EFFECTS OF PLYOMETRIC AND ISOKINETIC EXERCISE PROGRAMS ON VERTICAL LEAPING ABILITY

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ON VERTICAL LEAPING ABILITY

Abstract approved: Edward C. Rowe

Plyometric exercises, which contract a muscle while it is stretching, and isokinetic exercises, which provide resistance equal to the muscles tension, are significantly superior to control groups. This research was designed to compare the effects of plyometric and isokinetic exercise regimes on the vertical leaping ability of humans.

No significant difference was found between control groups and plyometric groups tested at grade levels one and two. There was a positive significant difference in favor of the plyometric program when compared to controls from the third grade level through the collegiate. There was a positive significant difference in favor of the isokinetic program when compared to control groups in the high school through collegiate levels.

There were no significant differences among the isokinetic treatment groups. There was a significant difference in favor of specific plyometric groups which had well controlled regimes when compared to less organized regimes of isokinetic treatment at the high school level. There were significant differences among the plyometric groups in favor of those that were given well controlled regimes at the high school and collegiate levels.

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Approved by Major Department

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

For the major part of this century, exercise physiologists have studied different training regimes for developing athletes' strength and power. An analysis of the literature on strength training indicates that training methods are evolving by integrating the two most general principles of development of motor capabilities in humans, progressive muscle tension (de Vries, 1980) and structural and functional correspondence of the strength exercises to the athletes' primary competitive movements (Ivanov et al., 1977).

These two principles have inherent weaknesses. To be efficient, the progressive muscle tension principle necessitates the lifting of maximum or near maximum weights to properly stimulate hypertrophy of the neuro-muscular system and multiple repetitions for securing new systems of temporary peripheral neural connections (Ivanov et al., 1977). Since the athlete is not capable of lifting maximum or near maximum weight levels for a large number of repetitions, he trains with medium weights in a large number of repetitions, which diminishes the desired training effect.

According to the principle of structural and functional correspondence of the strength exercises to competitive movements, training is the most efficient when the exercises are identical to the desired movements in competition. To accomplish this efficiently, the athlete must constantly train at his maximum capability. This situation initiates stagnation of intrinsic motivation because of overtraining.

An active search for means of solving the complex problems of these two general strength and power principles has resulted in two relatively new forms of exercises that combine the best qualities of both principles but differ in mode of action. The new exercise regimes are named isokinetics and plyometrics.

The term isokinetics refers to muscle contractions made at a constant velocity against an accommodating resistance which utilizes servo-mechanism controls (de Vries, 1980). Initial attempts to measure muscle velocity were originated in the early 1920's by A. V. Hill. He measured muscle force with an inertia wheel. This was a true measurement of the muscle's ability to produce force in movements identical to those used in related sports activities.

Isokinetic strength measurement probably received its impetus through the research of Asmussen and associates who designed a device using strain gauges by which the force of muscle contraction could be measured and recorded during the movement. The instrument could also limit the angular velocity of the appendages so that the velocity was constant (Asmussen et al., 1965).

Little additional research of isokinetics occurred through the 1960's due to the high cost of efficient testing equipment. The main testing apparatus during this time period was the $4,000 CYBEX.

In 1971, James Counsilman, swimming coach at Indiana University, became interested in testing isokinetic concepts but could not fund the expensive CYBEX equipment. A graduate student informed Counsilman of an exercise machine being marketed for $100 that was as effective as the $4,000 CYBEX. This new machine used a mechanical velocity-limiting mechanism that was far less expensive than the elaborate electrical construction of the CYBEX.

After two years of testing, Counsilman (1971) published the successful results of his isokinetic exercise program. The great success of his collegiate swimming teams and the world attention which focused on Mark Spitz, who set many world and Olympic records, helped create more interest in isokinetic research.

The apparatus used by Counsilman was improved by Fisher in 1967 (Lapham, 1976). A refined model of the original, the Mini-Gym Isokinetic Leaper, model 16XB, was used in this research program.

The regime for the model 16XB is specific to those muscle groups used in vertical jumping. It provides maximum accommodating resistance while maintaining constant angular velocity.

Plyometric is a word apparently derived from the Greek plethyein (Wilt, 1975), which means to increase and metric which means to measure. These word roots do not satisfactorily describe plyometric exercises.

The plyometric exercise causes a muscle that is being stretched to contract quickly. The muscle continues to lengthen while it is being contracted because the external load is greater than the internal tension. This type of exercise may be called negative work (de Vries, 1980) and it causes hypertrophy and associated strength gains when implemented properly. Plyometrics are designed to combine increases in strength and stimulation of specific muscle groups used in leaping.

The first research article on plyometrics in the United States was published by Fred Wilt in 1975. Research studies on modified forms of plyometrics have been done by Herman (1976), Parcells (1976) and Scoles (1978).

A previous comparison of the effects of plyometric and isokinetic training programs was researched by Blattner and Noble (1979), although their study utilized "depth bounds" which are a part of the full plyometric program limited to this research. Depth bounds are executed by jumping from different heights and immediately leaping into the air after contact with the floor. The body momentum obtained in the jump causes a quick stretching of the leg muscles prior to a contraction.

The ability to jump well is important in numerous athletic events. This research will compare the results of the isokinetic exercise regime to the plyometric exercise regime and their effects on vertical leaping ability. The complete plyometric regime has three basic exercises. These are the "power bounds", "speed bounds" and "depth bounds" (refer to Figure I for details). Presently, there is no published research comparing the effects of plyometric regimes to isokinetic regimes on the model 16XB. This study will relate the full plyometric program to the isokinetic program on the model 16XB and will extrapolate from other published research programs to determine the effects of each program on the vertical leaping ability of humans.

