COMPARISON OF A STRENGTH-TRAINING PROGRAM PERFORMED ON THE CONCEPT2 DYNO AND CYBEX CHEST PRESS MACHINE AMONG COLLEGE AGE MEN

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PREFACE

This study was conducted to provide new knowledge pertinent to designing resistance-training programs using the Concept2 Dyno, and it's comparison to established exercise equipment such as the Cybex chest press machine. An 8-week training program, using previously untrained subjects, consisting of three workout sessions per week was undertaken. Subjects performed three sets of six repetitions on the Dyno or three sets of a six repetition maximum on the Cybex. The free weight bench press was used as the pre- and post-testing method, with any increases in one repetition maximum on the bench press as the measured variable.

I would like to thank Concept2 and Quest Personal Training Inc. for their contributions of equipment to this project, and to the subjects that devoted their time and effort to completing the exercise sessions. I sincerely thank my doctoral committee-- Dr. Frank Kulling (Chair), Dr. Steve Edwards, Dr. Jack Ransone, and Dr. Ed Harris-- for their constructive guidance, encouragement, assistance and support in the completion of this research and my studies at Oklahoma State University.

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CHAPTER I

INTRODUCTION

It is generally accepted that undertaking a program of resistance training on a regular basis will produce increases in muscular strength (McArdle, Katch and Katch, 1991). In the search for the optimal strength training routine, a variety of factors have been manipulated in order to determine the quickest and most efficient means of increasing strength. The training load, repetitions per set, number of sets, frequency of training, rest periods, and the mode of resistance all contribute to the ultimate result of the training program in a specific way.

The optimal number of sets and repetitions, the appropriate training load, frequency and rest periods have been researched extensively, and accepted recommendations have been published (Baechle, Earle and Wathen, 2000). The final piece to the puzzle is determining which mode of resistance will produce the largest gains in muscular strength. This question is as yet unanswered because new types of equipment are constantly being developed and made available to the market.

As new strength training equipment is introduced to the general public, there is a need to determine if the new equipment is superior to existing equipment in its ability to produce strength gains with regular use. The ultimate goal of the public is to find results with the least amount of work. This requires that all new equipment be tested against current methods to find if a better mode of resistance has been designed.

In December of 1999, Concept2 introduced the Dyno. The Dyno, short for dynamometer, is an isoaccelerative-isokinetic strength-training machine that incorporates a seated leg press, seated row and seated chest press. To date, there has not been any published research comparing the Dyno to other exercise machines currently available. As the general public searches for the fastest and most efficient way of improving strength, a decision must be made between choosing the traditional isotonic form of training with machines such as the Cybex Chest Press, or using the new Dyno with it's isoaccelerative-isokinetic movement.

Statement of the Problem

The purpose of this study is to compare the Concept2 Dyno to the Cybex Chest Press machine, with respect to gain scores of 1RM free-weight bench press strength, among college age men participating in an eight-week training program.

Hypothesis

The following hypothesis will be tested at the .05 level.

1. There will be no significant differences in average strength-gain scores between CONTROL, DYNO and CYBEX groups.

Variables That Impact This Study

1. Subjects will not be chosen randomly.
2. There will only be 11 subjects in each group.

3. There will not be any attempt, other than instructions, to verify or account for the effect of the subject's extracurricular activities during the testing period.

4. Thirty-three male volunteers will be drawn from Oklahoma City University to serve as subjects. n=33

5. A 1RM free-weight bench press will be used to assess subjects' strength pre and post.

6. A Par-Q Health Assessment questionnaire will be used to determine subjects' current health status.

Assumptions

1. Subjects will comply with instructions to not participate in a training program outside of this study.

2. Subjects will comply with instructions to not use ergogenic aids during this study.

3. Subjects will make maximal efforts during pre- and post-tests.

4. Subjects will honestly and accurately answer questions on the Par-Q Health Assessment.

5. The Concept2 Dyno will self-calibrate at the beginning of each repetition and accurately represent the total workload at the end of each repetition.

Definitions

<u>Concept2 Dyno</u> - a variable resistance machine that uses air resistance to resist force

Cybex Weight Machines - a brand of variable resistance weight machines

Dynamometer - an instrument that measures force

Ergogenic Aid - the use of a nutritional, physical, mechanical, psychologic, or pharmacologic procedure to aid or improve physical work capacity or athletic performance

Free-weights - type of exercise resistance that uses plates of varying weight, usually attached to a barbell or dumbbell

Frequency - the number of times an exercise is done in a week

Hypertrophy – the increase in muscle mass through an increase in muscle fiber size

Isoacceleration - a type of resistance in which the speed of the movement follows a preset rate of acceleration independent of the amount of force applied

Isokinetic - a type of resistance in which the speed of movement is constant regardless of the amount of force applied

Isotonic - a type of resistance in which the training load is constant regardless of the speed of the movement

Muscular Endurance - the ability to perform repetitive sub-maximal muscular contractions against resistance for an extended period of time

Muscular Strength - the ability of a muscle to generate a one-time, maximal force against resistance

One Repetition Maximum (1RM) - a one repetition maximum lift. The maximum amount of weight that can be successfully lifted one time through the full range of motion before fatigue precludes additional repetitions

Power – the time rate of doing work, where work is the product of the force exerted on an object and the distance the object moves in the direction in which the force is exerted

Periodization Training – form of resistance training which involves the varying or cycling of training specificity, intensity, and volume to achieve peak levels of conditioning

Repetitions - the number of times a specific movement is repeated

Repetition Maximum (RM) - the number of repetitions that can be accomplished using a particular resistance, prior to volitional fatigue precluding additional repetitions

Resistance Training - a program using resistance exercises to increase strength or endurance

Resistance Training Components - number of repetitions, number of sets, and frequency of training

Set - a particular number of repetitions

Training Load - the weight or resistance setting applied to an exercise

Volitional Fatigue - fatigue which ensues from voluntary contractions and exercise repetition

CHAPTER II

REVIEW OF LITERATURE

History of Resistance Training

The origins of resistance training for the improvement of muscular strength date back to the times of the ancient Greeks and Romans (Forbes, 1971; Zeigler, 1973). The Greeks, from whom the modern Olympic games have descended, valued physical training as a type of sacrifice to the gods, and as a means of preparing for war. The Greek Olympic champion, Milo of Crotona, first demonstrated the principle of progressive resistance by lifting a bull calf over his head daily (Gardiner, 1930). Milo had to lift progressively more as the calf grew and gained weight. Because the reason for Milo's above average strength was not immediately understood, the components of resistance training were not immediately investigated.

The Romans understood that physical training would improve the physical condition of its soldiers, and so required troops to undergo constant training. The strength training practices they used were in no way similar to the ones used now. Free weights at that time mainly consisted of rocks and other inanimate objects. Frequently, "training" was done in the context of building roads, bridges, and housing. Objects were lifted, and men became stronger.

Since the times of the Romans, there was little information put forth concerning new and unique exercise practices. It was not until the beginning of the 20th century that strength-training practices were seriously examined. During this time the “strong man” was quite possibly the only true “weight lifter”. Feats of strength performed before an audience, usually as part of a traveling carnival, featured the weight lifting contest of that day. These strongmen were usually genetically gifted to begin with, but also undertook a certain amount of strength training to continue their trade. The training methods we have today are the direct descendants of the practices of the strongmen.

In 1940, MacFadden and his colleagues compiled the views on resistance training that had been passed down through the years. These included “offer a progressive degree of resistance”, and “do not lift within ten percent of the utmost limit” when working with barbells. The thought at the time was that lifting with low resistance for more repetitions was more advantageous than lifting heavier amounts for fewer repetitions. While few of the principles they wrote of could be proven, as very few were from research and most were anecdotal, the information was deemed true and served as the basis for strength training at the time.

The historic work of DeLorme (1945) took the information provided by MacFadden and produced the first set of “tested” resistance training practices. DeLorme had used resistance training in the rehabilitation of patients. The evidence suggested that adopting a program of 10 sets of 10 repetitions was the most beneficial in terms of increasing strength. DeLorme originally intended for patients to be able to complete the full schedule of sets and repetitions, working with the assumption that more repetitions produced greater strength. With this in mind, the load used was often less than a 10RM.

After further research, Delorme and Watkins (1948) edited the previous findings by stating that three sets of 10 RM was as effective as the previous program if the intensity or training load were adjusted upward so that patients were only able to complete three sets before volitional fatigue.

From this point on, many studies have sought to verify, test, and improve upon the claims of MacFadden, DeLorme and Watkins, and those before them. The search for the most efficient and effective combination of variables in a strength-training program continues today, including this research.

Components of Resistance Training

Several components of resistance training can be manipulated to produce a number of particular outcomes. These components include the training load, number of repetitions per set, number of sets per exercise, number or frequency of training sessions per week, amount of rest between exercise sets, length of training program, mode of resistance training used, type of contraction, and rest between repetitions (Fleck and Kramer, 1997). The results obtained from a training program depend on how these components are manipulated.

Training Load and Repetitions per Set:

The training load is the amount of weight or resistance applied to the muscle during a given exercise. Training load can be prescribed as a percentage of a subject's one-repetition maximum (1RM), or by specifying a maximum number of repetitions (a repetition maximum or RM). The amount of weight that can be used in a given exercise is always inversely proportional to the desired number of repetitions per set (Westcott, 1996). That is, the closer the training load is to a person's 1RM for an exercise, the fewer the number of repetitions they can perform before volitional fatigue. Decreasing the percentage of 1RM increases the number of repetitions that can be performed before failure.

