The Influence of Strength Training and Weighted Implement Training on Throwing Velocities in Baseball Pitchers

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ABSTRACT

Throwing with increased velocity is a key to improving the success of the baseball pitcher. Baseballs travelling at higher speeds are harder to hit than baseballs travelling at slower speeds. Curveballs break harder, sliders move more harshly, and fastballs reach home plate sooner. Higher pitching velocities mean the batter has less time to decide to swing or not to swing. This study examines the effect of weighted implement training in conjunction with conventional weight training on overhand pitching velocities. Six male pitchers, all of whom played on the 1991 NCAA National Championship baseball Team, were studied for a period of sixteen weeks. The pitchers were divided into two groups, a treatment group and a non-treatment group. This study compares participants' pitching charts from the years prior to the study to pitching charts compiled the year after the study. This study clearly shows an increase in both maximum and average pitching velocities in the treatment group ($p<0.05$) with no corresponding increases in the non-treatment group ($p>0.05$).

INTRODUCTION

An accomplished baseball pitcher who wants to throw faster must consider Sir Isaac Newton Second Law of Motion, force equals mass times acceleration. Newton's equation can be restated as "acceleration equals force divided by mass", in other words, if the mass of the object acted on remains constant, a greater force will produce a greater acceleration. Throwing with increased velocity can improve success for baseball pitchers and means that the batter has less time to make a decision. The mass of the baseball remains constant, therefore the pitcher who applies the greatest force on the ball throws fastest.

Traditionally, weight training has long been recognized as the standard method to increase an athlete's capacity to generate force and for that reason it seems logical to assume that resistance training has long been a part of the baseball pitchers routine workout. Logical, maybe, but not so.

The art of pitching requires a high level of complex coordination and neuromuscular control. Historically, coaches and players assumed that the increase in muscle mass which results from weight training reduced an athlete's flexibility and that the benefits were offset by disruption to pitching biomechanics. Recent studies show that those assumptions are not always correct. Those studies shows that certain new weight training methods can actually increase an athlete's flexibility offering benefit to the improvement of strength.[19] Why these new training methods provide a simultaneous benefit requires an understanding of the ways in which weight training increases strength. The first, most visible and easily measured, way in which resistance training increases strength is through an increase in muscle mass. It is this visible increase in muscle mass commonly associated with "lifting weights" that, sometimes correctly and sometimes not, gives the impression of lost flexibility. The second aspect by which weight training increases strength is through an increase in muscle fiber "recruitment." When an athlete makes a conscious effort to move, he sets in motion a series a complex motorneuron signals which fire a number of the available muscle fibers in the muscles used to accomplish the intended motion. No athlete is capable of firing all the available muscle fibers simultaneously, in fact, without specialized training; an athlete can fire only a very small percentage of the available fibers during a single muscle contraction.[14] This specialized training has been designed to increase baseball pitchers' abilities to fire a larger percentage of muscle fibers during each pitch. The greater the neuromuscular activation, the greater the force produced.[4]

Proper, specific training will enable the pitcher to throw with greater velocity.[9]

The purpose of this study was to develop a program of strength training for baseball pitchers; specifically, to use weighted implement training for the purpose of increasing throwing velocities, without interfering with biomechanics of the pitching motion by:

1. Developing a training program throwing weighted implements, at various frequencies, volumes, and intensities.
2. Developing a protocol for use before beginning weighted implement training as well as criteria for gauging levels of arm and total body fitness prior to beginning weighted implement training.
3. Examining the effects of high velocity and high intensity arm training on the days available verses the days not available for each pitcher.
4. Examining the effects of weighted implement training on maximum and average pitching velocity.

Methods

There were a total of six male subjects used in this study. All six played for the NCAA 1991 National Championship Baseball Team. All six subjects were pitchers, three starters and three relievers. Ages ranged from 19 to 21 years(X=20). All six subjects were volunteers. The pitchers were the most frequently used throughout the season and were randomly assigned. Three pitchers participated in the treatment and three pitchers did not participate in the treatment.

