THE EFFECTS OF WEARING PROPHYLATIC KNEE SLEEVES/BRACES ON SELECTED ISOKINETIC MEASURES DURING A VELOCITY SPECTRUM KNEE EXTENSION TEST

by

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Thesis submitted to the faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements

for the degree of

MASTERS OF SCIENCE

with emphasis in

EXERCISE PHYSIOLOGY

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July, 1998
Blacksburg, Virginia

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(ABSTRACT)

Twenty Virginia Tech varsity football players, age 18-24, volunteered as subjects to examine the effects of wearing prophylatic knee sleeves/ braces on selected isokinetic measures (i.e. strength, power and endurance). Each subject performed the Biodex (Multi-Joint System 2_{AP}) knee extension test in each of three experimental conditions: sleeved with the Don Joy Knee support (S-DJ); braced with the M^{c}David lateral knee support (B-MD); and the control, unsupported condition (C-UN). The order of experimental conditions and the specific knee tested were randomized. The subjects were administered a Biodex knee extension test at 60 deg/sec, 210 deg/sec, and 450 deg/sec. The test protocol consisted of five maximal repetitions at 60 deg/sec, twenty maximal repetitions at 210 deg/sec and thirty maximal repetitions at 450 deg/sec. The following isokinetic measures were recorded: (1) peak torque to body weight ratio at 60 deg/sec. (2) work to fatigue ratio at 210º and 450 deg/sec. (3) average power at 210º and 450 deg/sec, and (4) range of motion at 60º, 210º, and 450 deg/sec. One way repeated measures analysis of variance revealed significant difference ($p > .03$) in

peak torque to body weight ratio treatment groups; work to fatique ratio, average power and range of motion revealed no significant diference among the three experimental conditions. The investigator concluded that prophylatic knee sleeves/braces effects peak torque to body weight ratio; the effect of different levels of condition does not depend on what level of speed is present for work to fatique, average power and range of motion.

ACKNOWLEDGMENTS

I would like to thank the following individuals for their time and effort spent in assisting in the completion of this theisis.

Dr. Don Sebolt, mentor, for your direction and guidance with this research project; may you rest in peace. Thank you for being an inspiration to me always.

Mr. Mike Gentry, friend and committee member, for your support and teaching me about life. The discipline and the respect you have earned from your players; I only hope to gain half as much from my students and collegues.

Dr. Duane Lagan, committee member, for your encouragement and support. I thank you for the lessons you have taught me.

Dr. John Burton, committee chair, for all the hard work and understanding while finishing graduate school. I thank you for makeing this process smooth and painless.

My parents Dennis and Dreema, and sister Michelle, for their love, encouragement and support.

Lastly, Susan Owens Call, who has given endless support, motivation and lasting love throughout this project and graduate school. You've been beside me from the start; your belief in myself, friendship and love have meant everything to me . . . and I thank you.

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INTRODUCTION

Knee injuries is one of the major problems facing the sports medicine community. No injury category can compare with that involving the knee in terms of numbers, rate of occurrences, time henderence, or the necessity for surgical intervention.

Epidemiological studies have recognized also, that knee injuries are one of, if not the most common injuries in athletes.[27,32] The use of prophylatic knee sleeves by athletes is an attempt to reduce the occurrence and/or severity of injuries to the knee joint. Many team physicians and coaches have prescribed or required sleeve wearing by athletes in hopes of preventing injury and improving performance.

Structurally, the knee is a modified hinge joint capable of the fundamental motions of flexion and extension in addition to some rotation and gliding motion. Control of knee motion is shared by the capsular structures, intra- and extra articular ligaments, the joint contours and the muscles with their tendons which cross the joint anteriorly and posteriorly.[37] While sagittal plane motion (flexion/extension) consists of a large, free arc of approximately 150 degrees, motion in the coronal and transverse planes are very small and limited by ligamentous and capsular structures.[28] In a normal and fully extended knee axial rotation is less than 20 degrees and combined varus/valgus is less the five degrees.[22,31] While the knee is most stable when fully extended, it is also in this position that it is most vulnerable to injury, especially from lateral/medial forces. Therefore, the musculature of the knee becomes the most important defense against injury. Maximizing muscle strength may reduce the occurrence, but will not eliminate injuries totally.

Statistically, knee joint injuries occur more frequently than upper extremity injuries. On the average a college football team should expect approximately three to four game related knee episodes during the season. Knee injury statistics for Virginia Tech varsity football from the fall of 1979 through the spring of 1985 totaled 138 knee injuries, 28 of which required surgery.[25] Knee injury statistics for Virginia Tech varsity football from the fall of 1990 through the spring of 1994 have drastically decreased to at least half of the surgical fixations of the 1979 to 1985 years.

In an effort to minimize injury, the sports medicine team enacts various protocols (ie. weights, proprioceptive stretching, prophylatic support). Weights are administered as part of the strength and conditioning program for each athlete. However, particular attention should be centered around the knee. The use of different neurophysiological principles for facilitating the neural activation of the musculature, such as proprioceptive neuromuscular facilitation (PNF), enables the athlete to activate his/her musculature in normally occurring activities. This means for the knee joint the aim is to enhance dynamic stability including use of propioceptive information, motor control and appropriate muscle force development. Prophylatic supports are those braces/sleeves which are designed specifically to prevent or reduce the severity of injury to the knee resulting from an externally applied force.[4]

Economically, the rapid growth of knee sleeve usage is largely ascribed to intense promotions by manufacturers and preliminary reports of effectiveness.[11,35] The efficacy of such knee sleeves has been a controversy by researchers regarding the decrements of muscle inhibition that may decrease performance.[3,15,32] The discrepancies in efficacy of the prophylatic benefits of the sleeve has led to inconsistencies among the clinicians recommending their use.

Statement of the Problem

Previously, knee braces/sleeves were worn by football players that formerly sustained episodes to the knee. Hence, the brace/sleeve was regarded as the functional brace. However, today the use of knee braces/sleeves serve a prophylatic effect; preventive.

Economically, athletic departments spend a large amount of money to minimize the occurrence of serious injury. For example, the Virginia Tech athletic department has spent thousands of dollars over the years on prophylatic knee supports.

Physiologically, the athlete wears the brace or sleeve with the understanding that performance levels will at least remain unchanged, and that the joint stability will increase. Many coaches, therefore require players to wear the prophylatic knee support. Recent research however, suggests that performance can be impaired and even increase the occurrences of injury. Houston et al. showed marked performance reductions with braces during knee extension and flexion tests. Blood lactate levels were drastically higher with the use of knee supports. The data suggested that braces could also interfere with blood flow and hence oxygen delivery.[15]

The purpose of this study was to examine the influence of wearing protective knee supports during selected isokinetic tests. The specific measures included; sleeved, braced and controlled (unsupported) conditions. The prophylatic knee supports that were used in this study included the Don-Joy (006) knee support sleeve, and the M^{c}David lateral knee support brace.

Isokinetic parameters were measured using the Biodex Multi-Joint System 2_{AP} Dynamometer. Twenty football players at Virginia Tech participated in this investigation. Isokinetic speeds of 60º, 210º, and 450 degrees/sec. were used to measure isokinetic knee extension. The experimental measures included: Peak torque/body weight ratio, work/fatigue ratio, average power and range of motion.

Research Hypothesis

To delineate the purpose of this study, the following null hypothesis were established by the investigator:

1. There was no difference in peak torque to body weight ratio in isokinetic knee extension at 60 degrees per second joint angle velocity when the knee was tested in the sleeve, brace and control (unsupported) conditions.

2. There was no difference in work to fatique ratio in isokinetic knee extension at 210º and 450 degrees per second joint angle velocity when the knee was tested in the sleeve, brace and control (unsupported) conditions.

3. There was no difference in average power in isokinetic knee extension at 210º and 450 degrees per second joint angle velocity when the knee was tested in the sleeve, brace and control (unsupported) conditions.

4. There was no difference in range of motion in isokinetic knee extension at 60º, 210º, and 450 degrees per second joint angle velocity when the knee was tested in the sleeve, brace and control (unsupported) conditions.

Significance of the Study

Inconsistencies in the available literature have produced speculation regarding the effects in functional performance while wearing the prophylactic knee sleeve. The prophylactic knee sleeve may reduce leg muscle function and speed, both of which are essential to athletic performance.[10] Houston, studied the relationship between athletic performance and knee sleeves. Seven male athletes volunteered to perform knee extensions . Isometric torque of the quadriceps was measured at 90 degrees of knee flexion. Velocities of 30º, 90º, 180º, and 300 degrees per second joint angle velocity were used to measure dynamic torque. Power was measured using a short stair run, similar to the Margarine test.[15] Mean maximal isokinetic contractions of the knee extensor were significantly lowered from 12 to 30% compared to corresponding values without the knee sleeves. The data demonstrated that dynamic leg muscle performance was impaired by the use of prophylactic knee sleeves.[15]

Sforzo et al. examined the effect of wearing prophylatic knee bracing upon performance in ten female lacrosse players. Quadriceps peak torque and time to fatique were measured. The protocol design included three practice trials prior to performing eight maximal isokinetic knee extensions at 60 degrees per second. Maximal anaerobic power was calculated as the greatest output for a five second interval during the test. A post exercise blood sample was collected at the conclusion of each session (eg. establishes lactic acid levels following testing sessions). The data suggested that bracing significantly reduced isokinetic performance of peak torque to body weight. time to fatique and average power in college female lacrosse players.[33]

Farrar, also studied , the relationship between isokinetic strength, speed and agility using prophylatic knee supports. Fifty-two college age males performed isokinetic knee extensions. Isokinetic torque was conducted at 60º and 300 degrees/sec. Ratios between mean peak torque at the slow and fast velocities were then calculated relative to which torque decreased as progressive to higher velocity. No correlation was reported between mean maximal speed and leg strength, but showed significant decline (20%) in the 100 yard sprint, braced condition.[7]

Hofmann et al. studied knee stability in orthotic knee braces. Six knee orthoses were evaluated. The braces were tested using cadaveric specimen. Each knee was tested for anterior, valgus, and rotation stability. The data demonstrated that no brace was to equal that of an intact knee. Therefore the study suggested a prophylactic need for stability equal to and greater than that of an unimpaired or uninjured (intact) knee. However, the degree to which orthotic knee sleeves provide a preventive effect correlates to a decrement of performance. The amount of stress, strain and torque used to stabilize the knee suggests a decrement of performance.[16]

Teitz, designed a study to access whether preventive knee sleeves decreased the severity and/or incidence of knee injury in college football. Consequently, Teitz reported that not only did injury occur more often, but that indeed "preventive" braces are not preventive. Data was collected from 71 division I NCAA schools in 1984 (6,307 players) and 61 schools in 1985 (5,445 players). Variables such as player position, playing surface, injury mechanism, type of brace, and history of previous knee injury were included in the analysis. Overall, braced players had more injuries than did nonbraced players (1984, 11% vs. 6%; 1985, 9% vs. 6%). Thus, Teitz's investigation suggested that prophylatic sleeves are not preventive and may be harmful.[35] Overall, these results demonstrated that benefits of knee sleeves in terms of prophylactic /fuctional support come at the expense of an increased incidence of injury.

Conversely, Tedeschi studied the effect of the Anderson (lateral support brace) stabler on various components of knee function. Subjects were allowed three practice trials prior to performing five maximal isokinetic knee extension and flexion tests. The results suggested no significant difference in peak torque to body weight ratio by one wearing a prophylactic knee support. Agility was also measured using the Semo agility test. The study produced no significant difference in agility by subjects wearing a prophylactic knee support.[34]

In addition, Sforzo et al. examined the effect of wearing prophylatic knee bracing upon performance in twenty-five male football players. Each subject had a resting blood sample taken prior to each testing session (eg. to establish blood profile). Followed by three minute warm-up on a treadmill and dynamometer testing by the Cybex II.

Quadriceps peak torque and time to fatique were measured. The protocol design included three practice trials prior to performing eight maximal isokinetic knee extensions at 60 degrees per second. Following the identification of peak torque, the subject performed maximal leg extensions at 120 degrees per second until force output diminished by 1/2 peak torque. Additionally, three minutes after the isokinetic test, subjects performed a Wingate cycle test. Maximal anaerobic power was calculated as the greatest output for a five second interval during the test. A post exercise blood sample was collected at the conclusion of each session (eg. establishes lactic acid levels following testing sessions). MANOVA was performed to examine any performance difference that may have existed in the dependent variables (ie. PT, RT, TF, AP, and HLA) between braced and non-braced conditions. The data suggested that bracing did not significantly reduce isokinetic performance of peak torque to body weight. time to fatique and average power in college football players.[33]

Colley maintained that knee supports do provide enhanced mechanical stability even under high physiologic loads. Colley's unpublished research also indicated that knee bracing may restore normal or near normal kinematics under high physiologic loading. Futhermore, Colley also suggested that it can be resolvable argued that knee bracing may enhance joint stability through stimulation of cutaneous and possibly, capsular mechanoreceptors.[4]

Baker et al.[3] studied the biomechanics of the static stabilizing effect of knee braces. Athleic braces were evaluated for their effect on abduction forces applied to a cadaver knee with no instability and with experimentally created medial instability. Under computer control, abduction, external rotational forces were applied while simultaneous data were obtained from an electrogoniometer with 6 degrees of freedom and transducers applied to the ACL and superficial medial collateral ligament at 0 to 20 degrees of flexion. The results showed a reduction in abduction angle of Lenox Hill derotation brace, 31%; CT brace, 16%; Generation II poliaxial kneecage, 45%; PRO AM knee braces, 5%; Don-Joy, 17%;McDavid Knee Guard, 2%; and Anderson Knee Stabler, 0%. Overall, the data suggested that the prophylatic sleeve demonstrated no significant difference in range of motion and that functional braces decreased range of motion.[3]

Delimitations

The following delimitations were integrated into the research design:

1. The study was limited to twenty Virginia Tech varsity football players.
2. The muscular function variables included isokinetic knee extension at 60º, 210º and 450 degrees per second .
3. The response variables included peak torque to body weight ratio, average power, work to fatique ratio and range of motion.
4. The Don-Joy knee support and the McDavid knee support brace were the only prophylatic supports examined.