Over time it has become accepted that training for muscular strength requires a training load close to the 1RM, whereas training for muscular endurance utilizes a lower percentage of the 1RM (Fleck and Kramer, 1997; Baechle, Earle and Wathen, 2000). In a paper that presented a theoretical model of strength training that became the foundation for a form of training known as "periodization", Stone, O'Bryant, Garhammer, McMillan, and Rozenek (1982), stated that training for muscular strength is inherently different than training for muscular endurance, and that the difference is in the intensity of the exercise as it is manipulated by training percentages of the 1RM.

In a review of literature, McDonagh and Davies (1984) noted some general trends indicating that performing more than 12 repetitions per set with less than 67% of the 1RM will result in increased muscular endurance; while using loads greater than 85% of 1RM while performing six or less repetitions per set resulted in improved muscular strength.

This is consistent with later research by Herrick and Stone (1996) that compared traditional strength training, using progressively higher resistance, to periodization training, which manipulates the resistance up and down along with the volume of exercise done. They found that training with lower repetitions and a higher percentage of the 1RM (traditional strength training) elicited faster improvements in strength than using a combination of low repetitions/high %1RM and high repetitions/low %1RM.

There is also evidence to support using a specified maximum number of repetitions (RM) instead of a percentage of the 1RM when performing multiple-set training on machines. Wathen (1994a) points out that the number of repetitions that can be performed at a certain percentage of the 1RM is based on the assumption that only a single set of the exercise will be done. When multiple sets are performed, the load must be reduced in order to complete the desired repetitions in all of the sets. Additionally, nearly every study that examined the 1RM relationship was performed with free weights, so the application of the 1RM to machine exercises is as yet undecided (Fleck and Kramer, 1997; Tan, 1999).

Furthermore, in a pair of studies that involved subjects completing seven different exercises at the same percentage of the 1RM, subjects were able to complete different numbers of repetitions on each exercise; sometimes in the range of 20 plus repetitions (Hoeger, Barette, Hale and Hopkins, 1987; Hoeger, Hopkins, Barette and Hale, 1990). For these reasons, the subjects in this study will be prescribed a training load within a maximum number of repetitions per set instead of training with a percentage of their 1RM.

Number of Sets:

DeLorme and Watkins (1948) first suggested that the initial publications on resistance exercise used too many sets per exercise (normally 7-10), and recommended three sets of 10 repetitions to increase muscle hypertrophy and therefore strength. In a recent position stand published by the American College of Sports Medicine (1998), it was stated that performing multiple sets of resistance exercise did not elicit significantly greater gains in strength than one-set programs. The ACSM position stand was based on a literature review by Feigenbaum and Pollock (1997) comparing eight previous studies in which the majority of subjects performed eight to twelve repetitions per exercise.

For the purposes of gaining strength, as stated before and as is utilized in this research, repetitions should be kept at six or less. Previous investigations that used six or less repetitions per set for the purpose of increasing strength indicated that three sets of each exercise is the optimal number.

Stone, O'Bryant, and Garhammer (1981) noted in their first example of a periodization model that the traditional technique of using three sets of six repetitions was the basis of building muscular strength as compared to muscle hypertrophy or power. These conclusions were based on the work of Berger (1962), who divided subjects into nine groups, each group completing one, two, or three sets of either two, six or ten repetitions of bench press exercise per session for 12 weeks. Results indicated that the group performing three sets of six repetitions increased their 1RM bench press significantly more than the other groups.

In a study comparing strength gains from a single set of 8-10 repetitions per exercise versus 2-5 sets of varying repetitions (3-5, 8-10, or 12-15) per exercise, Kramer, Newton, Bush, Volek, Triplett, and Koziris (1995) found that the multiple set group showed significantly greater gains in bench press, military press, and leg press over the single set group throughout nine months of training.

Later work by Kramer, Stone, O'Bryant, Conley, Johnson, Nieman, Honeycutt, and Hoke (1997) found that strength gains (measured by a 1RM squat) using three sets of ten repetitions program were 50% greater than gains from a single set of 8-12 repetitions program over twelve weeks of training with lower body exercises. While both of these last studies used a higher number of repetitions than the current research proposes, strength gains were still noted, and those gains were higher in the multiple set groups.

Frequency of Training:

Training frequency is defined as the number of training sessions per week. Traditionally, three workout sessions per week, with at least one day of rest between sessions has been recommended by the popular media. Three workout sessions per week is also supported by published research.

Henderson (1970) investigated the effects of either a two- or three-days per week exercise program on the subjects' 1RM bench press. After eight weeks of training, the subjects in the 3-days per week group improved significantly more than the 2-days per week group.

Further research by Gillam (1981) also used the bench press exercise as the measurement tool for groups training either one, two, three, four, or five days per week for nine weeks. The groups that exercised three or more days per week showed greater improvement than the one or two days per week groups, and the four and five days per week groups showed more improvement than the three days per week group.

In an investigation by Gregory (1981), students that enrolled in a weight training class that met twice a week were compared to students enrolled in a weight training class that met three times a week. Both classes performed the same amount of exercise (sets x reps) per session for 14 weeks. At the end of the semester, results showed that three days per week produced slightly superior strength gains over two days per week.

Finally, Graves et al. (1988) had subjects train for either two or three days per week for 10 or 18 weeks (four groups). Analysis of results found that isometric strength had improved more for the subjects training three days per week compared to two days per week, and that similar results were apparent for both the 10 and 18-week studies.

Rest periods between sets:

The amount of rest needed between exercise sets largely depends on the amount of time required for full recovery of the energy system being utilized (Pauletto, 1986). The intense and short nature of strength training requires the use of the adenosine triphosphate (ATP) and creatine phosphate energy systems, which provide energy for bouts of high-intensity exercise of less than 30 seconds in duration (Wathen, 1994b). These systems require two and a half to three minutes to completely recover before the next exercise bout (McArdle, Katch, and Katch, 1991). Therefore, in a program designed to increase muscular strength, 3-5 minutes of rest is required in order for the energy systems to completely recover between exercise sets (Tesch and Larson, 1982; Weiss, 1991).

This conclusion is supported by several investigations. The affects of different rest periods on strength was studied by Robinson, Stone, Johnson, Penland, Warren, and Lewis (1995). Rest periods of 3, 1.5, and 0.5 minutes between sets were compared, and results indicated that the group that recovered for three minutes between sets was able to use greater training loads, and showed greater improvement over the five-week program.

Likewise, Abdessemed et al (1999), split subjects into groups that performed 10 sets of six repetitions with either one, three, or five minutes rest between sets. Mean power during each set was assessed, and results indicated that mean power decreased during the final sets of the group that had one minute of rest between sets, but did not decrease for groups that had three or five minutes of rest.

Larson and Potteiger examined the differences between a three-minute recovery period, a 1:3 work/rest ratio, and rest until 60% of post-exercise heart rate. Between four sets of squats with 85% of 10RM to exhaustion, the differences between the recovery conditions were not significant, but were found to be effective.

Length of Training Program

The subjects in this study will undergo an eight-week training program. It has been shown that an eight-week training program is sufficient to produce measurable increases in strength with previously untrained subjects.

Thorstensson, Karlsson, Viitasalo, Luhtanen, and Komi (1976) studied a progressive strength training program that included exercises performed for three sets of six repetitions, three times a week, for eight weeks. Subjects demonstrated increased squat strength, quadriceps EMG activity, and total leg force.

Dons, Bollerup, Bonde-Petersen, and Hancke (1979) measured subject's dynamic and isometric strength after just seven weeks of training three days per week, using a total of 12-20 repetitions per session. Their results indicated an increase of 42% in dynamic strength of knee extensors, but no increase in isometric strength, which was explained according to the principle of specificity.

Likewise, Moritani and deVries (1980) showed increased strength in subjects after eight weeks of training the elbow extensors three days per week, using two sets of 10 repetitions.

Investigations longer than eight weeks have produced larger gains in strength than studies that ended at eight weeks (Berger, 1962), but the time limit on strength gains due to hypertrophy is unknown and indefinite (deVries, 1986). Therefore, the proposed study will be limited to measuring the strength gains from eight weeks of training only.

It is known that both neural and hypertrophic factors are involved in the strength gains of untrained subjects that begin a training program (Moritani and deVries, 1979). The exact time course of contributions from neural factors or hypertrophy will vary among subjects, and cannot be identified without the use of muscle biopsy and EMG equipment (deVries, 1986; Powers & Howley, 1990). Since the focus of this study is any increase in strength made by the subjects as the result of the training program, there will not be any differentiation between neural and hypertrophic factors.

Mode of resistance:

An additional consideration when designing a strength-training program is the mode of resistance, or the type of resistance-generating equipment to use. Resistance training equipment used in this study falls into one of two categories: isotonic or isokinetic. Within these two categories there are differences in the type of contraction that a machine elicits, the resulting training load, and the amount of rest inherent between repetitions.

Isotonic

The most common type of equipment found in health clubs and fitness centers today is variable resistance machines, or isotonic equipment. While isotonic technically means "one resistance", such as is the case with barbells and dumbbells, isotonic equipment allows the user to select a training load, and commonly uses lever arms, cams, or pulley arrangements in an attempt to match the human resistive torque curve (Johnson, Colodny and Jackson, 1990; Harman, 1983). The result is that the amount of resistance provided by the machine changes as you move through the full range of motion. This is an attempt to provide a constant level of resistance during the exercise relative to the ability of the joint angle and the muscle length.

