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A Comparison of the Effects on Throwing Velocity of Straight Plane versus Diagonal Plane Shoulder Exercises on 18-30 Year Old Non-Athletes

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A COMPARISON OF THE EFFECTS ON THROWING VELOCITY OF STRAIGHT PLANE VERSUS DIAGONAL PLANE SHOULDER EXERCISES ON 18-30 YEAR OLD NON-ATHLETES

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This Scholarly Project, submitted by Jason Allred, Kevin O'Brien, and Peter Tran in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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(Chairperson, Physical Therapy)

PERMISSION

Title	A Comparison of the Effects on Throwing Velocity of Straight Plane Versus Diagonal Plane Shoulder Exercises on 18-30 Year Old Non-Athletes
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Signature(s) Jason D. Allred

Date 12/15/04

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ABSTRACT

The purpose of this study was to examine changes in throwing velocity exhibited by subjects placed in a straight-line resistance-training group, a proprioceptive neuromuscular facilitation (PNF) resistance-training group, and a control group in order to compare benefits between training programs. Subjects were comprised of 42 college students between the ages of 18 and 30. The subjects were placed in one of the three experimental groups (straight-line resistance-training, PNF resistance training, and control) using Theraband™ elastic tubing. Each subject's overhand throwing velocity was measured on two separate occasions separated by 8-weeks of training. Rate of perceived exertion (RPE) was used to assess subject intensity during training. Overhand throwing velocity in both the straight-line and the PNF resistance training groups showed a significant increase in throwing velocity when compared to the control group. There was no significant difference in throwing velocity exhibited between the straight-line and the PNF resistance-training groups. The results indicate that strength training can increase maximal throwing velocity in an 8 week period of time. Although the difference in velocity gains between the straight-line and the PNF resistance training groups were not statistically significant, the PNF program, due to the shorter time it takes to administer, may be of more benefit to the user than the straight-line resistance training program.

CHAPTER 1

LITERATURE REVIEW

With development of baseball training programs on the incline every year, many athletes are attempting to find a training regimen that will suit their specific needs. Areas that are often emphasized include increasing swing speed, increasing throwing velocity, improving throwing accuracy, and promoting proper overall technique. One area of baseball that is often misunderstood is training to increase overall throwing velocity. Many coaches and players may believe that by improving in other areas (e.g. increasing throwing accuracy and promoting proper overall technique) the athlete may indirectly increase throwing velocity. However, many coaches and players may be decreasing their overall potential by not directly training to increase throwing velocity. This may be due to a lack of understanding of the kinematics and kinesthetics involved in the overhand throw. This may also be due to confusion over which types of programs "work" and which ones do not.

The overhand throwing motion is a relatively complex sequence of events. There are 4 phases: the cocking phase (musculature placed in a stretched, more efficient position), the acceleration phase (muscles transition from an elongated state to a more shortened state), the ball release phase, and a recovery phase.[1] The kinematics and kinetics of an overhand throw use several parts of the body in order to propel the ball forward. Throwing technique is an area of emphasis when pertaining to overhand throwing velocity. Derenne et al[2] noted that proper throwing technique is vital to increasing throwing velocity. However, Van den Tillaar and Ettema[3] determined that instruction on technique of the throw did not change the subjects throwing technique in isolated trials. It appears that changes in throwing technique must be done over a period of time in order for results to be seen.

With a proper form overhand throw the hips, upper trunk, humerus, and hand all play a role along with the lower limbs.[4, 5] The nonthrowing shoulder joint motion is decreased substantially throughout the throw, more evident in more skilled subjects.[6] The upper trunk rotators and shoulder musculature play a significant role in accelerating the ball in the early phase of the throw, while the momentum produced by the shoulder and trunk cause a sudden elbow extension near ball release.[4] Also vital to the overhand throw are the wrist kinematics. During the cocking phase, the wrist flexors (like most muscles involved in throwing) are on stretch in extension. The wrist then progresses from full extension to flexion throughout the throw until ball release, after which the wrist returns to neutral.[1] Along with the upper extremity and trunk the lower extremities also play an important role using drive and ground reaction forces to propel the upper extremity forward.[5] Leg drive has been correlated to increased wrist velocity.[5] Increased wrist velocity up until ball release will greatly decelerate the wrist just before ball release, thus changing wrist torque.[7] However, torque may not be as important a contributor to throwing velocity as once thought.[8]

There have been several studies conducted on torque when related to throwing velocity. In the past researchers have looked at torque and inferred that increased torque must equal increased throwing velocity.[7] However, in a study conducted by Bayios et al[8] it was determined that internal and external rotational torque was not a good indicator for overhead throwing velocity in handball players. Thus training to increase torque may not produce the results that the player is seeking. Focus, rather, should be on improving muscular power and dynamic athletic performance.[9]