The treatment consisted of training five days per week (M-F), with two rest days at the end of the week (Sat and Sun). Weight training exercises were trained on Monday, Wednesday and Friday. (See Table 1.) Classic or linear periodization was used as the method of regulating training volumes and intensity. The training began with higher repetitions and lighter resistance intensities and progressed to lower repetitions and heavier resistance intensities. Repetitions ranged from a high of forty to a low of three. Weighted implement training, plyometric exercises and speed exercises were trained on Tuesday and Thursday. (Table 2.) The intensity of weighted implement training loads was controlled by the weight of the ball, distance the ball was thrown, and number of throws per ball. Plyometric training exercises were controlled and measured by the exercise, intensity, volume and frequency. Speed exercises were controlled by the distance travelled and the time the distance was traveled. Dynamic and static flexibility exercises were done before each training session. Dynamic and static flexibility exercises were controlled and measured by the exercise, volume and frequency. The non-treatment group participated in the same weight training program as the treatment group. The non-treatment group did not participate in the weighted implement training, plyometric training and speed training that were performed on Tuesday and Thursday. (Table 3.) Pre- and post-study tests were administered to assess the pitchers' level of muscular strength, endurance, power and lower body quickness. Each individual pitcher was given the same conditioning program based on the pre test results. All exercises, sets and repetitions were the same for each pitcher. The only difference was the amount of weight used for each of the different exercises based on the individual differences in strength. Individual pitching charts from the pre-study 1989 and 1990 seasons were compared to individual pitching charts from the end of the post-study 1991 season. Maximum velocities and average velocities were recorded from each game in which the pitchers played and were averaged. Results were grouped in pre- and post-treatment categories for the treatment group. Results were recorded and analyzed for both treatment and non-treatment groups at the end of the 1991 season.

DATA ANALYSIS

Because there were only six pitchers used in the study, the statistical method used will be a time series analysis with a repeated measures design to test individual differences within the same sample. The criterion for statistical significance will be $\alpha = .05$.

RESULTS

Subjects in the treatment group all experienced significant increases (P<0.05) in both maximum throwing velocities (X=1.84 mph) and average throwing velocities (X=1.26 mph). (See Table 4.) Subjects in the non-treatment group did not experience significant increases (P>0.05) in either maximum throwing velocities or average throwing velocities. In fact, subjects in the non-treatment group showed a decrease in average maximum velocity (X=0.19 mph) and only a (X=0.03 mph) increase in average velocity. (See Table 5.) All subjects in the treatment grouped showed an increase maximum single pitch velocity, while subject 6 showed a decrease in maximum single pitch velocity.

No injuries were reported during any training sessions, whether training with weights, or with weighted implements, nor were any injuries reported during any pitching performance during the 1991 baseball season.

Variables which could account for the significant increases in the treatment group must be presented. One subject showed an increase in bodyweight of 14.7 pounds. All subjects showed an improvement in muscular power and endurance. Skill proficiency is another factor which could affect performance, however both treatment and non-treatment groups were considered mechanically efficient with their pitching mechanics.

This study indicates the more powerful and "explosive" a pitcher, the faster he will throw a baseball. Pitching is a highly explosive, complicated physical act governed by conscious effort. The ability to consciously recruit more muscle fibers into the pitching motion enables the pitcher to throw at higher velocities. Proper training is required to provide a pitcher with a larger store of muscle fibers and enable him to recruit more of those fibers in a single pitch. Weighted implement training is the specific type of training needed to accomplish those goals.