The Cybex chest press machine used in this study uses this type of cam arrangement to provide resistance throughout the range of motion of the exercise. Strength gains from programs using this style of isotonic equipment have reported positive results.

An investigation by Hickson, Rosenkoetter, and Brown (1980) had subjects train with the original Universal Gym equipment, one of the first individual-exercise isotonic equipment lines commercially available. Subjects trained using the leg extension, leg curl, and leg press on alternating days, five days a week for 10 weeks. Each exercise was performed for three sets of five repetitions at 80% of the subject's 1RM for that exercise. After 10 weeks, subjects were tested for 1RM and experienced increases of 42% for the leg curl, 50% for the leg extension, and 38% for the parallel squat (free weight).

Using the same type of equipment, Meadors, Crews, and Adeyanju (1983) trained subjects three days per week for eight weeks, performing three sets of a 10RM leg extension and leg curl. Their final data showed that strength had increased significantly for both exercises over both the control and isokinetic trained groups.

Hurley, Seals, Ehsani, Cartier, Dalsky, Hagberg, and Holloszy (1984) utilized the increasingly popular Nautilus line of isotonic equipment during a sixteen week study in which subjects trained three to four days per week using a one set of 8-12RM scheme. Subjects were pre and post tested for 1RM on each of the exercises they performed, which included the leg extension, leg curl, hip and back, decline press, arm cross, pullover, lateral raise, overhead press, behind neck pulldown, triceps and biceps. Average results showed a 50% increase for upper-body strength, and a 33% increase in lower-body strength.

Similarly, Messier and Dill (1985) compared strength-training programs performed with free weights to Nautilus isotonic machines. Subjects trained three days a week for 10 weeks. Pre and post strength measurements were made using an isokinetic dynomometer. The Nautilus group trained one set of each exercise upper body (pullover, arm cross, decline press, lateral raise, shoulder press, biceps and triceps) 8-12RM and lower body (leg extension, leg curl, leg press, hip and back) 15-20RM. Final data showed an average of 9.4% increase in isokinetic strength across all muscle groups.

Staron, Malicky, Leonardi, Falkel, Hagerman, and Dudley (1989) conducted a 20-week training program for the lower body that included vertical leg press, leg extension and leg curl exercises. Subjects trained twice a week using a three sets of 6-8RM protocol. Results showed that isotonic strength, as measured by 1RM for each exercise, significantly increased through the first 16 weeks of the training program before leveling off for the final four weeks.

An investigation by Boyer (1990) used Nautilus equipment to train subjects three times a week for 12 weeks, using three sets of 6-10RM. Subjects were pre and post tested using free weight equivalents of the Nautilus leg press (leg sled), Nautilus bench (bench press), and Nautilus laterals (military press). Results showed that the use of isotonic equipment increased the subjects' 1RM by 11% for leg sled, 15% for bench press, and 10% for military press.

Finally, a group of subjects using the leg extension, leg curl, and bench press isotonic machines manufactured by Global Exercise Machines, trained three days per week for 12 weeks. Bench press was performed using three sets of 8-12RM, and leg curl and extension were performed using three sets of 15-20RM. Pre versus Post tests of 1RM for each exercise found a 30% increase in leg extension, 52% increase in leg curl, and 20% increase in bench press performance (Marcinik, Potts, Schlabach, Will, Dawson, Hurley, 1991).

Isokinetic

Isokinetic machines are another type of equipment that has been receiving increased attention (Brown, 2000). Isokinetic machines provide a constant rate of movement regardless of the amount of force applied. Isokinetic literally means "one speed". Any force applied to the machine results in an equal resistant force, up to the maximum amount of resistance applied at any point in the range of motion (Thistle, Hislop, Moffroid, and Lowman, 1967). Therefore, the resistance may change, but the speed of the movement remains constant throughout the full range of motion.

Since an isokinetic exercise is performed at a constant velocity, it is inherently different from isotonic training in that there is no set resistance to meet. As a result, subjects must be instructed to apply maximal force throughout the range of motion, as the resistance they must "overcome" is determined by their own efforts. Several investigations have examined the ability of isokinetic machines to elicit strength gains.

Gettman, Ayres, Pollock, Durstine, and Grantham (1979) used a series of isokinetic equipment for subjects to perform bench press, pulldown, knee flexion and extension, bicep curl, leg press, shoulder press and seated row. Training three days a week for eight weeks, completing two circuits of 10-15 repetitions for each exercise elicited significant strength gains in the bench press and leg press as measured with both isokinetic and isotonic equipment.

A study of only knee extension strength after training on isokinetic equipment three times a week for six weeks, determined that five sets of six maximal reps was sufficient to produce a 32% increase in peak torque (Coyle, Fiering, Rotkis, Cote, Roby, Lee, and Wilmore, 1981).

An interesting study by Kanehisa and Miyashita (1983) tested the ability of isokinetic training to elicit strength gains after an eight-week isometric training program had already increased the strength of previously untrained subjects. After eight weeks of five day a week isometric training for the elbow flexors, subjects performed a series of isokinetic elbow flexions for an additional six weeks. Isometric strength and isokinetic peak torque were measured before the isometric training and before and after the isokinetic training. Subjects increased isokinetic peak torque after the isokinetic training, but did not increase isometric strength.

Ewing, Wolfe, Rogers, Amundson, and Stull (1990) tested peak torque and power after 10 weeks of three days per week training for three sets of eight reps. Knee extension and flexion peak torque increased an average of 8.5%, and power increased 13.6% across all subjects.

Finally, a study divided subjects into one of two groups to train either concentric or eccentric movements on an isokinetic dynamometer (Tomberlin, Basford, Schwen, Orte, Scott, Laughman, Illstrup, 1991). Subjects trained three days per week for six weeks, completing three sets of six maximal repetitions. Results showed significant increases in both concentric and eccentric peak torque for the concentric trained group, and a significant increase in eccentric peak torque for the eccentric trained group.

The Dyno

Isokinetic equipment has to date been too expensive and complicated to produce or provide to the general public and the health club markets. For this reason, very few in the general public have experienced a workout using an isokinetic machine. With this in mind, Concept2 developed a simple and inexpensive resistance-training machine called the Dyno.

The Dyno is a hybrid form of isokinetic equipment known as an isoaccelerative-isokinetic machine. Isoacceleration means that instead of the speed remaining constant, there is a constant linear acceleration (Westing, Seger, and Thorstensson, 1991). In this instance, the resistance applied to the machine will be absorbed by the machine and returned as an equal resistance while acceleration is maintained. No matter how hard one pushes against the machine, the machine will push back with an equal force while accelerating at a constant rate; and increased force application does not increase acceleration (Seger, Westing, Hanson, Karlson, and Ekblom, 1988).

There is very little previous research concerning isoaccelerative-isokinetic equipment, so the effects that this machine will have upon strength are unknown.

Isotonic vs. Isokinetic

Several studies have investigated the difference in strength gains made through the use of isotonic equipment versus isokinetic equipment. The inherent problem with discussing strength gains from these two different types of machines is that the measurements are not made in comparable units. Isotonic strength is most commonly measured in terms of 1RM capability, noted in pounds lifted. Isokinetic strength is usually referred to as peak torque at a given velocity of movement. When testing for strength it is known that there exists a degree of specificity related to the type of training undertaken (Sale and MacDougall, 1981; Coyle, Feiring, Rotkis, Cote, Roby, Lee, and Wilmore, 1981). The carryover effect of training isokinetically and testing isotonically, or vice versa, will not always be equal because of the rules of specificity.

Davies (1977) tested subjects after training three days per week for nine weeks, either isokinetically (5, 10, or 15 repetitions at one of three speeds) or isotonically (three sets of five repetitions). He found that the isotonic group significantly increased strength when tested isotonically; and the isokinetic group significantly increased isokinetic strength.

In an early study, Thistle, Hislop, Moffroid, and Lowman (1967) conducted an eight week, four days per week training study using the then new isokinetic dynomometer. Testing was done using the isokinetic device only. Results showed that total work and maximum voluntary force produced by the quadriceps muscle was greater for the group that trained using the isokinetic machine, compared to the group using traditional isotonic weight training.

In a study comparing the effects of isokinetic and isotonic training, subjects completed workouts seven days a week for four weeks (Moffroid, Whipple, Hofkosh, Lowman, Thistle, 1969). Subjects trained using isotonic equipment for three sets of 10 reps, while the isokinetic group completed 30 maximal repetitions. Both groups were tested on the isokinetic device. Results showed that the isotonic group increased quadriceps strength 3%, and hamstring strength 1%. The isokinetic group increased quadriceps strength 11%, and hamstring strength 10%. Tests using isotonic equipment were not done.

Pipes and Wilmore (1975) conducted an eight week program in which subjects trained with the leg press, bench press, biceps curl, and bent-over row three days per week. The isotonic group showed improvement on the isotonic tests, but did not significantly increase peak force when tested on the isokinetic device. The isokinetic group increased isokinetic peak force and isotonic strength.

