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Effects of an extensibility exercise program upon agility and extent flexibility of the groin and hamstring muscles

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EFFECTS OF AN EXTENSIBILITY EXERCISE PROGRAM UPON AGILITY AND EXTENT FLEXIBILITY OF THE GROIN AND HAMSTRING MUSCLES

by

Dale E. Volpe

An Abstract

of a project submitted in partial fulfillment
of the requirements for the degree of
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Project Advisor: Dr. A. Craig Fisher

ABSTRACT

The effects of an extensibility exercise program upon agility and extent flexibility of the groin and hamstring muscles were examined. Fifty members of the Ithaca College varsity football team ranging from freshmen through seniors were selected as subjects. Twenty-five subjects were randomly assigned to the treatment group; the remaining 25 subjects served as the control group. The treatment group experienced an extensibility exercise program twice a week for six weeks in addition to the winter football conditioning program. The control group only participated in the winter football conditioning program. All subjects were administered four tests in order to measure the extent flexibility of the groin and hamstring muscles and one test for the purpose of measuring agility. Reliability coefficients ranged between .88 for the agility run and .97 for both the stand and reach and the standing spread eagle tests.

Multivariate analysis of variance (MANOVA) was used to determine whether differences existed between treatment and control groups. Discriminant function analysis identified which of the five test variables contributed significantly to the between groups variance.

The agility test and the four extent flexibility test results were then subjected to univariate analysis in

order to obtain significant F ratios of the difference between the treatment and control groups on each of the five tests. Univariate analysis indicated that significant differences existed between the treatment and control groups on each of the five test variables. This in turn led to the rejection of the null hypothesis.

EFFECTS OF AN EXTENSIBILITY EXERCISE PROGRAM UPON AGILITY AND EXTENT FLEXIBILITY OF THE GROIN AND HAMSTRING MUSCLES

A Research Project Presented to the Faculty
of the School of Health, Physical
Education and Recreation
Ithaca College

In Partial Fulfillment of the
Requirements for the Degree
Master of Science

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by
Dale E. Volpe
September 1977

Ithaca College
School of Health, Physical Education and Recreation
Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE RESEARCH PROJECT

This is to certify that the Research Project of

Dale E. Volpe

submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health, Physical Education, and Recreation at Ithaca College has been approved.

Research Project Advisor: ____

Candidate: ____

Chairman, Graduate Program in Physical Education: ____

Director of Graduate Studies: ____

Date: June 23, 1977

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Chapter 1

INTRODUCTION

Previous research in the area of speed and extent flexibility has been almost nonexistent. There has been a very limited number of studies designed to examine the effects of an extensibility exercise program upon such abilities as agility and extent flexibility. The limited research available indicates that there may be a relationship between increments in the level of extent flexibility and the agility of athletes.(24). In athletic performance, the athlete who has a longer muscle, and a longer stride length, is purported to be faster than his peers. Can an athlete obtain a higher level of agility and extent flexibility through an extensibility exercise program? This question provides the problem to be explored within the framework of this study.

Santa Maria (18) showed that in sprinting, runners need such characteristics as linear velocity, hip joint flexibility, shortened pre-motor reaction time, increased elasticity of muscle tissue, and increased stride length, in order to be successful. These physiological characteristics may be enhanced through a prescribed extensibility exercise program.

In football, all of the aforementioned physiological characteristics are required. The football player in all positions must exhibit great speed and agility. He must explode from his stance (acceleration) and reach a maximum speed (velocity) in the least amount of time possible. In addition, he must possess the ability to change the direction in which his body is moving, either abruptly or in one continuous motion (agility). Is it possible that these objectives might be accomplished through a prescribed extensibility exercise program? The question of whether or not an extensibility exercise program has an effect upon agility and extent flexibility is the purpose of this study.

Scope of Problem

This study dealt with the effect of a prescribed extensibility exercise program upon agility and extent flexibility. Fifty members of the Ithaca College varsity football team ranging from freshmentthrough seniors were selected as subjects. Twenty-five subjects were randomly assigned to the treatment group; the remaining 25 subjects served as the control group. The treatment group experienced an extensibility exercise program twice a week for six weeks in addition to the winter football conditioning program. The control group only participated in the winter football conditioning program. At the completion of the six-week conditioning program, all subjects were administered four tests in order to measure the extent flexibility of the groin and hamstring muscles and one test for the purpose of measuring agility.

All subjects were provided a brief explanation followed by a short demonstration by the investigator prior to the actual testing. The tests were administered in the Hill Physical Education Center during a time when varsity basketball practice was in session. The presence of both the basketball players and the football players waiting to be tested contributed some external confusion that might possibly have influenced the subject's performance either favorably or unfavorably depending upon the individual being tested. All subjects were allowed two trials on each test and each score was recorded for the agility run and for each test of extent flexibility.

Statement of Problem

The purpose of this study was to determine the effects of a six-week extensibility program upon agility and extent flexibility of the groin and hamstring muscles of college football players.

Null Hypothesis

The extensibility exercise program will not increase agility and extent flexibility of the groin and hamstring muscle groups.

Assumptions of Study

The following were assumed in this study:

1. The subjects had no previous experience in the agility test used.

2. The flexibility tests used were the most ideal means of testing those particular muscle groups isolated for this study.

3. The agility test was an accurate measure of speed of change of direction, as it was applied in this study.

4. The subjects gave their best effort on each trial of each test.

Definition of Terms

The following terms were operationally defined for the purpose of this study:

1. Extent Flexibility. This referred to the ability to move or stretch the body, or some part thereof, as far as possible in various directions.

2. Agility. This factor emphasizes the ability of the subject to change the direction of movement of the body, or parts thereof, either abruptly or in a continuous fashion (speed of change of direction).

3. Extensibility Exercise Program. This referred to the stretching program which utilized extent flexibility exercises.

Delimitations of Study

The delimitations of the study were as follows:

1. The subjects for this study were varsity football players at Ithaca College, Ithaca, New York.

2. Only two muscle groups were tested.

3. Only one test of agility was utilized.

4. Only four flexibility measurement tests were utilized, two of which apparently tested the same muscle group.

Limitations of Study

The limitations of the study were as follows:

1. The agility test administered in a different physical and/or psychological environment may have resulted in different findings.

2. The selection of an agility run other than the one used in this study may have resulted in different findings.

Chapter 2

REVIEW OF RELATED LITERATURE

The review of literature for the purpose of this investigation had as its concentration the following important areas: (1) tests of flexibility, (2) flexibility applied to speed or rate of movement, (3) different stretching programs, (4) specificity of flexibility, (5) flexibility and injury reduction, and (6) summary.

Tests of Flexibility

In Fieldman's (14) study, 33 college men were used as subjects to ascertain the relative contribution of the back and hamstring muscles to hip joint flexibility. The subjects, performing six tests over a five-week period, were photographed during each of their toe touch tests. Anthropometric measurements were taken prior to testing to determine if there was any relationship to flexibility. Making use of concentric circles and making reference points on the subject prior to testing, it was possible to ascertain the curvature of the back, the angle of straight back flexibility, and the angle of bent back flexibility.

Results indicated that the extensibility of the hamstring muscles appeared to be one of the main contributing factors to hip joint flexion, and since the warm-up did not affect the flexibility of the back, one might conclude that the back made no increased contribution to hip joint flexion, as measured in this study. There was no significant relationship to the angle of bent back flexibility.

Fieldman (15) furthered the results of his previous study. Thirty-three college males doing the toe-touch test were used as subjects to ascertain the relative contribution of selected extensibility exercises, arranged with progressive increases, to the flexibility of the hip joint. The subjects performed six tests over a five-week period. The first and sixth test had no warm-up while the second through fifth test had various degrees of warm-up. Results indicated that tests which included extensibility exercises allowed the subject to display greater flexibility at the .01 level of confidence. When the exercises became more active and were related to the activity, hip flexibility increased significantly with each added increment, as indicated by test scores.

Flexibility Applied to Speed or Rate of Movement

Carr (20) studied the effects of two stretching techniques upon sprinting velocity. The subjects (N=26) were measured for flexibility of the hip joint and filmed to measure selected aspects of running prior to and after receiving treatment. Each subject was placed in one of three groups (control, slow stretch, and proprioceptive neuromuscular facilitation) according to sprinting velocity, so that each group's mean was approximately equal. The two treatment groups received specialized training for seven weeks. One-way ANOVA and the multiple comparison technique showed the two training techniques used in this study caused horizontal linear velocity of sprinting and flexibility of the hip joint to increase ($p < .05$). However, neither treatment group was significantly superior to the other. Furthermore, the treatment groups did not cause a significant change ($p > .05$) in stride cycle length or angular velocity of the lower limb segments.

