraction force. The opposite theory states that it is necessary to train only the appropriate muscle groups, i.e., there is no need to have movement specific exercises. However, Pollock's conclusion is that the scientific evidence to date strongly favours specificity in training. Pollock (3) also agrees that the pattern of movement, velocity of training, and joint position are important factors in transfer of training.

McArdle (4) states that the training response is highly specific and cites some aerobic sport activities such as swimming, running, or cycling. He continues by saying that training must overload the appropriate muscles, and in each of these activities the appropriate overload consists of training in the actual activity. Specific training may not improve the strength in other types of activity (5). Jones concerning to strength training says that there is considerable doubt about whether weight training does anything other than train the athletes to lift weights (6).

It is suggested by McArdle (7) that speed, power, and endurance must be defined carefully within the context of the specific movement patterns and the specific metabolic and physiological requirements of an activity. When striving for muscle strength, for a particular activity, the best training is that activity (8).

The gain in strength when one is engaged in unfamiliar procedures is comparatively modest even when one activates the muscles which are being trained (9). Coyle (10) concludes that a slow-velocity activity with maximal muscular tension is best improved through training that specifically mimics the performance action, and that slow training, however, will not improve fast velocity performance. Rasch (11) extends the specificity principle to psychological factors which could make unique each aspect of performance development, and it is related to each repetition, too.

Despite the relatively clear and vast literature about specificity of training, the methodology that should be applied in order to obtain improvements in physical performance is not well defined in this context. Although Kannus at al. (12) conclude that, according to numerous studies, the effects of training on muscles can be well predicted, this conclusion should be taken only in physiologic terms.

Astrand (13) questions which is the most effective strength training program. He answers saying that it should be evident that this question is insoluble from a physiological point of view, and the important point is the purpose of training and the person's potential to respond to the training.

The ways that people are trained vary with many variables. Although, coaches, physical therapist, and personal trainers choose their own way to train their clients, the authors agree that a complete biomechanics analysis of the performance must be done before the training beginning and then, one or more methods could be chosen to complete one another. The problem arises when the situation eliminates the possibilities to use ordinary devices. As long the situation permits isometric contractions have been used to improve or maintain strength, but most of the human performances require dynamic movements and the limitations of isometric methods in this field are well known. This study was conceived to evaluate a method to develop, primarily, strength without the use of any accessory or devices, in a specific way, i.e., executing the desired movement using just the capacity to produce tension, and simulating the desired act.

METHODS AND PROCEDURES

Subjects - Five healthy voluntary adults, males, from 18 to 21 years old, were the subjects. They had no history of upper extremity arthritis, neuromuscular disease, or cardiovascular disease.

Training

Conventional Strength Training- The training of the hand-held weight arm consisted in elbow flexion and extension, concentric and eccentric contraction, respectively, throughout the full range of motion. One arm, chosen at random, was exercised with a hand-held weight. Each day of training (three days per week, during seven weeks) consisted of three blocks of exercises, in which the subjects performed 6 repetitions. The rest interval between blocks was five minutes. The weight was 80% of maximal load, which was inferred from the Maximal Voluntary Force as determined in the strength test before training begins (see strength test section below).

Maximal Voluntary Dynamic Force Training- The other, free-of-weight arm, was exercised throughout the same range of motion, at the same movement velocity, and at the same time and period as the hand-held weight arm. The subject was asked to develop a muscular contraction of his arm as if he was holding the same or a heavier weight of the hand-held weight arm, throughout the complete elbow movement. This maximal contraction force, concentric and eccentric, developed by each subject was the unique load applied to the arm trained without weight.

Strength Test- Both arms were tested under the maximal voluntary strength test, performed at two points, before, and at the end of the course of the training. On the first day, before training begins, the maximal voluntary strength was determined as the hand-held weight that a subject can lift through the full range of motion for "*n*Repetition". The following relationships between number of repetition and percentage of maximum strength was used to estimate 100% of maximum strength: 1RM ("nRM load" = number of repetitions maximal load) is 100% of the maximal force, 3RM = 90-95% of maximum force, 6RM = 85% of maximal force, 10 RM = 75% of maximal force, 15 RM = 65% of the 1 RM load **(14)**. This enables us to test subjects with a submaximal weight as long as the maximal number of repetitions is between 1 and 15, thereby reducing risk of injuries. The last test was identical to the first.

EMG Signals - The EMG signals were recorded from both arms, on strength test, first and second, with load. Also maximal voluntary force contraction, without load, concentrical and eccentrically, were measured by EMG. To evaluate EMG signals it was used portable Muscles Tester ME3000P, from Mega Electronics Ltd., Finland, with surface electrodes. The surface electrodes were placed oriented by a straight line that was traced from lateral to medial epicondyle of humerus; from the middle of that line a perpendicular was traced, and the electrodes were fixed one centimeter above the maximal circumference of the biceps. The maximal circumference of the biceps was taken with the arm fully flexed and fist clenched. The IEMG signals were ratified, and registered in averaged mode, time = 0.1s, with sampling frequency of 1000 Hz.

Girth Measurements - Circumferential measures of the biceps were taken before and after program period with the arm fully flexed and fist clenched.

RESULTS

Table 1 shows personal information of the subjects.