In recent years there has been a steady increase in the number of training programs that claim to increase overhand baseball throwing velocity. To date there have been relatively few studies conducted on which types of training programs work best to increase overhand throwing velocity, and which ones are most efficient. Most throwing velocity programs include some type of resistance training. Most often such a program is a combination of two types of training regimens: straight-line resistance training and functional diagonal resistance training (also known as proprioceptive neuromuscular facilitation) using elastic bands or tubing. As stated earlier, most studies have focused on torque assessment while few studies have established effective training programs for overhand throwing velocity. The area of interest for this particular study is to identify whether there is a significant effect among a control group, those who have been introduced to proprioceptive neuromuscular facilitation techniques (PNF) of the upper extremity for training (functional diagonal), and those who have been introduced to a straight-line resistance-training program. This study will attempt to answer the following hypothetical questions: Can PNF strengthening techniques, due to its more functional motion, be as beneficial as a straight-line resistance-training program on throwing velocity? Will PNF strengthening techniques show a significant difference in throwing velocity when compared to a control?

Sullivan[10] conducted a study that attempted to answer these same questions. He tested 48 healthy male and female undergraduate students on throwing velocity over a period of 6 weeks. He tested the students to determine if there was a significant difference among the throwing velocities of three groups: a straight-line resistance training group, a diagonal group, and a control group. There was a significant difference among throwing velocities for those who were a part of the straight-line resistance training group (+. 8 mph) when compared with the control group. He also found that there was a significant increase in throwing velocities when comparing the diagonal group with the control group. What was interesting, however, was that there was a significant increase in overhand throwing velocity in the straight-line resistance training group when compared with the diagonal simulated throwing group. A finding from the study also showed that there was no significant increase in throwing velocity between subjects who progressed their resistance compared to those who did not. Another important finding was that there was no significant difference in throwing velocities of those subjects who practiced throwing and those who did not.

Although Sullivan's study[10] showed significant differences in areas assessed, there have been few studies conducted that have been similar in design. As such it is difficult to determine the validity of such a study. However, there have been studies conducted on whether a combination of straight-line resistance training and diagonal training would increase overhand throwing velocity. According to Derenne et al[2] a combination of a straight-line resistance program and a diagonal program showed a significant increase in throwing velocity. There are other sports with similar biomechanical elements that demonstrate similar results. Treiber et al[11] conducted a study on the effects of resistance training on tennis serves. The protocol included both lightweight dumbbell training and Theraband™ training for internal and external rotator musculature of the shoulder to determine if these factors had any effect on serve velocity. The study found a significant effect with the dual exercise program showing an increase in peak speed and average speed.

It is noteworthy that gender appears to play a nonexistent role as pertaining to increasing throwing velocity on a resistance training program. Derenne et al[2] noted that gender did not have a significant role as related to increase in overhand baseball throwing velocity following a combination training program. In another study, Van den Tillaar and Ettema[12] determined that gender also did not play a significant role in determining overall throwing velocity when compared to individuals with similar muscle mass. To determine muscle mass these researchers used the Fat-Free Body Mass Scale (FFM). They concluded that female participants showed no significant decline when matched up against male participants with similar FFM scores. Another interesting finding was that there was no significant difference in strength when groups were matched up by muscle bulk. These studies' results contradict past views on gender as pertaining to overhand throwing velocity. As stated earlier, in order to improve throwing velocity, focus should be on improving muscular power and dynamic athletic performance as opposed to improving muscle torque.[9]

As pertaining to a resistance exercise program using elastic bands or tubing it may be difficult to determine which loads are appropriate in improving muscle power and performance. One possible way of determining appropriate forces would be to monitor the rate of perceived exertion. A study was conducted by Lagally et al[13] to determine the validity of the Borg rate of perceived exertion scale. This study tested rate of perceived exertion in one set of 15 repetitions at 30% of the one-repetition maximum. Active muscle and overall body ratings of perceived exertion were obtained immediately at termination of each of seven exercises (bench press, leg press, latissimus pull down, triceps press, biceps curls, shoulder press, and calf raises). They established that sensations of exertion in the active muscles during resistance exercise are greater than sensations for the overall body. They concluded that ratings of perceived exertion using the Borg scale could provide information regarding the intensity of resistance exercise with validity.

In another study Lagally and Costogan[14] tested whether there was test-retest reliability for the Borg RPE. They tested during two sessions at 40%, 50%, 60%, 70%, 80%, and 90% of one repetition maximum using this technique. They concluded that RPE increased significantly with increased exercise intensity in all groups. What they also concluded was that rate of perceived exertion increased with increased exercise intensity between sessions, thus promoting test-retest reliability of the Borg RPE scale.