Smith and Melton (1981) divided subjects into isotonic, slow-isokinetic (less than 180 degrees per second), and fast-isokinetic (greater than 180 degrees per second) groups for a three day a week training program for six weeks. At the end of the training program, all subjects were tested with both isotonic and isokinetic equipment. The isotonic group increased isotonic quadriceps strength 15%, and isokinetic quadriceps strength 2.5%. The isokinetic group increased isokinetic quadriceps strength 22.5%, and isotonic quadriceps strength 0.5%. Again demonstrating the specificity of training and testing.

An investigation by Kovaleski, Heitman, Trundle, and Gilley (1995) tested groups isometrically, isotonically, and isokinetically before and after six weeks of training the quadriceps three days per week using a 12 sets of 10 repetitions scheme. In this case, subjects were tested on isotonic, isokinetic, and isometric peak power. Isotonic training produced larger increases in isotonic peak power than did isokinetic training. Isokinetic training increased isokinetic peak power only.

O'Hagan, Sale, MacDougall, and Garner (1995) had subjects train one arm isotonically and one arm isokinetically. The isotonic arm completed 3-5 sets of 8-12RM, while the isokinetic arm completed 3-5 sets of 10 maximal contractions. After 20 weeks of training three days per week, the isotonic arm produced greater increases than the isokinetic arm on the 1RM test. Likewise, the isokinetic arm produced greater increases than the isotonic arm on the peak torque isokinetic test.

Similarly, Cordova, Ingersoll, Kovaleski, and Knight (1995) had subjects train one leg isotonically and the other leg isokinetically using a leg press exercise. After five weeks of three day a week training, both groups improved strength on their respective test modes, but the effect did not carry over between test modes. Each group was also tested to see which would increase one-legged jump reaction force. Neither group showed significant improvement on this third type of test.

Some of the other studies mentioned previously attempted to equalize the modes of resistance by measuring and comparing isotonic and isokinetic strength on a third measurement that would level the playing field and make comparisons relevant.

Davies (1977) measured work capacity as the number of repetitions that could be completed at one-half of the final 1RM or peak torque attained after training. This analysis found that isotonic groups outperformed the isokinetic groups regardless of contraction speed used during isokinetic training.

Smith and Melton (1981) tested the functional motor performance of their subjects after the isotonic and isokinetic training programs. Tests scores on vertical jump, standing broad jump, and 40-yard dash were improved by each of the training groups, but the isokinetic group showed significantly greater gains than the isotonic group (5.38% vs. 1.57% vertical jump, 9.14% vs. 0.28% standing broad jump, 10.11% vs. 1.35% 40-yard dash respectively).

Kovaleski et al. (1995) measured isometric peak power of both isotonic and isokinetic training groups. Both groups increased isometric peak power over the control group, but the isotonic group showed significantly more improvement than the isokinetic group. Also using isometric tests, Pipes and Wilmore (1975) found that an isotonic group increased only on biceps curl and leg press, while the isokinetic group increased for all movements tested (biceps curl, leg press, bench press, bent-over row).

Finally, there has also been research that suggests that the two methods are equal in ability to produce strength gains. Research by Gettman, Culter, and Strathman (1979) found that 20 weeks of training on 10 different exercises three days per week either isotonic or slow speed isokinetic both produced significant improvement in strength, but the increases were similar between groups.

Other relevant studies have compared differences in isotonic and isokinetic training. In a study comparing muscle action potentials from electromyography, both

Rosentswieg and Hinson (1972), and Keogh, Wilson, and Weatherby (1999) found that the isokinetic instruments elicited greater excitation and recruitment of the involved muscle groups than isotonic machines. Additionally, Keogh and colleagues found that the isokinetic training produced significantly greater levels of force production than isotonic training.

In a five year study of patients' rehabilitation after knee surgery, those who completed isotonic training of three sets of 10 repetitions 3-4 times a week had a 7% success rate, as measured by not having to have follow-up surgery. The patients that completed isokinetic training of three sets of 10 repetitions three times a week had a 61% success rate, significantly greater than isotonic training.

Isoacceleration-Isokinetic Training

Only one study has investigated the differences between training on an isokinetic machine versus an isoacceleration-isokinetic machine (Westing et al., 1991). The results indicated that both modes of training were equal, but that the isoacceleration technique appeared to offer the advantage of more accurately reflecting muscle contractions during natural movements. As mentioned before, there has not been any published data related to the Dyno's ability to produce increases in muscular strength, or comparing the Dyno to other methods of strength training. It is therefore unknown whether this particular form of strength training will produce effects similar to isotonic training, or to what extent strength gains may be made.

Contraction Types

A major difference between isotonic and isokinetic exercise machines is the type of contraction that each elicits. Isotonic exercises, such as the Cybex machine used in this study, require both concentric and eccentric actions; while isokinetic machines typically work only concentrically. The concentric portion of the exercise used in this study is the movement of the bar from the chest to the point where the arms are extended. At this point, the isotonic machine requires the weight to be "lowered" or returned to the starting position at the chest. This puts the user of the isotonic machine in the position of exerting effort to concentrically contract the involved muscles to press the bar away from the chest, and then to eccentrically use those same muscles to return the bar to the chest in a controlled manner.

Most isokinetic machines remove the "weight" after the concentric portion of the movement is complete, and requires the bar to be returned to the chest by activating the back and bicep muscles to pull the bar back to the starting position. There is usually little or no effort required to return to the starting position.

Concentric versus Concentric/Eccentric

Several investigations have examined training with concentric only versus combined concentric/eccentric exercise, and have found differing results. Some researchers concluded that concentric only training was equal to concentric/eccentric training.

Goodwin et al. (1989) examined differences in strength gained after a 10-week training program in which groups were divided to train the quadriceps with concentric only or concentric/eccentric movements. Their results did not show any difference in strength gains between the experimental groups, although both showed significant gains over the control group.

Hortobagyi and Hatch (1990) studied subjects completing 12 weeks of either concentric only or concentric/eccentric bench press and supine squat exercises performed at an intensity of 1-6RM. Improvements in the free weight bench press and squat were similar for both groups (24% con, 22% con/ecc); as were force, torque and power as tested on an isokinetic dynamometer (8% for both groups).

A study that compared groups completing 12 weeks of training using eight different exercises on either a concentric-only program or concentric/eccentric program found that both groups showed increases in strength, but the increases were specific to the type of training performed (Stanforth, Painter, and Wilmore, 1992).

Other studies have found that training with concentric and eccentric actions produces greater gains in strength than concentric alone.

Lacerte, deLateur, Alquist, and Questad (1992) measured isokinetic peak torque after groups trained the quadriceps five days a week for 12 weeks either concentric only or concentric/eccentric. They found that the peak torque of the combination concentric/eccentric training group was greater as measured on the isokinetic dynamometer across a spectrum of velocities.

Using maximum isometric resistance as the measurement tool for strength increases, Walker, Brunotte, Marcer, Cottin, Casillas, Gras, and Didier (1998) had subjects complete three sets of 10 repetitions of ankle plantar and dorsi flexion (concentric/eccentric group), or ankle plantar flexion only (concentric group). Two training sessions a week for five weeks resulted in 103% increase in maximal isometric resistance for the concentric/eccentric group, and 65% increase for the concentric group.

In an interesting study that further shows the effect of combined concentric and eccentric actions, Colliander and Tesch (1990) placed subjects into either a concentric only group that completed 12 maximum concentric knee extensions, or a concentric/eccentric group that completed six pairs of knee extensions and flexions on an isokinetic dynamometer. Subjects trained three times per week for 12 weeks. Results showed that whereas both groups experienced increased eccentric and concentric peak torques, the concentric/eccentric group showed greater increases in peak torque, vertical jump height, and three-repetition maximum leg extension than the concentric only group, even though the concentric group performed twice the number of concentric repetitions as the concentric/eccentric group.

Likewise, a study that compared three groups to determine if the eccentric component of resistance training was necessary, tested the hypothesis that concentric only, concentric/eccentric, and concentric only with double the number of sets would be equal (Dudley, Tesch, Miller and Buchanan, 1991). The results showed that the concentric/eccentric group increased 26% on the leg press, outperforming both the concentric only (8%) and double concentric groups (15%) in the leg press exercise.

Effect of Eccentric Movements

While the outcome of a training program that compares concentric only to concentric/eccentric training is not agreed upon by all investigations, there is enough evidence to support the statement that adding eccentric movements to a training program may affect its outcome. To this end, a discussion of the effects of eccentric movements is warranted.

It is known that the tension developed during eccentric movements is less than that during concentric movements (Johnson, Adamaczyk, and Tennoe, 1976; Jones and Rutherford, 1987). This increase in tension is a direct result of a smaller number of muscle fibers actively resisting weight that was lifted concentrically. It stands to reason that if fewer muscle fibers are at work, then the metabolic cost of an eccentric movement should be less than its concentric partner.

This was found to be true in the case of a study by Lastayo, Reich, Urquhart, Hoppeler, and Lindstedt (1999), which measured the effect of eccentrically resisting a modified stationary cycle. Results showed that even with a work rate 7 times that of the concentric group, the eccentric training group had a lower oxygen demand during the exercise. This finding was supported by previous research by Bigland-Ritchie and Woods (1976), who determined that the oxygen requirement of submaximal eccentric cycling was only one-sixth to one-seventh that of concentric cycling.

Later work by Dudley, Tesch, Harris, Golden, and Buchanan (1991) found that this same effect of lower metabolic cost is also true for resistance training. They examined subjects while performing repetitions of a supine leg press. The eccentric group performed the same resistance as the concentric group but used only one-seventh the oxygen.