Limitations

The following limitations were noted by the investigator:

1. The intact group sampling employed in this investigation reduced the

generalizability of the results.

2. The subjects were participating in fall football practice during the time of data collection.

Basic Assumptions

The following assumptions were made by the investigator:

1. The subjects were apparently healthy and free from any physical impairments that might affect performance.

2. Each subject induced maximum effort during each of the experimental testing sessions.

Definitions of Terms and Symbols

Average Power (AVP): The total work divided by the time it takes to perform the work. Power is used to measure muscular efficiency.

Don Joy Knee Sleeve (S): Protective knee sleeve designed by DonJoy Inc. which consists of neoprene and velcro straps.

M^c^David Knee Brace (B): Protective knee brace designed by M^c^David which consists of a single hinge and is made from hard plastic.

Peak Torque to Body Weight Ratio (PK/BW): A ratio displayed as a percentage of the maximum torque production to the subject's body weight.

Range of Motion (ROM): Measure in degrees of an extremity, through a particular movement, such as extension and flexion.

Work to Fatique Ratio (W/F): the ratio of the difference, expressed as a percentage, between the work in the first third to work in the last third of the test bout.

Summary

Knee injuries occur often and in most instances require extensive rehabilitation. There are preventive measures that are employed today to minimize the risk of serious knee injury. These preventive measures include, but are not limited to strengthening the muscle that surround the knee joint, neural training (PNF stretching), prophylatic knee supports and functional braces

Commercial knee braces seem to fall into one or two categories: functional or prophylatic. Previously knee braces were worn as functional knee braces, but the trend is moving toward prophylatic protection at all levels of competition..

Colley, Tedeschi, Sforzo et al. have investigated the prophylatic effect on isokinetic measures. There investigation suggests that isokinetic measures are not hampered by the prophylatic knee supports. On the other hand, Houston, Teitz, Farrar and others, have suggested the use of prophylatic supports decrease isokinetic performance, and may contribute to increasing the incidence of injury. The discrepancies in efficacy of the prophylatic benefits of the supports have led to inconsistencies among clinicians recommending their use.

This study investigated the effects of prophylatic knee sleeves/braces on selected isokinetic measures during a velocity spectrum isokinetic knee extension test. The isokinetic measures included: peak torque/body weight ratio, work/fatique, average power, and range of motion.

CHAPTER II
REVIEW OF LITERATURE

This chapter was organized in the following manner: (1) introduction; (2) the effects of wearing knee braces/sleeves on strength, power and endurance. (3) summary.

Introduction

Taping has been used for decades for improving joint stability. However, in the past five years prophylactic supports have gained significant popularity. Athletic trainers and coaches have primary dictated the mandatory usage of prophylatic supports in hopes of preventing injury and increasing performance. In an effort to minimize injury, the sports medicine team enacts various protocols (ie. weights, proprioception, prophylatic support). Weights are administered as part of the strength and conditioning program for each athlete. Predominately the lower extremities (ie. hips, knees) generate the most power during an explosive sport. Therefore, particular attention should be centered around the knee. Proprioceptive effects enable the athlete to activate his/her musculature in normally occurring activities. This means for the knee joint the aim is to enhance dynamic stability including use of propioceptive information, motor control and appropriate muscle force development. Prophylatic supports are those braces/sleeves which are designed specifically to prevent or reduce the severity of injury to the knee resulting from an externally applied force.[4]

Economically, the rapid growth of knee support usage is largely ascribed to intense promotions by manufacturers and preliminary reports of effectiveness.[10] The efficacy of such knee sleeves has been examined by researchers regarding the decrements of muscle inhibition that may decrease performance.[15,32] Conflicting research regarding its prophylatic benefits of the sleeve has led to inconsistencies among the clinicians recommending their use.

Unpublished isokinetic studies by Tedeschi, Johnson, May, Hawkins, and Martindale were conducted on subjects using prophylactic supports.
Each study suggested that performance was not affected while the knee was supported.

Tedeschi studied the effect of the Anderson stabler on various components of knee function. Subjects were allowed three practice trials prior to performing five maximal isokinetic knee extension and flexion tests. The results suggested no significant difference in peak torque to body weight ratio by one wearing a prophylactic knee support. Agility was also measured using the Semo agility test. The data also, suggested no significant difference in agility by one wearing a prophylactic knee braces on isokinetic performance.[34]

Johnson examined the effects of knee supports (Arco) on running and agility performance. Fourteen volunteer graduate students participated in the study. The protocol design consisted of an experimental (braced) and control (unsupported) group. Each group/subject then was asked to complete a maze and time (sec) was recorded. The data demonstrated no significant difference on running performance between the experimental (braced) and the control (unsupported) subjects.[18]

May conducted an investigation that was similar to Johnson's. May however, used a forty yard maze, as related to football agility. Thirty graduate students participated in the study. Each subject completed the agility test with and without a brace. No significant difference were reported between braced and the unbraced subjects during agility measures of muscle performance.[24]

Hawkins reinforced May's[24] and Johnson's[18] investigation through repetition of similar testing methodologies. Running speed however, was determined by timing subjects in a thirty yard sprint. The knee support was worn on the knee of the subjects preferred limb during testing. No significant difference of running speed was reported between braced or unbraced conditions.[12]

Consequently, Sforzo (1989) examined the effect of wearing prophylatic knee bracing upon performance in twenty-five male football players. Each subject had a resting blood sample taken prior to each testing session (eg. to establish blood profile). Followed by three minute warm-up on a treadmill and dynamometer testing by the Cybex II. Quadriceps peak torque and time to fatique were measured. The protocol design included three practice trials prior to performing eight maximal isokinetic knee extensions at 60 degrees per second. Following the identification of peak torque, the subject performed maximal leg extensions at 120 degrees per second until force output diminished by 1/2 peak torque. Additionally, three minutes after the isokinetic test, subjects performed a Wingate cycle test. Maximal anaerobic power was calculated as the greatest output for a five second interval during the test. A post exercise blood sample was collected at the conclusion of each session (eg. establishes lactic acid levels following testing sessions). MANOVA was performed to examine any performance difference that may have existed in the dependent variables (ie. PT, RT, TF, AP, and HLA) between braced and non-braced conditions. The data suggested that bracing did not significantly reduce isokinetic performance of peak torque to body weight. time to fatique and average power in college football players. [33]

Futher research by Polascik suggested that knee braces under three randomized conditons did not effect muscle and agiltiy performace. Thirty-two varsity football players performed a Semo agility test under three conditons: braced with a Anderson knee stabler, braced with a Arco knee stabler and unbraced. Each subject completed a Cybex test at 60 degrees per second for 3 repititions and 40 reptitions at 300 degrees per second. Data suggested that knee braces did not statistically effect agility or muscle performace.[23]

A biomechanics engineer with DonJoy (Colley), suggested that knee supports do provide enhanced mechanical stability even under high physiologic loads. Colley's unpublished research also indicated that knee bracing may restore normal or near normal kinematics under high physiologic loading. Futhermore, Colley also suggested that it can be resolvable argued that knee bracing may enhance joint stability and produce no effect on performance through stimulation of cutaneous and possibly, capsular mechanoreceptors. [4]

Baker et al.[3] studied the biomechanics of the static stabilizing effect of knee braces. Athleic braces were evaluated for their effect on abduction forces applied to a cadaver knee with no instability and with experimentally created medial instability.

Under computer control, abduction, external rotational forces were applied while simultaneous data were obtained from an electrogoniometer with 6 degrees of freedom and transducers applied to the ACL and superficial medial collateral ligament at 0 to 20 degrees of flexion. Overall, the data suggested that the prophylatic sleeve demonstrated no significant difference in range of motion.

On the contrary, Houston evaluated leg performance characteristics of young male athletes with and without their prescribed knee support braces. Isometric torque of the quadriceps was measured at 90 degrees of knee flexion. Velocities of 30º, 90º, 180º and 300 degrees per second were used to measure isokinetic torque. Power was measured using a short stair run. The Cybex II dynamometer was used as a measuring device. Testing took place over a 4-week period, with at least 1 day rest between trials. Mean maximal isokinetic contractions of the knee extensions declined 12 to 30% when compared to values without the knee support. The data revealed that dynamic leg muscle performance was impaired by the use of prophylactic knee braces.[15]

Teitz assessed whether preventive knee supports decreased the severity and/or incidence of knee injury in college football. Data were collected from 71 division I NCAA schools in 1984 (6,307 players) and from 61 of those schools in 1985 (5,445 players). Variables such as player position, playing surface, injury mechanism, type of brace and history of previous knee injury were included in the analysis. The results suggest that braced players had significantly more knee injuries than did nonbraced players (1984,11% vs. 6%; 1985, 9% vs. 6%; $P < 0.001$), and the incidence of injuries was not significantly different between 1984 and 1985. Aside from bias in the overall School data, the results indicate that prophylatic braces are not preventive and may be harmful to the athlete.[33]

Knutzen investigated a biomechanical analysis of two knee braces. Twenty-one subjects were assigned to one of three groups based on medical records. Four test conditions were investigated: (1) healthy or control limb, (2) injured and experimental limb, (3) Generation II knee brace, and (4) Marquette knee stabilizer knee brace. Subjects attended three experimental sessions. Once fitted for the brace, the subject practiced running through the experiment (ie. treadmill running). Ground reaction forces were measured using electrogoniometry. Data were collected for ten force platform trials and five test conditions. Both knee brace applications where shown to drastically reduce knee flexion during swing and support, total rotation, and total varus/valgus movement parameters of the experimental knee joint movement. Both brace applications were also shown to alter the experimental limb by increasing the relative time to the achievement of the initial collision force, creating a greater collision and thereby creating larger impulses in both the vertical and foreaft directions during the initial contact phase.[20]

Wojtys assessed the relative restraints that are provided by current knee braces, using six cadaver knee joints (legs). The tests were conducted at 30º and 60 degrees of flexion of the knee joint, and a mechanical loading system applied loads that caused anterior - posterior translation and internal - external rotation. After the specimens were thawed, each was tested for ligamentous integrity with use of manual clinical-testing procedures. One specimen served for the development of the testing procedures, and five specimens were used in the experimental protocol. Anterior and posterior loads were applied with a pneumatic cylinder in series with a load cell that was connected, in parallel, with a linear potentiometer. Rotations were produced through a bicylce sprocket that was coupled to the tibial spline, with the chain wrapped halfway around the sprocket and the ends attached to a pneumatic cylinder in series with a load cell. The measurements of force were multiplied by the lever-arm length to calculate the torsional loads. The data suggested that knee braces limit abnormal tibiofermoral displacements by ten to seventy-five percent in translation. This study demonstrated that knee supports provide a restraining influence on range of motion, that maybe beneficial in the control of abnormal displacement of the knee, but that the degree of restraint varies considerably between braces.[38]

Sforzo studied the effect of prophylatic knee bracing on performance. However, during the investigation Sforzo's subjects included ten female lacrosse players. Each subject had a resting blood sample taken prior to each testing session (eg. establishes blood profile). Followed by three minutes warm-up on a treadmill and dynamometer testing by the Cybex II. Quadriceps peak torque and time to fatique were measured. The protocol design included three practice trials prior to performing eight maximal knee extensions at 60 degrees per second. Following the identification of peak torque, the subject performed maximal leg extensions at 120 degrees per second until force output diminished by 1/2 peak torque. Additionally, three minutes after the isokinetic test, subjects performed a Wingate cycle test. Maximal anaerobic power was calculated at the greatest output for a five second interval during the test. A postexercise blood sample was collected following each session (eg. establishes blood lactic acid level). MANOVA was performed to examine any performance difference that may have existed in the dependant variables between braced and non-braced conditions. The results suggested that knee bracing in female lacrosse players significantly reduced isokinetic knee performance.[33]

The testing methodologies represented in these studies provide similar results that are grouped in one of two categories. The first group maintained an approval of knee supports due to non significant differences in performance. The latter denied the usage of knee supports, while concluding that knee supports may indeed increase the incidence of injury and decrease performance. Likewise, both categories provided similar testing methods and maintained a combination of asympotmatic and symptomatic subjects. Sofzo's study was the only study to employe identical protocols with different subjects (ie. gender difference). An explanation of the differences between results may be explained due to type of subjects tested, type of brace used, and familarity of subjects with prophylatic braces/sleeves.