Another study by Pincivero et al[15] tried to determine if there was a significant difference between male and female college students scoring on the Borg RPE scale. In the study they scored at 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90% of their three highest hamstring muscle contractions. They concluded that although males generated a significantly greater overall torque than female subjects, there was no significant difference in rate of perceived exertion among male and female subjects when related to their percent of MVC. They concluded that RPE did not differ between male and female subjects. It was also established that the RPE increased with increasing stresses via increased resistance.

Although it is important to note factors that increase overhand throwing velocity, it is also important to note factors that may decrease velocity. One variable that may decrease throwing velocity is an attempt by the subject to improve accuracy. According to Fick's Law,[16] by attempting to increase accuracy a subject will compensate by decreasing velocity. Van den Tillaar and Ettema[16] conducted research on this topic using handball players. They determined that when instructions increasingly emphasized accuracy, velocity of the throw decreased, thus supporting Fick's Law. What was interesting about this study was that despite the loss in velocity, accuracy was not improved when the subjects were told to focus on it.

Another variable that can decrease throwing velocity is extended play. Murray et al[17] concluded that increased throwing time can decrease ball velocity. It was unknown as to whether this was due to a protective mechanisms or fatigue. They also determined that extended throwing time decreases maximal shoulder external rotation, knee angle at ball release, maximal distraction forces at the shoulder and elbow, and horizontal adduction torque.

To summarize, due to the lack of research in this area and the beneficial effects that this type of training regimen could have on speed of overhand baseball throwing, more research needed to be conducted in this area with more of an emphasis on training programs that could increase velocity of the overhand throw since that is the goal of most people who train in this manner. We believe that our study will assist in that regard.

CHAPTER 2

METHODS

Subjects from the population of students at the University of North Dakota were recruited on a volunteer basis to participate in the 8-week study. Inclusion criteria was set to include males and females between the ages of 18 and 30 that were not currently involved in any organized throwing sports or throwing exercise training. Potential subjects were screened via a written questionnaire for any active or previous shoulder pathology, joint laxity, pregnancy, or other systemic diseases or conditions that may contraindicate maximal velocity throwing or strength training. The questionnaire also included general questions regarding previous experience with throwing and strength training, as well as current throwing activities or workout regimens in which they are participating (Appendix A). Forty three subjects met the criteria for inclusion into the study group. The group consisted of 18 males and 25 females, with a mean age of 24.1 years. Based on the results of the questionnaire, 23% of the participants had previous throwing experience or instruction, 68% were involved in some type of exercise regimen and 82% had previous experience with strength training.

The baseline and end throwing velocity testing was conducted using official weight 5.25 ounce baseballs and a hand-held Doppler radar gun. The gun measures linear velocity of a moving object by projecting a radar wave which reflects from a moving object. This reflected wave is detected by a receptor on the gun, which calculates the frequency difference between the transmitted wave and the reflected wave. This frequency alteration, referred to as a Doppler shift, occurs when an object is moving toward or away from the radar source.[1] The amount of frequency change is calculated by the radar gun receptor to determine the linear velocity of the moving object, in this case a thrown baseball. According to manufacturer's specifications, the radar gun is accurate to +/- 1.0 mile per hour and is most accurate if the radar waves are projected between 0 to 25 degrees from parallel with the direction of the moving object.

Resistance for the strength training component of the study was provided using Theraband™ (The Hygenic Corporation, 1245 Home Ave. Akron, OH 44310) elastic therapy tubing. This elastic tubing is commonly used for strength training and was most appropriate for this study due to its low cost, wide variability of use for multidirectional exercise, ease of use, and portability. Theraband™ resistance is graded by color, with lighter colors having low resistive qualities and darker colors providing higher levels of elastic resistance. Since the shoulder complex of healthy individuals is comprised of relatively strong musculature, the two highest resistance grades of Theraband™ tubing, blue and black, were used in this study. Following the manufacturer's specifications, resistance was progressively increased during the strengthening protocols by shortening the length of the tubing or by adding a second piece of tubing.

All subjects were required to attend an informational meeting one week before throwing velocity testing began to provide the subjects with documentation on the general overview of the study and any potential risks to the participants, as well as to obtain participant informed consent to participate (Appendix B). This meeting also provided an opportunity for the researchers to answer any questions that the participants might have regarding the study. All subjects agreed to refrain from regular participation in any organized throwing sports, throwing practice, or upper extremity strength training that was not given to them as part of this study.