DISCUSSION

How important is throwing velocity for the pitcher? Converting the conventional measure of baseball speed from miles per hour to feet per second shows what occurs when a baseball travels at increased velocity. Knowing that the pitching rubber and home plate are sixty feet and six inches apart and knowing the velocity of the baseball in feet per second, we can calculate the time it takes the baseball to reach home plate. A pitch thrown at 85 miles per hour travels at a rate of 124.1 feet per second, or 12.4 feet per 0.10 seconds and takes 0.48 seconds to reach home plate. A pitch thrown at 90 miles per hour travels at a rate of 131.4 feet per second, or 13.1 feet in 0.10 seconds and takes 0.46 seconds to reach home plate. The two hundredths of a second time differential between 85 mph and 90 mph pitches seems small until you realize that if the two pitches were thrown simultaneously, the 90 mph would be over three feet ahead of the 85 mph pitch when it reached home plate. The more velocity with which the pitcher throws, the less time the batter has to decide whether to swing or not to swing. In typical strength training, weights are lifted without regard for speed. The load is lifted at a constant, isotonic rate. Experiments have demonstrated that the utilization of conscious maximum effort can create in targeted muscles a more forceful movement through a process known as "recruitment".[12] A high level of recruitment means that a large number of muscle fibers are recruited to fire simultaneously, thereby increasing the force of a muscle contraction without an increase in muscle mass. Research shows that athletes can learn to control the firing of a single motor unit through conscious effort. Recent studies note several different experiments that have demonstrated with appropriate EMG biofeedback procedures, subject only need basic instructions and about fifteen minutes of practice to learn to contract, "recruit" muscle fibers served by a single motor unit. Because the muscular contractions involved in pitching are primarily voluntary, and in light of these observations, it is conceivable that proper training can elevate the force generated by the muscles used in the pitching motion to a very high level.[15] Hakkinen, et al (1989), examined the effect of neural activation and force production of elbow arm flexors during constant and variable resistances. The neurological activation of the elbow arm flexors during maximal concentric contractions remained on the same maximal level throughout almost the entire range of motion when variable resistance was used. The neuromuscular activation of the elbow flexor muscles against variable resistance loading indicates a high efficient stimulation of arm flexors during variable resistance contractions.[12] The theory of variable resistance loading with weighted implement lies within the all or none principle, which states when either a muscle or nerve fiber is stimulated above threshold, it will contract maximally.[18] A recent study by Delito, A, et al (1989) used high intensity neuromuscular stimulation to the quadriceps muscles along with weight training to examine the increase in muscular contraction (recruitment) and the increase in fiber numbers (mass). The study clearly indicated that the increase in muscular strength and force were due to an increase in recruitment, not an increase in muscle fiber numbers, and that the greater the neuromuscular activation, the grater the force produced.[6] Overwhelming evidence indicates that the central nervous system determines which motor units contract according to various physiological characteristics. Research shows that as muscle tension is increased through voluntary mechanisms, motor units are recruited into an active muscle fiber unit in proportion to muscle unit tension and conduction velocities. It follows that if the nervous system is regulating recruitment according to tension and conduction velocities, a training regimen which increases muscle tension and conduction velocities will result in an increase in muscle fiber recruitment.[5] Studies have shown that motorneurons influence the contractile properties of the muscle fibers they innervate.[9] The correlation between motor neuron discharge rate and motorneuron unit force is strongly influenced activation intensity. This suggests that many forms of muscle activation intensities induce different levels of discharge rates and muscle unit forces.[23] When only a few motor units are activated, little force is generated. Forces rise in proportion to the level of discharge rates until maximum discharge achieves maximum force. It is important to note that conscious thought can increase the rate motorneuron discharge, and therefore the level of force generated by the affected muscle group, the greater the neuromuscular activation, the greater the force produced.[24] A study by Kojima (1991) examined the force/velocity relationship of human elbow flexors in voluntary isotonic contraction under heavy loads. When external resistance stayed high throughout the entire range of motion, the result was low velocity.