Summary

Recent research on the efficacy of the prophylatic knee supports convey inconsistences. The protocols were described as in favor of the usage of prophylatic supports that do not affect performance or the denial of the prophylatic supports that may affect performance and even increase the incidence of injury.

Tedeschi, Johnson, May, Sforzo, Polascik and Colley, examined respectively, the effects of prophylatic knee supports on performance. The general experimental protocol design was similar in each investigation. Thus, each study collaborately supported each of their findings. Consequently, their results revealed that prophylatic supports did not alter performance. Conversely, Houston, Teitz, Knutzen, and Sforzo examined respectively, the effects of isokinetic performance and speed. Their results suggested a decrement of all isokinetic performance measures. Peak torque to body weight ratio, work to fatique ratio, average power and range of motion were shown to decrease with the use of the prophylatic knee support. The results also revealed that prophylatic knee supports increased the rate of injury occurrence. Teitz suggested that not only did the prophylatic supports hender performance but increased the rate of injury. Compartively, the methodologies are similar within each investigation. However, the difference between the two respective theories are the aggressiveness of the protocol and the type of subjects participating The protocols that were consider agressive were characterized by the ability to perform aerobic and anerobic protocols. The type of subjects used was either normal (asymptomatic) or abnormal (symptomatic). In most instances the latter abnormal was used. Therefore, indicating and thus accounting for the discrepancy of isokinetic performance results. This study attempted to compare a normal knee with the knee sleeve and knee brace. However, the approriate protocol would be one that could solve the efficacy of prophylactic knee support and minimizing the risk of comparing the lab results (ie. isokinetic variables) to the actual (ie. field variables). Futhermore, an attempt to compare prophylactic sleeves (preventive) to prophylatic braces (functional) may also, solve the efficacy knee supports.

CHAPTER III

JOURNAL MANUSCRIPT

THE EFFECTS OF WEARING A PROPHYLATIC KNEE SLEEVE ON SELECTED ISOKINETIC VARIABLES DURING A VELOCITY SPECTRUM KNEE EXTESION TEST.

MICHAEL H. CALL

ABSTRACT

Twenty Virginia Tech varsity football players, age 18-24, volunteered as subjects to examine the effects of wearing prophylatic knee sleeves/ braces on selected isokinetic variables (i.e. strength, power and endurance). Each subject performed the Biodex (Multi-Joint System 2_{AP}) knee extension test in each of three experimental conditions: sleeved with the Don Joy Knee support (S-DJ); braced with the M^{c}David lateral knee support (B-MD); and unbraced/ sleeved (Un). Each condition and limb was randomized. The subjects were then administered a Biodex knee extension test at 60 deg/sec, 210 deg/sec, and 450 deg/sec. The test protocol consisted of five maximal repetitions at 60 deg/sec, twenty maximal repetitions at 210 deg/sec and thirty maximal repetitions at 450 deg/sec. The following isokinetic variables were recorded: (1) peak torque to body weight at 60 deg/sec. (2) work to body weight at 210 and 450 deg/sec. (3) average power at 210 and 450 deg/sec, and (4) range of motion at 60, 210, and 450 deg/sec. Two way repeated measures analysis of variance revealed no significant difference ($p > .05$) in peak torque to body weight, work to fatique, average power and range of motion as they were tested within the two experimental conditions and one control condition. One way repeated measures analysis of variance in absolute peak torque revealed significant diffference ($p > .05$) within the experimental conditions. The investigator concluded that prophylatic knee sleeves/braces effects peak torque to body weight ratio; the effect of different levels of condition does not depend on what level of speed is present for work to fatique, average power and range of motion.

<u>Introduction</u>

Reducing the incedence of injury remains the primary concern within the sports medicine field. However, no injury can compartivly be matched (in terms of rehabilitation) with that involving the knee. Many team physicians and coaches have prescribed and/or required the use of prophylatic knee supports. In this regard, an attempt to minimize injury, improve stability and increase performance is hypotheized. Besides, providing preventive measures, a knee brace should not impede performance. Nevertheless, in the last decade prophylatic supports have reached economic maturity. Futhermore, the efficacy of prophylatic knee sleeves remain virtually independant upon researchers. In light of the conflicting reports regarding the effiacy of the prophylatic knee support, maximizing the performance of each althlete has been a standard goal of the medical, training, and coaching staff. Hence, this investigation was to examine the effiacy conflict of the prophylatic knee supports (ie. Don-Joy/sleeve; M^{C}David/brace) upon performance as measured by laboratory variables in healthy college football players. In addition this study attempts to compare the performance variables of the DonJoy sleeve against the M^{C}David lateral support brace.

METHODOLOGY:

Twenty physically active, healthy, male college football players with no prior history of sleeve use will perform this study. Exclusion criteria included any previous knee pathology requiring surgical intervention, anterior cruciate ligament deficiency and/or patella dysfunction. Each subject performed the Biodex knee extension test at 60º/second, 210º/second and 450º/second. Each subject performed the test in experimental and control conditions. The order of the test will be randomized. A screening with identification of deficit concluded each subject as a viable candidate. The test protocol consisted of 5 repetitions at 60º/second, 20 repetitions at 210º/second and 30 repetitions at 450º/second. The following isokinetic variables were recorded: (1) peak torque to body wieght ratio at 60º/second. (2) work to fatique ratio at 210º/second and 450º/second. (3) average power at 210º/second and 450º/second, and (4) range of motion at 60º/second, 210º/second and 450º/second. The HPE division and the Human Subject Committee at Virginia Tech reviewed this study. Each participant signed an informed consent prior to testing.

Statistical Results:

Each subject was administered a control and two experimental conditions (repeated measures). The order of testing was randomized. The Jandel Sigma Statistical System[15] was used to analyze the data.

Repeated measures analysis of variance was used to calculate intraclass reliability for the investigation of peak torque to body weight ratio for each condition. The control condition produced reliability of R = .96, the sleeve condition produced reliability of R = .97 and the brace condition produced reliability of R = .98.

Peak Torque to Body Weight:

Two way repeated measures analysis of variance was used to test the hypothesis of no difference of peak torque to body weight ratio. Significant (p > .01) main effects of speed were found. No significant interaction between condition and speed was noted.

Work to Fatique Ratio:

Two way repeated measures analysis of variance was used to test the hypothesis of no difference of work to fatique ratio. Significant ($p > .01$) main effects of speed was found. Significant ($p > .05$) main effects of condition was found. No significant interaction between condition and speed was noted.

Average Power:

Two way repeated measures analysis of variance was used to test the hypothesis of no difference of average power. Significant ($p > .01$) main effects of speed was found. No significant interaction between condition and speed was noted.

Range of Motion:

Two way repeated measures analysis of variance was used to test the hypothesis of no difference of range of motion. Significant ($p > .01$) main effects of speed was found. Significant ($p > .01$) main effects of condition was found. No significant interaction between condition and speed was noted.

No interaction between condition and speed was noted in all performance measures. Therefore, each performace variable was independent of the experimental condition and isokinetic speeds.

Research Discussion

Most questions regarding the efficacy of prophylatic supports are unanswered, due to inconsistencies. Many thought the question of efficacy was due to the methodology and subjects, however one may concluded that the efficacy has never been challenged. The majority of the supporting literature that was used in of this study revealed testing procedures on fuctional supports; due to the natural of the subjects that were participating.

There is a substantial body of literature on knee bracing and the efficacy of bracing. What has to be done is to evaluate the literature for methodology, subject selection and most importantly the delineation of type of supports being used. Indeed, their is little controversy over the efficacy of functional supports and the ability to enable symptomatic subjects to participate in athletics successfully. Another factor in selection subjects would be gender. Most studies look at the only male athletes. Sforzo et al. was the only researcher that examined the identical protocol upon male and female subjects. This would explain differences upon gender related studies and this present study. Most studies like Houston, Hansen and Teitz used subjects that had previous knee pathologies. The problem with subjects having previous knee pathologies is their reliability to produce maximum efforts during the testing procedures. Another problem may be in the validity of the testing results when comparing them with other subjects with no knee pathology. The Biodex isokinetic multi - joint system has shown valid and reliable data for measuring muscle function. In this study, peak torque to body weight was shown to support Houston's study and produce significant difference between baseline (control) and braced/sleeved conditions. Futhermore, peak torque, work to fatique and average power in this present study contraindicated the results of Hansen and Teitz. The only similarity to Hansen and Teitz was that range of motion differed independently in speed and condition across all conditions.

The results of this present study however, showed no significant effect in healthy asymptomatic subjects; upon isokinetic muscle strength in peak torque to body weight ratio, work to fatique ratio, average power and range of motion. This taken in conjunction with the existing research leads the investigator to suggest that wearing prophylatic knee sleeves or braces does not significantly affect performance in male subjects with normal knee function. Additionally, the results indicated that the ROM characteristic at 60 degrees per second differed from 210 and 450 degrees per second respectively. The differences appear affected due to pre-load conditions and possibly the number of repetitions. Knutzen et al. reported that all range of motion values for the two non-brace conditions were considered greater than these for the two brace conditions. The difference in Knutzen's study and this present study may be in the selection of participants (ie. normal vs. surgical intervened).

Functional discussion

An increasing number of orthopaedic surgeons are using braces for the knee following surgery. Presumably, an increasing number of athletic trainers are using prophylactically sleeves and braces for the knee.

One of the most important findings of this prospective, randomized study was that there were communication barriers between the economic market and medically personnel. A brief description of the two reveal that fuctional braces are considered and marketed as braces that are used following surgical intervention. The prophylatic braces is used as a preventive measure and with some discretion a psychologically anomaly. The focus on future research may provide substantial evidence to the efficacy; as more research is concluded using prophylatic supports that differ in material and in mechanical, which affect support function.

REFERENCES

Astrand P.O., Rodahl K: Textbook of Workphysiology: Physiological bases of exercise. Ed. 2 New York, Mcgraw & Hill, 1977.

Collie, P., Interview, Senior Research Engineer for Don-Joy Incorop.1994

Davies, G.J. A Compendium of Isokinetics in Clinical Usage. LaCrosse, WI: S &S Publishing; pp.22, 24, 39, 43, 173.1984.

Fujiwara, L.M., Perrin, D.H., & Buxton, B.P. "The Effect of Three Lateral Knee Braces on Speed and Agility in Experienced and Non-experienced Weareres.

JNATA.160-161, 1990.

Hansen, B.L., J.C. Ward, and R.C. Diehl. "The Preventive Use of the Anderson Knee Stabler in Football". Physician & Sportsmedicine. 14: 257-260, 1985.

Hawkins, H.A." The Effect of the Arco Knee Guard on Running Speed". Unpublished master's thesis, Indiana State University, Terre Haute, Indiana. 1977.

Hewson G.F. R.A. Mendini., J.B.Wang, " Prophylactic Knee Bracing in College Football". Am.J Sports Med. 14: 262-266, 1986.

Houston, M.E. "Leg Muscle Performance of Athletes With and Without Knee Support". Arch Phys Med Rhab. Vol. 63. pp. 431-432. 1982.

Hofmann, A.A. "Knee Stability in Orthotic Knee Braces". Am. J. Sport Med. Vol.12 pp.371-374. 1984.

Jandel Corporation,. Sigma Statistical Analysis Program. 1985-1995.

Johnson, A. " The Effects of Wearing a Knee Guard on Agility". Unpublished master's thesis, Indiana State University, Terre Haute, Indianal. 1969.

Klafs, C.L. D.D. Arnheim. Modern Principles of Athletic Training Science of Sports Injury Prevention & Management. Ed. 5, St Louis, CV Mosby, 1981.

Knutzen K. M. "A Biomechanical Analysis of Two Functional Knee Braces". Med. Sci Sports Exerc. Vol. 19. pp. 303-309.1987.

Polascik, M., Unpublished master's thesis. "The Effect of Protective Knee Braces on Agility and Muscle Performance". Virginia Tech, Blacksburg, Virginia. 1989.

Rasch, P.J. and R.K. Burke, "The Science of Human Movement," Kinesology and Applied Anatomy", Lea & Febiger. pp. 285-310. 1978.

Sforzo. G.A., N.M. Chen, C.A. Gold and P.A. Frye, " The Effect O Prophylactic Knee Bracing on Performance," Medicine and Science in Sports and Exercise, Vol.21, No. 3, 1989, pp. 254-257.

Tedeschi A.J.," The Effect of the Anderson Knee Stabler on Various Components of Knee Function". Unpublished master's thesis, University of the Pacific, Stockton, California . 1984.

Teitz C.C., Hermanson B.A., Kronmal R.A., Dieher P.H. "Evaluation of the Use of Braces OT Prevent Injury to the Knee in Collegiate Football Players". J Bone JointSurg.Vol. 69-A. pp. 2-8. 1980.