All subjects were then tested for an individual baseline average velocity of three maximal overhand throws of an official weight baseball using a hand-held Doppler radar gun. The testing was conducted outdoors on a level grass surface, with the thrower and catcher aligned perpendicular to the wind to minimize the effect of wind acceleration / deceleration on the linear velocity of the thrown ball. The subjects participated in a 15 minute warm-up period for stretching and submaximal velocity throwing in order to prevent injury to the shoulder complex from throwing "cold." Following warm-up, the subject threw a series of three maximal effort throws with their dominant arm at a stationary target 20 feet from the thrower. The throwers were given no instruction on throwing mechanics or velocity increasing techniques, and were only instructed to throw the ball as they normally would. However, subjects were not permitted to use sidearm or underarm throwing techniques toward their maximal velocity scores. Each participant's three maximal scores were averaged, and this score was recorded as their base throwing velocity.

Following the baseline throwing velocity measurements, all subjects were electronically randomized into one of three exercise protocol groups. Each group was assigned a different exercise protocol, which was to be performed three times per week for eight weeks. The first group, the control group, consisting of 17 individuals, was given no exercise protocol, and was instructed not to engage in any upper extremity strength training or throwing practice during the course of the 8 week study. The control group would be compared to both exercise protocol groups at the end of the study to determine what effect resistive exercise versus no exercise has on overhand throwing velocity.

All subjects assigned to the two exercise groups were given written and verbal instruction on how to use and set up Theraband™ elastic tubing and the procedure for how and when to increase resistance in order to progressively strengthen the shoulder musculature. The method selected to progress the exercise protocol intensity was the Borg Rate of Perceived Exertion Scale (Appendix C). The scale was explained to the subjects, and they were instructed to increase the amount of resistance via adding a second strand of therapy tubing or changing to a higher resistance tubing type when they felt that they were no longer exerting beyond a level of 16 on the Borg scale, which is the established level of effort at which the greatest increase in muscle strength has been shown by research to occur.[13,14] As with the control group, exercise group subjects were asked to refrain from regular participation in any organized throwing sports, throwing practice, or upper extremity strength training that was not given to them as part of this study.

The first experimental group X1, consisted of 13 participants, and was given a set of upper extremity resistance exercises performed in straight anatomical frontal, sagittal, and transverse planar patterns (Appendix D). The exercises included shoulder flexion and extension, elbow flexion and extension, shoulder abduction and adduction, and shoulder internal and external rotation. These exercises were to be performed for 15 repetitions apiece, 3 times per week for the duration of eight weeks. Resistance was provided by graded elastic therapy tubing, with the resistance force being applied in the plane of movement in which each exercise was performed. The subjects were given written and verbal instruction on how to perform the exercises properly and were given two different grades of elastic tubing, black and blue, to use during the course of the study. Additional tubing was available to the subjects by request if they required it.

The second experimental group, X2, consisted of 13 subjects and was given an exercise program consisting of a D2 PNF flexion and extension pattern of the shoulder (Appendix E). This pattern combines shoulder motions involving all three primary anatomical planes. D2 extension consists of shoulder flexion, abduction, and external rotation. Conversely, D2 flexion is achieved by placing the shoulder into extension, adduction, and internal rotation. The transition between D2 extension to D2 flexion closely resembles the mechanics of overhand throwing, with the shoulder moving from a flexed position into extension, while at the same time moving from external to internal rotation. Subjects in this group were instructed to perform D2 extension to flexion diagonal patterns, as well as the reverse D2 flexion to extension pattern in order to strengthen the shoulder symmetrically. Resistance was applied via the elastic tubing in the plane of movement, with attachment point of resistance to D2 flexion being posterior, superior, and ipsilateral to the upper extremity being strengthened and resistance to D2 extension being anterior, inferior, and contralateral respectively. In order to eliminate the effect of elbow strengthening on throwing velocity as a differential factor between the exercise groups, the X2 PNF diagonal group was also given resisted sagittal plane elbow flexion and extension as part of their strengthening protocol. As with the X1 group, X2 subjects were given written and verbal instruction on how to perform and set up the exercises, and were told to perform 15 repetitions of each exercise three times per week for eight weeks.

After the eight week exercise phase was completed, all subjects were retested for their end throwing maximal throwing velocity in the same manner as the testing to establish their baseline maximal throwing velocity at the beginning of the study. The end throwing velocity measurements were conducted with the same radar gun, in the same location, and on a day with similar weather conditions to minimize any atmospheric variables affecting the outcome of the throwing measurements. After all of the subjects had been tested for end velocity scores, the data were compiled and statistically analyzed for results.