METHODS AND MATERIALS

Research data were collected between September, 1977, and December, 1980. To facilitate comparisons, some published and unpublished data from sources other than those controlled by this research program are included in this study. The data from these additional sources were collected from September, 1979, through December, 1980.

Figure 1 describes the plyometric and isokinetic exercise regimes. Questions from participants about specific aspects of the regimes were answered by oral or written communication.

Table I gives the composition of test groups by grade level, gender and exercise regime. A total of 416 subjects, 320 males and 96 females, were tested.

The plyometric program tested 218 subjects, of which 156 were males and 62 were females. The test subjects included 108 male and 35 female elementary students, 25 male high school students, and 21 male and 27 female college students.

The isokinetic program tested 51 subjects, 47 males and 4 females. The test subjects include 25 male high school students, 22 male and 4 female college students.

The control groups included 147 subjects, 117 males and 30 females. Elementary school subjects included 102 males and 15 females. College students included 15 males and 15 females.

Data collected by other investigators but used for comparison of programs included 94 individuals. Fifteen male and 16 female college students were in the plyometric program; 25 male high school students and 11 male

Figure 1. Standardized Information Sheet on Isokinetic and Plyometric regimes sent to each supervisor.

ISOKINETIC AND PLYOMETRIC PRACTICE REGIME

A. Use the pre-test procedure for measuring the height of five vertical leaps.

B. Basic exercise programs
   1. Isokinetic
      a. Assume the half-squat position on the mini-leaper.
      b. Perform thirty consecutive jumps at maximum repetition speed.

   2. Plyometric
      a. Power-bounds
         1. Set position
            a. Feet in the set position are shoulder width apart.
            b. The heels are on the floor.
            c. The thighs are parallel to the floor.
            d. The arms are straight with the hands located posterior to the gluteals.
         2. Leap
            a. After five seconds in the set position, leap forward striving for maximum height and distance.
            b. Upon landing immediately assume the set position and after five seconds repeat the procedure.
            c. Advance the length of the basketball court from baseline to baseline.
      b. Speed-bounds
         1. Set position
            a. Feet are together and remain together throughout the bound.
            b. The fingers are enmeshed.
            c. The palms are put directly on top on the head. (not back of head)
         2. Bounding
            a. From the set position the bound is accomplished by flexion to the quarter-squat position and jumping forward to the next set position.
            b. The speed bounds are repetitive and continuous with speed being emphasized.
            c. Advance one full lap around the basketball court along the baseline.

TABLE I. Composition of test groups by grade level, gender and exercise regime.

Gender	Grade Level	Plyometrics	Isokinetics	Control	Total
Male	Elementary	108	0	102	210
Female	Elementary	35	0	15	50
Male	High School	27	25	0	52
Female	High School	0	0	0	0
Male	College	21	22	15	58
Female	College	27	4	15	46
TOTAL		218	51	147	416

Data on male and female elementary students was collected by Ron Ewy, Syracuse Elementary School, Syracuse, Kansas. Male high school students in the plyometric regime were tested by Pando Markuly, Greensburg High School, Greensburg, Kansas. Male high school students in the isokinetic regime were tested by Ron Stevens, Shawnee Mission Northeast High School, Shawnee Mission, Kansas. Twenty one college males in the plyometric regime included three tested by Markuly, seven tested by Mark Frase, in his Emporia State University weight training class, and 11 tested by Blattner at Kansas State University. Twenty two male college students tested with isokinetics included 10 tested by Frase and 12 tested by Blattner. The control group of male college students included 15 tested by Blattner. Female college students in the plyometric regime included 8 tested by Markuly, 3 by Frase and 6 tested by Russ Polhemus, Texas Technological University, Lubbock, Texas. Four female college students were tested with isokinetics by Frase. The 15 control female college students were tested at Texas Technological University by Polhemus.

college students were in the isokinetic program. Twelve male and 15 female college students were in the control group.

The control groups of the elementary physical education classes received standard physical fitness and life sports activities which were identical for the treatment groups. There were no control groups for the high school students. College level control groups composed of females who received a weight training program that was identical to the treatment groups. The college level male control group received a weight training and general conditioning program that was identical to the treatment groups.

Table II is a delineation of the test groups by age, number of subjects, gender, treatment and the duration of the regime. Fifteen test groups were compared in this study. Published research from three other studies were tabulated and compared. These studies were by Polhemus, 1979, Stevens, 1980, and Blattner and Noble, 1979, and are included in the tables. The fifteen test groups were divided into 29 subgroups based upon differences in gender and treatment.

Test groups one, two and three were tested at Emporia State University. Test groups four through nine were tested at Syracuse Elementary School, Syracuse, Kansas. Test groups 10 through 12 were tested at Greensburg High School, Greensburg, Kansas. Group 13 was tested at Texas Technological University, Lubbock, Texas. Group 14 was tested at Shawnee Mission High School, Shawnee Mission, Kansas. Group 15 was tested at Kansas State University, Manhattan, Kansas.

Measuring techniques were standardized to reduce variables in test groups one through 12. Test groups 13 through 15 varied in treatment but used the same technique for the measurement of vertical leap as was used in this study. Figure 2 was the standard information sheet sent to each

TABLE II. Summary of Test Groups by age, number of participants, gender, exercise regime, identification abbreviations, regime duration and year of testing.