CHAPTER IV

SUMMARY OF THE STUDY

This study investigated the effect of prophylatic braces/sleeves on isokinetic knee extension. Twenty Virginia Tech varsity football players, age 18-24, volunteered as subjects to examine the effects of wearing prophylatic knee sleeves/ braces on selected isokinetic measures (i.e. strength, power and endurance). Each subject performed the Biodex (Multi-Joint System 2_{AP}) knee extension test in each of three experimental conditions: sleeved with the Don Joy Knee support (S-DJ); braced with the M^c^David lateral knee support (B-MD); and the control, unsupported condition (C-UN). The order of experimental conditions and the specific knee tested were randomized. The subjects were administered a Biodex knee extension test at 60 deg/sec, 210 deg/sec, and 450 deg/sec. The test protocol consisted of five maximal repetitions at 60 deg/sec, twenty maximal repetitions at 210 deg/sec and thirty maximal repetitions at 450 deg/sec.

The following isokinetic measures were recorded: (1) peak torque to body weight ratio at 60 deg/sec. (2) work to fatigue ratio at 210º and 450 deg/sec. (3) average power at 210º and 450 deg/sec, and (4) range of motion at 60º, 210º, and 450 deg/sec.

Peak torque to body weight ratio was found to be at the highest foot pound between or on repetition two and three in all experimental conditions. Descriptive statistics for peak torque to body ratio across three experimental conditions and across the three isokinetic speeds revealed that peak torque to body weight ratio was independent of the experimental conditions and isokinetic speeds in all three experimental conditions. The main effects of peak torque to body weight ratio revealed no significant interaction between condition and speed in all three experimental conditions.

Descriptive statistics for average power among conditions revealed that mean foot pounds increased as progressive with the repetitions. Average power was found to be at the highest foot pound between or on repetitions two and three in all experimental conditions. The results also, revealed that average power was independent of the experimental conditions and isokinetic speeds in all three experimental conditions. The main effects of work to body weight ratio revealed no significant interaction between condition and speed in all three experimental conditions, however, significant ($p > .01$) differences was found independently in speed.

Descriptive statistics for work to fatique ratio among trials revealed that mean foot pounds increased as progressive with the repetitions. Work to fatique ratio was found to be at the highest foot pound between or on repetitions two and three in all experimental conditions. Descriptive statistics for work to body ratio across three experimental conditions and across the three isokinetic speeds revealed that work to body eight ratio was independent of the experimental conditions and isokinetic speeds in all three experimental conditions. The main effects of work to fatique weight ratio revealed no significant interaction between condition and speed in all three experimental conditions, however, significant ($p > .01$) differences were found independently in main effects of speed and at the ($p > .05$) difference on condition in all three experimental conditions.

Descriptive statistics for range of motion among trials revealed that mean degrees increased as progressive with the repetitions. Range of motion was found to be at the highest degree between or on repetitions two and three in all experimental conditions. Descriptive statistics for range of motion across three experimental conditions and across the three isokinetic speeds revealed that range of motion was independent of the experimental conditions and isokinetic speeds in all three experimental conditions. The main effects of range of motion revealed no significant interaction between condition and speed in all three experimental conditions, however, significant ($p > .01$) differences were found independently in both speed and condition in all three experimental conditions.

The two way repeated measures analysis of variance was used to test the hypothesises. The ANOVA tested the hypothesis that peak torque to body weight ratio was independent of the experimental conditions and isokinetic speeds. Significant ($p > .01$) main effects of speed were found. The ANOVA tested the hypothesis that average power was independent of the experimental conditions and isokinetic speeds. Significant ($p > .01$) main effects of speed were found. Futhermore, the two way repeated measures analysis was also used to test the hypothesis that work to fatique ratio was independant of the experimental conditions and isokinetic speeds and the hypothesis that range of motion was independent of the experimental conditions and isokinetic speeds. Two way ANOVA indicated ($p > .01$) was found with each, work to fatique ratio and range of motion. Significant ($p > .05$) main effects of condition was found on work to fatique ratio and significant ($p > .01$) main effects of condition was found on range of motion. No significant interaction between condition and speed were noted for either work to fatique ratio or range of motion.

The conclusions from this study suggest that individuals who use these prophylatic supports should overlook previous suggestions about the decrement of performance. As the data indicated, prophylactic supports produced no significant difference in isokinetic knee extension measures. The changes that were reported however, show no correlation with the interaction between speed and condition and thus, should be reviewed independently.

Electrogoniometry and force dynamometry allow for a more comprehensive evaluation of brace function during the activity for which the support is prescribed. The basic problem with these various clinical assessments, however, is the lack of generalizability to knee supports usage during dynometery performance and equating laboratory data to locomotive performance. Nevertheless, quantification of these observations should provide valuable information for both future research and medical personnel.

Recommendations for Future Research

The following recommendations for further study are suggested:

1. Further testing of the material and mechanical aspects of knee supports.
2. Further testing that would focus on gender differences on isokinetic strength performance; as it relates to the efficacy of knee supports.
3. Further testing using electromyography to determine the contractile rate of the quadriceps in knee extension with the use of knee supports .
4. Invitro study investigating the presence or inhibition of oxygen delivery with the use of knee supports.

Reference

1. Astrand P.O., Rodahl K: Textbook of Workphysiology: Physiological bases of exercise. Ed. 2 New York, Mcgraw & Hill, 1977.

2. Baker, B.E., VanHanswyk, E., Bogosian, S.P., & Werner, F.W. " The effect of knee braces on impact loading of the knee". Am J. Sports Med. 17:182-186. 1989

3. Baker, B.E., VanHanswyk, S. Bogosion, F.W. Werner, and D.Murphy. " A Biomechanical Study of the Static Stabilizing Effect of Knee Braces Used for Medical Stability". Am.. J. Sports Med. 12: 409, 1987
.

4. Collie, P., Interview, Senior Research Engineer for Don-Joy Incorop.1994

5. Cybex. Isolated Joint Testing Exercise: A Handbook for Using the Cybex. Rokonkoma, NY: Cybex;1983.

6. Davies, G.J. A Compendium of Isokinetics in Clinical Usage. LaCrosse, WI: S &S Publishing; pp.22, 24, 39, 43, 173.1984.

7. Farrar, M., Thorland, W." Relationship Between Isokinetic Strength and Sprint Times in College-age Men". J /Sports Med Phys Fitness. Vol. 27; 368-372. 1984.

8. Ferrell, E., Interview, Head Althletic Trainer for Virginia Tech. 1994

9. Fujiwara, L.M., Perrin, D.H., & Buxton, B.P. "The Effect of Three Lateral Knee Braces on Speed and Agility in Experienced and Non-experienced Weareres. JNATA. 160 - 161, 1990.

10. Garrick, J.G., Requa, R.K. "Prophylactic Knee Bracing". Am J Sport Med. No.5 Vol.15:471-477,1987.

11. Hansen, B.L., J.C. Ward, and R.C. Diehl. "The Preventive Use of the Anderson Knee Stabler in Football". Physician & Sportsmedicine. 14: 257-260, 1985.

12. Hawkins, H.A." The Effect of the Arco Knee Guard on Running Speed". Unpublished master's thesis, Indiana State University, Terre Haute, Indiana. 1977.

13. Hewson G.F. R.A. Mendini., J.B.Wang, " Prophylactic Knee Bracing in College Football". Am.J Sports Med. 14: 262-266, 1986.

14. Hindtze, J.L., Number Cruncher Statistical System. Kaysville, Utah,1995.

15. Houston, M.E. "Leg Muscle Performance of Athletes With and Without Knee Support". Arch Phys Med Rhab. Vol. 63. pp. 431-432. 1982.

16. Hofmann, A.A. "Knee Stability in Orthotic Knee Braces". Am. J. Sport Med. Vol.12 pp.371-374. 1984.

17. Jandel Corporation,. Sigma Statistical Analysis Program. 1985-1995.

18. Johnson, A. " The Effects of Wearing a Knee Guard on Agility". Unpublished master's thesis, Indiana State University, Terre Haute, Indianal. 1969.

19. Klafs, C.L. D.D. Arnheim. Modern Principles of Athletic Training Science of Sports Injury Prevention & Management. Ed. 5, St Louis, CV Mosby, 1981.

20. Knutzen K. M. "A Biomechanical Analysis of Two Functional Knee Braces". Med. Sci Sports Exerc. Vol. 19. pp. 303-309.1987.

21. Lysom, J. "The Effect of a Patellar Brace on Performance in a Knee Extension Strength Test". Am. J. Sport Med. Vol. 12. pp. 110-113. 1984.

22. Markolf, K.L., A. Graff-Radford, and H.C. Amstutz, "In Vivo Knee Stability," Journal of Bone and Joint Surgery, 60A:5. pp. 664-674. 1984.

23. Martindale, A., " Effect of the Arco Knee Guard on Agility". Unpublished master's thesis, Indiana State University, Terre Haute, Indiana. 1973.

24. May, T.L. " Effect of the Arco Knee Guard Upon Agility Determined by the Forty Yard Maze Test". Unpublished master's thesis, Indiana State University, Terre Haute, Indiana. 1971.

25. Polascik, M., Unpublished master's thesis. "The Effect of Protective Knee Braces on Agility and Muscle Performance". Virginia Tech, Blacksburg, Virginia. 1989.

26. Powel, J.W. " Pattern of Knee Injuries Associated with College Football 1975-1982". JNATA. Vol. 20. pp. 104-109.1984.

27. Prentice, W. E. "The Effects of Lateral Knee Stabilizing Braces on Running Speed and Agility". JNATA.Vol. 15. pp. 11-116. 1987.

28. Rasch, P.J. and R.K. Burke, "The Science of Human Movement," Kinesology and Applied Anatomy", Lea & Febiger. pp. 285-310. 1978.

29. Rovere, G.D., H.A. Haupt, and C.S. Yates. "Prophylactic Knee Bracing in College Football". Am. J. Sports Med. Vol. 15. pp. 111-116, 1987.

30. Scriber K., Matheny M. "Knee Injuries in College Football: an 18 year report". JNATA. Vol. 25. pp. 233-236. 1985.

31. Seering, W.P., R.L. Piziali, D.A. Nagel and D.J. Schurman, "The Function of the Primary Ligaments of the Knee in Varus-Valgus and Axial Rotation," Journal of Biomechanics, Vol. 13, pp. 785-794. 1980.

32. Sitler M., Ryan J., Hopkinson W., et al. "The Efficacy of a Prophylactic Knee Brace to Reduce Knee Injuries in Football". Am J Sport Med. Vol. 18. pp. 310-315. 1990.

33. Sforzo. G.A., N.M. Chen, C.A. Gold and P.A. Frye, " The Effect O Prophylactic Knee Bracing on Performance," Medicine and Science in Sports and Exercise, Vol.21, No. 3, 1989, pp. 254-257.

34. Tedeschi A.J.," The Effect of the Anderson Knee Stabler on Various Components of Knee Function". Unpublished master's thesis, University of the Pacific, Stockton, California . 1984.

35. Teitz C.C., Hermanson B.A., Kronmal R.A., Dieher P.H. "Evaluation of the Use of Braces OT Prevent Injury to the Knee in Collegiate Football Players". J Bone JointSurg.Vol. 69-A. pp. 2-8. 1980.

36. Thorstensson A., G. Grimby., J. Karlsson. " Force-velocity relations and Fiber Composition in Human Knee Extensor Muscles. J Appl. Physiol. 40: 12-16,1976.

37. Welsh, R.P., "Knee Joint Structure and Function," Clinical Orthopaedics and Related Research",Vol. 147, pp. 7-14. 1980.

38. Wojtys, E.M., P.V. Loubert., S.Y. Serafin and D.M.Viviano. "Use of a Knee Brace for Control of Tibial Translation and Rotation". The Journal of Bone and Joint Surgery. Vol. 72-A, No. 9, pp. 1323-1329, 1990.

APPENDIX A:

DETAILED METHODOLOGY

METHODOLOGY

Introduction:

The purpose of this study is to investigate the effects of knee sleeves and knee braces on selected isokinetic measures during knee extension. Isokinetic variables were measured using a Biodex isokinetic dynamometer. Speeds of 60, 210 and 450 degrees/second joint angle velocity were used to measure peak torque to body weight ratio, work to fatique ratio, average power, and range of motion.

Selection of Subjects:

Twenty male Virginia Tech varsity football players volunteered to participate in this investigation. The following criteria was used for the selection of the subjects:

1. The subjects did not have any predisposing orthopaedic condition of the knee, hip, low back or ankle (eg. prior corrective surgery or extreme laxity of the ligaments or tendons surrounding the knee, hip, or ankle joint).
2. The subjects completed and passed a subject screening evaluation. The orthopaedic screening form is found in Appendix B.
3. The subjects tested were limited to freshman and/or scout team players.
4. This investigation was approved by the division of Human Nutrition &

Foods human subject committee. Each participant read and signed the informed consent form prior to their participation in this study. The informed consent form is found in Appendix C.