Nelson (26) studied two groups of 20 subjects, each from two activity classes in body conditioning at UCLA. They were equated on the basis of hip hyperextension and flexion, and 50-yard dash time. The experimental groups in each class trained for seven weeks to increase hip and ankle flexibility; the control groups did not. The correlations between running speed and the various flexibilities were not significant. The experimental group showed significant increases over the control group in most aspects of flexibility, but the two groups remained equal in speed. Increasing hip and ankle flexibility apparently did not increase running speed.

Burley, Dobell, and Farrell's (12) study was conducted to determine the differences among seventh, eighth, and ninth grade girls in both speed and flexibility.

Six flexibility measures and six anthropometric measures were correlated with scores made in the 50-yard dash to determine the relationship between these variables. When the speed score for each subject was correlated with each of her flexibility measures, no coefficient of correlation greater than -.163 was obtained. For these subjects flexibility of the appendages was not significantly related to their speed in running a 50-yard dash.

Santa Maria (18) obtained pre-motor and motor reaction time scores from 24 male subjects using a knee flexion task. It was predicted that an increased arousal state due to proprioceptive feedback from stretched hamstring muscles would shorten pre-motor reaction time while motor reaction time would shorten because of changes in muscle tension development due to changes in the series elastic and/or contractile components of the muscle tissue. A finger reaction time test was also included in order to determine whether other factors not related to changes in the stretch of the hamstring muscle were operative. Motor reaction time decreased with increased muscle stretch and constituted 46 percent of leg reaction time. Pre-motor reaction time as well as finger reaction time increased rather than decreased with increased muscle stretch.

Fleishman (2) in analyzing the relationship of speed of change of direction with extent flexibility utilized the stand and reach test and a simple shuttle run (N. Y. S. shuttle run) and found correlations of .39, .49

and .55. The tests required stretching of the trunk, back, and hamstring muscles as far as possible.

These tests emphasized both speed and flexibility of repeated trunk and/or limb movements. Apparently, the factors involve the ability to make repeated, rapid, flexing or stretching movements, where the extent of the movement is either short and/or long.

Different Stretching Programs

Embry (22) tested the effects of dynamic weight training upon flexibility. Sixty college age subjects were tested for flexibility using eight specific measurements. Thirty of the subjects then participated in a six-week weight training program, while the remaining subjects were not required to perform any regular activity. All subjects were retested at the end of the six-week period. Analysis of the data indicated that there were no significant differences between initial and final scores.

In the Long (25) study, a Leighton Flexometer was used to obtain measurements of the range of hip joint abduction of 54 college females, immediately following and three weeks after participation in a six-week exercise program of either static, dynamic or combined stretching. During the training period all groups engaged in 10-minute bouts consisting of a series of four exercises. Two groups (static and dynamic) trained three times per week, and four groups (static, dynamic, and two combined) trained twice each week. A significant amount of flexibility improvement occurred and was retained by all groups following the training and retention periods. No differences were found in the amount of flexibility developed or retained as a result of either static or dynamic or combined programs, nor were there significant differences between the groups which trained two, as opposed to three days per week.

Meyers (17) explored the effects of selected combinations of rate of movement, resistance, and two variations of deep knee squat on collateral ligament stretch in the knee joint, quadriceps muscle strength measured at two leg extension angles, and knee joint flexibility. Sixty-nine male volunteer, Caucasian, university students provided the data. The total experiment was 10 weeks in duration, one week pretesting and post-testing and eight weeks for experimental exercises. The main hypotheses involved the testing of selected treatment cells into planned contrast. MANCOVA failed to reject the null hypothesis ($p > .05$). Selected variations of the deep squat and half-squat exercises did not produce significant differences in their effects on collateral ligament stretch, quadriceps muscle strength, or knee joint flexibility.

The Holt, Travis, and Okita (16) study involved comparison of three techniques for increasing range of motion. Fast stretch (ballistic), slow stretch, and IA-CA (isometric contraction of the agonists, IA, followed by a concentric contraction of the antagonists, CA), a modified version of proprioceptive neuromuscular facilitation (PNF) were compared using 24 male subjects. Six groups of four subjects each were administered the treatments, and the difference between pre-exercise and post-exercise measures were observed. Multiple regression analysis indicated the superiority of the IA-CA approach.

Puhl (27) measured right and left shoulder flexion and extension, trunk flexion and extension, trunk lateral flexion, and right and left hip abduction. College females in two basic movement classes were paired on the basis of the initial test. Both groups had regular class activities and the experimental group had additional static stretching exercises for four weeks before being selected. Seven members of the university gymnastic team were also tested. The female gymnasts had significantly greater right and left hip abduction and trunk flexion-extension flexibility than the normal sample. The experimental group showed significantly greater improvement in trunk flexion-extension, left hip abduction, and left shoulder extension.

Bridell's (19) study involved college males (N=92) who were measured for hip flexibility before and after a nine-week training program. Subjects were divided into four exercise groups: (1) static stretching, (2) dynamic stretching, (3) combination stretching, and (4) control group. Each group performed a series of four exercises. In comparing the means of the pretest and post-test, no significant difference was found among groups. Significant gains in flexibility were recorded in all groups except the control group.

Specificity of Flexibility

Harris (23) completed a factor analytic study of flexibility at the University of Wisconsin. Of the 53 variables included in the major analyses, 38 were measures of joint actions, 13 of composite measures, and two of anthropometric measures. Subjects were 147 college females selected at random. A major conclusion was that there was no evidence that flexibility exists as a single general characteristic within the human body. Thus, neither one composite test nor one joint action can give a satisfactory measure of the flexibility characteristics of an individual.

Dickinson (13) best described the belief of specificity of flexibility. The problem was to determine whether flexibility is a general property, equally apparent in all joints of the individual, or whether there is room for localized flexibility depending on the bodily part. For some time flexibility was considered a general quality, and a measurement of ability to touch the toes was considered an adequate evaluation of this quality. Several studies have profided evidence that flexibility is specific to the different joints of the body.

Dickinson (21), in another study, further pointed out the fact that if flexibility was specific to flexion and extension movements of a joint, then range of motion would be a combination of unrelated measures that would give a general indication of flexibility, but might also hide important limitations of flexibility requiring therapy or exercise.

Steffen (28) completed a study to determine the relation of body fat to hip flexibility and cardiovascular fitness. This study was conducted with 25 male subjects from the University of Wisconsin varsity football team. The tests were administered over a two-week period in the human performance laboratory at the university. Each subject was administered the three flexibility tests. Pearson product-moment reveal correlations of -0.23 and -0.27 between body fat and hip flexibility, and body fat and cardiovascular fitness, respectively. A simple t test for correlated data was used to test the significance between the means. It was concluded that the higher degrees of body fat did not affect hip flexibility or cardiovascular fitness.

Flexibility and Injury Reduction

Mathews (7) stated that muscle is elastic and follows the properties of Hook's Law in that the amount of elongation is directly proportional to the stretching force. The extensibility of the muscle is increased after four or five preliminary stretchings and the muscle is more extensible when contracted than when relaxed. Hence, resistance to muscle tearing can be increased by a few preliminary stretching exercises before physical participation.

Because muscle is composed of blood vessels, connective tissue, and fat, Hook's Law does not hold exactly. However, if joint structure is normal, the flexibility of a muscle may be increased through stretching exercises within a few weeks. Additional information seems to indicate that those individuals possessing a satisfactory degree of flexibility are less susceptible to fiber tear as a result of sudden movements.

Holt (24) illustrated that athletes and dancers perform stretching exercises in order to accomplish one or more of the following objectives: (1) to reduce injuries due to tearing of muscle tissue, (2) to increase the amplitude of movements inherent in the activity, (3) to promote muscle relaxation, and (4) to increase metabolism in muscles, joints and associated connective tissues. In sporting events such as diving, gymnastics, swimming and in virtually all forms of dance, the demand for high levels of flexibility is apparent. Preparation for these activities usually involves some type of stretching exercises. This does not exist in typical training programs for the majority of sporting activities. Preparation for sports where the need for increased flexibility is less obvious centers generally on skill acquisition, circulorespiratory fitness, and strength development. Indeed, many popular stretching exercises executed incorrectly, actually shorten the muscle groups exercised rather than lengthen them. For example, traditional stretching that involves a series of bouncing movements often causes injury to the athlete prior to training or competition, or predisposes the athlete to injury when he does perform.