Group Number Subgroup	Age Group	Number	Gender	Exercise Regime	Identification Abbreviation*	Regime Duration in Weeks	Test Year	Investigator
1a	College	3	Male	Plyometric	1CMP	6	1980	Markuly
b	College	8	Female	Plyometric	1CFP	6	1980	Markuly
2a	College	7	Male	Plyometric	2CMP	6	1979	Frase
b	College	3	Female	Plyometric	2CFP	6	1979	Frase
3a	College	10	Male	Isokinetic	3CMI	6	1979	Frase
b	College	4	Female	Isokinetic	3CFI	6	1979	Frase
4a	Elementary	14	Male	Plyometric	4EMP	18	1979	Ewy
b	Elementary	20	Female	Plyometric	4EFP	18	1979	Ewy
c	Elementary	15	Male	Control	4EMC	18	1980	Ewy
d	Elementary	15	Female	Control	4EFC	18	1980	Ewy
5a	Elementary	21	Male	Plyometric	5EMP	18	1979	Ewy
b	Elementary	17	Male	Control	5EMC	18	1980	Ewy
6a	Elementary	22	Male	Plyometric	6EMP	18	1979	Ewy
b	Elementary	16	Male	Control	6EMC	18	1980	Ewy
7a	Elementary	18	Male	Plyometric	7EMP	18	1979	Ewy
b	Elementary	16	Male	Control	7EMC	18	1980	Ewy
8a	Elementary	17	Male	Plyometric	8EMP	18	1979	Ewy
b	Elementary	20	Male	Control	8EMC	18	1980	Ewy
9a	Elementary	16	Male	Plyometric	9EMP	18	1979	Ewy
b	Elementary	18	Male	Control	9EMC	18	1980	Ewy
10a	High School	11	Male	Plyometric	10BBMP	8	1977	Markuly
11a	High School	8	Male	Plyometric	11BBMP	8	1978	Markuly
12a	High School	8	Male	Plyometric	12PEMP	8	1978	Markuly
13a	College	16	Female	Plyometric	13FP	6	1979	Polhemus
b	College	15	Female	Control	13FC	6	1979	Polhemus
14a	High School	25	Male	Isokinetic	14AMI	6	1980	Stevens
15a	College	11	Male	Plyometric	15AMP	8	1979	Blattner
b	College	15	Male	Control	15BMC	8	1979	Blattner
c	College	12	Male	Isokinetic	15CMI	8	1979	Blattner

TABLE II - continued

* CMP is college male plyometrics

CFP is college female plyometrics

CMI is college male isokinetics

CFI is college female isokinetics

EMP is elementary male plyometrics

EFP is elementary female plyometrics

EMC is elementary male control

EFC is elementary female control

BBMP is basketball male plyometrics

PEMP is physical education male plyometrics

Independent Test Groups 13-15

FP is college female plyometrics

FC is college female control

AMI is high school male isokinetics

AMP is college male plyometrics

BMC is college male control

CMI is college male isokinetic

Figure 2. Standard Information Sheet given to each investigator.

PRE-TEST: MINI-LEAPER (ISOKINETIC) AND PLYOMETRIC RESEARCH

Record all data on the provided sheet.

1. Record the height, weight and age.

2. Record a resting pulse rate for thirty seconds.

3. Run in place for thirty seconds and immediately take an active pulse rate for thirty seconds. Lift the knees up to the waist and run briskly in place.

4. Measure the upper leg at three points. These are the proximal end, distal end above the knee and at a point near the middle between the first two measurements.

5. Measure the lower leg at three points, at the proximal end just below the knee, at the distal end above the malleolus, and at the thickest part of the body of the gastrocnemius.

6. Record the height of five vertical leaps. The technique for these must remain consistent. Choose the best position to allow the greatest height. Using a rocker step, try both feet as pivot points and choose the one that allows maximum height. Once the proper pivot foot is determined, stand perpendicular to the wall with your pivot foot about five inches from the wall. Rock back on the off-leg and using your arms for maximum momentum, make a vertical leap. After you regain composure, repeat until all of the trials have been completed. Record the heights.

7. All measurements of lower leg segments must be made while the body is in the erect position and the muscles are relaxed.

supervisor in this study. It was used to insure standard measuring techniques. Optional measurements of limb segments and cardiovascular functions were included on the data sheet but were not an integral part of this study. No adjustments in jumping technique were made after pretest instruction.

Figure 3 was the pretest data sheet used for each participant. Data placed on this sheet included the participants' name, age, height, weight, resting and active pulse rate, leg measurements of the segments and the results of five pretest vertical leap trials.

Figure 4 was the data sheet used during the isokinetic regime. It provides a brief description of the programs' duration, starting date and appropriate boxes to record leap trial heights.

Figure 5 was the plyometric data sheet. It was provided to each administrator and briefly describes the duration and limits of the plyometric regime. Boxes are provided to record the heights of the vertical leap trials and a place is provided for a starting date.

The Student t test was used to determine statistically significant differences between selected test groups at the 95 percent level of probability. Twenty nine Student t tests were administered under the following conditions: 13 were applied to homologous gendered and heterologously treated groups; 11 were applied to homologous gendered and homologously treated groups; one was applied to heterologous gendered and homologously treated groups; four were applied to heterologous gendered and heterologously treated groups. Inferences were derived from vertical leap mean value increases for the supplemental test groups 13 through 15. Student t tests on these groups were not included because of the lack of vital information.

Figure 3. Pretest Data Sheet given to each participant.

FULL NAME (Last, First)	AGE	HEIGHT	WEIGHT	RESTING PULSE RATE	ACTIVE PULSE RATE

UPPER LEG MEASUREMENTS

LEFT PROXIMAL	RIGHT PROXIMAL	LEFT MIDDLE	RIGHT MIDDLE	LEFT DISTAL	RIGHT DISTAL

LOWER LEG MEASUREMENT

LEFT PROXIMAL	RIGHT PROXIMAL	LEFT MIDDLE	RIGHT MIDDLE	LEFT DISTAL	RIGHT DISTAL

VERTICAL LEAP TRIALS

1	2	3	4	5

Figure 4. Isokinetic Data Sheet (Mini-Leaper).

The isokinetic exercise program involves thirty repetitions on the Mini-Leaper. This is to be executed two days a week with one day of rest between. Record each participants' five vertical leap trials in the proper boxes. The vertical leap trials are to be tested prior to the isokinetic regime.