These studies have shown that while eccentric movements are not as taxing as concentric movements, they do however add to the total metabolic work being done. As such, the total mechanical work done is also increased when eccentric movements are added. To state that a concentric only exercise is equal to a combined concentric/eccentric exercise is not supported, since it is now known that the eccentric movement does add to the overall cost of the exercise. How this added metabolic and mechanical cost affects the outcome of a training program is still being debated, although the majority of the evidence supports a training program combining concentric and eccentric work.

Rest Between Repetitions

Because of the design of the equipment used in this research, there exists a difference in the amount of rest that will be experienced between repetitions. The Dyno involves concentric only movements, and requires the bar to be returned to the chest by means of a concentric contraction of the biceps and back muscles instead of lowering the bar to the chest though eccentric movements as will be done on the Cybex chest press machine.

If performed correctly, subjects training with the Dyno will return the bar to the chest in a time frame of less than one second. This inherent rest period for the chest and triceps muscles involved in the exercise could confound the results because the Cybex training group will not have such a rest period, however small.

Only one study was found that had compared rest intervals similar to what will be experienced in this investigation. Byrd, Centry, and Boatwright (1988) conducted training which consisted of three sets of 6-10 repetitions at six stations on a Universal Gym machine. One group did not rest between repetitions, one group rested for one second between repetitions, and a third group rested for two seconds between repetitions.

1RM strength testing on the bench press revealed no significant differences between groups. The different amounts of rest had no effect on strength gains.

Conclusion and Expected Results

As the evidence has shown, there are several components of resistance exercise that can be manipulated to achieve the desired effect of increased muscular strength. To this end, an eight-week training program that incorporates three sets of six or less repetitions, performed three days per week, with 3-5 minutes of rest between sets should produce improvements in muscular strength. What is as yet unseen is if there will be a difference in strength gains between groups training with isotonic equipment (Cybex chest press) or isoaccelerative-isokinetic equipment (Dyno).

Strength increases from investigations utilizing isotonic training have ranged from 10-50% for upper body exercises, and 11-52% for lower body exercises (Table I). Comparable strength increases from isokinetic training programs have ranged from 8-46% for upper body exercises, and 8.5-32% for lower body exercises (Table II). It is expected that this investigation will produce strength increases that are inline with those shown in previous research, but it is unknown if one method will produce greater gains than the other.

TABLE I

STRENGTH INCREASES FROM ISOTONIC TRAINING PROGRAMS

Investigator	Amount of training	Training volume	Strength increases
Hickson	5days/wk 10wks	3sets/5reps 80%1RM	42% leg curl
			50% leg extension
			38% squat
Hurley	3-4days/wk 16wks	1set/8-12RM	50% upper body
			33% lower body
Messier	3days/wk 10 wks	1set/8-12RM upperbody	9.4% *
		1set/15-20RM lowerbody	9.4% *
Boyer	3days/wk 12wks	3sets/6-10RM	11% leg sled
			15% bench press
			10% military press
Marcinik	3days/wk 12 wks	3sets/8-12RM	30% leg extension
			52% leg curl
			20% bench press

* tested with isokinetic equipment

TABLE II

STRENGTH INCREASES FROM ISOKINETIC TRAINING PROGRAMS

Investigator	Amount of training		Training volume	Strength increases
Gettman	3days/wk	8wks	2sets/10-15max reps	11% bench press
				18% leg press
				8% arm curl
Coyle	3days/wk	6wks	5sets/6 max reps	32% knee extension
Kanehisa	5days/wk	8wks	13-29 max reps	34-46% elbow flexion
Ewing	3days/wk	10wks	3sets/8 max reps	8.5% knee extension
				8.5% knee flexion
Tomberlin	3days/wk	6wks	3sets/6 max reps	10-12% knee ext.

CHAPTER III

METHODOLOGY

Subjects:

A total of 33 men were recruited to participate in this study. They were volunteers from Oklahoma City University (ages 18-23, weight 154-267, height 65-74"), and had not been involved in a strength-training program for the previous six months. Additionally, all subjects were classified as "Low Risk" by a modified Par-Q Health Assessment questionnaire (Appendix A).

Location and Supervision:

The study and all resistance training was performed at the Personal Training Studio, 9412 N. Georgia, Oklahoma City, Oklahoma, 73120. All training sessions were overseen by the investigator to ensure accurate data recording.

Equipment and Workload Measurement:

The Concept2 Dyno (Concept2, Morrisville, VT) and Cybex Seated Chest Press (Cybex International, Medway, MA) were used (Appendix B). The Dyno was on loan from Concept2 Inc. for the duration of the study. The Cybex machine was the property of Quest Personal Training Inc..

The concentric workload for the Cybex Seated Chest Press was determined by multiplying the total number of repetitions for each set by the weight used for those repetitions. The concentric workload for each set was summed, and one-seventh of that workload was added to the concentric workload to account for the eccentric component and obtain the total workload for that session. This calculation of the workload is supported by the work of Dudley et al. (1991) who found that the eccentric component of a movement requires one-seventh of the metabolic demand of the concentric movement.

The workload for the Concept2 Dyno was determined by the Dyno itself. The resistance changes as the force applied to the machine by the subject changes. At the end of each repetition, the Dyno averages the force applied throughout the range of motion for that repetition and provides a measurement of the average force in pounds. The total workload for a session is the sum of the average workload for each repetition in that session.

Pre-Conditioning:

It is known that untrained individuals will experience improvement in performance through practice and learning effects. Because the subjects were untrained, and hence unfamiliar with the exercises involved, a two-week pre-conditioning period was used to familiarize the subjects with the equipment and teach correct lifting techniques. This format is based on studies by O'Shea and Wegner (1981), and Lacerte, deLateur, Alquist, and Questad (1992) in which all subjects learned correct lifting technique and how to apply force properly prior to the 1RM testing. During the two-week pre-conditioning phase, the training load was set so that subjects could complete two sets of 8-12 repetitions per exercise. Subjects also learned proper technique on the free-weight bench press that was used for testing. No attempts at establishing a 1RM were made.

Pre-training 1RM Testing:

At the end of the two-week pre-conditioning phase, subjects were tested for 1RM on the free-weight bench press. The 1RM method of measuring chest press strength was used as it is easy to administer, and it has been determined to be a valid measure of upper body strength (Dalton and Wallace, 1996). Additionally, the use of a free-weight bench press for testing will remove any bias due to specificity of training. The 1RM Testing Protocol outlined by Earle (1999) was used (Appendix C). To reduce the amount of trial-and-error associated with 1RM testing, the initial (step 1) warm-up weight was the weight that subjects used during the pre-conditioning phase.

Separating into Dyno and Cybex groups:

Eleven subjects were assigned to serve as controls and did not participate in the training program. Using the 1RM data for the remaining subjects, exercise groups were formed by the Matched Pairs method. Subjects were paired according to their 1RM totals, and each subject in the pair was randomly placed into either the Dyno (n=11) or Cybex (n=11) group. Final groups were subjected to a one-way ANOVA to establish equality on 1RM strength before the eight-week training period began.

Resistance Training:

The training program lasted for eight weeks, and began after the two-week pre-conditioning period. The Dyno group completed three sets of six repetitions per exercise. Because the Dyno resistance varies with the amount of force applied, subjects were instructed to apply maximal force to each repetition in each set. The average force applied during each repetition was displayed by the Dyno, and recorded on the workout data form (Appendix D).

The resistance setting or training load for the Cybex group was calculated using the RM method. The Cybex group completed three sets per exercise. Subjects initially used 85% of their 1RM. This load was adjusted so that subjects were able to complete at least one repetition and no more than seven repetitions per set. Subjects were instructed to attempt to complete the maximum of seven repetitions. If the subject completed seven repetitions, the training load in future sets was increased by five pounds. This rule was applied throughout the eight-week training period. Every time the subject was able to complete more than six repetitions, the load was increased. The load and repetitions completed for each set were recorded on the workout data form (Appendix D).

Post-training 1RM Testing:

At the end of the eight-week training program, each subject completed another 1RM for the free-weight bench press following the protocol outlined in Appendix C.

Statistical Analyses:

Each group's mean Pre- and Post-1RM were compared using a 2x3 repeated measures ANOVA design, with the Newman Keuls Multiple Range Test as a post hoc, to establish if there was a statistically significant difference at the .05 level between the means for Control, Dyno and Cybex groups. Additionally, independent T-tests were used to examine possible differences between the Cybex and Dyno groups in number of repetitions completed and total volume of work.

CHAPTER IV

RESULTS AND DISCUSSION

1RM Strength Results

The purpose of the study was to determine whether the Concept2 Dyno or the Cybex Chest Press was superior in promoting increases in 1RM free-weight bench press following an eight-week strength-training program.

A total of 33 subjects completed the eight-week training period. Each of the three groups (Cybex, Dyno, and Control) consisted of 11 subjects that were initially matched on free-weight bench press 1RM strength test scores obtained at the end of the two-week preconditioning period. Appendix E shows the Pre- and Post-1RM scores for each subject.

A 2x3 repeated measures ANOVA was used to analyze the mean Pre- and Post-1RM free-weight bench press strength test scores among the Control, Cybex and Dyno groups (Table III). The Pre- and Post-1RM test means and standard deviations are shown in Table IV.