[13] This was true even with high muscle fiber recruitment. The purpose of this study was to show that the weights of the implements varied, and all of the subject pitchers were able to accelerate the implements through the entire range of motion. As a result, the resistance did not remain the same throughout the range of motion. Pitching a baseball requires a unique neuromuscular response. Virtually all acceleration forces are directed to the baseball. Toward the end of the acceleration phase of overhand throwing, the elbow is extending through an arc at approximately 500,000/sec2. Such high accelerations are only possible through maximum conscious effort on the part of the pitcher.[16] In order to effect the benefits of recruitment to a pitcher who is already putting out maximum conscious effort, training methods must incorporate high conscious output along with proper increases in resistance, maintained a proper levels through the entire range of pitching motion. Such training will produce the specific neuromuscular changes that are needed for the muscle fiber recruitment along with the synchronization of muscle contractions during the pitching motion. Overcoming varying loads is vital to successful recruitment.[7] One theory based on this method is the principle of kinesthetic aftereffect. This principle states that when muscle force is applied against variable resistances, muscle force and speed will increase. It is a well known fact that strength development requires work against high resistance with few repetitions. It is also well known fact that speed of movement requires work with a mass that can be moved with high acceleration throughout the range of motion.[25] These two training methods are exactly what is required to increase fiber recruitment. This study adapted these training methods specifically to baseball pitchers by using over and under weighted baseballs as implements thrown at velocities greater than or as close as possible to peak performance levels. A skilled pitcher can throw a baseball accurately and repetitively with consistently high velocity because his muscle movements have been coordinated and conditioned to a high degree through repetitive practice.[17] The pitching motion begins in the lower body and continues upward through the trunk to the shoulder, elbow, wrist and fingers. A proper conditioning program must not ignore any of these areas. A conditioning program must develop flexibility, cardiorespiratory endurance, muscular power and endurance, and a balance of all so perfectly that it will aid in the optimal level of performance.[21] During the different phases of pitching, different muscle become active. Each muscle group used in pitching performs a different function; there are prime movers, steering muscles, depressors, and stabilizers. All are vitally important and must be trained according to the role they serve.[26] Some muscles must be able to produce great amounts of force and acceleration throughout the entire range of motion, some muscles must maintain certain amounts of static tension for joint stabilization, and some must create tension while decelerating.[20] There are a wide variety of exercises used to train the pitcher. They may range from rotator cuff exercises for the shoulder to medicine ball exercises for the trunk. A proper training regimen must acknowledge the specific purpose of targeted muscle groups and train those muscle groups for that purpose. Incorrect training can hinder pitching performance.[10] Incorrect training can cause undesirable adaptations. Studies have shown that high resistance training and endurance training done concurrently will cause an interference phenomenon, which in effect limits strength development. This research suggest that strength and endurance training done simultaneously are at least somewhat incompatible.[1, 2] Other studies have shown that fast twitch fibers (vital to high speed force output) can be trained and will exhibit slow twitch fiber characteristics (associated with endurance) under stimuli generated from endurance training.[22] Proper training methods tune the pitcher to meet his precise needs by balancing the development of these fast and slow twitch fibers. A study by Ackland, et al, (1990) of elite water polo players corroborates the above assertions. Ackland, et al, showed that strength training used with regular pool training sessions increased players' arm girth, muscle mass, the strength of medial rotators, as well as endurance over pool training alone. However, the strength training methods used by Ackland, et al, did not produce an increase in arm velocities.[3] A training program must engage the neuromuscular system in producing high neural output close to or greater than the actual performance. Present conditioning programs for baseball pitchers primarily focus on preventing injury. Because pitching a baseball produces extreme joint reaction forces, and because deceleration puts extreme tension on the rotator cuff muscles, proper weight training programs should address injury prevention as well as the need to balance strength and endurance. However, injury prevention clearly should not be the sole aim of a conditioning program.[11] The purpose of this study was to show that improving the neuromuscular system of pitchers can produce significant results in pitching performance. Proper training of pitchers' neuromuscular system is the key to increased throwing velocities.