NAME ______________________________ STARTING DATE ____________________________

	DAY 1 LEAP TRIALS					DAY 3 LEAP TRIALS				
WEEK 1										
WEEK 2										
WEEK 3										
WEEK 4										
WEEK 5										
WEEK 6										
WEEK 7										
WEEK 8										
WEEK 9										
WEEK 10										

Figure 5. Plyometric Data Sheet.

The plyometric exercise program involves power bounds and speed bounds. The power bounds are executed for the length of the basketball court. Speed bounds are to be executed for a full lap around the baseline of the basketball court. This is to be repeated two days a week with one day of rest between. Record each participants' five vertical leap trials in the proper boxes. The vertical leap trials are to be tested prior to the plyometric regime.

NAME ______________________________ STARTING DATE ______________________________

DAY 1 LEAP TRIALS

WEEK 1					
WEEK 2					
WEEK 3					
WEEK 4					
WEEK 5					
WEEK 6					
WEEK 7					
WEEK 8					
WEEK 9					
WEEK 10					

DAY 3 LEAP TRIALS

RESULTS

Table III summarizes the statistical data for the test groups. Listed are the test groups that were compared, treatment applied to each test group, gender, number of participants, the mean increase in vertical leap for each group, degrees of freedom and the values for tabulated t and calculated t at the 95 percent level of probability. The independent test groups 13 through 15 were not statistically compared with the test groups of this research because of differences in treatment and lack of vital data.

Table IV summarizes the statistical comparisons of pairs of test groups from this study and illustrates which groups had significant differences or non-significant differences. The groups marked by an asterisk under the column of test groups which had a significant difference had larger improvements in vertical leap.

Thirty-three tests are listed with 16 showing no significant differences and 17 demonstrating significant differences. Included with these results are four tests from other researchers. These show no significant differences in one test group and a significant difference among the other three test groups.

Significant differences were found among the following test groups: (1) a female plyometric program given to a college exercise physiology class compared to a female plyometric program given to a college weight training class, (2) males and females on a plyometric program from a college exercise physiology class compared to males and females on a plyometric program from a college weight training class, (3) a male plyometric program from a high school physical

TABLE III. Summary of test group statistical data.

Test Group	Treatment[a]	Gender	N[b]	$\overline{X}$[c]	DF[d]	Tabulated t[e]	Calculated t[f]
1a	P	Male	3	3.8333	8	2.31	1.2483
2a	P	Male	7	2.5000			
1b	P	Female	8	1.2500	10	2.23	0.4095
3b	I	Female	4	1.7500			
1b	P	Female	8	1.2500	9	2.2660	2.9036
2b	P	Female	3	7.0000			
2b	P	Female	3	7.0000	5	2.5700	2.2480
3b	I	Female	4	1.7500			
1ab	P	Male/Fe.	11	1.9546	19	2.09	2.1781
2ab	P	Male/Fe.	10	3.8500			
1ab	P	Male/Fe.	11	1.9546	23	2.07	0.4713
3ab	I	Male/Fe.	14	2.2857			
2ab	P	Male/Fe.	10	3.8500	22	2.07	1.6463
3ab	I	Male/Fe.	14	2.2857			
1a	P	Male	3	3.8333	11	2.20	1.0032
3a	I	Male	10	2.5000			
12a	P	Male	8	5.6250	14	2.14	1.7756
11a	P	Male	8	4.3750			
12a	P	Male	8	5.6250	17	2.11	2.1885
10a	P	Male	11	4.2727			
10a	P	Male	11	4.2727	17	2.11	0.4789
11a	P	Male	8	4.3750			
1a	P	Male	3	3.8333	9	2.26	1.3937
11a	P	Male	8	5.6250			
2a	P	Male	7	2.5000	13	2.16	4.2390
12a	P	Male	8	5.6250			
3a	I	Male	10	2.5000	16	2.12	4.1997
12a	P	Male	8	5.6250			
1a	P	Male	3	3.8333	9	2.26	0.5157
11a	P	Male	8	4.3750			

TABLE III - continued

Test Group	Treatment[a]	Gender	N[b]	$\overline{X}$[c]	DF[d]	Tabulated t[e]	Calculated t[f]
2a	P	Male	7	2.5800	15	2.16	3.4448
11a	P	Male	8	4.3750			
3a	I	Male	10	2.5000	18	2.12	3.0218
11a	P	Male	8	4.3750			
1a	P	Male	3	3.8333	12	2.18	0.3306
10a	P	Male	11	4.2727			
2a	P	Male	7	2.5000	16	2.12	8.4641
10a	P	Male	11	4.2727			
3a	I	Male	10	2.5000	19	2.09	3.2461
10a	P	Male	11	4.2727			
4a	P	Male	14	2.0000	27	2.05	1.5468
4c	C	Male	15	1.4000			
4b	P	Female	20	1.6500	33	2.03	0.2647
4d	C	Female	15	1.5333			
11ab	P	Male/Fe.	34	1.7941	62	2.00	0.8237
4cd	C	Male/Fe.	30	1.4667			
5a	P	Male	21	2.4286	36	2.03	1.5238
5b	C	Male	17	1.7647			
6a	P	Male	22	2.3636	36	2.03	2.6770
6b	C	Male	16	1.3750			
7a	P	Male	18	3.1111	32	2.04	2.6500
7b	C	Male	16	1.6875			
7ac	P	Male/Fe.	33	3.0000	47	2.01	2.7012
7b	C	Male	16	1.6875			
8a	P	Male	17	3.2765	35	2.03	7.7780
8b	C	Male	20	1.0500			
9a	P	Male	16	3.5000	32	2.04	11.5141
9b	C	Male	18	1.9444			
Independent Test Groups							
13a	C	Female	15	1.4000	Polhemus, 1979		
13b	P	Female	16	4.0000			
14a	I	Male	25	2.7200	Stevens, 1980		
15a	P	Male	11	2.0460	Blattner, 1979		
15b	C	Male	15	0.2830			
15c	I	Male	12	1.9370			

TABLE III - continued

a - P is plyometrics, C is control and I is isokinetics

b - the number of treatments applied

c - the mean average increase of each groups vertical jump in inches

d - the degrees of freedom used in the Student t test at the 95 percent level of probability calculated by the total number of treatments minus two. The higher the DF the greater the probability for validity

e - for the Student t test this is derived from a standardized table with set values for the DF

f - the result of statistical analysis. If tabulated t is larger than calculated t, there is no significant difference. If calculated t is larger than tabulated t, there is a significant difference

TABLE IV. Summary of test group comparisons: significant and non-significant differences.