TABLE III

ANOVA data table

Source	SS	df	MS	F(observed)	Sig
Group(G)	3250.8	2	1625.4	0.44	.648
S/G	110836.4	30	3694.5		
Time(T)	3637.9	1	3637.9	66.14	.000*
GxT	1837.1	2	918.6	16.70	.000*
TxS/G	1650.0	30	55.0		
Total	121212.2	65	9931.4		

* Significant to $p<0.05$.

TABLE IV

Group means and standard deviations with margin means.

		Time: Pre	Time: Post	
	Control	204.1 (±38.8)	204.5 (±38.8)	204.3
Group	Dyno	210.0 (±45.6)	228.6 (±42.5)	219.3
	Cybex	206.4 (±47.6)	231.8 (±45.7)	219.1
		206.8	221.7	

The main effect of Time was statistically significant as indicated in Table III. Mean 1RM strength increased from 206.8 to 221.7 pounds from Pre to Post, indicating that the training programs did have an effect on strength. Since the interaction of Group and Time was significant, the Newman-Keuls Multiple Range Test was performed as the *post hoc* test. The Control group did not increase 1RM, but each experimental group showed an increase in 1RM ability after the eight-week training program. More importantly, there was no difference between the Post-1RM scores for Cybex and Dyno groups. Therefore, both experimental programs were effective in increasing 1RM free-weight bench press strength, but neither group showed an advantage over the other.

The total volume of work completed during the eight-week training period between the two experimental groups was compared using an Independent T-test. The results showed a significant difference ($t=2.84$, $p<.01$) between the two groups favoring the Dyno group (mean=78538.7) over the Cybex group (mean=70617). The subjects training on the Dyno performed significantly more work per training session than the Cybex group; an average of 7,921 more pounds moved over the eight-week training period.

An independent T-test was performed to compare the total number of repetitions performed between the two groups during the eight-week training program. The Dyno group (mean=432) performed significantly more repetitions ($t=12.91$, $p<.05$) than the Cybex group (mean=326.4).

Discussion

The results point out, as has been shown elsewhere, that an eight-week training program, in which subjects train three days per week with three sets of a 6RM load is sufficient to improve strength (Thorstensson et al., 1976; Dons et al., 1979; Moritani and deVries, 1980). The Dyno group showed an 8.9% increase in strength; while the Cybex group showed a 12.3% increase; both similar to previous research. What is interesting is that the two experimental groups, which used completely different methods of applying the training load (isokinetic concentric vs. isotonic concentric/eccentric), had similar increases in strength.

These results are consistent with the previous research of Goodwin et al., 1989; Hortobagyi and Hatch, 1990; and Stanforth et al., 1992. Each of these previous studies compared an isokinetic concentric exercise to an isotonic concentric/eccentric exercise and found the strength gains from both groups to be similar.

The results of this study are in contrast to those found by Lacerte et al., 1992; Walker et al., 1998; and Colliander and Tesch, 1990. These investigations all compared concentric only to concentric/eccentric exercise, and in each case found that the concentric/eccentric groups had greater improvements in strength. The difference between the present investigation and these previous investigations can be found in the training modalities used. Lacerte et al. and Colliander and Tesch had both groups train on an isokinetic device; and Walker's subjects trained isotonically. These studies did not compare different training modes (isokinetic vs. isotonic) combined with differences in movement types (concentric vs. concentric/eccentric) as the present investigation did. Therefore, the present investigation's results cannot be compared to these studies because of differences in the study design.

Although 1RM strength improvement was similar between the experimental groups, there may have been a difference in the total amount of work done between groups since the Dyno involved only concentric movements and the Cybex involved concentric and eccentric movements.

To investigate this further, total volume of work can be calculated using the formula:

$$\text{Work} = \text{Force} \times \text{Distance},$$

where Force equals the weight being moved, and Distance is how far that weight is moved. The exact distance the weight was moved during each repetition was not measured or calculated for each subject, but treated as a constant. This was purposefully done because the distance the weight was moved depended on the subject's arm length, which means the distance the weight was "lifted" and "lowered" would be equal for each repetition a subject completed. The distance was not equal between subjects because of differences in arm length, and could not be manipulated. This leaves the definition of total volume of work, as it is used in this investigation, to mean the total amount of force that is generated during each repetition. It is the difference in force generation between each group that is of interest.

Total volume of work for the Dyno group was simply a summation of the force exerted during each concentric repetition of each set for all subjects (Appendix E). Total work for the Cybex group is a combination of the work done during the concentric "lifting" of the weight and the eccentric "lowering" of the weight. In mathematical terms, the concentric and eccentric components would be equal since the weight did not change between portions of the movement, and the distance "lifted" and "lowered" was equal for each repetition. But, as was stated in the review of literature, it is known that the metabolic oxygen demand of eccentric work is approximately one-seventh that of concentric work during resistance training (Dudley et al., 1991). With this for support, the concentric volume of work for the Cybex group was calculated by multiplying the repetitions completed in each set by the training load (weight used); then summing the results from each set. To account for the eccentric component, one-seventh of the concentric amount was added to the concentric portion to obtain the total volume of work.

As the Independent T-test comparing total volume of work between the Dyno and Cybex group shows, subjects training on the Dyno performed significantly more work per training session than the Cybex group. Add this discovery to the previous results, and we find that at the end of the training program, the Dyno group had performed more work than the Cybex group, but obtained the same increases as the Cybex group in 1RM free-weight bench press strength.

Of the previous studies that found similar strength gains from two different modalities (Goodwin et al., 1989; Hortobagyi and Hatch, 1990; Stanforth et al. 1992), none reported the volume of work actually completed. It can be assumed that there were probably differences in workload volume given that the subjects were required to complete a range of repetitions (1-10RM) for each set. As was found with this study, when a range of repetitions is completed rather than a set number of repetitions, differences in total volume of work are possible.

Differences in total volume of work are the result of completing different numbers of repetitions and/or sets. It has been shown, and is generally recognized, that strength gains will be greater when the total volume of training is higher; given that the subjects work with a sufficient percentage of the repetition maximum to elicit strength gains (Stowers, McMillian, Scala, Davis, Wilson, and Stone, 1983; McGee, Jessee, Stone, and Blessing, 1992; Willoughby, 1993).

It would seem that the results of the present study are not in line with previous research concerning volume of training and increases in strength. The current results might be explained by the differences between the two modes of exercise; which are mainly differences in the design of the equipment, and how they provide resistance during the exercise movements.

The position of the subject's body, both at the beginning and end of the range of motion, for both exercises was controlled and similar, as were the muscles activated during the motion. This eliminates any differences in mechanical efficiency or specific muscular activation between the machines. There are however differences between the Dyno and the Cybex machines that might account for this investigation's results.

The first difference is between performing repeated maximal lifts on the Dyno and performing submaximal lifts to failure on the Cybex. The design of the Dyno allows the subject to perform a maximal chest press with each repetition. The subjects in this study were encouraged to push as hard as possible throughout the range of motion of each repetition. The Dyno's adjustment to the applied force allowed changes in the resistance with each repetition, depending on the subject's efforts, so that six repetitions could be performed during each set. If the subjects performed the exercise correctly, then each repetition would be a maximal effort.

Oppositely, the Cybex chest press was set at a predetermined resistance that did not change according to the subject's efforts throughout the range of motion. Again, subjects were encouraged to push as hard as possible throughout the range of motion of each repetition, and to complete each repetition. The training load for the Cybex group was designed to elicit a 6RM, so that if subjects completed more than six repetitions in any given set, the training load would be increased on the next set. As subjects fatigued during a set, their ability to complete additional repetitions diminished, resulting in subjects completing varying numbers of repetitions (1-7) during each set, though never exceeding seven.

The observation was made during the training program that increases in the training load on the Cybex machine were made in five-pound increments, whereas the training load on the Dyno was adjusted in one-pound increments. While Hostler, Crill, Hagerman, and Staron (2001) noted that such differences in weight increases would not affect strength increases themselves over eight weeks of training, the larger increase in the training load on the Cybex machine would explain the drop in repetitions completed immediately after a load increase. A heavier load cannot be lifted as many times as a lighter load, therefore the repetitions completed in each set by the Cybex group had a larger range than the Dyno group (1-7 versus 6). The difference between completing six repetitions with every set (Dyno), and completing somewhere in the range of 1-7 repetitions (Cybex) explains the difference in total volume of work completed.

The independent T-test performed to compare the number of repetitions completed by the Dyno and Cybex groups in fact showed that the Dyno group performed significantly for repetitions. This shows that there is a difference in performing submaximal repetitions to failure, or performing a set number of maximal repetitions that is dependent on the training load used.

Along the same lines, it was apparent from looking at the data for the Dyno group that in most cases, as the set progressed there was a decreasing amount of weight moved. This is consistent with the earlier explanation of the repetition maximum (RM) : as more repetitions are performed, less weight must be used. When stating that the Dyno group performed maximal repetitions, what actually occurred is that each repetition was maximal at that given time. Since not enough time was allowed between each repetition (less than one second) for full recovery of all energy systems, the effort expressed in each repetition should be slightly less than the one before. As the body was depleting its short-term energy supplies, the force producing capabilities of the muscle were decreased.

This idea is supported in a study by Pincivero, Lephart, and Karunakara (1998), which found that between groups performing concentric maximal repetitions on an isokinetic dynamometer, the group that had longer rest intervals between sets did not decrease peak torque, average power, and total work as much as with a short rest period. Likewise, Young and Bilby (1993) compared series of fast and slow concentric contractions during sets, and found that the slow group experienced greater gains in strength than the fast group.