Since 1967, Holt (24) has introduced his static stretching method (3S) to hundreds of gymnasts, swimmers and dancers. Improvements in flexibility have been observed at the initial work-out, and positive effects upon performance during competition have been noted. A limited number of athletes in sports such as hockey, soccer, football and badminton have integrated stretching into their warm-up routines and they have found not only a reduction in injuries, but an improvement in technique as a result of increased range of motion. Athletes involved in vigorous activities, such as baseball, basketball, ice hockey and football would derive both short term and long term benefits from the 3S approach if these exercises were incorporated into the daily training program. Athletes have observed a long lasting effect after as little as one month of stretching for 10 minutes each day.

Morehouse and Rasch (8) stated that by stretching a muscle the extension causes additional blood to enter the working tissues, which will in turn aid in the rise of body temperature. Elevated body temperature also shortens the periods of muscular relaxation and aids in reducing stiffness. As a result of these two processes there is an improvement in accuracy, strength and speed of movement, and an increase in tissue elasticity which lessens the liability to injury.

Karpovich (5) showed that as in any elastic body, for instance a rubber band, muscle increases in elasticity after a few preliminary stretchings. The elasticity of a contracted muscle is greater than that of a relaxed muscle. This means that a contracted muscle can stretch more than a relaxed one. Undoubtedly, this increased extensibility serves as a safety device, protecting muscle from rupturing during sudden contraction.

Klafs and Arnheim (6) found that most authorities in sports medicine consider flexibility, or the ability to move freely in various directions, one of the most important objectives in the conditioning of athletes. Good flexibility increases the athlete's ability to avoid injury since it creates a greater degree of movement within the joint and, therefore, the ligaments and other collagenous tissues are not so easily strained or torn. It also permits a greater degree of movement in all directions. The "tight" or inflexible athlete performs under a considerable handicap in terms of movement, besides being much more injury prone. Repetitive stretching of the collagenous ligamentous tissues over a long period of time permits the athlete to obtain an increased range of motion. Stretching also provides an excellent warm-up activity. Klafs and Arnheim (6) went on to report that the athlete who possesses good flexibility can change direction of movement more easily, is able to fall properly and with less chance of injury, and physically is more adaptable to almost any game situation. The wise trainer will single out inflexible athletes and have them placed on a program consisting of static stretching exercises. This is one way in which a high incidence of injury can be materially reduced.

The athlete who gains improved flexibility and increased range of joint movement is able to use his body more effectively and efficiently, and he is better able to avoid a potential injury-provoking situation. In addition, when such a situation is unavoidably encountered, the joints involved are far more stable and can withstand a stress or torque considerably in excess of that which can be resisted by a less flexible person. Increased flexibility further aids in reducing impact shock such as that encountered in the contact sports or in activities in which the body comes into forceful contact with a relatively unyielding surface, for example, the landing phase included in gymnastics, jumping or vaulting.

Although the end results of static and ballistic stretching may closely parallel each other, static stretching is preferred because it does not result in the small muscle tears and pulls that are so often the results of vigorous ballistic stretching. After a muscle has been thoroughly warmed up through static stretching and through a program of general conditioning exercises, the athlete may proceed to ballistic stretching if he so desires, although it is doubtful that it will contribute anything additional in terms of flexibility.

The groin presents a greater problem in regard to increased flexibility and injury reduction. Gray (3) states that the groin (gracilis) muscle is in composition a tendon, composed primarily of areolar tissue and collagenous fibers. The tendon which provides support and stability is less likely to elongate and/or stretch due to its tendonous nature and fibrous composition.

Thorndike (10) presented an interesting reason as to why the groin does not lend itself to stretching. The groin consists mainly of collagen fibers with rows of tendon cells in between. The groin evolved from the surrounding muscle structures which formed a scaffolding into which grew the connective tissue cells (inflexible) of the sheaths and the tendon cells themselves. As mentioned earlier, connective and support tissues are less susceptible to stretching due to the elastic limitations of such structures.

Summary

In studies conducted by Holt (24), Klafs and Arnheim (6) and Mathews (7), it was purported that extent flexibility and agility, although somewhat neglected in the experimental literature, have been recognized as two of the most important physical characteristics contributing to athletic success.

Studies completed by Bridell (19), Puhl (27) and Fieldman (14,15) indicated that significant gains in flexibility were recorded through an extensibility (static) exercise program.

The two studies completed by Fieldman (14,15) can be directly applied to this study. Results indicated that tests which included extensibility exercises allowed the subject to display greater flexibility. When the exercises became more active and were related to the activity, hip flexibility increased significantly with each added increment, as indicated by test scores.

Nelson (26) and Burley, Dobell and Farrell (12) found that the relationship between speed in running a 50-yard dash and flexibility was insignificant. The experimental group showed significant increases over the control group in most aspects of flexibility, but the two groups remained equal in speed.

The study conducted by Long (25) stated that there were no significant differences in the amount of flexibility developed or retained as a result of the various stretching programs utilized (static, dynamic, or combined). And yet, Holt, Travis, and Okita (16) found through multiple regression analysis a superiority of the IA-CA (combined stretching) approach. Klafs and Arnheim (6) also pointed out the many advantages of the static stretching program as opposed to the ballistic stretching program.

Many different stretching programs and techniques were examined that either provided no significant effect upon flexibility, or provided some increase, depending upon the muscle groups examined.

Chapter 3

METHODS AND PROCEDURES

This chapter outlines the methods and procedures used in gathering the data for this study. More specifically, this chapter deals with: (1) selection of subjects, (2) testing design, (3) testing environment, (4) testing procedure, (5) methods of data collection, (6) scoring of data, (7) treatment of data, and (8) summary.

Selection of Subjects

The subjects for this study were 50 Ithaca College varsity football players. At the time of the investigation, all subjects were involved in the winter football conditioning program. The players were randomly assigned to one of two training groups. Each group was required to train twice a week as part of their winter football conditioning program (Appendix A). Groups were randomly assigned as either treatment or control by the toss of a coin. The Monday-Wednesday group (N=25) was assigned as the treatment group and the Tuesday-Thursday section (N=25) served as the control group. In addition to their six-week winter football conditioning program, an extensibility exercise program (Appendix B) was administered to the treatment group. The control group only participated in the six-week winter football conditioning program.

Testing Design

Tuckman's (11) Post-test-only control group design was utilized in this study. The subjects reported to the designated testing area in groups of 12 or 13 members. The subjects were then tested on an individual basis with each subject given two trials on each of the five tests administered. All subjects followed the same testing format, namely the Illinois Agility Run first, followed by the four tests of extent flexibility completed in the following order: (1) stand and reach test, (2) standing spread eagle test, (3) sit and reach test, and (4) sitting spread eagle test for administrative feasibility.

Testing Environment

A complete explanation and demonstration of the agility run and the four flexibility tests was provided and any questions were answered. The tests were administered in the Hill Physical Education Center during a time when varsity basketball practice was in session. The presence of both the basketball players and the football players waiting to be tested contributed some external confusion that might possibly have influenced the subject's performance either favorably or unfavorably depending upon the individual being tested.

Testing Procedure

The 25 subjects who were members of the treatment group performed nine extensibility exercises (Appendix B) each for a specified time and/or repetition. These exercises were administered twice a week immediately following the winter football conditioning program (Appendix A). The remaining 25 subjects served as the control group who participated in the winter football conditioning program, but did not partake in the extensibility exercise program. At the completion of the six-week conditioning program, all 50 subjects were tested under identical conditions and procedures. The test directions were explained and demonstration was provided if necessary. Explanation and demonstration was repeated if the subject had any questions about the proper procedure to follow.

All subjects followed the same testing format, namely the Illinois Agility Run first, followed by the four tests of extent flexibility completed in the following order: (1) stand and reach test, (2) standing spread eagle test, (3) sit and reach test, and (4) sitting spread eagle test.

Illinois Agility Run

This test proposed to measure a speed of change of direction factor. This factor emphasizes the ability of the subject to change the direction of movement of the body, or parts thereof, either abruptly or in a continuous fashion. The subject stood behind a starting line and could begin when he so desired. When he crossed the starting line he triggered an electronic beam which engaged a multi-stage photoelectric timing apparatus. The subject then sprinted to a line 30 feet away touching the line with his foot, turning and sprinting 30 feet to the original starting line. The subject then ran a maze of four cones twice, once up and once back,(cones extended over the 30 foot course placed at 10 feet intervals) (Appendix C). Once again, the subject was told to touch the designated line with his foot, turn, and sprint the final 30 feet through the finish line. The subject's score was the elapsed time recorded to the nearest one-hundredths of a second on a Hunter Klockounter.