	Age(y)	Height(m)	Weight(kg)	Free-Load Arm
Subject 1	20	1.68	68	Right
Subject 2	18	1.70	73	Left
Subject 3	20	1.82	63	Right
Subject 4	19	1.73	70	Right
Subject 5	20	1.70	73	Left

Table 1: Personal information

Table 2 shows the results of the right arm (RA) and left arm (LA) on first and second strength test, which were before and after, respectively.

	1st Test		2nd Test	
	RA	LA	RA	LA
Subject 1	12kg	12kg	14kg	14kg
Subject 2	12kg	12kg	14kg	14kg
Subject 3	14kg	14kg	16kg	14kg
Subject 4	14kg	14kg	18kg	18kg
Subject 5	12kg	12kg	14kg	12kg

Table 2: First and second strength test

Table 3 shows the peak activity of the biceps, in microvolt, on the initial and final strength test, and initial and final maximal voluntary force contraction measures.

	RALB	RAWB	LALB	LAWB	RALA	RAWA	LALA	LAWA
Subject 1	1652	2145	1137	1029	2058	2189	1204	1598
Subject 2	2953	2717	2510	1033	3004	3266	1274	346
Subject 3	1817	1376	2596	921	1071	2167	2549	1861
Subject 4	1018	1955	2679	737	1693	1923	1212	1058

Subject 5	917	286	1192	214	642	380	1310	707

Table 3: Peak activity of both, initial and final strength test, and maximal voluntary force contraction

RALB: right arm with load before program
RAWB: right arm without load before program
LALB: left arm with load before program
LAWB: left arm without load before program
RALA: right arm with load after program
RAWA: right arm without load after program
LALA: left arm with load after program
LAWA: left arm without load after program

Table 4 shows the circumference measures in centimetres.

	RAB	RAA	LAB	LAA
Subject 1	29	29	30	30
Subject 2	34	34	33	33
Subject 3	30	31	29	30
Subject 4	30	31	31	31
Subject 5	34	34	34	34

Table 4: Circumference measures (cm)

RAB: right arm before program
RAA: right arm after program
LAB: left arm before program
LAA: left arm after program

DISCUSSION

Table 5 shows the percentage of strength gain of free-of-load (FOLA) and hand-held arms (HHA) of all subjects.

	FOLA	HHA
Subject 1	17%	17%
Subject 2	17%	17%
Subject 3	14%	0%
Subject 4	29%	29%
Subject 5	0%	17%

Table 5 - Percentage of strength gain of free-of-load (FOLA) and hand-held arms (HHA)

The median strength gain, in percentage, of the free-of-load arms was 15%, and of the hand-held arm was 16%. Repeated overload of muscle is factor that can increase the muscle mass (15). Therefore, it increases strength in the same way. Despite the size of the sample, the maximal voluntary force executed, methodologically, is a kind of overload and can be considered when there is no possibility to use other more reliable method.

Table 6 shows the percentage of increase EMG peak activity, after the program, of free-of-load arm (FOLA) and hand-held arm (HHA).

	FOLA		HHA	
	Load	Without Load	Load	Without Load
Subject 1	25%	2%	55%	6%
Subject 2	-49%	-67%	2%	20%
Subject 3	-41%	57%	-2%	100%
Subject 4	66%	-1.6%	-55%	44%
Subject 5	10%	230%	-30%	33%

Table 6 - Percentage of increase EMG peak activity after the program of free-of-load arm (FOLA) and hand-held arm (HHA).

The relation between the processed EMG and force is out of the purpose of this study, and these data must be carefully analyzed. EMG is a well accepted method to obtain general idea of muscles activation and it represents the active control input of the muscles. The frequency of firing increases with increased voluntary effort to generate muscles tension. In relation to those who obtained positive increases, on one hand, it can be understood as an improvement in quality of Tension-Developing Capacity. The performance of motor activities is dependent upon an adequate Tension-Developing Capacity within the muscles involved **(16)**. Thus, increasing the ability of muscles generate tension is important by the human performance viewpoint. On the other hand, for those who obtained EMG measures decreased it can be interpreted as a better efficiency of the involved muscle, since more force was performed per unit of EMG.

Table 7 shows the increase in circumference measures of free-of-load (FOLA) and hand-held arms (HHA) after the program.

	FOLA	HHA
Subject 1	0 %	0 %
Subject 2	0 %	0 %
Subject 3	3 %	3.5 %
Subject 4	3 %	0 %
Subject 5	0 %	0 %

Table 7 - Increase in circumference measures of free-of-load (FOLA) and hand-held arms (HHA) after the program.

Circumference measure is of limited value, but change in these data may prove valuable indicators of the neuromuscular alterations.

Many hours of training are spent every day by athletes or ill persons in order to get a better performance in a specific activity. Despite the technique itself, related to any activity, the strength is a very important quality to most movements in human life, and the necessity to develop it for the life situations is a challenge for anyone who is involved with strength and movement training. To increase force it is necessary an overload, methodologically applied. Muscular contraction and imitation of the desired movement represent load. The authors believe that this study presented a methodology that, despite the poor sample, can offer, to elbow flexion, the possibility to access muscular strength training, and muscle strength development without devises or machines.

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