Test Groups	No Significant Difference		Significant Difference	
Intracollegiate	1a (1CMP)	2a (2CMP)	* 1b (1CFP)	2b (2CFP)
	1b (1CFP)	3b (2CFI)	* 1ab (1CMP) (1CFP)	2ab (2CMP) (2CFP)
	2b (2CMP)	3b (3CFI)		
	1ab (1CMP) (1CFP)	3ab (3CMI) (3CFI)		
	2ab (2CMP) (2CFP)	3ab (3CMI) (3CFI)		
	1a (1CMP)	3a (3CMI)		
Intra-high school	11a (11BBMP)	12a (12PE)	*12a (12PEMP)	10a (10BBMP)
	11a (11BBMP)	10a (10BB)		
High School vs. College	12a (12PEMP)	1a (1CMP)	*12a (12PEMP)	2a (2CMP)
	11a (11BBMP)	1a (1CMP)	*12a (12PEMP)	3a (3CMI)
	10a (10BBMP)	1a (1CMP)	*11a (11BBMP)	2a (2CMP)
			*11a (11BBMP)	3a (3CMI)
			*10a (10BBMP)	2a (2CMP)
			*10a (10BBMP)	3a (3CMI)
Intra-elementary School	4a (4EMP)	4c (4EMC)	* 6a (6EMP)	6b (6EMC)
	4b (4EFP)	4d (4EFC)	* 7a (7EMP)	7b (7EMC)
	4ab (4EMP) (4EFP)	4cd (4EMC) (4EFC)	* 7ac (7EMP) (7EFP)	7b (7EMC)
	5a (5EMP)	5b (5EMC)	* 8a (8EMP)	8b (8EMC)
			* 9a (9EMP)	9b (9EMC)
College independent test groups	15a (15AMP)	15c (15CMI)	*13b (13FC)	13a (13FP)
			*15a (15AMP)	15b (15BMC)
			*15c (15CMI)	15b (15BMC)

* Significantly greater improvement in vertical leap

Refer to page 11 for explanation of abbreviations.

education class in a weight training program compared to a male plyometric program given to a high school basketball team, (4) a male plyometric program given to a high school advanced physical education class in a weight training program compared to a male plyometric program given to a college weight training class, (5) a male plyometric program given to a high school advanced physical education class in a weight training program compared to a male isokinetic program given to a college weight training class, (6) a male plyometric program given to a high school basketball team compared to a male plyometric program given to a college weight training class, (7) a male plyometric program given to a high school basketball team compared to a male isokinetic program given to a college weight training class, (8) a male plyometric program given to a high school basketball team compared to a male plyometric program given to a college weight training class, (9) a male plyometric program given to a high school basketball team compared to a male isokinetic program given to a college weight training class, (10) a male plyometric program given to third grade physical education students compared to third grade male physical education students serving as controls, (11) a male plyometric program given to fourth grade physical education students compared to fourth grade male physical education students serving as controls, (12) a fourth grade male and female plyometric program given to physical education students compared to fourth grade males serving as controls, (13) a fifth grade male plyometric program in a physical education class compared to fifth grade males in a physical education class serving as controls, (14) a sixth grade male plyometric program given to a physical education class compared to sixth grade males in a physical education class serving as controls, (15) a female plyometric program given to college basketball players in a weight training program compared to female college basketball players in a weight training program serving as controls, (16) a male plyometric program given to a college weight training class compared to males in a college weight training class serving as controls and (17) a male isokinetic program given to a college weight training class compared to a male college weight training class serving as controls.

No significant differences were found among the following test groups: (1) a male plyometric program given to a college exercise physiology class compared to a male plyometric program given to a college weight training class, (2) a female plyometric program given to a college exercise physiology class compared to a female isokinetic program given to a college weight training class, (3) a male plyometric program given to a college weight training class compared to a female isokinetic program given to a college weight training class, (4) a male and female plyometric program given to a college exercise physiology class compared to a male and female isokinetic program given to a college weight training class, (5) a male and female plyometric program given to a college weight training class compared to a male and female isokinetic program when given to a college weight training class, (6) a male plyometric program given to a college exercise physiology class compared to a male isokinetic program given to a college weight training class, (7) a male plyometric program given to a high school basketball team compared to a male plyometric program given to a high school advanced physical education class in a weight training program, (8) a male plyometric program given to a high school basketball team compared to a male plyometric program given to a high school basketball team, (9) a male plyometric program given to a high school advanced physical education class in a weight training program compared to a male plyometric program given to a college exercise physiology class, (10) a male plyometric program given to a high school basketball team compared to a male plyometric program given to a college exercise physiology class, (11) a male plyometric program given to a high school basketball team compared to a male plyometric program given to a college exercise physiology class, (12) a first grade male plyometric program given to a physical education class compared to first grade males in a physical education class serving as controls, (13) a first grade female plyometric program given to a physical education class compared to a first grade female physical education class serving as controls, (14) a first grade male and female plyometric program in a physical education class compared to first grade males and females in a physical education class serving as controls, (15) second grade male plyometric program in a physical education class compared to second grade males in a physical education class serving as controls and (16) a male plyometric program given to a college weight training class compared to a male isokinetic program given to a college weight training class.