Stand and Reach Test

This test proposed to measure the extent flexibility in the hamstring muscles from the standing position. Maximum stretch was placed upon the hamstring muscles in this standing and reaching position. The subject stood on a bench placing his toes even with the front edge. He bent over and reached down as far as possible while keeping his knees locked. A measuring scale (yardstick) was placed so that it extended 18 inches above and below the front edge of the bench at the point even with the subject's toes. The subject's score was that distance on the scale he could touch and hold for two seconds recorded to the nearest one-quarter of an inch. No bobbing was allowed.

Standing Spread Eagle Test

This test was designed to measure the extent flexibility in the groin muscle from the standing position. Maximum stretch was placed upon the groin muscle in lowering to a side split position. The subject slides his feet apart lowering the body downward until his crotch is as close to the floor as possible. This position must be held long enough for an accurate measurement to be taken. As the legs are separating, the tester from behind the subject extends a ruler horizontally outward from the edge of the vertical yardstick so that it rests just under the crotch of the subject. As the subject lowers, the ruler should lower sliding down the edge of the yardstick until the point nearest the floor is reached. The subject was not allowed to use his hands by placing them on the floor in front. The subject's score was that distance on the scale to which he could lower measured to the nearest one-quarter inch.

Sit and Reach Test

This test proposed to measure the extent flexibility in the hamstring muscles from the sitting position. Maximum stretch was placed upon the hamstring muscles in this sitting and reaching position. The subject sat on the floor placing his feet and toes tightly against the lower portion of the measuring device (holding the device tightly between his feet). The top portion of the measuring scale (yardstick) placed between his feet extended 18 inches on either side of the point even with the subject's toes. He bent over and reached as far as possible while keeping his knees locked. The subject's score was that distance on the scale he could touch and hold for two seconds recorded to the nearest one-quarter inch. No bobbing was allowed.

Sitting Spread Eagle Test

This test was designed to measure the extent flexibility in the groin muscle while assuming the sitting position. Maximum stretch was placed upon the groin muscle by spreading the legs as far apart as possible. The subject's hands could not be in contact with the floor and his knees had to remain locked. The score was the total number of inches measured from heel to heel recorded to the nearest one-quarter inch.

Methods of Data Collection

The Illinois Agility Run was administered in the Ben Light Gymnasium. A multi-stage photoelectric timing apparatus was utilized for recording times to the nearest one-hundredth of a second.

A yardstick which was marked from zero through 36 inches was used to measure the subject's level of extent flexibility. The data from four extent flexibility tests were collected from each subject. A bench had to be utilized for the collection of data on the stand and reach test since a subject would extend below the point of his toes, acquiring a higher flexibility score. On the standing spread eagle test, a ruler was utilized to mark the point to which a subject lowered on the vertical yardstick measuring scale. A tape measure had to be used for the collection of data on the sitting spread eagle test since a subject could spread his legs much further apart than a yardstick could accurately measure. Each subject was allowed two trials on each of the tests administered in the following order: (1) Illinois Agility Run, (2) stand and reach test, (3) standing spread eagle test, (4) sit and reach test, and (5) sitting spread eagle test.

Scoring of Data

Scores for the Illinois Agility Run were recorded to the nearest one-hundredth of a second. Upon completion of each extent flexibility test, the scores to the nearest one-quarter inch were recorded for each subject.

Treatment of Data

Trials one and two of the agility test and the four extent flexibility tests data were subjected to intercorrelation from which reliability coefficients were derived.

Multivariate analysis of variance (MANOVA) was used in order to analyze all five variables simultaneously in determining whether differences existed between treatment and control groups. MANOVA was repeated minus one variable (agility run) in order to obtain an analysis on the four homogeneous variables of extent flexibility. If the multivariate F ratios are significant, results would then be subjected to a discriminant function analysis to identify which of the five variables contributed significantly to the between groups variance. The discriminant function analysis variable weightings obtained enabled the investigator to compute the percent of variance attributed to each of the variables and to rank each variable according to its discriminant power. The discriminant function analysis program was repeated in order to assess each individual extent flexibility variable's discriminant power. The agility test and the four extent flexibility test results were then subjected to univariate analysis in order to obtain a significant F ratio of the difference between the treatment and control groups on each of the five tests.

Summary

The subjects for this study were 50 Ithaca College varsity football players. During the time of this investigation, all subjects were engaged in the winter football conditioning program. The players were randomly assigned to one of two training groups. Each group was required to train twice a week as part of their winter football conditioning program. Groups were randomly assigned as either treatment or control by the toss of a coin.

In addition to their winter football conditioning program, an extensibility exercise program was administered to the treatment group. The control group only participated in the six-week winter football conditioning program.

Multivariate analysis of variance (MANOVA) was used to determine whether differences existed between the treatment and control groups. If the multivariate F is significant, discriminant function analysis would be used to identify which of the five variables contributed significantly to the between groups variance.

The agility test and the four extent flexibility test results could then be subjected to univariate analysis in order to obtain a significant F ratio of the difference between the treatment and control groups on each of the five tests.

Chapter 4

ANALYSIS OF DATA

This chapter presents the results of the statistical analysis of data from this study. The findings are presented in terms of the following: (1) test reliability, (2) intercorrelation matrix of the five tests used, (3) MANOVA of the treatment and control groups, (4) discriminant function analysis of the treatment and control groups, (5) ANOVA between groups on all variables, and (6) summary.

Reliability

The Pearson product-moment technique was used to compare the mean scores of trial one with the mean scores of trial two for each of the five tests utilized. Reliability coefficients ranged between .88 for the agility run and .97 for both the stand and reach and the standing spread eagle tests. All reliability coefficients obtained were significant beyond the .05 level. Table 1 illustrates the data from each comparison.

Intercorrelation Matrix

Table 2 shows the intercorrelation matrix obtained from the five test variables. Intercorrelation analysis indicated positive correlations between the four tests of

Table 1

Reliabilities of Agility and Extent Flexibility Tests

Variable	Trial 1 $\bar{X}$	Trial 1 SD	Trial 2 $\bar{X}$	Trial 2 SD	r	p
Agility Run (sec.)	15.28	.71	15.08	.73	.88	<.001
Stand and Reach (in.)	19.84	3.00	20.09	2.97	.97	<.001
Standing Spread Eagle (in.)	19.08	3.62	19.55	3.74	.97	<.001
Sit and Reach (in.)	21.47	2.82	21.90	3.13	.94	<.001
Sitting Spread Eagle (in.)	59.67	5.52	60.34	5.70	.96	<.001

Table 2

Intercorrelations of Agility and Extent Flexibility Tests

Variables	2	3	4	5
1. Agility Run	-.51	-.34	-.47	-.24
2. Stand and Reach		.53	.92	.56
3. Standing Spread Eagle			.54	.65
4. Sit and Reach				.56
5. Sitting Spread Eagle				

extent flexibility ranging from .53 to .92. There were negative correlations between the agility run and all tests of extent flexibility ranging from -.24 to -.41. Since greater performance in the agility run was measured in reduced times and greater performance in the flexibility tests was measured in increased inches the negative values are indicative of a positive correlation between the agility run and the four tests of extent flexibility.

MANOVA

Multivariate analysis of variance was performed twice, once on all five test variables, and a second time on the four extent flexibility test variables minus the agility run test variable. Table 3 contains MANOVA results. For all five variables the approximate F statistic obtained was 5.08 which, with five and 44 degrees of freedom, was significant beyond the .05 level. For the four extent flexibility measures, the approximate F statistic obtained was 6.04 which, with four and 45 degrees of freedom, was also significant beyond the .05 level. The findingssindicated significant differences between the treatment and control groups.

Discriminant Function Analysis

Discriminant function analysis was used to determine the percent of variance that each of the five test variables contributed to the between groups variance. This procedure

Table 3

MANOVA of Treatment and Control Groups

Subproblem	df	Approximate F-statistic	p
All variables	5.44	5.08	.03
All variables less Agility Run	4.45	6.04	.02

identified two significant test variables 74.53 percent of the between groups variance was contributed by the agility run and 21.75 percent was contributed by the sit and reach test. The remaining test variables of the stand and reach test, the sitting spread eagle test, and the standing spread eagle test were shown to be not statistically significant to the between groups variance. A ranking was then formulated based upon the percent of variance contributed by each test variable. The discriminant function analysis program was repeated minus the agility run, this time determining the percent of variance that each of the four extent flexibility test variables contributed to the between groups variance. This procedure also identified two significant test variables 71.64 percent of the between groups variance was contributed by the sit and reach test and 27.31 was contributed by the stand and reach test. The remaining test variables were shown not to be statistically significant to the between groups variance. A ranking was then formulated based upon the percent of variance contributed by each test variable. Table 4 presents the test variables ranked according to the percent of variance each contributed (discriminant power).