Calibration Verification:

Calibration of the Biodex System II was performed by the investigator before the study and just after the final performance test. The calibration/verification procedure recommended by Biodex Medical System were followed.

Sleeve and Brace Positioning:

The DonJoy prophylatic knee sleeve was positioned according to manufactures suggestion. The sleeve was pulled over the knee with the "donut" (hole in brace) surrounding the patella. The proximal and distal strapes were then tightened.

The McDavid prophylatic knee brace was also positioned according to manufactures suggestion. The brace was positioned with the braces hinge to the subjects normal knee joint movement.

Subject Positioning:

Once the subject was properly fitted, he was secured in the proper test position by the use of velcro stabilizer straps. The straps included the upper torso strap, the pelvic strap, the quadriceps strap and the ankle strap. The stabilizer straps secured the subject and minimized the effect of muscle substitution.

Experimental Protocol:

Each subject performed the Biodex knee extension test at the speeds of 60º/second, 210º/second, and 450º/second. Each subject performed the test in both the experimental and control conditions. The order of experimental conditions and its specific knee tests were randomized. The test protocol consisted of 5 repetitions at 60º/second, 20 repetitions at 210º/second and 30 repetitions at 450º/second. The following isokinetic measures were recorded during the testing sessions : (1) peak torque to body weight ratio at 60º/second. (2) work to fatique ratio at 210º/second and 450º/second. (3) average power at 210º/second and 450º/second, and (4) range of motion at 60º/second, 210º/second and 450º/second. A typical testing procedure consisted of the following:

Orientation Session :

1. The subjects body weight was recorded.
2. The subject warmed-up for 4-5 minutes on a bicylce ergometer.
3. A metronome was used to maintain the correct pedaling rate. The metronome was set for 50 rev/min.
4. The seat of the bicycle was adjusted for each subject.
5. Subject then stretched for 3-5 min.
6. Task orientation was provided for both the preferred and nonpreferred limbs.
7. The following test protocol was administered:

   60º/second x 5reps, 210º/second x 20 reps, 450º/second x 30 reps respectively.

   2 minute recovery period was allowed between each isokinetic test.

Experimental Session 1: (3 condition randomization)

1. The subjects body weight was recorded.
2. The subject warmed-up for 4-5 minutes on a bicylce ergometer.
3. A metronome was used to maintain the correct pedaling rate. The metronome was set for 50 rev/min.
4. The seat of the bicycle was adjusted for each subject.
5. Subject then stretched for 3-5 min.
6. Randomization of condition (eg. Control, Sleeve, Brace) and limb (preferred, nonpreferred) then depicted order of testing. {Example sleeve/preferred}
7. After randomization occurred, the follow test protocol was administered: 60º/sec x 5reps, 210º/sec x 20 reps, 450º/sec x 30 reps respectively. 2 minute recovery period was allowed between each isokinetic test.

Experimental Session 2: (2 condition randomization)

1. The subjects body weight was recorded.
2. The subject warmed-up for 4-5 minutes on a bicylce ergometer.
3. A metronome was used to maintain the correct pedaling rate. The metronome was set for 50 rev/min.
4. The seat of the bicycle was adjusted for each subject.
5. Subject then stretched for 3-5 min.
6. Randomization of condition (eg. Control, Brace) and limb (preferred, nonpreferred) then depicted order of testing. {Example control/preferred}
7. After randomization occurred, the follow test protocol was administered: 60º/sec x 5reps, 210º/sec x 20 reps, 450º/sec x 30 reps respectively. 2 minute recovery period was allowed between each isokinetic test.

Experimental Session 3: (remaining condition)

1. The subjects body weight was recorded.

2. The subject warmed-up for 4-5 minutes on a bicylce ergometer.

3. A metronome was used to maintain the correct pedaling rate. The metronome was set for 50 rev/min.

4. The seat of the bicycle was adjusted for each subject.

5. Subject then stretched for 3-5 min.

6. Final condition was tested (eg. Brace) and randomization of limb occurred (preferred, nonpreferred) {Example: brace/preferred}

7. After randomization occurred, the follow test protocol was administered: 60º/sec x 5reps, 210º/sec x 20 reps, 450º/sec x 30 reps respectively. 2 minute recovery period was allowed between each isokinetic test.

Results of the Investigation:

The purpose of this study was to examine the influence of wearing protective knee supports during selected isokinetic tests. The specific measures included; sleeved, braced and controlled conditions. The prophylatic knee supports that were used in this study included the Don-Joy knee supports sleeve, and the M^c^David knee support brace. Isokinetic parameters were measured using the Biodex Multi-Joint System 2_{AP} Dynamometer. Twenty football players at Virginia Tech participated in this investigation. Isokinetic speeds of 60º, 210º, and 450 degrees/sec. were used to measure isokinetic knee extension. The experimental measures included: Peak torque/body weight ratio, work/fatigue ratio, average power and range of motion. The Jandal statistical system for windows software [15] computer program was used for all statistical analysis.

Reliability Estimates:

Repeated measures (ANOVA) was used to calculate the intraclass reliability estimates for the isokinetic measure of PK/BW for each experimental condition (control, sleeve, brace). The intraclass reliability estimates computed from the repeated measures ANOVA ranges from R = .96 (control) to R = .98 (braced). The intraclass reliability estimate for the sleeve condition (sleeve) was R = .97 The repeated measures (ANOVA) source table and the intraclass relability estimates appear in appendix D (STAT).

Statistical Testing

Two-way repeated measures ANOVA were performed to determine main effects and interactions of experimental conditions (control, sleeve, and brace) and isokinetic speeds (60, 210, 450 degrees per second joint angle velocity). Simple effects ANOVA's were performed when there was a significant ($p < 0.05$) condition*speed interaction. Multiple comparisons using Tukey's HSD post-hoc test was then performed when there were significant main effects.

The investigator tested the research hypotheses using a one-way ANOVA for repeated measures and a two-way ANOVA for repeated meaures (Jandel Scientific, 1997) The alpha level for all statistical tests was ($P<.05$). Complete Statistical tables and results are located in Appendix D.

1. To test the hypothesis:

Ho: There was no difference in peak torque to body weight ratio in isokinetic knee extension at 60 degrees per second joint angle velocity when the knee was tested in the sleeve, brace and control (unsupported) conditions.

A one-way ANOVA for repeated measures was used to test this hypothesis. There was a significant ($P = 0.03$) among the treatment groups. Therefore the investigator rejected the null hypothesis.

An all pairwise multiple comparision procedure (Tukey Test) was utilized to isolate the group or groups that were different.

Comparisons for the factor, conditions are found in Appendix D.

2) To test the hypothesis:

Ho: There was no difference in work to fatique ratio in isokinetic knee extension at 210º and 450 degrees per second joint angle velocity when the knee was tested in the sleeve, brace and control (unsupported) conditions.

A two-way ANOVA for repeated measures was used to test this hypothesis. The effect of different levels of condition does not depend on what level of speed is present ($P = 0.394$). There is no significant interaction between condition and speed. Therefore the investigator failed to reject the null hypothesis.

3) To test hypothesis:

Ho: There was no difference in average power in isokinetic knee extension at 210º and 450 degrees per second joint angle velocity when the knee was tested in the sleeve, brace and control (unsupported) conditions.

A two-way ANOVA for repeated measures was used to test this hypothesis. The effect of different levels of condition does not depend on what level of speed is present (P = 0.786). There is no significant interaction between condition and speed. Therefore the invetigator failed to reject the null hypothesis.

4) To test the hypotheis

Ho: There was no difference in range of motion in isokinetic knee extension at 60º, 210º, and 450 degrees per second joint angle velocity when the knee was tested in the sleeve, brace and control (unsupported) conditions.

A two-way ANOVA for repeated measures was used to test this hypothesis. The effect of different levels of condition does not depend on what level of speed is present (p = 0.835). There is no significant interaction between condition and speed. Therefore, the investigator failed to reject the null hypothesis.

Results

Peak Torque to Body Weight Ratio:

Table 4 (Appendix D) provides the descriptive statistics for peak torque to body weight ratio among trials. Peak torque was found to be at the highest foot pound during the second repetition in all experimental conditions. The control condition was found at 225.95 ft/lbs. The sleeve and brace conditions were found at 209.55 and 210.01 ft/lbs.

Table 5 provides descriptive statistics for peak torque to body weight ratio across the three experimental conditions and across the three isokinetic speeds. The force/velocity curve theory was found to applicable; as speed was increased the force decreased. At 60º/sec joint angle velocity the mean ratio was 103.15 % . At 210º/sec and 450º/sec joint angle velocity the ratio (%) decreased progressively as speed increased (210º/sec - 63.60%; 450º/sec - 45.30%). The sleeve condition force-velocity relationship was shown at 60º/sec - 94.60% to 450º/sec - 45.15%. The brace condition force-velocity relationship was also shown at 60º/sec - 94.80% to 450º/sec - 43.30%. The average peak torque to body weight ratio for the main effects of condition and speed and the interactions between condition and speed revealed no significant interaction between condition and speed in all three experimental conditions. The results appear on Table 6 (Appendix D).

Two way repeated measures ANOVA revealed no significant differences ($p > .05$) among the three experimental conditions with range up to 1000 (control .671, sleeve .681, brace .706).

There was a significant ($p < .01$) difference among the three isokinetic test speeds (60, 210, 450 deg/second). Tukey's pairwise comparisons using a family error rate (p.05), produced a critical value of 3.46. The PK/BW of .975 for the 60 deg/second speed is significantly greater than the PK/BW of .637 for the 210 deg/second speed and the PK/BW of .445 for the 450 deg/second speed. The PK/BW between the isokinetic speeds of 210 deg/second and 450 deg/second were also significantly different. The ANOVA results appear on Table 7 in Appendix D.

Work to Fatique Ratio:

The descriptive statistics for work to fatique ratio among trials. Work to fatique was found to be the second repetition in all experimental conditions. The control condition was found at 225.95 ft/lbs. The sleeve and brace conditions were found at 209.55 and 210.01 ft/lbs. Table 9 provides descriptive statistics for work to fatique ratio across the three experimental conditions and across the three isokinetic speeds. The work theory was found to applicable; as speed and repetition was increased the fatique increased. At 60º/sec joint angle velocity the mean ratio was 11.55 % . At 210º/sec and 450º/sec joint angle velocity the ratio (%) increased progressively as speed increased (210º/sec - 23.45%; 450º/sec - 32.90%). The sleeve condition work theory relationship was found at 60º/sec - 11.63% to 450º/sec - 33.40%. The brace condition force-velocity relationship was also shown at 60º/sec - 14.32% to 450º/sec - 35.60%. The mean work to fatique ratio for the main effects of condition and speed and the interactions between condition and speed revealed no significant interaction between condition and speed in all three experimental conditions. The results appear on Table 10.

The repeated Two-way repeated ANOVA on two factors with work fatique as the dependent variable Table 8(Appendix D) revealed:

The difference in the mean values among the different levels of condition is not great enough to exclude the possibility that the difference is just due to random sampling variability after allowing for the effects of difference in speed. There is not a statistically significiant difference ($p = 0.306$).

The difference in the mean values among the different levels of speed is greater than would be expected by chance after allowing for effects of difference in condition. There is a statistically significant difference (p = <0.0001).

The effect of different levels of condition does not depend on what level of speed is present. There is not a statisically significant interaction between condition and speed. (p = 0.394)

Average Power:

Tables 12 (Appendix D) provides the descriptive statistics for average power among trials. Average power was found to be at the highest foot pound during the second repetition in all experimental conditions. The control condition was found at 189.05 Watts. The sleeve and brace conditions were found at 186.10 and 190.55 Watts. Table 13 (Appendix D) provides descriptive statistics for average power across the three experimental conditions and across the three isokinetic speeds. The force/velocity curve theory was found not applicable. As speed was increased the force increased at 210 deg/second joint angle velocity and Ironically, decreased at 450 deg/second joint angle velocity. At 60º/sec and 210º/sec joint angle velocity the mean ratio was 190.20 % and 318.70%. At 450º/sec joint angle velocity the ratio (%) decreased from 318.70% to 252.20%). The sleeve condition relationship was shown increasing as velocity increased to 210º/sec and decreasing when velocity was increased to 450º/sec joint angle velocity (60º/sec - 183.60%, 210º/sec - 316.00, 450º/sec - 258.50%). The brace condition relationship was also shown to increased as velocity increased to 210º/sec and decrease when velocity was increased to 450º/sec joint angle velocity (60º/sec - 178.80%, 210º/sec - 304.5%, 450º/sec - 247.10%). The average power for the main effects of condition and speed and the interactions between condition and speed revealed no significant interaction between condition and speed in all three experimental conditions. The results appear on Table 14 (Appendix D). The repeated Two-way repeated ANOVA on two factors with average power as the dependent variable Table 15 (Appendix D) revealed:

The difference in the mean values among the different levels of condition is not great enough to exclude the possibility that the difference is just due to random sampling variability after allowing for the effects of difference in speed. There is not a statistically significiant difference ($p = 0.494$).