CONCLUSIONS

Based on the finding of this study it can be concluded that:

1. Specifically training the nervous system will result in more forceful muscular contractions.
2. The subjects that participated in the treatment showed increases in maximum throwing velocity and average throwing velocity.
3. Resistance training alone did not engage the neuromuscular system with sufficient exercise range of motion patterns and intensity patterns required to restructure the neuromuscular system for increased neural output and fiber recruitment.

REFERENCES

1. Bagnall, K, G.J. Bell, S.R. Petterson, H.A. Quinny, and J, Wessel. Physiological adaptations to concurrent endurance training and low velocity resistance training. International Journal of Sports Medicine. P. 384-390, Vol 12, No 4 1991.

2. Bell J. Gordon, Stewart R. Peterson, J. Wessel, K. Bagnall, and Aurthur Quinney. Adaptations to endurance and low velocity resistance training performed in a sequence. Canadian Journal of Sports Sciences. P. 186-192, Vol16, No 3, 1991.

3. Bloomfield, John, Brian A. Blanksby, T R. Acland, and GT.Allison. The influence of strength training on overhand throwing velocity of elite water polo players. Department of human movement and recreation Studies, University of Western Australia. The Australian Journal of Science and medicine in Sport. P. 69-73, Sept, 1990.

4. Coleman, A. Eugene. In-Season Strength training in major league baseball players. The Physician and Sports Medicine Journal. P. 125-132. Vol10, No 10, Oct 1982.

5. Cope, T.C., and B.D. Clark. Motor unit recruitment in the decerbrate cat: Several Unit Properties are equally good predictors of order. Department Physiology and Biophysics, Habnermann University, Journal of Neurophysiology. P. 1127-1137, Vol66, No 4, Oct 1991.

6. Delito, A., M. Brown., M.J. Strube, S.J. Rose, and R.C. Lehman. Electrical Stimulation of quadriceps femoris in an elite weight lifter. A single subject experiment. Washington School of Medicine, Program in Physical Therapy. International Journal of Sports Medicine. P. 187-191., 10, 1989.

7. DeRenne, Coop., Physical demands and biomechanical basis for baseball conditioning. University of Hawaii. National Strength and Conditioning Journal. P. 33-38, Vol 12, No 4, 1990.

8. Foehring, Robert C. and John B. Minson. Motoneuron and muscle Unit Properties after long term direct innervations of the soleusmuscle by medial gastrocnemius nerve in cat. Department Neuroscience, University of Florida College of Medicine. Journal of Neurophysiology. P. 947-961, Vol 64, No 3, Sept 1990.

9. Harre, Dietrich. Principles of Sports Training based on experience and scientific research in sport in the German Democratic Republic. Sportwerlag. Sept, 1982.

10. Jobe, Frank W., Charles E. Giangarra., Ronald S. Glousman. Anterior Capsulolabral reconstruction of the shoulder in athletes in overhand sports. The American Journal of Sports Medicine. P. 428-434, Vol 19, No 5, 1991.

11. Jobe, Frank W,. and Marilyn Pink. Shoulder injuries in the athlete. The instability continuum and treatment. Journal of Hand Therapy. P.69-73, April-June, 1991.

12. Kauhanen, Heikki, Keijo, And PavoV. Komi, Neural activation and force production of arm muscles during normal and fatigue loading against constant and variable resistance. Department of Biology and Physical Activity, University of Jyvaskyia, Finland, Scandinavian Journal of Sports Sciences, P.79-86,11 (2),1989.

13. Kojima, T. Force velocity relationship of human elbow flexors in voluntary isotonic contraction under heavy loads. Department of Sports Sciences and College of Arts and Sciences. University of Tokyo. International Journal of Sports Sciences. P. 208-213, 12,1991.

14. Kokkonen, Jouko., Blauerr Bangerter,. Elmos Roundy., and Arnold Nelson., Improved performance through digit strength gains. Brigham Young University. Research Quarterly for Exercise and Sport. P.57-63, Vol 59, No 1, 1988.