ANOVA Between Groups on All Variables

Only scores for trial one were used to obtain a mean and a standard deviation for both the treatment and

Table 4

Discriminant Function Analysis of
Treatment and Control Groups

Condition	Ranking	Standardized Discriminant Weighting	% Variance
All variables	1. Agility Run	-.86333	74.53
	2. Sit and Reach	.46633	21.75
	3. Stand and Reach	.18368	3.37
	4. Sitting Spr. Eagle	.05815	.34
	5. Standing Spr. Eagle	.00922	.01
All variables less Agility Run	1. Sit and Reach	.84640	71.64
	2. Stand and Reach	.52261	27.31
	3. Sitting Spr. Eagle	.07288	.53
	4. Standing Spr. Eagle	.07186	.52

control groups on each of the five tests utilized. Univariate analysis was then used to obtain F ratios of the difference between the treatment and control groups on each of the five tests. The F ratios obtained ranged from 7.29 on the standing spread eagle test to 24.21 on the sit and reach test. All were significant beyond the .05 level. The findings of significant differences between groups on each of the five test variables led to the rejection of the null hypothesis. Table 5 contains the results of the univariate analysis.

Summary

Test reliability was established by use of the Pearson product-moment technique. An intercorrelation program was used to derive correlations between the five tests used.

Multivariate analysis of variance was used to determine whether significant differences existed between treatment and control groups. This led to the rejection of the null hypothesis.

Discriminant function analysis was utilized to show which test variables contributed significantly to the between groups variance.

Univariate analysis indicated that significant differences existed between the treatment and control groups on each of the five test variables.

Table 5

ANOVA between Groups on All Variables

Variable	Treatment Group $\bar{X}$	Treatment Group SD	Control Group $\bar{X}$	Control Group SD	F	p
Agility Run (sec)	15.00	.57	15.57	.74	9.21	.004
Stand and Reach (in)	21.55	2.25	18.13	2.76	23.04	<.001
Standing Spread Eagle (in)	20.39	3.47	17.76	3.42	7.29	.009
Sit and Reach (in)	23.10	2.32	19.84	2.37	24.21	<.001
Sitting Spread Eagle (in)	61.80	4.68	57.53	5.66	8.44	.006

Chapter 5

DISCUSSION OF RESULTS

This investigation was conducted for the primary purpose of examining both agility and extent flexibility, two of the most important physical characteristics which contribute to athletic success.

Studies conducted by Holt (24), Klafs and Arnheim (6) and Mathews (7), purported that extent flexibility and agility, although somewhat neglected in the experimental literature, have been recognized as two of the most important physical characteristics leading to athletic success. In addition to this fact, studies completed by Bridell (19), Puhl (27) and Fieldman (14,15) indicated that significant gains in flexibility were recorded through the utilization of an extensibility exercise program. This investigator also utilized an extensibility exercise program as the treatment variable. Both the hamstrings and the groin muscles were examined for the purpose of measuring significant gains in extent flexibility and agility.

Fleishman (2), in analyzing the relationship of agility with extent flexibility of the hamstrings, utilized the stand and reach test and a simple shuttle run. In the present investigation the stand and reach test was also utilized for measuring extent flexibility of the hamstrings and the Illinois Agility Run (Appendix C) was utilized for measuring agility (speed of change of direction).

The Pearson product-moment technique was used to compare the mean scores of trial one with the mean scores of trial two for each of the five tests utilized in this study. Reliability coefficients ranged between .88 for the agility run and .97 for both the stand and reach and the standing spread eagle tests. All reliability coefficients obtained were significant beyond the .05 level. The reliability coefficients obtained in this study were higher than those reported by Fleishman (2), Burley, Dobell and Farrell (12) and Harris (23). Reliability coefficients obtained in similar studies ranged from .30 reported by Harris (23), to .55 as reported by Fleishman (2).

Intercorrelation analysis indicated positive correlations between the four tests of extent flexibility ranging from .53 to .92. The negative correlations between the agility run and all tests of extent flexibility were expected and actually represent a positive relationship between the five variables. Since greater performance in the agility run was measured in reduced times and greater performance in the flexibility tests was measured in increased inches, the negative values obtained are indicative of a positive relationship between the agility run and the four tests of extent flexibility.

Multivariate analysis of variance indicated that significant differences did exist between the treatment and control groups. Discriminant function analysis identified two variables that contributed significantly to the between groups difference. The treatment group's performance was superior to the control group's performance on the agility run and the four tests of extent flexibility. Univariate analysis was then applied in order to obtain F ratios of the difference between the treatment and control groups on each of the five tests. The F ratios obtained ranged from 7.29 on the standing spread eagle test to 24.21 on the sit and reach test, all significant beyond the .05 level. These findings of significance between groups differences on each of the five test variables led to the rejection of the null hypothesis.

In reviewing related literature, this investigator found total agreement on the fact that an extensibility exercise program of some kind (static, dynamic and/or combined) definitely would increase muscular flexibility. Fieldman's (14) results indicated that tests which included extensibility exercises allowed the subject to display greater flexibility at the .01 level of confidence. Carr (20) studied the effects of two stretching techniques upon sprinting velocity. Both training techniques used in his study produced changes in horizontal linear velocity of sprinting and flexibility of the hip joint. This was a valuable concern to this investigator since this study dealt with both sprinting velocity through the agility run evaluation, and extent flexibility through the four extensibility tests. Carr's (20) hypothesis was supported by this investigation since increments in both extent flexibility and sprinting velocity were characteristic of the treatment group. Nelson (26) also reported similar results. His experimental group showed significant increases over the control group in most aspects of flexibility. Long (25) also reported that a significant amount of flexibility improvement occurred and was retained by all groups following the training periods. No differences were found in the amount of flexibility developed or retained as a result of either static, dynamic or combined programs, nor were there significant differences between the groups which trained two, as opposed to three days per week. Holt, Travis and Okita (16) reported that all techniques, fast stretch (ballistic), slow stretch, and IA-CA, improved flexibility and increased the range of motion. Bridell's (19) findings are also directly applicable to this investigation. Bridell (19) divided subjects into four exercise groups: (1) static stretching, (2) dynamic stretching, (3) combination stretching, and (4) control group. Significant gains in flexibility were recorded in all groups except the control group. Results from both Bridell's (19) study and the present study would indicate that stretching programs would provide considerable increments in flexibility. This belief received direct support from Mathews (7) who reported that the flexibility of a muscle may be increased through stretching exercises within a few short weeks.

Klafs and Arnheim (6) provided the best rationale for why static stretching exercises were utilized in this study. They reported that although the end results of static and ballistic stretching may closely parallel each other, static stretching is preferred because it does not result in the small muscle tears and pulls that are so often the results of vigorous ballistic stretching. After a muscle has been thoroughly warmed up through static stretching and through a program of general conditioning exercises, the athlete may proceed to ballistic stretching if he so desires, although it is doubtful that it will contribute anything additional in terms of flexibility. Holt (24) felt even more strongly about the damaging effect that ballistic stretching may have upon the muscle. He reported that traditional stretching which involves a series of bouncing movements often causes injury to the athlete prior to training or competition, or predisposes the athlete to injury when he does perform.

While the proper selection and organization of an extensibility exercise program is important, one should not overlook the all-important time factor. Stretching should be done on a daily basis when possible particularly in regards to the groin (gracilis) muscle where the smallest increments in flexibility are found to exist. Thorndike (10) provided a logical explanation as to why the groin seems to possess a high resistance to stretching. The groin consists mainly of collagen fibers separated by rows of tendon cells. The groin evolved from the surrounding muscle structures which formed a scaffolding into which grew the connective tissue cells (non-flexible) of the sheaths and the tendon cells themselves. As mentioned earlier, connective and supportive tissues are less susceptible to stretching due to the elastic limitations of such structures. Gray (3) also supported Thorndike's explanation as he continued to report that the groin muscle is in composition a tendon, composed primarily of areolar tissue and collagenous fibers. The tendon which provides support and stability is less likely to elongate and/or stretch due to its tendonous nature and fibrous composition. A practical approach to extensibility would demand that more time be spent stretching the groin than any other muscle of the leg. For example, in this study, greater increments in flexibility were obtained in the hamstring muscles which are composed of long strands of elastic muscle tissue and fibers with a capacity to elongate based upon the amount of pressure exerted upon them. Mathews (7) stated that muscle is elastic and follows the properties of Hook's Law in that the amount of elongation is directly proportional to the stretching force. However, the groin is a short and tight supportive tendon which does not possess the same amount of elastic properties referred to in Hook's Law. Thus the groin will demand repetitions and longer stretching periods.