The difference in the mean values among the different levels of speed is greater than would be expected by chance after allowing for effects of difference in condition. There is a statistically significant difference ($p = <0.0001$).

The effect of different levels of condition does not depend on what level of speed is present. There is not a statisically significant interaction between condition and speed. ($p = 0.786$)

Range of Motion:

Table 17(Appendix D) provides descriptive statistics for range of motion across the three experimental conditions and across the three isokinetic speeds. At 60º/sec joint angle velocity the mean ratio was 96.15º . At 210º/sec and 450º/sec joint angle velocity the degrees were found at 96.15º and 95.95º. The sleeve condition was found at 60º/sec -

92.15º to 450º/sec - 91.65º. The brace condition was also shown at 60º/sec - 94.40º to 450º/sec - 93.10º. The mean range of motion for the main effects of condition and speed and the interactions between condition and speed revealed no significant interaction between condition and speed in all three experimental conditions. The results appear on Table 18 (Appendix D).

The repeated Two-way repeated ANOVA on two factors with range of motion as the dependent variable Table (Appendix D) revealed:

The difference in the mean values among the different levels of condition is not great enough to exclude the possibility that the difference is just due to random sampling variability after allowing for the effects of difference in speed. There is not a statistically significiant difference ($p = 0.033$).

The difference in the mean values among the different levels of speed is greater than would be expected by chance after allowing for effects of difference in condition. There is a statistically significant difference ($p = 0.003$).

The effect of different levels of condition does not depend on what level of speed is present. There is not a statisically significant interaction between condition and speed. ($p = 0.835$)

APPENDIX B

SUBJECT SCREENING FORM

ORTHOPAEDIC ASSESSMENT FORM

BIODEX TEST SCREENING FORM
FOR KNEE EXTENSION/FLEXION

Name:______________________________________ Date:________________________
Age:_______________ Sex:_______________
Address:____
____
Phone:______________________________________

1. Have you experienced any type of knee pain within the past 6 months? YES NO If yes, please explain.____
____
____

2. Have you ever sustained an injury or trauma, or had surgery to your knee joint, hip joint or the muscles surrounding these joints? YES NO If yes, please explain.________
____
____

3. Do you feel in any way that you have orthopaedic or medical problems that may hamper your performance in this Biodex knee extension/flexion test? YES NO

Signature of participant:______________________________________

Date:______________

Witness:____

APPENDIX C

INFORMED CONSENT

ISOKINETIC VELOCITY SPECTRUM KNEE EXTENSION TEST

INFORMED CONSENT:

I,______________________________, do hereby voluntarily agree and consent to participate in a research project conducted by Michael Hutchinson Call.

The purpose of this study is to investigate the effects of knee sleeves and knee braces on selected isokinetic measures during knee flexion and knee extension. All isokinetic variables will be measured using a Biodex isokinetic dynamometer.

I voluntarily agree to serve as a subject in this investigation. It is my understanding that my participation will include:

1. A 5 repetition isokinetic knee extension/flexion test at 60 degrees/second joint angle velocity.
2. A 20 repetition isokinetic knee extension/flexion test at 210 degrees/second joint angle velocity.
3. A 30 repetition isokinetic knee extension/flexion test at 450 degrees/second joint angle velocity.

Each of the above experimental test protocols will be performed with the knee:

A. Unbraced

B. Braced with a sleeve

C. Braced

I understand that participation in this experiment may produce certain discomforts and risks. These include but are not limited to: increased heart rate, light headiness and the possibility of delayed muscular soreness.

I have been informed that proper exercise warm-up and testing procedures will be followed and that proper emergency equipment is available if needed. Knowing these risks, it is my desire to participate in this experiment.

I understand that certain personal benefits may also be expected from participation in this investigation. It is my understanding that the results of this investigation will provide me with a muscular baseline profile that would be of value in rehabilitation from a knee injury.

I understand that any data of a personal nature will be held confidential and will be used for research purposes only. I also understand that these data may only be used when not identifiable with me.

I understand that I may abstain from participation in any part of the experiment or withdraw from the experiment should I feel the activities might be injurious to my health. The experimenter may also terminate my participation should he feel that the activities might be injurious to my health.

I understand that it is my personal responsibility to advise the researchers of any preexisting medical problem that may affect my participation or of any medical problems that might arise in the course of this experiment and that no medical treatment or compensation is available if injury is suffered as a result of this research. A telephone is available which would be used to call the local hospital for emergency service.

I understand that both coach Frank Beamer and Mike Gentry have approved of my participation in this investigation.

I have read the above statements and have had the opportunity to ask questions. I understand that the researchers will, at anytime, answer my inquires concerning the procedures used in this experiment.

Date:____________________ Time:___________a.m./p.m.

Participant signature_______________________________________

Witness____

Thesis Chair Dr. Don Sebolt____________________Telephone 231-5104

To receive the results of this investigation, please indicate this choice by marking in the appropriate space provided below. A copy will then be distributed to you as soon as the results are made available by the investigator. Thank you for making this important contribution.

_________ I request a copy of the results of this study.

Should I have any questions about this research or its conduct, I will contact:

Michael Call	552-3005
Don Sebolt	231-5104
Ernest Stout	231-9359

APPENDIX D

Table 1

Repeated Measures ANOVA for Peak Torque to Body Weight
Control Condition

Source	DF	SS	MS
A (subject)	19	83828.71	4412.09
B (trial)	4	3195.36	798.840
AB	76	14269.44	187.765
Total (adjusted)	99	101294.5	
Total	100		

Intraclass Correlation Estimate of Reliability

$$R = \frac{\text{MS subjects} - \text{MS error (AB)}}{\text{MS subjects}}$$

$$R = \frac{4412.09 - 187.765}{4412.09}$$

R= .96

Table 2

Repeated Measures ANOVA for Peak Torque to Body Weight
Sleeve Condition

Source	DF	SS	MS
A (subject)	19	138379.2	7283.114
B (trial)	4	3453.26	863.315
AB	76	14313.54	188.3361
Total (adjusted)	99	156146	
Total	100		

Intraclass Correlation Estimate of Reliability

$$R = \frac{\text{MS subjects} - \text{MS error (AB)}}{\text{MS subjects}}$$

$$R = \frac{7283.114 - 188.3361}{7283.114}$$

R= .97

Table 3

Repeated Measures ANOVA for Peak Torque to Body Weight
Brace Condition

Source	DF	SS	MS
A (subject)	19	156214.3	8221.808
B (trial)	4	2776.5	694.125
AB	76	12719.9	167.3671
Total (adjusted)	99	171710.8	
Total	100		

Intraclass Correlation Estimate of Reliability

$$R = \frac{\text{MS subjects} - \text{MS error (AB)}}{\text{MS subjects}}$$

$$R = \frac{8221.808 - 167.3671}{8221.808}$$

R= .98

Table 4

Descriptive Statistics Among Trials for Peak Torque To Body Weight

Variable	Trial	Mean (Ft/lbs)	SD	STD Error
CONTROL	1	213.50	36.83	8.24
	2	225.95	31.56	7.06
	3	222.40	32.00	7.15
	4	220.30	31.54	7.05
	5	210.70	28.14	6.29
SLEEVE	1	193.55	37.99	8.49
	2	209.55	41.99	9.39
	3	208.30	41.70	9.32
	4	206.90	42.57	9.52
	5	201.60	35.77	8.00
BRACE	1	196.01	46.30	10.4
	2	210.01	45.80	10.2
	3	206.15	40.66	9.09
	4	199.25	41.93	9.38
	5	198.20	35.11	7.85

Table 5

Descriptive Statistics Among Conditions and Speeds for Peak Torque Body Weight Ratio

CONDITION	Mean	SD
control		
60º/sec	103.15	2.48
210º/sec	63.60	2.48
450º/sec	45.30	2.48
sleeve		
60º/sec	94.60	2.48
210º/sec	64.55	2.48
450º/sec	45.15	2.48
brace		
60º/sec	94.80	2.48
210º/sec	63.05	2.48
450º/sec	43.30	2.48

Table 6

Mean Peak Torque to Body Weight Ratio for the Main Effects of Condition, Speed and the Intereaction of Condition * Speed

Condition		N	ROM
1		60	70.683
2		60	68.100
3		60	67.050
Speed			
60º/sec		60	63.733
210º/sec		60	44.583
450º/sec		60	97.517
Condition	Speed		
control	60º/sec	20	63.60
control	210º/sec	20	45.30
control	450º/sec	20	103.15
sleeve	60º/sec	20	64.55
sleeve	210º/sec	20	45.15
sleeve	450º/sec	20	94.60
brace	60º/sec	20	63.05
brace	210º/sec	20	43.30
brace	450º/sec	20	94.80

Table 7

Two Way Repeated Measures ANOVA for Peak Torque to Body Weight Ratio

Source	DF	SS	MS	F	P
A (cond)	2	419.54	209.77	.36	.702
B (A)	17	9893.01	581.94	12.97	.000
C (speed)	2	86199.48	43099.74	248.74	.000
AC	4	605.55	151.38	.87	.489
BC (A)	34	5891.18	173.27	3.86	.489
S	120	5386	44.88		
Total (adjusted)	179	108394.8			
Total	180				

* Term significant at alpha = 0.05

Tukey's HSD Multiple-Comparison Test

Alph = 0.050 Error Term = BC (A) DF = 34 MSE = 173.2703 Critical Value = 3.465

Group	Count	Mean	Different from Groups
2	60	63.73	4,6
4	60	44.58	2,6
6	60	97.51	4,2

Table 8

Two Way Repeated Measures ANOVA Two Factors
Dependent Variable: wk/fatq

Source	DF	SS	MS	F	P
Subject	19	2001.54	105.34	1.066	.424
Condition	2	153.83	76.917	1.223	.306
Cond X Subject	38	2420.75	63.704		
Speed	1	3399.692	3399.692	59.114	<0.001
Speed X Subject	19	1104.971	58.156		
Cond X Speed	2	43.249	21.625	0.955	.394
Residual	36	815.001	22.639		
Total	117				

One Way Repeated Measures ANOVA

Source	DF	SS	MS	F	P
Between Subjects	19	14740.983	774.841		
Between Treatments	2	817.733	408.867	6.979	0.003
Residual	38	2226.267	58.586		
Total	59	17784.983			

Tukey Test

Comparisons for factor: **Condition**

Comparison	**Diff of Means**	**p**	**q**	**P<0.05**
1.000 vs. 2.000	8.400	3	4.908	YES
1.000 vs. 3.000	7.100	3	4.148	YES
3.000 vs. 2.000	1.300	3	0.760	NO

Table 9

Descriptive Statistics Among Conditions for Work to Fatique Ratio

CONDITION	Mean	SD
control		
60º/sec	11.55	1.58
210º/sec	23.45	1.58
450º/sec	32.90	1.58
sleeve		
60º/sec	11.63	1.58
210º/sec	22.55	1.58
450º/sec	33.40	1.58
brace		
60º/sec	14.32	1.58
210º/sec	24.80	1.58
450º/sec	35.60	1.58

Table 10

Mean Work Fatique Ratio for the Main Effects of Condition, Speed and the Intereaction of Condition * Speed

Condition		N	ROM
1		60	22.633
2		60	22.525
3		60	24.908
Speed			
60º/sec		60	23.600
210º/sec		60	33.967
450º/sec		60	12.500
Condition	Speed		
control	60º/sec	20	23.450
control	210º/sec	20	32.900
control	450º/sec	20	11.550
sleeve	60º/sec	20	22.550
sleeve	210º/sec	20	33.400
sleeve	450º/sec	20	11.625
brace	60º/sec	20	24.800
brace	210º/sec	20	35.600
brace	450º/sec	20	14.325

Table 11

Two Way Repeated Measures ANOVA for Work to Fatique Ratio

Source	DF	SS	MS	F	P
A (cond)	2	217.35	108.67	.76	.483
B (A)	17	24535.22	143.24	4.33	.000
C (speed)	2	13829.91	6914.95	106.72	.000
AC	4	16.45	4.11	.03	.992
BC (A)	34	2204.96	64.79	1.96	.004
S	120	3971.833			
Total (adjusted)	179	22673.74			
Total	180				

* Term significant at alpha = 0.05

Tukey's HSD Multiple-Comparison Test

Alph = 0.050 Error Term = BC (A) DF = 34 MSE = 64.2703 Critical Value = 3.465

Group	Count	Mean	Different from Groups
2	60	23.6	6,4
4	60	33.9	6,2
6	60	12.5	2,4

Table 12

Descriptive Statistics Among Trials for Average Power

Variable	Trial	Mean (Watts)	SD	STD Error
CONTROL	1	182.05	31.53	7.05
	2	189.05	27.90	6.24
	3	187.45	26.81	6.00
	4	182.50	27.02	6.04
	5	177.45	25.42	5.68
SLEEVE	1	175.45	38.42	8.59
	2	186.10	36.50	8.16
	3	181.10	36.36	8.13
	4	175.60	37.53	8.39
	5	175.25	31.99	7.15
BRACE	1	177.20	39.33	8.79
	2	190.55	44.22	9.89
	3	183.15	34.54	7.72
	4	174.70	34.28	7.67
	5	170.25	31.30	7.00