15. Magill, Richard A. Motor learning Concepts and applications. Louisiana State University. Wm. C. Brown Publishers. Dubuque, Iowa, 1989.

16. Michaud, Thomas. Biomechanics of unilateral overhand throwing motion. An Overview. Chiropractic Sports Medicine. P.13-25, Vol 4, No 1, 1990.

17. Moynes, Diane R., Jaquelin Perry., Daniel, J. Antonelli., and Frank W. Jobe. Electromyography and motion analysis of the upper extremity in sports. Physical Therapy. P. 1905-1911, Vol 66, No 12, Dec 1996.

18. Noble, Bruce J. Physiology of exercise and Sport. University of Wyoming. Times Mirror / Mosby College Publishing. 1986.

19. Pappas, Arthur M., Richard M. Zawaski, and Clairef McCarthy. Rehabilitation of the Pitching Shoulder. The American Journal of Sports Medicine. P. 223-235, Vol13, No 4, 1985.

20. Pappas, Arthur M., Richard M. Zawaski, and Thomas J. Sullivan. Biomechnics of baseball pitching. A preliminary report. The American Journal of Sports Medicine. P. 216-222, Vol 13, No 4, 1985.

21. Pappas, Arthur M., and Richard M. Zawaski. Baseball: Too much on a young pitchers shoulder. The Physician and Sports Medicine Journal. P. 107-117, Vol 19, No 3, 1991.

22. Pette, Dirk. Activity induced fast to slow transitions in mammalian muscle. Medicine and Science and Sport Exercise. P. 517-528, Vol16, No 6, 1984.

23. Powers, Randall K. and Marc D. Binder. Effects of low frequency stimulation on the tension frequency of fast twitch motor units in cats. Department Physiology and Biophysics, University of Washington School of Medicine. Journal of Neurophysiology. P. 905-918, Vol 66, No 3, Sept 1991.

24. Powers, Randall K. and Marc C. Binder. Summation of motor unit tensions in the tibialis posterior muscle of the cat under isometric and nonisometric conditions. Department Physiology and Biophysics, University of Washington School of Medicine. Journal of Neurophysiology. P. 1838-1845, Vol 66, No 6, Dec 1991.

25. Sage, George H. Introduction to Motorbehavior. A neuropsychological Approach. University of Northern Colorado. 1971.

26. Townsend, Hal, Frank W. Jobe, Marilyn Pink, and Jaquelin Perry. Electromyographic analysis of the glenohumeral muscles during a baseball rehabilitation program. The American Journal of Sports Medicine. P. 264-272, Vol 19, No 3, 1991.

TABLE 1

RESISTANCE EXERCISES

1. Flat Dumbell Bench Press
2. Stretch Flys
3. Block Pushups
4. Standing Alternate Dumbell Press
5. Seated Dumbell Press
6. Scare Crows
7. Dumbell External Rotation
8. One Arm Dumbell Row
9. Dumbell Pullovers
10. Hammer Curl
11. Alternate Dumbell Curl
12. Lying Tricep Extension
13. Standing One Arm Tricep Extension
14. Back Squats
15. Pitcher Squats
16. Step Ups
17. Single Leg Squats
18. Glute /Ham Back Extensions
19. Barbell Wrist Curls
20. Tubing Finger Flexions
21. Partner Toe Touches
22. Dumbell Side Bends
23. Crunches

Static Flexibility

1. Knee to Armpits #
2. Foot Toward Head #
3. Knee-supported Hamstring #
4. Elbow Beside Head #
5. Elbow Under Chin
6. Partner Pectoralis Stretch

Dynamic Flexibility

1. Leg Swings Frontal / Sagital *
2. Supine Leg Crossover *
3. Roll Tucks *
4. Two Arm Row
5. Shoulder / Elbow / Wrist
6. Wrist Circumduction