There were four tests utilized for measuring extent flexibility of the groin and hamstring muscles. Two tests were selected for measurement and evaluation of each muscle and/or muscle group. The reason two tests were utilized for each muscle is twofold. It was unknown which test would represent the best criteria for measurement of extent flexibility. Which test would contribute most to the between groups variance was unknown. The other reason was explained clearly in Harris' (23) factor analytic study of flexibility. He stated that no one composite test nor one joint action can give a satisfactory measure of the flexibility characteristics of an individual. Also, two studies reported by Dickinson (13,21) emphasizing the specificity of flexibility to a particular joint or muscle group prompted a dual evaluation of the same muscle on two separate tests. Such specificity of flexibility exists as was evident in the discussion of groin as opposed to hamstring elasticity.

There is much speculation as to the reasons why there were significant differences between the treatment and control group on the agility run test variable. Santa Maria (18) predicted that an increased arousal state due to proprioceptive feedback from stretched hamstring muscles would shorten pre-motor reaction time while motor reaction time would shorten because of changes in muscle tension development due to changes in the series elastic and/or contractile components of the muscle tissue. Motor reaction time did decrease with increased muscle stretch and constituted 46 percent of leg reaction time. This evidence may lend itself to the possibility that the treatment group was able to start much quicker and also to change directions more rapidly due to both shortened motor reaction time, and the enhancement of proprioceptive feedback from the stretched hamstring muscles. Holt (24) reported that athletes and dancers perform stretching exercises in order to accomplish many objectives, one of which is to increase the amplitude of movements inherent in an activity. This concept is directly applicable to the movements required in the agility run in that increased amplitude of movements meant decreased running time and a better individual score. Morehouse and Rasch (8) also reported that through a daily stretching program which provides for both increases in strength and tissue elasticity, speed of movement can be improved. Klafs and Arnheim (6) provided the best explanation as to why flexibility may directly complement agility. They reported that improved flexibility permits a greater degree of movement in all directions. This was an important prerequisite for success in the agility run. The "tight" or inflexible athlete performs under a considerable handicap in terms of movement; this was often times visually observable during the testing of the control group subjects. Klafs and Arnheim (6) went on to say that the athlete who is flexible can change direction of movement more easily. Once again, this was observable during the testing of the treatment group and was evident in the agility run test results.

The final section in this review that warranted discussion is that of both injury reduction and other valuable antecedents acquired through an intense stretching program. Some very interesting and stimulating studies may appeal to both the practitioner and/or coach and to the researcher of extent flexibility. Mathews (7) reported that resistance to muscle tension can be increased by a few preliminary stretching exercises before physical participation. Additional information provided by Holt (24), Morehouse and Rasch (8), Karpovich (5), and Klafs and Arnheim (6) seem to indicate that those individuals possessing a satisfactory degree of flexibility are less susceptible to fiber tear as a result of sudden movements.

Holt (24) illustrated that athletes and dancers perform stretching exercises in order to accomplish many objectives, the primary objective being to reduce injuries due to tearing of muscle tissue. As mentioned earlier, he also reported that traditional stretching that involves a series of bouncing movements often causes injury to the athlete prior to training or competition, or predisposes the athlete to injury when he does perform. In 1967, Holt (24) introduced his static stretching method (3S) to hundreds of gymnasts, swimmers, and dancers. Improvements in flexibility have been observed at the initial work-out, and positive effects upon performance during competition have been noted. A limited number of athletes in sports such as hockey, soccer, football and badminton have integrated stretching into their warm-up routines and they have found not only a reduction in injuries, but an improvement in technique as a result of increased range of motion. Holt (24) also felt that athletes involved in vigorous activities, such as baseball, basketball, ice hockey and football would derive both short term and long term benefits from the 3S approach if these exercises were incorporated into the daily training program. Athletes have themselves observed a long lasting effect after as little as one month of stretching for 10 minutes each day.

Morehouse and Rasch (8) stated that by stretching a muscle the extension will induce additional blood to enter the working tissues, which will in turn aid in the rise of body temperature. Elevated body temperature also shortens the periods of muscular relaxation and aids in reducing stiffness. As a result of these two processes there is an improvement in accuracy, strength, and speed of movement, and an increase in tissue elasticity which lessens the liability to injury. Karpovich (5) lent support to Morehouse and Rasch as he showed that as in any elastic body, for instance a rubber band, muscle increases in elasticity after a few preliminary stretchings. Undoubtedly this increased elasticity serves as a safety device, protecting muscles from rupturing during sudden contraction. Klafs and Arnheim (6) found that most authorities in sports medicine consider flexibility, or the ability to move freely in various directions, as one of the most important objectives in the conditioning of athletes. Good flexibility increases the athlete's ability to avoid injury since it creates a greater degree of movement within the joint and, therefore, the ligaments and other collagenous tissues are not so easily strained or torn. The "tight" or inflexible athlete performs under a considerable handicap in terms of movement, besides being much more injury prone. Klafs and Arnheim (6) also reported that the athlete who possesses good flexibility is able to fall properly with less chance of injury, and physically is more adaptable to almost any game situation. The wise trainer will single-out inflexible athletes and have them placed on a program consisting of static stretching exercises. This is one way in which the high incidence of injury can be materially reduced.

The athlete who gains improved flexibility and an increased range of joint movement is able to use his body more effectively and efficiently, and he is better able to avoid a potential injury-provoking situation. In addition, when such a situation is unavoidably encountered, the joints involved are far more stable and can withstand a stress or torque considerably in excess of that which can be resisted by a less flexible person. Increased flexibility further aids in reducing impact shock such as that encountered in the contact sports (football) or in activities in which the body comes into forceful contact with a relatively unyielding surface, for example, the landing phase included in gymnastics, jumping and/or vaulting.

Summary

The treatment group was superior to the control group on all test variables. Increments in extent flexibility were found in both the groin and the hamstrings indicating a convincing superiority of the treatment group. Treatment subjects' flexibility mean scores were superior to control subjects' flexibility mean scores within a range of 2.63 inches to 4.27 inches more flexible depending upon the muscle tested and the particular test utilized. The treatment group also proved to be superior in performance on the agility run, turning in a mean time of 15.00 seconds as opposed to that of 15.57 seconds computed for the control group; representing a between groups mean difference of .57 seconds, in favor of the treatment group. Thus, the null hypothesis related to the effects of an extensibility exercise program upon extent flexibility and agility was rejected.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

The effects of an extensibility exercise program upon agility and extent flexibility of the groin and hamstring muscles were examined. Fifty members of the Ithaca College varsity football team ranging from freshmen through seniors were selected as subjects. Twenty-five subjects were randomly assigned to the treatment group; the remaining 25 subjects served as the control group. The treatment group experienced an extensibility exercise program twice a week for six weeks in addition to the winter football conditioning program. The control group only participated in the winter football conditioning program. All subjects were administered four tests in order to measure extent flexibility of the groin and hamstring muscles and one test for the purpose of measuring agility.

Subjects were provided a brief explanation followed by a short demonstration by the investigator prior to the actual testing. The tests were administered in the Hill Physical Education Center during a time when varsity basketball practice was in session. All subjects were allowed two trials on each test

Multivariate analysis of variance (MANOVA) determined that a significant difference between treatment and control groups did exist. Discriminant function analysis identified two variables, the agility run and the sit and reach test, as those that contributed most significantly to the between groups variance.

The agility test and the four extent flexibility test results were then subjected to univariate analysis. The approximate F statistic obtained ranged from 7.29 on the standing spread eagle test to 24.21 on the sit and reach test. All wereesignificant beyond the .05 level. The findings of significant differences existing between the treatment and control groups on all five test variables led to the rejection of the null hypothesis.

Conclusions

On the basis of the findings and within the limitations of this study the following conclusions were supported:

1. Although, as stated earlier in the text, the groin muscle seems to resist elongation due to a lack of elasticity, it was found that an extensibility exercise program administered twice a week for six weeks did improve the extent flexibility of the groin muscle.

2. The extensibility exercise program, as expected, did improve the extent flexibility of the hamstring muscles.

3. The extensibility exercise program quite

surprisingly also improved the agility of the football players tested.

4. An extensibility exercise program administered for a duration of twice a week for six weeks (12 stretching sessions) will improve agility and the extent flexibility of the groin and hamstring muscles. This in turn might possibly aid in the production of better football performance and reduce football injuries.