Table 13

Descriptive Statistics Among Conditions and Speeds for Average Power

CONDITION	Mean (watts)	SD
control		
60º/sec	190.20	12.06
210º/sec	318.70	12.06
450º/sec	252.20	12.06
sleeve		
60º/sec	183.60	12.06
210º/sec	316.00	12.06
450º/sec	258.50	12.06
brace		
60º/sec	178.8	12.06
210º/sec	304.5	12.06
450º/sec	247.1	12.06

Table 14

Mean Average Power for the Main Effects of Condition, Speed and the Intereaction of Condition * Speed

----

Condition		N	ROM
1		60	253.70
2		60	252.70
3		60	243.48
Speed			
60º/sec		60	313.08
210º/sec		60	252.62
450º/sec		60	184.18
Condition	Speed		
control	60º/sec	20	318.70
control	210º/sec	20	252.20
control	450º/sec	20	190.20
sleeve	60º/sec	20	316.00
sleeve	210º/sec	20	258.50
sleeve	450º/sec	20	183.60
brace	60º/sec	20	304.55
brace	210º/sec	20	247.15
brace	450º/sec	20	178.75

Table 15

Two Way Repeated Measures ANOVA on Two Factors
Dependant Variable: Avg. Power

Source	DF	SS	MS	F	P
Subject	19	265360.633	13966.349		
Condition	2	3004.800	1502.400	.718	.494
Cond X Subject	38	79546.867	2093.339		
Speed	1	109686.533	109686.53	68.184	<.001
Speed X Subject	19	30564.800	1608.67		
Cond X Speed	2	546.067	273.03	.242	.786
Residual	38	42923.600	1129.56		
Total	119	531633.300	4467.50		

Table 16

Descriptive Statistics Among Conditions and Speeds for Range of Motion

CONDITION	Mean (degree)	SD
control		
60º/sec	96.15	1.69
210º/sec	97.95	1.69
450º/sec	95.95	1.69
sleeve		
60º/sec	92.15	1.69
210º/sec	93.60	1.69
450º/sec	91.65	1.69
brace		
60º/sec	94.40	1.69
210º/sec	95.30	1.69
450º/sec	93.10	1.69

Table 17

Mean Range of Motion for the Main Effects of Condition, Speed and the Intereaction of Condition * Speed

Condition		N	ROM
1		60	96.683
2		60	92.467
3		60	94.267
Speed			
60º/sec		60	95.617
210º/sec		60	93.567
450º/sec		60	94.233
Condition	Speed		
control	60º/sec	20	97.950
control	210º/sec	20	95.950
control	450º/sec	20	96.150
sleeve	60º/sec	20	93.600
sleeve	210º/sec	20	91.650
sleeve	450º/sec	20	92.150
brace	60º/sec	20	95.300
brace	210º/sec	20	93.100
brace	450º/sec	20	94.400

Table 18

Two Way Repeated Measures ANOVA for Range of Motion

Source	DF	SS	MS	F	P
Subject	19	6289.972	331.051		
Condition	2	537.211	268.606	3.725	.033
Cond X Subject	38	2740.344	72.114		
Speed	1	131.211	65.606	6.970	.003
Speed X Subject	19	357.678	9.413		
Cond X Speed	2	7.289	1.822	0.361	.835
Residual	38	383.156	5.042		
Total	119	10446.861	58.362		

APPENDIX E

RAW DATA

Intra-Class Correlation
Torque Reps (1-5) at 60º/sec

		1	2	3	4	5
ID# 100	(C)	260	277	267	244	239
	(S)	298	304	281	283	270
	(B)	280	275	266	248	256
ID#101	(C)	173	193	200	183	164
	(S)	183	183	192	174	192
	(B)	194	194	199	161	179
ID#102	(C)	169	195	153	192	180
	(S)	165	182	183	161	180
	(B)	153	150	173	153	164
ID#103	(C)	240	227	221	203	230
	(S)	192	202	198	196	194
	(B)	215	230	235	234	221
ID#104	(C)	232	237	208	232	210
	(S)	195	181	181	176	185
	(B)	176	193	208	203	197
ID#105	(C)	184	210	205	207	195
	(S)	203	219	209	205	209
	(B)	207	225	210	210	192
ID#106	(C)	222	218	207	203	201
	(S)	208	222	207	221	198
	(B)	180	213	206	194	190
ID#107	(C)	190	214	230	227	185
	(S)	172	213	226	210	204
	(B)	228	230	191	188	172

Intra-Class Correlation
Torque Reps (1-5) at 60º/second

		1	2	3	4	5
ID#110	(C)	226	237	230	218	210
	(S)	221	228	240	228	214
	(B)	204	223	211	209	202
ID#111	(C)	245	238	228	214	210
	(S)	194	189	185	193	176
	(B)	164	161	151	150	159
ID#112	(C)	197	249	245	241	232
	(S)	172	213	226	210	204
	(B)	171	184	181	188	193
ID#113	(C)	252	262	253	273	264
	(S)	228	226	220	240	220
	(B)	278	284	274	277	262
ID#114	(C)	276	286	286	291	256
	(S)	186	236	260	265	241
	(B)	193	233	230	236	236
ID#115	(C)	260	266	259	269	247
	(S)	208	300	291	292	287
	(B)	271	289	283	270	258
ID#116	(C)	154	198	211	211	192
	(S)	113	125	124	130	141
	(B)	113	128	143	143	188

Intra-Class Correlation
Torque Reps (1-5) at 60º/second

		1	2	3	4	5
ID#117	(C)	212	204	213	215	219
	(S)	198	200	196	207	195
	(B)	209	227	214	198	189
ID#119	(C)	163	172	161	158	160
	(S)	125	149	140	140	136
	(B)	106	124	124	112	119
ID#120	(C)	167	181	234	204	209
	(S)	185	181	181	176	185
	(B)	176	193	208	203	197
ID#122	(C)	222	218	207	203	201
	(S)	204	210	186	203	187
	(B)	200	222	205	199	188
ID#124	(C)	226	237	230	218	210
	(S)	221	228	240	228	214
	(B)	204	233	211	209	202

Intra Class
Work Reps (1-5) at 60º/second

		1	2	3	4	5
ID# 100	(C)	294	301	305	285	284
	(S)	315	318	299	304	294
	(B)	297	310	298	283	276
ID#101	(C)	212	245	243	231	214
	(S)	223	226	227	213	220
	(B)	235	244	239	216	230
ID#102	(C)	173	182	165	186	169
	(S)	185	191	182	173	178
	(B)	171	168	188	160	173
ID#103	(C)	255	261	248	243	253
	(S)	205	208	210	207	204
	(B)	208	217	212	223	210
ID#104	(C)	226	241	225	234	231
	(S)	208	210	212	202	211
	(B)	199	204	216	206	203
ID#105	(C)	165	183	186	192	189
	(S)	184	200	206	186	194
	(B)	176	205	195	207	193
ID#106	(C)	206	211	190	193	190
	(S)	179	195	178	198	171
	(B)	178	216	199	191	203
ID#107	(C)	210	256	283	261	233
	(S)	180	213	212	206	198
	(B)	246	246	202	196	171

Intra-Class Correlation
Torque Reps (1-5) at 60º/second

		1	2	3	4	5
ID#110	(C)	240	257	252	248	239
	(S)	250	265	272	258	250
	(B)	248	258	249	249	242
ID#111	(C)	271	269	267	256	253
	(S)	215	222	213	310	188
	(B)	189	191	181	172	175
ID#112	(C)	195	245	247	243	242
	(S)	180	213	212	206	198
	(B)	201	215	213	215	214
ID#113	(C)	239	249	242	249	252
	(S)	241	203	217	213	209
	(B)	244	252	240	241	237
ID#114	(C)	292	297	301	303	267
	(S)	194	252	256	271	255
	(B)	190	251	247	255	243
ID#115	(C)	278	307	297	305	291
	(S)	230	342	329	330	312
	(B)	291	316	313	294	291
ID#116	(C)	161	207	217	219	208
	(S)	137	160	156	150	163
	(B)	130	138	148	149	158

Intra-Class Correlation
Torque Reps (1-5) at 60°/second

		1	2	3	4	5
ID#117	(C)	205	150	202	184	195
	(S)	174	186	160	163	155
	(B)	210	213	215	203	201
ID#119	(C)	140	146	159	158	145
	(S)	111	140	130	128	132
	(B)	102	121	120	122	124
ID#120	(C)	144	157	176	160	172
	(S)	208	210	212	202	211
	(B)	199	204	216	206	203
ID#122	(C)	206	211	190	193	190
	(S)	198	198	176	191	178
	(B)	175	196	191	183	179
ID#124	(C)	240	257	252	248	239
	(S)	250	265	272	258	250
	(B)	248	258	249	249	242

Intra Class
Power Reps (1-5) at 60º/second

		1	2	3	4	5
ID# 100	(C)	238	238	225	217	209
	(S)	286	280	255	252	247
	(B)	260	253	241	238	219
ID#101	(C)	149	176	174	157	146
	(S)	185	173	177	167	160
	(B)	177	175	169	162	154
ID#102	(C)	129	131	119	136	130
	(S)	152	142	139	130	130
	(B)	129	124	138	116	126
ID#103	(C)	177	181	178	172	183
	(S)	176	184	184	184	176
	(B)	173	198	184	179	159
ID#104	(C)	206	196	190	197	190
	(S)	176	167	157	151	170
	(B)	168	167	193	177	185
ID#105	(C)	144	157	154	170	162
	(S)	173	187	186	172	183
	(B)	167	200	184	177	164
ID#106	(C)	202	196	188	177	167
	(S)	194	215	180	199	166
	(B)	177	196	198	183	174
ID#107	(C)	180	184	203	191	156
	(S)	153	169	168	166	165
	(B)	224	216	176	161	144

Intra Class
Power Reps (1-5) at 60º/second

		1	2	3	4	5
ID#110	(C)	184	193	198	184	186
	(S)	208	227	228	215	214
	(B)	193	202	194	193	188
ID#111	(C)	208	202	194	178	184
	(S)	183	185	182	128	156
	(B)	151	155	148	139	143
ID#112	(C)	159	185	186	181	185
	(S)	153	169	168	166	165
	(B)	153	167	155	152	151
ID#113	(C)	217	224	225	237	229
	(S)	212	203	208	216	198
	(B)	243	244	249	230	238
ID#114	(C)	215	220	215	214	198
	(S)	160	195	216	216	204
	(B)	162	202	200	194	190
ID#115	(C)	219	229	219	224	216
	(S)	170	227	222	213	216
	(B)	213	293	223	220	213
ID#116	(C)	161	195	191	190	182
	(S)	110	128	124	123	136
	(B)	111	125	129	129	136

Intra Class
Power Reps (1-5) at 60°/second

		1	2	3	4	5
ID#117	(C)	188	190	189	175	176
	(S)	153	173	157	165	151
	(B)	200	219	194	175	158
ID#119	(C)	136	140	139	128	134
	(S)	103	130	115	115	121
	(B)	105	112	112	110	117
ID#120	(C)	143	155	176	161	163
	(S)	176	167	157	151	170
	(B)	168	167	193	177	185
ID#122	(C)	202	196	188	177	167
	(S)	178	174	171	167	163
	(B)	177	195	189	189	173
ID#124	(C)	184	193	198	184	186
	(S)	208	227	228	215	214
	(B)	193	202	194	193	188

Raw Data
Peak Torque/Body Weight
60 º/second; 210º/second; 450º/second

		1	2	3
ID#100	(C)	97.4	64.0	52.5
	(S)	107.1	68.2	49.7
	(B)	98.4	62.4	48.1
ID#101	(C)	97.7	61.9	52.0
	(S)	93.7	66.7	50.5
	(B)	96.9	59.3	38.3
ID#102	(C)	109.4	69.0	47.2
	(S)	97.1	66.7	41.6
	(B)	102.9	73.8	38.9
ID#103	(C)	94.0	55.4	44.4
	(S)	79.4	56.0	46.2
	(B)	92.5	61.8	48.2
ID#104	(C)	93.1	54.5	45.8
	(S)	73.1	50.9	37.6
	(B)	81.6	51.0	39.3
ID#105	(C)	120.5	73.0	58.9
	(S)	125.7	78.9	41.3
	(B)	129.3	79.4	51.8
ID#106	(C)	82.3	47.6	36.8
	(S)	77.7	48.9	44.7
	(B)	74.6	44.9	38.0
ID#107	(C)	96.0	53.2	35.1
	(S)	81.2	65.8	44.1
	(B)	83.2	57.6	45.7