TABLE 2

PLYOMETRIC EXERCISES

1. Med Ball Hip Throw
2. Med Ball Torso Exchange
3. Med Ball Trojan Walks
4. Between the Leg Forward *
5. Overhead and Back *
6. Opposite Shoulder Throw *
7. Med Ball Pullover Throws
8. Med Ball Eccentric Drops
9. Med Ball Drops with Pullover Throws
10. Med Ball Seated Overhead Throws
11. Med Ball Standing Overhead Throws
12. Med Ball Prone Arm Ab / Adds
13. Med Ball Rock and Fire
14. Med Ball Prone Catch and Toss
15. Med Ball Shuffle Scoop Toss
16. Med Ball Hikes
17. Med Ball Wrist Flips
18. Med Ball Behind Back Toss
19. Med Ball Prone Overhead Throws
20. Dynamic Step-ups
21. Hurdle Jumps

Medicine Balls weighed 3 kg and 5 kg.

* Performed with an 8-lb shot put.

WEIGHTED IMPLEMENTS
1. 16 ounces
2. 10 ounces
3. 4 ounces
4. 2 ounces

SPEED EXERCISES
1. 20 Meter Sprints
2. 5-10-5 Short Shuttle

TABLE 3

MUSCULAR ENDURANCE AND POWER TEST

	Bench Press		Vertical Jump		Side Jumps	
	Pre-test	Post-test	Pre-Test	Post-test	Pre-test	Post-test
	Weight/Repetitions				Repetitions/30 Seconds	
Subject 1	135x19	135x25	23 inches	27 inches	32	38
Subject 2	135x19	135x29	24 inches	29 inches	37	41
Subject 3	115x16	115x20	20 inches	24 inches	24	33
Subject 4*	135x9	135x14	21 inches	21 inches	31	33
Subject 5*	115x12	115x15	23 inches	24 inches	33	34
Subject 6*	135x14	135x16	25 inches	25 inches	32	32

TABLE 4

TREATMENT GROUP

Subject	Age	Ht/In	Bwt/Kg
#1	20	74	90.71
#2	20	72	81.64
#3	21	70	73.93
	X = 20.3333	X = 72	X = 82.0933
	SD = 0.4717	SD = 1. 6329	SD = 6.8579

AVERAGE MAXIMUM VELOCITY

Subject	PRE	POST	P < 0.05
#1	88.74	90.87	0.0001
#2	90.65	92.00	0.004
#3	80.33	82.36	0.0506
	X = 86.57	X = 88.41	X = 0.0182
	SD = 4.48	SD = 4.30	SD = 0.0229

AVERAGE VELOCITY

Subject	PRE	POST	P < 0.05
#1	86.58	88.03	0.0018
#2	87.37	88.28	0.0408
#3	79.08	80.51	0.0505
	X = 84.34	X = 85.60	X = 0.0310
	SD = 3.73	SD = 3.60	SD = 0.0210

TABLE 5

NON-TREATMENT GROUP

Subject	Age	Ht/In	Bwt/Kg
#4	19	77	89.81
#5	19	74	79.83
#6	21	71	92.53
	X = 19.6666	X =73.66	X =87.39
	SD = 0.9428	SD = 2.4944	SD = 5.498

AVERAGE MAXIMUM VELOCITY

Subject	PRE	POST	P < 0.05
#4	89.56	89.70	0.7618
#5	89.17	89.15	0.2456
#6	85.85	85.16	0.9671
	X = 88. 19	X = 88. 00	X = 0. 6581
	SD = 1.66	SD = 2.02	SD = 0.3035

AVERAGE VELOCITY

Subject	PRE	POST	P < 0.05
#4	87.00	87.80	0.1028
#5	86.91	87.01	0.7796
#6	83.56	82.76	0.2099
	X = 85.82	X = 85.85	X = 0.3641
	SD = 1.60	SD = 2.21	SD = 0.2970