Recommendations for Further Study

The following recommendations are offered for further investigation:

1. A future study could more closely examine the effects of an extensibility exercise program upon agility through the utilization of a multiple agility test battery.

2. A long range study could investigate the effects of an extensibility exercise program upon injury reduction within any athletic setting.

3. A follow-up study could investigate how other muscles of the leg such as the quadriceps and the gastrocnemius muscle groups are affected by an extensibility exercise program.

4. An investigation could examine the rate at which increments in flexibility are lost due to a state of total abstinence from stretching.

APPENDICES

Appendix A

WINTER FOOTBALL CONDITIONING PROGRAM

This program is quite unique in its off-season approach to player conditioning. Extreme emphasis is placed upon muscle tone and cardiovascular endurance. The training is composed of a circuit consisting of 10 stations. An individual may begin at any station that he so desires, but he must proceed in proper order thereafter. The stations are constructed in a chronological order and are properly numbered. Each station is unique from the others and has its own instructions and/or repetitions for the player to follow. The player is allowed 60 seconds at each station after which time the whistle sounds, and he must then move on to the next station. Five seconds is allotted between stations. The station-by-station breakdown is as follows:

1. Stairs: the player must run up and down a set of 10 stairs, (one round-trip equals 20 stairs). He must complete 10 roundtrips in one minute.

2. Sit-ups: the player secures himself to the 45 degree incline plane on the universal gym, he then must complete 30 sit-ups, with elbows touching knees within the one minute time limit.

3. Quads and Hams: the universal gym is also utilized for this station, the player selects a weight which is approximately one-third of his total body weight, after securing his selected weight on the machine he lies flat upon his stomach and hooks his ankles behind the curling bar, he then curls the weight with his right leg 10 times. This procedure is repeated using the left leg also curling the weight 10 times. This procedure must also be completed within the one-minute time limit.

4. Bench Press: the player now proceeds to the bench attachment of the universal gym. He must now select a weight which represents at least three-quarters of his total body weight. He must proceed to bench press that weight 10 times within the one-minute time limit.

5. Jump Rope: each player must jump rope for the entire one-minute while visiting this station.

6. Barbell Swings: two barbells with 30 pounds of weight attached to each are situated upon a warm-up mat. The player secures a barbell in each hand and must swing the weight in a forearm lift movement to a height even with his shoulder. He does this in an alternating fashion 30 times or 15 times with each arm.

7. Beam Jump: a piece of lumber 2x6 is placed upon its side acting as the beam. The player must hop back-and-forth from side-to-side while clearing the beam for the entire one-minute duration.

8. Shoulder Press: the player now proceeds to the shoulder press attachment of the universal gym. He then selects a weight which represents at least three-quarters of his total body weight. He must press this weight over his head with arms fully extended 10 complete times.

9. Leg Press: the player then proceeds to the leg press attachment of the universal gym. He now selects a weight which represents at least twice his total body weight. He must press this weight by extending his legs with his knees completely locked 20 times within the one-minute time period.

10. Curls: the player proceeds to the curl attachment of the universal gym. He selects a weight which represents at leat three-quarters of his total body weight. He must curl this amount of weight 10 times within the one-minute time period.

As mentioned earlier, each player is required to complete the entire circuit three times each training period. The player must partake in the circuit program twice a week, either Mondays and Wednesdays or Tuesdays and Thursdays.

Two coaches are present at every training period to maintain order. One coach keeps time and sounds the whistle, while the other moves from station-to-station to see that all weight specifications are met.

Since this is a six-week program, at the end of each two-week period the players are required to raise the weight at least 10 pounds at each station, while 10 seconds are deleted from the time period. During weeks three and four players are allotted 50 seconds and must work with an additional 10 pounds of weight at each station. At the completion of the conditioning program (weeks five and six), players are allotted a mere 40 seconds and must work with an additional 20 pounds of weight at each station.

Appendix B

EXTENSIBILITY EXERCISE PROGRAM

The program should take approximately 12-16 minutes when it is familiar to the subject. Until familiarity a time of 20-30 minutes should be alloted to the stretching exercises.

Single Stretching:

1. Full Squats: 15 repetitions

   Subject stands with feet at shoulder width apart, keep heels flat on the floor. Place hands on hips. Flex at the knees and lower the buttocks as close to the floor as possible. Back must be straight. Hands should be thrust out in front to aid balance.

2. Standing Head to Knee Stretch; Legs together: Hold position for 10 seconds and repeat procedure to each knee for three repetitions.

   Subject stands straight with feet and legs placed tightly together. Slowly bend forward from the waist reaching for the ankles with both hands. Interlock hands behind the ankles. (Behind lower legs if not flexible enough to reach the ankles). Begin to pull the upper torso in towards the lower limbs. Attempt to assume a jack-knife position with the forehead touching the kneecaps. Knees must remain extended (straight).

3. Standing Tunnel Stretch: Hold the position for 10 seconds and repeat procedure three repetitions

   Subject spreads his legs as far apart as possible without losing balance. From this spread eagle position, bend slowly forward grabbing the left ankle with the left hand and right ankle with the right hand. Now begin to pull the upper torso in through the tunnel formed by the spread of the legs. Pull to a point where the subject can go no further and look through the tunnel. Knees must remain extended (straight).

4. Standing Head to Knee Stretch; Legs apart: Hold position for 10 seconds and repeat procedure to each leg for three repetitions.

   Subject spreads his legs as far apart as possible without losing balance. From this spread eagle position bend forward slowly and grab the right ankle with both hands. Pull the upper torso in towards the right knee in an attempt to touch the forehead to the kneecap (or as close as possible). Hold 10 seconds. Repeat the same procedure to the left side. Three repetitions to each knee. Knees must remain extended and locked.

5. Hurdlers Stretch: Hold the position for 10 seconds and repeat procedure three repetitions.

   Subject sits on the floor with one leg extended in front and the other forming a right angle with the knee flexed and the foot to the rear. From this position reach forward in an attempt to grab the bottom of the foot of the extended leg while lowering the forehead to the extended knee (or as close as possible). Hold 10 seconds and repeat three repetitions. Extend opposite leg and repeat entire procedure. The knee of the extended leg must be locked with the back of of the knee touching the floor. His foot must remain straight with his toe pointing at the ceiling at all times.

6. Sitting Butterfly Stretch: Hold for 10 seconds and repeat for three repetitions.

   Subject sits on the floor placing the soles of his feet together, bending the knees. Pull the heels of the feet as close to the buttocks as possible by grabbing the toes with the hands. Place the elbows upon the inner thighs and with elbowspressure force the knees downwards in an attempt to have them touch the floor.

Partner Stretching:

7. Spread Eagle Stretch: Hold for 10 seconds and repeat procedure for three repetitions.

   Subject sits on the floor and spreads his legs as far apart as possible. Bend forward slowly reaching for the bottom of both feet with both hands simultaneously. Partner places his hands on the subject's back just below the shoulders and slowly and easily pushes the upper torso towards the floor. The subject commands the partner to stop pushing when he gets to the point where he cannot comfortably bend further. The partner then holds the subject in that position for 10 seconds. Three repetitions are made with the subject attempting to bend a little further under added pressure each time. The subject must lock his knees and reach for the bottom of the foot. The partner should release his tension gradually after each repetition.