DISCUSSION

The purpose of this research was to differentiate the effects of plyometric and isokinetic exercise regimes on human vertical leaping ability. Two major factors that affected the validity of this test were problems with recruitment of large numbers of volunteers and variables in the application of each exercise regime due to multiple administrators.

One hundred forty three elementary students were recruited for the plyometric program and 117 participated as controls. None was enlisted for the isokinetic program because of negative attitudes by parents and administrators concerning the use of the Mini-Leaper model 16XB. The results indicated that there were no significant differences between the control group and those in the plyometric program in grades one and two. For grades three, four, five and six there consistently were significant differences in favor of the plyometric groups over the control groups.

Test groups at the high school level did not have access to an isokinetic exercise machine. There were no significant differences between the 1977 and 1978 basketball teams with both male groups on plyometric programs. There were no significant differences between the 1978 basketball team and the 1978 advanced physical education class. Both groups were composed of males on a plyometric program. In another comparison, there was a significant difference in favor of the 1978 physical education class compared to the 1977 basketball team. This significant difference may have been due to the fact that the 1978 advanced physical education class had used plyometrics the previous year and were on a high intensity weight training program whereas the 1977 basketball team had no previous plyometric training or supervised weight training program.

It may be noted that 25 males from Shawnee Mission Northeast High School, using an isokinetic program, improved their vertical jump by a mean average of 2.72 inches. This is a very moderate increase compared to those on a plyometric program. High school volunteers needed to serve as controls could not be recruited, nor could female high school students for the plyometric or isokinetic program. The omission of these three groups may have affected the overall results at the high school level.

The college data indicate no significant differences between plyometric and isokinetic programs. There was, however, a significant difference between two plyometric programs, one from an exercise physiology class and one from a weight training class. Those from the exercise physiology class received a more structured and controlled application of the exercise regime which probably accounts for the greater improvement of vertical leap.

When the college aged plyometric groups were compared to the high school aged plyometric groups there were no significant differences between the males in the college exercise physiology program compared to the 1977 or 1978 male high school basketball teams or the 1978 male high school advanced physical education class. The males in the college exercise physiology class were interested in the coaching of sports and this may have been a motivational factor equal to that of the high school athletes who wanted to improve their athletic ability.

There were significant differences between the 1977 and 1978 male high school basketball teams and the 1978 male high school physical education class, all of which were using plyometrics, when compared to the students from the male college weight training classes who were using isokinetic and plyometric exercise programs. The favorable advantage of the 1977 and 1978 high school basketball volunteers over the college weight training classes may have been due to improper supervision and low motivation found in the college weight training class.

While this study was in progress, two related studies were published. In a study at Kansas State University (Blattner and Noble, 1979) no significant differences between college males treated with isokinetics and plyometrics were found. The plyometric program that he used consisted of depth bounds, which may be less effective than the full plyometric program used in this research project. There were favorable significant differences between males on isokinetic or plyometric programs compared to males participating as a control group. In another study at Texas Technological University, Polhemus (1979) demonstrated that women on a plyometric program significantly improved their leaping heights compared to women in a control group. The plyometric exercises used in this study were of the depth bound variation but resulted in a mean improvement in vertical leap that compared favorably to the college women on a full plyometric program in this study.

Proposed Theories

Plyometric and isokinetic exercise regimes are of high intensity and short duration. The energy usage during high intensity exercises for a duration of less than two minutes classifies these exercises as anaerobic. Komi et al. (1977) studied anaerobic capacity and found that the main determinant of muscular performance of high intensity exercises was muscle fiber composition. Table V is a general classification of human skeletal muscle types and their individual characteristics.

Muscle fibers mainly expected to be affected by plyometric and isokinetic regimes are the fast twitch, types IIa and IIb. Komi et al. (1977) found a correlation coefficient of 0.37 between vertical leaping ability and the percentage of fast twitch fibers. Table V illustrates that both types of fast

TABLE V. General Classification of Human Skeletal Muscle Fibers (de Vries, 1980)

Nomenclature	Type I	Type IIa	Type IIb
New System	Slow, oxidative (SO)	Fast, oxidative, glycolytic (FOG)	Fast, glycolytic (FG)
Older System	Red Slow twitch (ST)	White Fast twitch (FT)	
Characteristics			
1. Speed of contraction	Slow	Fast	Fastest
2. Strength of contraction	Low	High	Highest
3. Fatiguability	Fatigue resistance	Fatiguable	Most fatiguable
4. Aerobic capacity	High	Medium	Low
5. Anaerobic capacity	Low	Medium	High
6. Size	Small	Largest	Large
7. Capillary density	High	High	Low

twitch fibers contracting at a much faster rate than the slow twitch fibers, produce a high level of tension and fatigue easily. These characteristics are observable and consistent with the effects of the plyometric and isokinetic exercise programs.

Type IIa fast twitch fibers are intermediate in nature between type I and type IIb fibers. Type I fibers tend to be adapted for aerobic performance. Type IIb fibers seem to be adapted for anaerobic performance. Plyometric and isokinetic exercise regimes are expected to stimulate type IIa and IIb fibers through anaerobic means and would result in their hypertrophy and increases in strength (de Vries, 1980). Type IIa fast twitch fibers are larger than either type IIb or type I. Type IIa fibers have a higher capillary density than type IIb, which may make them less fatiguable. Type IIb fast twitch fibers are large in size but are the most fatiguable. This may be explained because the lower capillary density of tye type IIb fiber may not remove the lactates which inhibit fiber contraction whereas the greater capillary supply of the type IIa and type I fibers may remove lactates more efficiently.