The initial and final throwing velocities for each individual were analyzed and reduced to a numerical velocity change value for each subject. This velocity change was used as the dependent variable for statistical analysis, with the nominal dependent variable being the exercise protocol groupings. These data sets, for the experimental and control groups, were used to determine whether the average change in a subject's throwing velocity associated with a given exercise protocol were statistically significant. A one-way analysis of variance (ANOVA) was performed to determine this significance. Based on the statistical results of the one-way ANOVA, *post hoc* analysis for pair-wise differences was computed using the Scheffé procedure. In order to gain statistical power, the alpha level for significance was set at .05 for all hypotheses. Descriptive and inferential statistics were computed using SPSS for Windows, version 11.5 (SPSS Inc. Headquarters, Chicago, Illinois 60606).

CHAPTER 3

RESULTS

One subject was excluded from the study due to a shoulder injury incurred shortly after the initial testing velocity testing, rendering the subject unable to complete the exercise protocol or participate in final velocity testing. With this one exception, follow up data was obtained from all 42 initial participants, measuring the maximal throwing speeds at baseline and after eight weeks of straight plane strengthening, PNF D2 pattern strengthening, or control. There were 13 subjects (mean age 24.6 years) in the straight plane exercise group, 12 subjects (mean age 24.2 years) in the PNF D2 pattern exercise group, and 17 subjects (mean age 24.1) in the control group. A one-way ANOVA, $F(2, 37) = 10.417$, $p<.001$ showed a power of .982 (see Table 1).

Table 1. Results of One-Way Analysis of Variance for Maximal Throwing Velocity Between Experimental Groups

	df	SS	MS	F	P	Power
Experimental group	2	60.713	30.357	10.417	<.001	0.982
Error	39	113.651	2.914			
Total	42	175.043				

The PNF D2 (X2) exercise group demonstrated the largest average gain of 1.36 miles per hour in maximal throwing velocity between initial velocity testing and final velocity testing. Subjects in the straight plane exercise group (X1) increased by an average of .87 miles per hour in maximal throwing velocity, while the control group revealed an average decrease of 1.31 miles per hour in maximal throwing velocity (see Table 2).

Table 2. Baseline and Endpoint Maximal Throwing Velocity Results (in miles per hour)

	Baseline	Post test	Difference
Straight Plane Exercise group (X1)	47.56	48.43	0.87
PNF D2 Exercise group (X2)	47.25	48.61	1.36
Control Group	42.86	42.55	-0.31

The *post hoc* testing conducted using the Scheffé test, revealed significance for the pair-wise comparisons between the control group and the PNF D2 exercise group (X2), as well as significance between the straight plane exercise group (X1) and the control group. However, no significant pair-wise difference was found between the two exercise protocol groups (see Table 3).

Table 3. Post Hoc Scheffe's Test

(I) Group number	(J) Group number	Mean Difference (I-J)	Std. Error	Sig.
Control group	Straight plane exercise	-2.1852*	0.62895	0.005
	PNF D2 exercise	-2.6729*	0.64363	0.001
Straight plane exercise	Control group	2.1852*	0.62895	0.005
	PNF D2 exercise	-0.4877	0.68338	0.776
PNF D2 exercise	Control group	2.6729*	0.64363	0.001
	Straight plane exercise	0.4877	0.68338	0.776

*The mean difference is significant at the .05 level

Chapter 4

DISCUSSION

This study demonstrated that strength training can increase maximal throwing velocity in an 8-week period of time. While the difference in velocity gains between the two exercise groups were not significant, the fact that the PNF D2 program takes much less time to complete and is at least as effective at increasing throwing velocity as the straight plane group illustrates that the PNF D2 program is more efficient at accomplishing the task.

The implications involved in our study are widespread. First, we showed that upper extremity strengthening does improve maximal throwing velocity, even in as little as 8 weeks. This information can help overhand throwing athletes who are trying to improve their throwing velocity, as well as physical therapists and athletic trainers who are working with athletes that have suffered a shoulder injury and are trying to return to their sport or increase their throwing velocity.

We also demonstrated that a PNF D2 flexion and extension pattern can provide the same amount or even more improvement in maximal throwing velocity than a program of straight plane exercises consisting of internal and external rotation, flexion and extension, and abduction and adduction of the shoulder. In this study, the PNF exercise program took roughly half the time each session to complete as the straight plane exercise program. There were 4 total exercises in the PNF workout, while there were 8 exercises in the straight plane workout, with flexion and extension of the elbow being the same for both groups. Each exercise should take about the same amount of time to complete, and changing the position and securing the band between exercises also takes some time. The amount of time saved by the PNF exercise program can be used to do a number of things. Obviously time is a precious commodity, and when one exercise program can save a significant amount of time over another without compromising results, the program that is of a shorter duration will allow the person more time to do other activities. An overhand throwing athlete can use the time saved to work more on sport specific skills or lower extremity strengthening. Due to the competitive nature of athletics, that amount of time may have a big impact on a single or even multiple contests.