The decrease in force production and load moved with each repetition may have given rise to a lesser training effect compared to the Cybex group that was forced to complete subsequent repetitions with the same weight. This is supported by the results of this study which found that the Dyno group did perform more total repetitions, but did not experience a greater training effect than the Cybex group.

Although not measured, there may also have been a difference in the amount of fatigue that each mode of exercise produced. It has been shown that a greater level of fatigue at the end of an exercise session leads to greater increases in strength (Berger and Smith-Hale, 1991). Subjects in the Cybex group completed as many repetitions as possible during each set, being restricted only by reaching seven repetitions or volitional fatigue. The Dyno group never reached volitional fatigue and always completed six repetitions.

In a study of fatigue patterns of subjects exercising on an accommodating resistance exercise machine similar to the Dyno, investigators found that fatigue was linear instead of the curvilinear pattern reported for isotonic resistance ; and that subjects experienced only 20-30% strength loss compared to 50% on isotonic equipment for the same number of sets and repetitions (Gabriel, 1991).

Pearson and Costill (1998) also studied constant external resistance (isotonic) versus isokinetic exercise. They reported that isotonic exercise produced significantly greater gains in strength and muscle hypertrophy, and that there were significant differences in the number of repetitions necessary to produce equal work bouts between the two exercise modalities. Both of these studies support the possibility of differences in work and fatigue contributing to differences in strength gains.

Closely related, the second major difference in the two machines is that the Dyno provides for concentric contractions only, whereas the Cybex machine necessitates both concentric and eccentric contractions during each repetition. The effects of the eccentric load covered earlier in the review of literature did show that the eccentric portion of an exercise is different from the concentric portion in metabolic cost.

Investigations have examined the relationship between concentric only and concentric/eccentric work with respect to metabolic costs. Research by Dudley, Tesch, Harris, Golden, and Buchanan (1991) examined the differences between concentric only and concentric plus eccentric work with respect to the total work performed and metabolic costs of each exercise. Each subject performed four sets of 7-10 repetitions to failure using either a concentric only leg press, or concentric and eccentric leg press. They found that the absolute work per set performed by the concentric only group was significantly greater, but that the net oxygen and caloric costs per unit of work were moderately greater for the concentric/eccentric group.

The increased metabolic cost of concentric/eccentric work was also noted by Walker et al. (1998) while studying the bioenergetics of concentric only versus concentric/eccentric resistance training. They found that maximal oxidative power and oxidative phosphorylation increased significantly in the concentric/eccentric group only.

LaStayo, Reich, Urquhart, Hoppeler, and Lindstedt (1999) measured the metabolic cost of the eccentric component of exercise versus the concentric component; finding that while the eccentric component requires a much smaller amount of oxygen per unit of exercise, it does add significantly to the overall oxygen cost. This indicates that concentric/eccentric training may be more fatiguing than concentric alone, thus leading the Cybex group to making strength increases with less work than the Dyno group.

A final difference between the modalities is that while the Cybex group was forced to produce a level of effort and contraction to move the predetermined weight, the Dyno group had no predetermined weight to move, so their level of effort was completely voluntary. The group was instructed to give a maximal effort on each repetition of each set, and encouragement was given during the set to help in that effort. If subjects did indeed give maximal effort, we would expect to see gradual increases in force production over each set throughout the eight weeks of training. However, after studying the data for the Dyno group, the exertion levels wavered to different degrees between subjects and did not show a steady increase, but rather moved up and down between sets while still showing an overall increase in work over eight weeks. In this case, there may not have always been a maximal effort put forth by all subjects, which may have decreased their fatigue levels, contributing to the results found in this investigation.

Thus far the literature has not given a clear picture of the cause for differences in strength from training concentric only versus training concentric and eccentric. Previous research contains conflicts as to whether the eccentric training component is necessary to produce strength gains. As noted above, some research, including this investigation, found equal gains in strength (Goodwin et al., 1989; Hortobagyi and Hatch, 1990; Stanforth et al., 1992), while some research showed decreased strength gains when training concentric only (Lacerte et al., 1992; Walker et al., 1998; Colliander and Tesch, 1990); and some noted differences in amount of work performed between groups and the metabolic cost of that work (Lastayo et al., 1999; Dudley et al, 1991). Whether there were differences in the metabolic cost of the exercise modalities used in this investigation, and whether they may have played a role in the results obtained is unknown. Likewise, measures of fatigue were not gathered beyond one group working to fatigue and another group working until the set number of repetitions was completed.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this investigation was to determine whether a training program using the Dyno or Cybex machine was better at increasing 1RM free-weight bench press strength. The data from this study have shown that the Dyno group and the Cybex group experienced similar increases in strength despite the Dyno group performing more total volume of work and completing more repetitions than the Cybex group. The reasons for the differences in total work volume and repetitions have been examined and compared to previous research. There is a possibility that differences in fatigue states between the two modalities because of the difference the training loads allowed the Dyno group to perform more work and repetitions without achieving greater gains in strength than the Cybex group.

Findings

The hypothesis that there would be no significant differences in average gain scores between the Control, Dyno and Cybex groups is rejected. A significant difference was found in the gain scores of the Dyno and Cybex groups over the Control group. No difference was found between the gain scores of the Dyno and Cybex groups.

Conclusions

This investigation found that the strength-training program was effective in increasing the 1RM free-weight bench press strength of subjects in both the Cybex and Dyno groups. The control group did not experience any increase in strength. Additionally, there was no difference found between the effectiveness of the Cybex machine compared to the Concept2 Dyno.

Recommendations

Further research is needed to determine if the Dyno would be an equal alternative to isotonic training given the differences found in total work volume and repetitions completed between the Cybex and Dyno groups. This investigation focused only on the chest press function of the Dyno. Additional studies focusing on the leg press and seated row functions need to be made under the same conditions used in this study to validate the protocol and results. There is the possibility that the other functions of the Dyno do not require as much stimulus (total training load) to elicit a strength increase.

Concentric only workloads using dynamometers as the training modality need further investigation and comparison to isotonic training modalities. Attempts to equalize the total workload so that it is comparable to concentric/eccentric isotonic training need to be made so that a more accurate comparison in regards to improvement in strength is possible. It may be necessary for future investigations to limit the workload on the Dyno so that it does not become significantly greater than the isotonic modality, as occurred in this study.

Equalizing the total work time or contraction time of the two modalities is another way that comparisons in strength can be made. Since the Dyno involves concentric only contractions performed at a constant speed, and the isotonic machines involve both concentric and eccentric contractions performed at varying speeds, a time limit for each repetition would need to be set equal to the repetition time of the Dyno. Additionally, the Dyno subjects would have to perform twice as many repetitions as the isotonic group because they only perform concentric contractions, which is equal to half of the total contraction time of the isotonic group. Under this condition, work rates can be equalized, and strength gains can be compared.

Finally, comparisons of metabolic cost of work on the Dyno should be made and compared to equivalent work on isotonic equipment. With the understanding that maximal contractions involve more total muscle mass than submaximal contractions, any exercise on the Dyno should result in greater metabolic cost than working on an isotonic machine if the two modalities are equalized some way.

If this study were to be repeated, I would use female subjects to compare their responses to that of the males. I would also extend the total training time of the study to 20-24 weeks to determine if strength gains from both modalities peak and level off at the same time, or if differences between the two modalities are experienced after a greater training time.

Finally, given the results of this investigation, I would recommend the use of the Dyno for the general population as a regular training tool primarily because it does not require training to fatigue, which can be both physically and mentally exhausting on the average person. Any exercise that can provide similar results with lower levels of fatigue

(Dyno does not require volitional fatigue), will be readily accepted by the general population. The Dyno also provides immediate feedback on workout efforts, giving the user something to work towards (increasing force each repetition). This provides additional motivation to the user, which will ultimately serve to improve exercise retention.

The Dyno also has use as a testing tool. The usual discussions of how strong a person is are centered on how much they can lift, not lower. For these purposes, a machine such as the Dyno would prove useful because of it's concentric (lifting) only functions, and the fact that it accommodates everyone regardless of strength without the need for spotters or guessing how much weight needs to be applied.

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APPENDIX A

Modified Par-Q Health Assessment Questionnaire

NAME____ SS#__________________

Please CIRCLE the correct response to each question.