8. Sitting Head to Knee Stretch: Hold for 10 seconds and repeat for three repetitions.

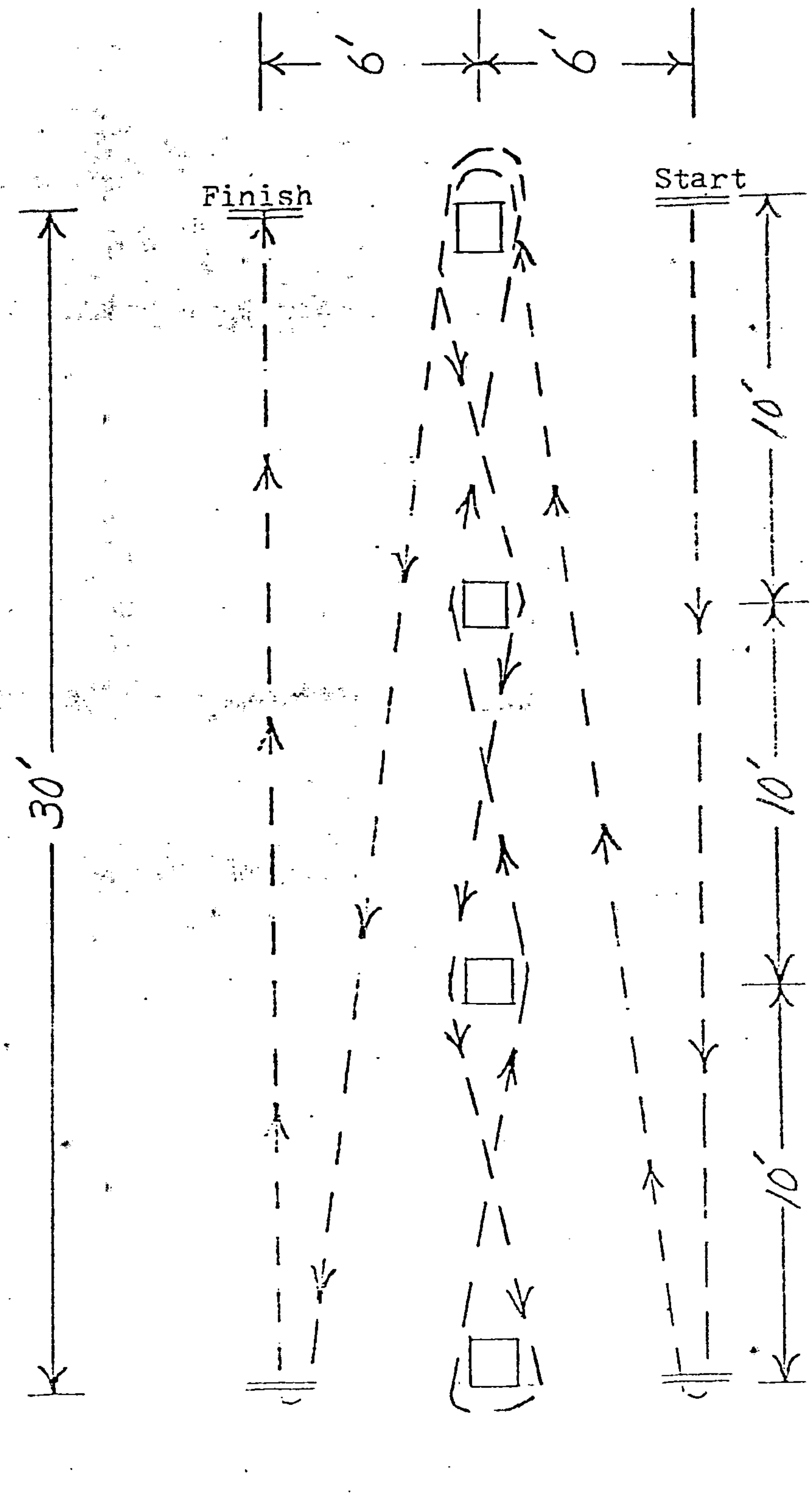
Subject sits on the floor and spreads his legs as far apart as possible. Bend forward slowly grabbing the right ankle with both hands. Pull the upper torso down towards the right knee in an attempt to touch the forehead to the kneecap. The partner places his hands upon the back just below the shoulders of the subject and slowly and easily pushes the torso towards the floor. The subject commands the partner to stop pushing when he cannot comfortably bend further. The partner then holds the subject in that position for 10 seconds. Partner releases the tension gradually and repeats the process for three repetitions. The entire process is repeated for the left side. Subject must lock knees keeping the back of the knees on the floor and the legs must be spread apart as far as possible.

9. Standing Punters Stretch: Hold for 10 seconds and repeat for three repetitions.

Subject stands facing his partner with his back flush against the wall. Partner bends his knees assuming a squat position in front of the subject. Subject raises one leg placing it on the shoulder of the partner. The partner slowly begins to stand thus raising the subject's leg, until the subject commands him to stop. Both of the subject's knees must be extended and locked. From this position the subject leans forward reaching for the ankle of the extended leg in an attempt to touch the forehead to the knee. An attempt should be made to lift the leg higher with each repetition. Repeat the entire process for the opposite leg. The partner must be careful not to raise the leg too high or too quickly.

Appendix C

ILLINOIS AGILITY RUN



BIBLIOGRAPHY

Books

1. Cureton, T. K. Physical Fitness of Champion Athletes. Urbana, Illinois: University of Illinois Press, 1951.

2. Fleishman, E. A. The Structure and Measurement of Physical Fitness. Englewood Cliffs, New Jersey: Prentice-Hall, 1964.

3. Gray, G. Anatomy of the Human Body. Philadelphia: Lea and Febiger, 1973.

4. Johnson, B. L., and J. K. Nelson. Practical Measurements for Evaluation in Physical Education. Minneapolis: Burgess, 1970.

5. Karpovich, P. V. Physiology of Muscular Activity. Philadelphia: W. B. Saunders, 1966.

6. Klafs, C. E., and D. D. Arnheim. Modern Principles of Athletic Training. St. Louis: C. V. Mosby, 1969.

7. Mathews, D. K., R. W. Stacy, and G. N. Hoover. Physiology of Muscular Activity and Exercise. New York: Ronald Press, 1964.

8. Morehouse, L. E., and P. J. Rasch. Scientific Basis of Athletic Training. Philadelphia: W. B. Saunders, 1958.

9. Singer, R. N. The Psychomotor Domain: Movement Behavior. Philadelphia: Lea and Febiger, 1972.

10. Thorndike, A. "Evolution of the Groin." In L. A. Larson, and D. E. Herrmann, eds. Encyclopedia of Sport Sciences and Medicine. New York: Macmillian, 1971.

11. Tuckman, B. W. Conducting Educational Research. New York: Harcourt Brace Jovanovich, 1972.

Periodicals

12. Burley, L. R., H. C. Dobell, and B. J. Farrell. "Relations of Power, Speed, Flexibility, and Certain Anthropometric Measures of Junior High School Girls," Research Quarterly, 32:443-448, 1961.

13. Dickinson, R. V. "The Specificity of Flexibility," Research Quarterly, 39:792-793, 1968.

14. Fieldman, H. "Effects of Selected Extensibility Exercises on the Flexibility of the Hip Joint," Research Quarterly, 37:326-331, 1966.

15. ________. "Relative Contribution of the Back and Hamstring Muscles in the Performance of the Toe-Touch Test After Selected Extensibility Exercises," Research Quarterly, 39:518-523, 1968.

16. Holt, L. E., T. M. Travis, and T. Okita. "Comparative Study of Three Stretching Techniques," Perceptual and Motor Skills, 31:611-616, 1970.

17. Meyers, E. J. "Effect of Selected Exercise Variables on Ligament Stability and Flexibility of the Knee," Research Quarterly, 42:411-422, 1971.

18. Santa Maria, D. L. "Pre-Motor and Motor Reaction Time Differences Associated With Stretching of the Hamstring Muscles," Journal of Motor Behavior, 2:163-174, 1970.

Unpublished Sources

19. Bridell, G. E. "A Comparison of Selected Static and Dynamic Stretching Exercises on the Flexibility of the Hip Joint." Master's thesis, Southeast Missouri State College, 1969. (Abstract.)

20. Carr, G. L. "The Effects of Slow Stretch and Proprioceptive Neuromuscular Facilitation-Reversal of Antagonist Exercises on Sprinting Velocity." Master's thesis, Southern Illinois University, 1971. (Abstract.)

21. Dickinson, R. V. "Flexibility Measurement: Range of Motion vs. Limitation of Movement in One Direction." Master's thesis, University of Illinois, 1973. (Abstract.)

22. Embry, R. L. "The Effects of Dynamic Weight Training Upon Flexibility." Master's thesis, University of North Texas State, 1967. (Abstract.)

23. Harris, M. L. "A Factor Analytic Study of Flexibility." Doctoral dissertation, University of Wisconsin, 1967. (Abstract.)

24. Holt, L. E. "Scientific Stretching for Sport." Unpublished manuscript, Dalhousie University, n.d.

25. Long, P. A. "The Effects of Static, Dynamic, and Combined Stretching Programs on Hip Joint Flexibility." Master's thesis, University of Maryland, 1971. (Abstract.)

26. Nelson, R. P. "The Effect of Hip and Ankle Flexibility on Speed in Running." Master's thesis, University of California at Los Angeles, 1960. (Abstract.)

27. Puhl, J. "Flexibility of Women and Effects of Specific Stretching Exercises on Flexibility." Master's thesis, Southern Illinois University, 1965. (Abstract.)

28. Steffen, D. T. "A Study to Determine the Relationship of Body Fat to Hip Flexibility and Cardiovascular Fitness." Master's thesis, University of Wisconsin-LaCrosse, 1972. (Abstract.)