Another interesting aspect of this study was the demonstration of the amount of decline that the control group experienced. They were asked not to engage in any organized throwing sports, throwing practice, or upper extremity strength training. After only 8 weeks of refraining from these activities, the control group demonstrated a loss of 0.31 mph on their maximal throwing velocity. This also contains implications for the athletic and rehabilitation populations as well as the general population regarding atrophy and disuse in as little as 8 weeks. Alkner and Tesch[19] found significant muscle atrophy in the quadriceps and triceps surae after only 29 days of bed rest. While our subjects in the control group were not "immobilized," they were asked not to participate in any strengthening activities. So, even in a situation where an extremity is not completely immobilized, the effects of muscle atrophy can be rapid.

The limitations of our study were that we did not factor previous throwing experience into the results. The participants possessed a wide range of ability and experience levels, and we did not do a great deal of instruction in technique for them. Van den Tiller and Ettema[3] found that technique training in short duration was not effective, so we decided not to analyze this. If this study design were replicated on a population of elite overhand throwers, however, the technique they already possess might lead to even more significant results. The study by Derenne et al[2] observed that proper throwing technique is vital to increasing throwing velocity, and by taking throwers who already possessed the proper technique, and may see a decrease in variability, leading to valuable results. A study could also compare elite or at least experienced throwers with those who had not had any throwing experience to see how much difference that experience makes in increasing throwing velocity.

Another limitation of the study was that there were no measures in place to effectively monitor adherence to the exercise programs. A workout log or supervised exercise would be effective ways to oversee this. Supervision or a follow up about the exercise techniques would also allow the researchers to be more certain that the exercises were being done correctly.

The testing took place outdoors on several different days, and slight differences in the wind and weather could possibly have had an effect on the results. In future studies that desire to control more external variables, the testing could all be done inside on one day for the initial testing and one day for the follow up testing. This does become difficult with volunteer subjects, though, especially with a large group of participants.

The analysis did not take into account any exercise progression that the participants did to maintain their rate of perceived exertion of 16. Future studies may want to address this and compare results of those who had to increase resistance to maintain their RPE versus those who didn't change their resistance. Another limiting aspect of this study is it lasted only 8 weeks. Longer studies could perhaps establish even more reliable results.

This study included a small window of ages and utilized a "healthy" population. To validate the implications across a wider spectrum, individuals who are injured or undergoing rehab could be used as subjects as well as expanding the age range of the participants.

CHAPTER 5

CONCLUSION

The results of our study demonstrate that strength training can significantly increase maximal throwing velocity in as little as 8 weeks. Though the differences between exercise programs were not significant, the PNF D2 exercise program took half the time to complete and did increase throwing velocity more than the straight plane exercise program. The similar results combined with the efficiency of the PNF program could have widespread implications on the fields of athletic and rehabilitative therapy. Further testing will need to be done to monitor carryover into other populations including older and younger age groups, as well as elite or injured throwers.

APPENDICES

APPENDIX A

ID#: __________

Date: __________

Throwing Velocity Scholarly Project Questionnaire

Age: _________ Gender: M or F

1. Do you presently suffer from any conditions (i.e. surgeries, injuries, past medical conditions, psychological conditions, etc.) that would affect your throwing ability? Please Describe.

2. Are you presently on a workout program (i.e. weight lifting, cardio, etc.)? Please describe.

3. Do you have any resistant training experience (i.e. weight training, Thera-Band resistance training, etc.)?

4. Do you have any experience with throwing a baseball, softball, or other similar objects?

5. Are you presently throwing a baseball, softball, or other similar objects on a consistent basis?

6. Is there any other information that you would like to share that may limit your ability to participate in this research project? Please describe.

APPENDIX B

Consent to Participate in Research

A Study on the Effects of Various Shoulder Exercise Protocols on Maximal Throwing Velocity

You are invited to voluntarily participate in a scholarly research project conducted by students of the UND Physical Therapy Program (Kevin O'Brien, Peter Tran, and Jason Allred) under the direction of physical therapy professor Dr. Mark Romanick. This study is to determine the effectiveness of straight plane exercise at the shoulder compared to diagonal plane or no exercise has on a person's throwing speed of a baseball. The findings of this study will help to determine the most effective method for functionally strengthening the shoulder muscles in order to increase throwing speeds as it applies to athletic training or a therapy program designed to strengthen the shoulder after an injury. The results of this study will be available to all participants upon request.

As a participant in this study you will be asked to complete a short survey about your throwing experience, general health questions, as well as any injuries you may have that may affect your performance or make participation in this project unsafe for you. This survey will take approximately 5 minutes to complete. All volunteers must meet the following inclusion criteria: a UND student ages within the ages of 18-30, the ability to demonstrate safe, competent body mechanics (technique) of overhand throwing, no previous shoulder injuries that required surgery or specialist care.