Plyometric and isokinetic exercise programs almost certainly involve substrates necessary for anaerobic metabolism. The major energy reserves for both exercise regimes are, (1) catabolism of the phosphagens, adenosine triphosphate (ATP) and creatine phosphate (CP), and, (2) glycolysis of glucose to pyruvate and lactic acid via the Krebs cycle. The phosphagen utilization ordinarily can support maximum effort during high intensity exercises for about four seconds (de Vries, 1980). After this, energy substrate is depleted and the anaerobic breakdown of glycogen for additional energy is necessitated.

Two separate groups of investigators (Hultman et al., 1967; Karlsson et al., 1971) have proposed that CP depletion is probably the limiting factor during high intensity exercises of short duration, as found in plyometric and isokinetic regimes. Yakovlev (1975) determined that this type of anaerobic training results in an increase of creatine phosphate deposition in fast twitch muscle fibers. The additional CP deposition would allow more energy substrate to be available for utilization during plyometric and isokinetic regimes. The creatine phosphate deposition may be the most important adaptation of fast twitch muscle fibers caused by isokinetic and plyometric regimes.

MacDougall et al. (1977) observed that anaerobic exercise regimes of the plyometric and isokinetic types induce an increase of ATP deposition within muscle fibers. This would provide energy storage and facilitate fast twitch fiber performance.

Plyometric and isokinetic anaerobic regimes improve glycolytic capacity of fast twitch muscle fibers. This is a result in the increase in the enzyme phosphofructokinase (PFK), which is the best indicator of glycolytic capacity (Gollnick et al. 1973). The increase in PFK appears to be limited to fast twitch white fibers under anaerobic conditions.

Plyometric and isokinetic exercise regimes require maximum or near maximum contractions of specific muscle groups. The high level of muscle tension developed causes the hypertrophy and resulting increase in strength (de Vries, 1980). Recent evidence (de Vries, 1980) indicates that hypertrophy may be exclusively limited to type IIa fast twitch fibers whereas limited hypertrophy appears in type IIb fast twitch fibers. This specific result is limited to high intensity, high resistance regimes where numbers of repetitions are low because fatigue occurs rapidly at these high levels of resistance.

If the plyometric regime or the isokinetic regime consists of high resistance with low numbers of repetitions, the transition of type IIb fast twitch white fiber to the type IIa fast twitch fiber would be expected to occur. This effect (de Vries, 1980) results in a character transition towards the type I slow twitch muscle fiber because type IIa has characteristics intermediate between type I and type IIb fibers. Both plyometric and isokinetic regimes use high resistance and fast contractions in high numbers of repetitions, which would theoretically avoid the loss of type IIb characteristics.

Both exercise regimes affect the same muscle groups involved in vertical leaping. To produce more power for leaping it is necessary to increase the speed of muscle contraction. The speed of muscle contraction is dictated by the tension within a muscle and related to the resistance. Tension exerted by a muscle is dependent upon the amount of prestretch, within limits (Astrand and Rodahl, 1977). The maximum velocity of a muscle is developed with zero resistance although the tension within decreases as the speed of shortening increases.

The isokinetic regime challenges the involved muscle groups by providing positive accommodating resistance equal to the tension within the muscles. The velocity of movement is held constant. Additionally, in order to develop maximum tension, prestretch of a muscle is at the most efficient level when joint flexion does not exceed 90 degrees (Astrand and Rodahl, 1977). Problems in developing maximum tension appear with the use of the Mini-Leaper model 16XB when the following factors are considered: (1) if the participants' angular velocity is constant, the tester must continuously adjust the servo-mechanism to allow maximum speed of articulation and additionally challenge muscle groups with maximum resistance, (2) muscle prestretch, which is necessary for the development of maximum tension, requires a joint flexion of 90 degrees. When considering the first problem, it is probable that the servo-mechanism resistance is increased, resulting in a reduced velocity of muscle contractions which would theoretically result in the transition of IIb to IIa fibers. When considering the prestretch necessary for maximum muscle tension one should consider that a joint angle other than 90 degrees reduces efficiency. The initial height of the Mini-Leaper is fixed, therefore a narrow range of skeletal heights will allow the 90 degree angle of leg flexion. Modifications may be made to allow for 90 degree joint flexion of people with different skeletal heights. Modifications might be a safety factor if equipment used were not secured properly.

The plyometric regime consists of two types of bounds, power bounds and speed bounds. The power bounds start from a 90 degree joint angle, which results in maximal muscle prestretch necessary to produce a high degree of muscle tension. Muscle tension is high initially but decreases during the leap because of joint angle acuteness. During this articulation, acceleration is increased while tension and resistance decrease. Frequency of repetition is decreased due to the time factor of the participants' realigning to the set position.

The resistance of the plyometric power bound is the force of gravity on the body. A complex formula has been published for computing the exact resistance in relative and absolute values (Barham, 1978). Visual observations would indicate that initial resistance is high, which would help to develop hypertrophy of fast twitch fibers. The increased acceleration of this movement would facilitate type IIb fiber development. The frequency factor, however, could activate the transition of the type IIb fibers toward type IIa fibers, which is not desirable.

The plyometric speed bounds may lack the tension and resistance necessary to induce the anaerobic adaptations of the power bounds. This is theoretically a result of limited prestretch of the muscles caused by acute joint angles. Speed bounds provide for high numbers of repetition at a fast speed of repetition, which evoke increased hypertrophy of type IIb white fibers and possibly a transition of type IIa white fibers toward type IIb.

The plyometric exercise regime has an advantage in its effects compared to the isokinetic regime because the power and speed bounds could negate each others' undesirable effects. The most critical balancing factor between the two exercise regimes may be a function of a neuromuscular phenomenon related to the myotatic reflex.