1. Has your doctor ever said you have heart trouble or any cardiovascular problems?	Yes	No
2. Do you frequently suffer from pains in your chest?	Yes	No
3. Have you ever suffered from a heart attack?	Yes	No
4. Do you ever experience an irregular or racing heart rate during exercise or at rest?	Yes	No
5. Do you often feel faint or have spells of severe dizziness?	Yes	No
6. Has a doctor ever said that your blood pressure is too high?	Yes	No
7. Do you often have difficulty breathing?	Yes	No
8. Has a doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be aggravated with exercise?	Yes	No
9. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?	Yes	No
10. Are you diabetic?	Yes	No
11. Are you asthmatic, or has a doctor ever said you have asthma?	Yes	No
12. Do you smoke?	Yes	No
13. Has a doctor ever told you that you have high cholesterol (>240 mg/dl)?	Yes	No
14. Does anyone in your immediate family have a history of coronary or other atherosclerotic disease prior to age 55?	Yes	No

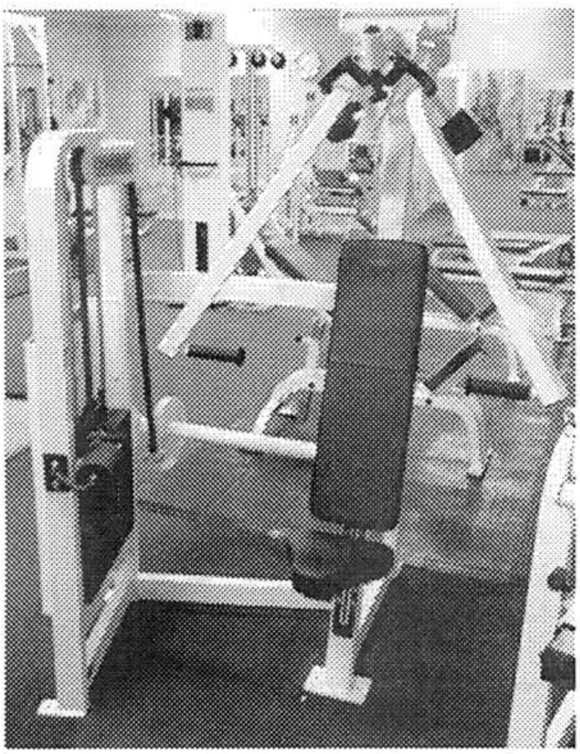
____

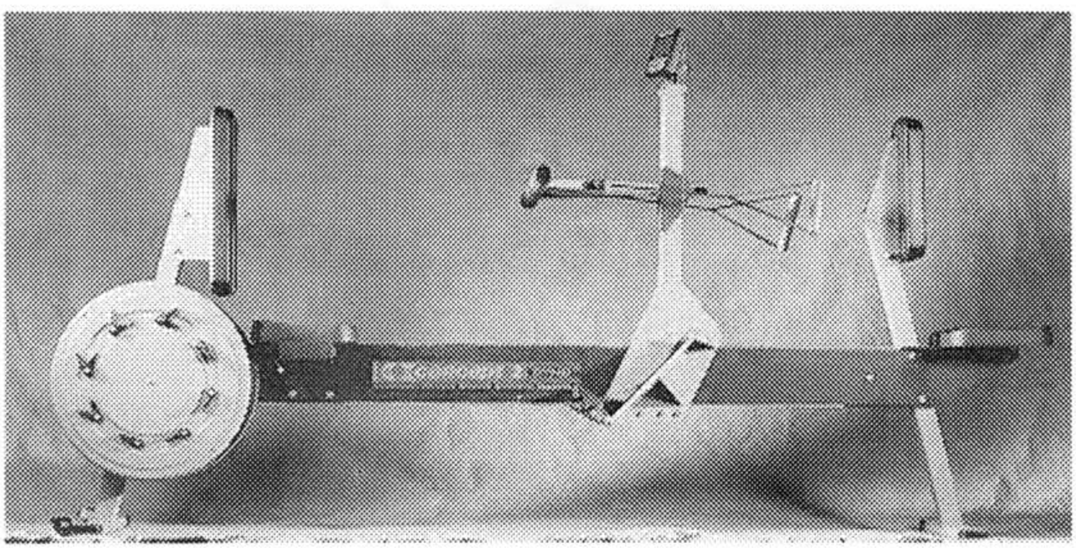
SIGNATURE DATE

APPENDIX B

Training Equipment

Cybex Seated Chest Press





Concept2 Dyno

APPENDIX C

1-RM Testing Protocol

1. Instruct subject to warm up with a light resistance that easily allows 5-10 repetitions.

2. Provide a 1-minute rest period.

3. Estimate a warm-up load that will allow the subject to complete 3-5 repetitions by

   adding: * 10-20 lb or 5-10% for upper body exercise, or

   * 30-40 lb or 10-20% for lower body exercise.

4. Provide a 2-minute rest period.

5. Estimate a conservative, near maximum load that will allow the subject to complete

   2-3 repetitions by adding: * 10-20 lb or 5-10% for upper body exercise, or

   * 30-40 lb or 10-20% for lower body exercise.

6. Provide a 2-4 minute rest period.

7. Make a load increase:

   * 10-20 lb or 5-10% for upper body exercise, or

   * 30-40 lb or 10-20% for lower body exercise.

8. Instruct the subject to attempt a 1RM.

9. If the subject was successful, provide a 2-4 minute rest period and go back to step 7.

   If the subject failed, provide a 2-4 minute rest period, decrease the load by subtracting:

   * 5-10 lb or 2.5-5% for upper body exercise, or

   * 15-20 lb or 5-10% for lower body exercise,

   then return to step 8.

Continue increasing or decreasing the load until the subject can complete one repetition with proper exercise technique.

APPENDIX D

Workout Data Form

CYBEX Training Date:________ Name:________________________

Set 1: Wt:_______ Reps:_______
Set 2: Wt:_______ Reps:_______
Set 3: Wt:_______ Reps:_______

DYNO Training Date:_________ Name: _______________________

Set 1: Rep1 Wt:______ Rep2 Wt:______ Rep3 Wt:______
Rep4 Wt:______ Rep5 Wt:______ Rep6 Wt:______

Set 2: Rep1 Wt:______ Rep2 Wt:______ Rep3 Wt:______
Rep4 Wt:______ Rep5 Wt:______ Rep6 Wt:______

Set 3: Rep1 Wt:______ Rep2 Wt:______ Rep3 Wt:______
Rep4 Wt:______ Rep5 Wt:______ Rep6 Wt:______

APPENDIX E

Pre and Post 1RM Test Data

Control	Pre1RM	Post1RM	Volume = 0	Age	Ht	Wt
1	260	255		23	73”	225lb.
2	255	255		21	70”	241lb.
3	255	260		19	71”	217lb.
4	225	230		21	72”	224lb.
5	205	205		18	69”	186lb.
6	200	195		20	68”	190lb.
7	175	170		22	72”	184lb.
8	175	175		18	68”	170lb.
9	170	175		21	67”	180lb.
10	165	170		20	71”	172lb.
11	160	160		18	69”	165lb.

Dyno	Pre1RM	Post1RM	Volume	Age	Ht	Wt
12	280	285	88374	22	74”	250lb.
13	200	230	84655	20	71”	195lb.
14	185	195	79363	18	70”	206lb.
15	285	290	84683	21	72”	266lb.
16	225	235	81029	19	69”	215lb.
17	145	165	60741	18	65”	154lb.
18	245	275	90690	21	67”	217lb.
19	160	175	58794	19	67”	165lb.
20	190	235	83552	20	69”	183lb.
21	180	200	79792	22	72”	185lb.
22	215	230	72253	19	73”	213lb.

Cybex	Pre1RM	Post1RM	Volume	Age	Ht	Wt
23	190	225	74000	18	68”	192lb.
24	225	250	85543	21	72”	218lb.
25	230	265	86743	20	71”	207lb.
26	140	155	34000	19	65”	150lb.
27	190	230	58749	18	69”	200lb.
28	180	200	67851	22	70”	187lb.
29	295	310	98337	21	73”	267lb.
30	240	250	81006	20	71”	223lb.
31	260	280	82171	19	72”	253lb.
32	160	210	56537	20	69”	170lb.
33	160	175	51846	21	71”	175lb.

APPENDIX F

Oklahoma State University
Institutional Review Board

Protocol Expires: 4/26/02

Date : Friday, April 27, 2001   IRB Application No ED01107

Proposal Title: COMPARISON OF A STRENGTH-TRAINING PROGRAM PERFORMED ON THE CONCEPT2 DYNO AND CYBEX CHEST PRESS MACHINE AMONG COLLEGE AGED MEN

Principal Investigator(s) :

Patrick S. Hagerman
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Edmond, OK 73083

Frank Kulling
103 Colvin
Stillwater, OK 74078

Reviewed and Processed as: Expedited

Approval Status Recommended by Reviewer(s) : Approved

Signature

Carol Olson, Director of University Research Compliance

Friday, April 27, 2001
Date

Approvals are valid for one calendar year, after which time a request for continuation must be submitted. Any modifications to the research project approved by the IRB must be submitted for approval with the advisor's signature. The IRB office MUST be notified in writing when a project is complete. Approved projects are subject to monitoring by the IRB. Expedited and exempt projects may be reviewed by the full Institutional Review Board.

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VITA

Patrick Scott Hagerman

Candidate for the Degree of

Doctor of Education

Thesis: COMPARISON OF A STRENGTH-TRAINING PROGRAM PERFORMED ON THE CONCEPT2 DYNO AND CYBEX CHEST PRESS MACHINE AMONG COLLEGE AGE MEN

Major Field: Applied Educational Studies

Biographical:

Education: Received Bachelor of Science degree in Health from Oklahoma State University, Stillwater, Oklahoma in May 1993; and Master of Science degree in Exercise Physiology from the University of Louisville, Louisville, Kentucky in May 1995. Completed the requirements for the Doctor of Education degree with a major in Applied Educational Studies at Oklahoma State University in December, 2001.

Experience: Served as an adjunct faculty in department of health and physical education at Oklahoma City University; and as a graduate teaching assistant at Oklahoma State University and the University of Louisville. Currently serving as President of Quest Personal Training Inc. in Oklahoma City, Oklahoma, as a column editor for the Strength and Conditioning Journal, and as Director of the Oklahoma Strength and Conditioning Association.

Professional Memberships: American College of Sports Medicine, National Strength and Conditioning Association, USA Weightlifting, US Windsurfing Association, USA Triathlon