Part I: Participants will be required to attend a short (10-15 minute) educational session reviewing this study and discussing safety, proper technique, and how to complete their randomly assigned exercise program. Any questions can be answered by the researchers at this time or any time during the study. Participants will be provided with a copy of this consent form as well as a packet that has a written and diagram instructions of the exercises they are to complete, as well as how to progress this exercise program throughout the 8 weeks of the study.

Part II. Participant's maximum throwing speed will be assessed using the average of 3 throws at the participant's greatest effort. Speeds will be measured using a radar gun. Participants will be required to warm up for 20 minutes prior to the speed testing by lightly throwing a baseball to prevent any injuries to their shoulder.

Part III. Participants will follow an assigned 8 week exercise program for the shoulder. This program uses Theraband resistive tubing to provide resistance to movement. Theraband will be provided to you at the educational session, or any time as needed during the study. You will be randomly assigned to an exercise program that is either straight plane (keeping the shoulder moving in horizontal and vertical movements), diagonal plane (combined movements of the shoulder, simulates throwing), or no exercise. You will be shown how to perform these exercises, as well as instructed on when to increase the resistance to increase strength gains. Some exercises of the elbow will also be given to the two exercise groups to prevent either group from targeting those muscles more than the other. This exercise program will be individual and unsupervised; however the researchers are available for contact at any time for continued instruction, to address concerns, or to report an injury or problem.

Part IV. After 8 weeks of exercise your maximal throwing speeds will again be measured in the same manner as described in Part II. This data will then be compared to the initial measurements, and the results of the study will be calculated.

Although there is a risk of injury involved in any experimental study, the exercises and throwing pose minimal risk to you if performed properly and you do some warm up throwing before trying to throw your hardest. As a participant you stand to gain shoulder strength and possibly throwing speed from participation in this study, as well as a greater understanding of exercise, warm-ups, and sports training. There is no cost to you to participate in this study.

The results of this study will remain confidential and your data will be identified by a number only know to the investigators. These results will be kept in a locked confidential file in the UND Physical Therapy department for three years following the completion of this study. After that period of time, all records will be shredded and completely destroyed. Only the researchers, advisers, and IRB procedure auditors will have access to this data.

As a voluntary participant you are free to withdraw from this study at any time for any reason. If during any portion of this study you experience pain, discomfort, fatigue or any other symptoms affecting your health, please contact one of the researchers immediately. In the unlikely event that participation in this study results in physical injury or medical treatment including first aid, emergency treatment, or any follow-up care, the investigators and advisors, along with the University of North Dakota are not responsible for any such injury or treatment. However these resources will be available as they are to the general public. The payment for such treatment will be provided by you and your insurance if applicable.

Please contact any of the investigators with any questions, concerns, or instruction you may require concerning this study. Please contact Kevin at (701)777-9609 or email kevin_obrien@und.nodak.edu with any questions or if you wish to be directed to another one of the researchers. Dr. Mark Romanick is available for contact at (701)777-2831. Again, thank you for your participation.

I have read all of the above and fully understand what has been presented to me. I willingly agree to participate in this study as it has been explained to me by the researchers.

Participant Signature Date

Witness Signature Date

University of North Dakota
Institutional Review Board
Approved on JUN 8 2004
Expires on JUN 7 2005

APPENDIX C

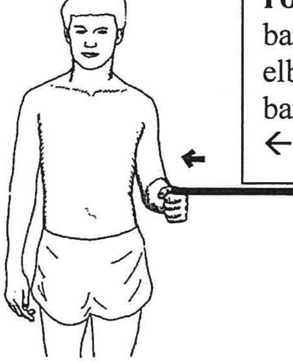
Information for participants on using the Borg Rate of Perceived Exertion Scale

- The Borg RPE scale is used to numerically represent how much effort you feel it takes to accomplish a task. This effort should be based on fatigue, muscle sensation: "I can't push any more", or "I probably could push a little more", and an overall appraisal of how hard you feel it is to accomplish the exercise.
- Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how you feel it may compare to other people's. Look at the scale below and give your effort a number.