The stretch reflex, or myotatic reflex, is a monosynaptic arc. The mechanism of this reflex arc may reflect differences in primary modes of action between isokinetic and plyometric regimes relating to tension and the resulting hypertrophy of type IIb fast twitch fibers.

The focus of this proposal concerns two major kinesthetic proprioceptors. These are the (1) muscle spindles and (2) Golgi tendon organs.

Muscle spindles are autogenic governors of motor-nerve activity. Their importance in contributing to the control of motor activity is suggested by the fact that they constitute one third of efferent neurons to skeletal muscles (de Vries, 1980).

Skeletal muscle fibers are composed of extrafusal and intrafusal fibers. Extrafusal muscle fibers are responsible for gross muscle contractions. Contained within the extrafusal muscle fibers are bundles of intrafusal fibers, which are part of the muscle spindle receptor units. The intrafusal muscle fibers when stimulated may shorten but do not contribute to the contractile tension of the extrafusal fibers. The intrafusal fibers are arranged in groups of five to nine within the muscle spindle receptor units (Mountcastle, 1974).

The density of intrafusal muscle fibers varies from muscle to muscle. They lie parallel to the extrafusal muscle fibers. There are two types of intrafusal muscle fibers. The first are nuclear bag fibers, which are the longer, thicker, filled with a maximum of 12 nuclei, and usually found within a spindle. The second type are nuclear chain fibers which are the shorter and thinner of the two fibers. The latter are named because their nuclei are arranged in a chain configuration in the midsection of the spindle. They are found in the spindles in quantities of three to seven. Near the ends of the intrafusal fibers are motor poles which are contractile in nature and are composed of striated myofibrils (de Vries, 1980).

Two types of sensory neurons are located within the spindles. The primary endings are named the annulospiral and the secondary endings are named the flower spray. The annulospiral afferent nerve axon innervates the spindle with a one-to-one ratio. It sends twigs that wrap around the nuclear bag fiber and also sends lesser developed terminals through most of the nuclear chain fibers (Mountcastle, 1974). The smaller flower spray afferent fibers innervate nuclear chain fibers almost exclusively (de Vries, 1980). There are one or two flower spray nerve endings per spindle.

When either the plyometric or isokinetic exercises cause a prestretch on the extrafusal fibers, the intrafusal fibers are also stretched since they lie in parallel. This results in the annulospiral afferent neurons firing a fast conducting nerve impulse. Simultaneously, the flower spray endings fire slow conducting afferent impulses. The afferent discharge from the spindle results in a contraction of the muscle that was stretched. This constitutes the myotatic reflex arc or stretch reflex.

This myotatic reflex arc may increase tension within the muscle and therefore increase the training effects of the isokinetic and plyometric regime. The fast conducting annulospiral afferents respond to phasic stretch which is found in the isokinetic regime and the speed bounds of the plyometric regime. They also respond to the static stretch found exclusively in the set position of the plyometric power bounds.

The flower spray afferents respond almost exclusively to static stretch which is found only in the set position of the power bounds of the plyometric regime. Phasic stretching does not affect the flower spray afferents.

The stimulation of the annulospiral afferents results in a rapid reflex arc, creating a high speed response of extrafusal tension upon contraction. The total plyometric program may have an advantage in tension produced over the isokinetic program because of the combined effects of the annulospiral afferents alone caused by the phasic stretching of the isokinetic program.

The Golgi tendon organ is found in the musculotendinous junctions and in the perimysial connective tissues. It lies in series with skeletal muscle and therefore is activated whether the muscle is being stretched or contracted. While the spindles facilitate muscle contractions, the Golgi tendon organ inhibits contractions to prevent hyperextension. The inhibitions of the Golgi tendon organ may affect the entire muscle functional group (de Vries, 1980). The excitation of the Golgi tendon organ is an inverse myotatic reflex arc (Sage, 1971).

The power bounds of the plyometric program and the isokinetic regime cause high intensity contractions which are mediated by the Golgi tendon organ. Extremely fast repetitions of the plyometric speed bounds may fool the Golgi tendon organ, allowing more tension within the muscle to develop. This may be explained by the fact that the Golgi tendon organ has a much higher threshold to stretch than the spindles. The limited amount of stretch occurring in the speed bounds are phasically activated but the Golgi tendon organ may not have reached the threshold of sensitivity necessary to fire its inhibitory reflex arc. The role of the Golgi tendon organ in affecting the efficiency of tension created within the muscle may be questioned when one considers that the Golgi tendon organ is also sensitive to contractions whereas the spindles are not.

De Vries (1980) noted that the leg extensors involved in the vertical leap have a well developed static stretch component incorporated within them whereas the flexors do not. Both the flexors and extensors involved in vertical leap have the phasic component. The overall effect producing favorable advantages for power bounds consequently may be the diminished inhibition of muscle concentricity caused by the Golgi tendon organ.

Plyometric programs which involved high levels of intrinsic motivation and efficient administration of the exercise regimes were significantly better than isokinetic programs or plyometric programs which lacked these characteristics. The final proof of isokinetic and plyometric effects on vertical leaping ability could be determined by pretest and posttest muscle biopsies used to determine specific fiber transitions and hypertrophies. Both of these exercise regimes could be used to develop muscular strength in other areas of the body. Therefore, more research should be instituted to determine the strengths and the full potential of each regime.

SUMMARY

This research attempted to determine the effects of plyometric and isokinetic exercise regimes on the vertical leaping ability of humans.

Data from the major test groups demonstrated no significant difference between the effects of plyometric and isokinetic exercise programs on the vertical leaping ability of humans. Plyometric and isokinetic exercise programs were significantly different in their effects on vertical leaping ability when compared to control groups. The significant difference of both exercise regimes is favorable for the increase in vertical leaping ability when compared to control groups which received neither exercise regime.

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