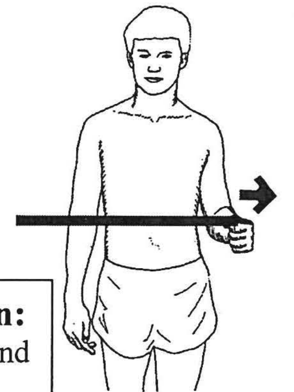
6	No exertion at all (same as sitting in a chair)
7	Extremely light (such as just moving a limb by itself)
8	
9	Very light (easy walking slowly at a comfortable pace)
10	
11	Light
12	
13	Somewhat hard (It is quite an effort; you feel tired but can continue)
14	
15	Hard (it becomes difficult to accomplish the task)
16	
17	Very hard (very strenuous and fatiguing, can do 10-15 before resting)
18	
19	Extremely hard (You can not continue for long, can do 2-3 repetitions
20	Maximal exertion (Cannot complete, or can only do one repetition)

- For this study we want you to always try to score as close to 16 as possible, if you feel that the exercise is too easy, increase the resistance by a gripping the elastic tubing closer to the tied off (fixed) end, or by adding a second piece of tubing to double the resistance)
- Please follow your assigned exercised protocol exactly

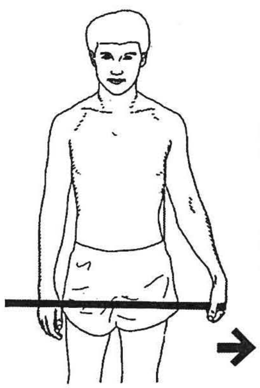
APPENDIX D



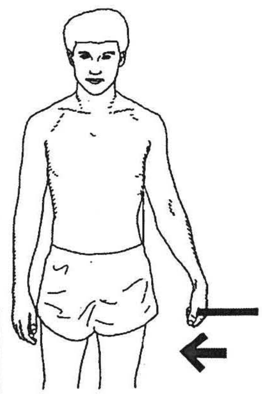
Internal rotation: With band secured and elbow at side, pull band across body. ←



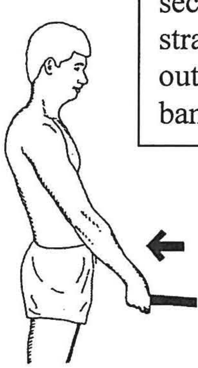
External rotation: With band secured and elbow at side, pull band across body. →



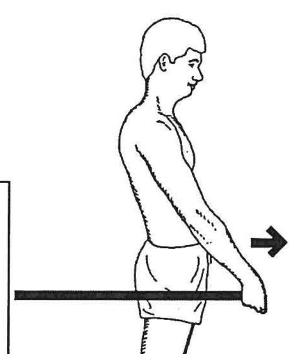
Abduction: With band secured and elbow kept straight, pull band across body by moving arm up and away from the body. ←



Adduction: With band secured and elbow kept straight, start by holding band out away from body and pull band across body. →



Extension: With band secured and elbow kept straight, start by holding band out in front of body and pull band behind body. ←



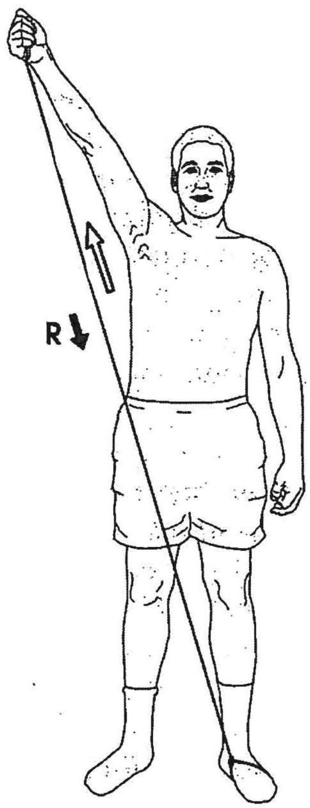
Flexion: With band secured and elbow kept straight, start by holding band behind body and pull band in front of body. →

Biceps: Secure the band below you. (under your feet) With your elbows held at your side, hold the band and bring your hand toward your shoulder.

Triceps: Secure the band above and behind you. Holding the band with your elbows close to your side and your hands starting close to your shoulder, straighten your elbow, pulling your hand away from your shoulder.

*****With all exercises, do 3 sets of 10-12 repetitions, trying to maintain the RPE of 16. To increase effort, shorten the band, to decrease resistance, lengthen it.*****

APPENDIX E



D2 Flexion: Wrap band around opposite foot or in a door jam. Take up some slack and begin by holding the band like you are drawing a sword. Pull up and across your body to end up looking like this.

D2 Extension: Secure the band in a door jam above and behind your head. Begin by holding the band in the position to the left. Pull down and across your body, ending looking like you are ready to draw a sword from your belt.

Biceps: Secure the band below you (under your feet). With your elbows held at your side, hold the band and bring your hand toward your shoulder.

Triceps: Secure the band above and behind you. Holding the band with your elbows close to your side and your hands starting close to your shoulder, straighten your elbow, pulling your hand away from your shoulder.

With all exercises, do 3 sets of 10-12 repetitions, trying to maintain the RPE of 16. To increase effort, shorten the band, to decrease resistance, lengthen it.

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