Raw Data
Peak Torque/Body Weight
60º/second; 210º/second; 450º/second

		1	2	3
ID#110	(C)	103.8	63.0	42.5
	(S)	105.1	71.4	53.3
	(B)	97.9	67.2	45.0
ID#111	(C)	102.2	58.5	45.5
	(S)	68.3	60.8	51.2
	(B)	80.7	65.3	44.2
ID#112	(C)	124.6	76.9	46.3
	(S)	113.2	75.7	42.6
	(B)	96.5	65.6	37.6
ID#113	(C)	105.0	70.0	45.1
	(S)	92.4	66.7	36.7
	(B)	109.1	68.4	41.1
ID#114	(C)	124.0	70.9	49.6
	(S)	112.7	70.4	54.3
	(B)	100.4	60.3	49.7
ID#115	(C)	110.0	66.7	41.3
	(S)	122.5	73.6	47.3
	(B)	118.1	81.8	50.5
ID#116	(C)	77.2	62.8	45.5
	(S)	61.6	56.4	55.6
	(B)	51.0	50.3	43.7
ID#117	(C)	104.6	66.7	35.3
	(S)	99.4	63.7	32.7
	(B)	109.6	67.6	41.6

Raw Data
Peak Torque/Body Weight
60º/second; 210º/second; 450º/second

		1	2	3
ID#119	(C)	114.6	64.4	48.9
	(S)	100.9	63.1	36.5
	(B)	82.3	57.3	37.7
ID#120	(C)	97.3	64.3	52.3
	(S)	64.5	51.8	39.8
	(B)	82.5	51.7	39.5
ID#122	(C)	107.2	71.5	39.5
	(S)	105.2	66.8	42.5
	(B)	111.6	72.6	43.8
ID#124	(C)	104.1	63.5	43.7
	(S)	105.2	71.5	53.9
	(B)	98.3	67.8	45.2

Raw Data
Work/Body Weight
60º/second; 210º/second; 450º/second

		1	2	3
ID#100	(C)	107.2	76.6	40.2
	(S)	112.2	74.7	40.2
	(B)	109.3	71.8	42.7
ID#101	(C)	119.3	77.5	43.9
	(S)	110.4	77.7	47.2
	(B)	119.0	76.3	37.9
ID#102	(C)	104.8	86.3	57.0
	(S)	105.4	80.2	43.4
	(B)	107.3	84.6	43.3
ID#103	(C)	102.3	70.7	43.0
	(S)	82.7	60.7	42.3
	(B)	87.1	63.3	35.2
ID#104	(C)	94.3	60.8	33.2
	(S)	83.0	59.2	33.0
	(B)	84.5	54.2	32.0
ID#105	(C)	110.3	75.5	51.8
	(S)	118.0	85.2	47.9
	(B)	119.0	79.6	45.6
ID#106	(C)	80.8	53.3	23.6
	(S)	69.3	42.3	22.5
	(B)	75.3	44.2	22.6
ID#107	(C)	102.1	67.3	40.1
	(S)	90.5	61.1	39.0
	(B)	88.9	55.7	39.2

Raw Data
Work/Body Weight
60º/second; 210º/second; 450º/second

		1	2	3
ID#110	(C)	112.6	71.8	35.5
	(S)	119.6	78.1	46.5
	(B)	112.9	78.9	47.6
ID#111	(C)	112.7	71.1	41.0
	(S)	79.3	68.2	43.2
	(B)	92.5	71.2	39.5
ID#112	(C)	123.1	77.0	47.3
	(S)	113.6	80.2	45.4
	(B)	107.4	78.9	39.8
ID#113	(C)	96.6	72.0	45.1
	(S)	92.9	68.5	42.1
	(B)	96.9	61.6	44.3
ID#114	(C)	128.9	82.3	52.1
	(S)	115.0	78.5	43.5
	(B)	107.9	67.2	40.0
ID#115	(C)	125.3	80.5	40.7
	(S)	139.2	86.9	51.0
	(B)	128.8	88.6	44.2
ID#116	(C)	79.2	62.3	28.7
	(S)	57.5	52.4	33.6
	(B)	59.6	54.8	31.4
ID#117	(C)	88.3	60.5	37.7
	(S)	89.6	58.5	32.1
	(B)	103.4	72.9	42.8

Raw Data
Work/Body Weight
60º/second; 210º/second; 450º/second

		1	2	3
ID#119	(C)	105.6	69.6	39.5
	(S)	92.7	68.4	32.2
	(B)	82.1	64.2	36.4
ID#120	(C)	107.2	76.5	40.6
	(S)	112.9	74.7	40.2
	(B)	109.3	71.5	42.8
ID#122	(C)	105.0	67.9	39.3
	(S)	99.2	66.8	42.2
	(B)	98.3	65.2	33.5
ID#124	(C)	113.6	71.9	37.6
	(S)	120.6	78.2	47.8
	(B)	113.1	79.1	48.8

Raw Data
Work/Fatique
60º/second; 210º/second; 450º/second

		1	2	3
ID#100	(C)	17.3	33.9	45.9
	(S)	19.3	32.7	39.6
	(B)	17.0	42.1	45.0
ID#101	(C)	10.9	18.9	39.5
	(S)	13.9	24.7	40.5
	(B)	14.8	21.3	37.5
ID#102	(C)	13.1	30.3	32.2
	(S)	14.1	22.1	34.2
	(B)	24.6	34.3	37.4
ID#103	(C)	9.9	10.9	29.7
	(S)	8.2	19.9	38.2
	(B)	14.0	13.2	26.3
ID#104	(C)	15.8	17.7	27.8
	(S)	11.3	11.0	27.5
	(B)	3.8	20.8	28.3
ID#105	(C)	5.0	17.4	32.5
	(S)	10.8	29.8	36.4
	(B)	21.2	23.7	42.7
ID#106	(C)	12.3	20.9	10.1
	(S)	19.0	31.5	19.5
	(B)	14.7	34.4	28.9
ID#107	(C)	15.3	21.1	24.9
	(S)	25.2	18.8	22.9
	(B)	35.8	16.5	38.7

Raw Data
Work/Fatique
60º/second; 210º/second; 450º/second

		1	2	3
ID#110	(C)	10.7	13.2	38.0
	(S)	7.1	22.8	43.1
	(B)	10.6	20.9	28.5
ID#111	(C)	15.7	31.7	33.4
	(S)	12.6	23.4	28.9
	(B)	17.6	17.9	25.9
ID#112	(C)	9.9	32.5	36.9
	(S)	10.7	17.7	38.2
	(B)	14.9	24.0	40.5
ID#113	(C)	3.1	25.3	33.8
	(S)	9.9	24.8	35.0
	(B)	13.3	24.3	38.4
ID#114	(C)	13.5	18.6	38.4
	(S)	-2.5	28.1	23.3
	(B)	-1.5	25.1	37.7
ID#115	(C)	9.1	20.4	19.5
	(S)	6.4	11.4	24.6
	(B)	13.5	31.4	34.2
ID#116	(C)	4.2	18.9	19.5
	(S)	9.6	18.8	27.1
	(B)	9.5	12.5	35.2
ID#117	(C)	9.1	20.4	19.5
	(S)	9.9	24.8	35.0
	(B)	14.9	24.0	40.5

Raw Data
Work/Fatique
60º/second; 210º/second; 450º/second

		1	2	3
ID#119	(C)	12.5	31.7	29.6
	(S)	12.9	27.9	35.2
	(B)	4.2	28.4	38.7
ID#120	(C)	18.2	34.4	45.5
	(S)	19.6	32.1	39.2
	(B)	17.4	42.8	45.3
ID#122	(C)	15.1	30.4	44.9
	(S)	18.6	26.9	40.7
	(B)	10.7	33.5	44.6
ID#124	(C)	11.2	13.8	38.6
	(S)	7.2	23.9	43.5
	(B)	11.3	21.1	29.8

Raw Data
Average Power
60º/second; 210º/second; 450º/second

		1	2	3
ID#100	(C)	228.9	382.0	245.0
	(S)	267.4	426.3	306.8
	(B)	244.7	356.9	303.4
ID#101	(C)	165.0	283.2	252.6
	(S)	176.0	300.8	250.6
	(B)	170.5	257.8	194.9
ID#102	(C)	130.3	278.1	294.3
	(S)	127.9	272.0	222.4
	(B)	140.9	276.1	212.0
ID#103	(C)	180.6	327.0	272.6
	(S)	184.2	328.3	295.5
	(B)	183.1	330.5	264.2
ID#104	(C)	196.5	332.8	243.0
	(S)	166.8	310.8	243.5
	(B)	180.3	307.5	244.8
ID#105	(C)	161.9	296.4	279.4
	(S)	182.3	313.8	251.3
	(B)	180.0	288.3	219.0
ID#106	(C)	191.8	263.4	204.8
	(S)	193.4	277.3	190.0
	(B)	83.3	105.5	84.7
ID#107	(C)	186.4	341.8	299.2
	(S)	183.5	333.5	273.8
	(B)	187.8	316.9	258.0

Raw Data
Average Power
60º/second; 210º/second; 450º/second

		1	2	3
ID#110	(C)	196.2	352.2	208.8
	(S)	222.1	390.1	291.3
	(B)	195.9	381.8	339.1
ID#111	(C)	190.5	297.8	222.2
	(S)	149.2	294.0	230.5
	(B)	178.1	311.8	242.7
ID#112	(C)	183.8	342.5	240.2
	(S)	169.2	336.2	254.1
	(B)	157.4	316.1	206.6
ID#113	(C)	229.4	416.8	353.2
	(S)	209.9	428.6	366.5
	(B)	242.7	407.3	397.0
ID#114	(C)	209.8	360.1	345.4
	(S)	205.3	351.5	317.1
	(B)	195.5	311.7	281.9
ID#115	(C)	222.1	367.7	279.2
	(S)	212.2	378.4	375.6
	(B)	224.0	406.1	321.8
ID#116	(C)	322.2	186.1	391.1
	(S)	251.6	126.8	331.3
	(B)	266.9	125.3	300.9
ID#117	(C)	197.1	289.7	234.2
	(S)	165.9	278.6	219.5
	(B)	190.4	306.1	239.6

Raw Data
Average Power
60º/second; 210º/second; 450º/second

		1	2	3
ID#119	(C)	138.5	219.6	171.2
	(S)	113.4	209.1	152.3
	(B)	114.9	207.8	152.9
ID#120	(C)	229.2	382.1	245.5
	(S)	267.3	426.2	306.8
	(B)	244.7	356.5	303.4
ID#122	(C)	184.3	299.9	195.5
	(S)	172.8	282.5	225.4
	(B)	185.2	291.1	188.4
ID#124	(C)	196.2	351.9	208.4
	(S)	222.3	385.3	292.7
	(B)	196.8	392.8	339.5

Raw Data
Range of Motion
60º/second; 210º/second; 450º/second

		1	2	3
ID#100	(C)	100	105	100
	(S)	94	95	94
	(B)	99	100	102
ID#101	(C)	103	102	101
	(S)	96	96	94
	(B)	111	110	108
ID#102	(C)	106	108	105
	(S)	103	103	100
	(B)	105	104	99
ID#103	(C)	108	107	105
	(S)	89	87	86
	(B)	92	92	89
ID#104	(C)	93	92	92
	(S)	100	96	94
	(B)	94	92	91
ID#105	(C)	86	86	85
	(S)	84	98	95
	(B)	91	89	89
ID#106	(C)	85	85	84
	(S)	74	73	72
	(B)	85	83	82
ID#107	(C)	110	108	105
	(S)	92	94	92
	(B)	89	89	89

Raw Data
Range of Motion
60º/second; 210º/second; 450º/second

		1	2	3
ID#110	(C)	92	92	93
	(S)	91	90	90
	(B)	99	97	96
ID#111	(C)	105	104	104
	(S)	95	94	93
	(B)	94	100	98
ID#112	(C)	95	95	94
	(S)	92	93	92
	(B)	101	99	98
ID#113	(C)	84	88	87
	(S)	88	92	90
	(B)	80	90	90
ID#114	(C)	105	103	98
	(S)	89	89	88
	(B)	93	93	90
ID#115	(C)	106	107	104
	(S)	113	112	107
	(B)	102	101	95
ID#116	(C)	86	85	85
	(S)	91	87	83
	(B)	99	97	89
ID#117	(C)	106	107	104
	(S)	88	92	90
	(B)	101	99	98

Raw Data
Range of Motion
60º/second; 210º/second; 450º/second

		1	2	3
ID#119	(C)	88	90	89
	(S)	85	90	87
	(B)	84	90	86
ID#120	(C)	100	105	100
	(S)	94	95	94
	(B)	99	100	100
ID#122	(C)	89	97	95
	(S)	92	93	91
	(B)	81	86	83
ID#124	(C)	90	102	101
	(S)	96	95	94
	(B)	95	96	94

APPENDIX E:

VITA

Michael H. Call was born on September 22, 1970 in Marion, Virginia. He grew up in southwest Virginia, attending Marion high school. He received a Bachelor of Science degree in Exercise Physiology , with a minor in Biology, from Carson-Newman College, Jefferson City, Tennessee. While at Carson-Newman College he started and played football for the five time National Champion Eagles. In July of 1992, Michael entered the exercise physiology program at Virginia Tech. During this time he also served as the graduate assistant in strength and conditioning for Virginia Tech. Presently, Michael is the Director of Sports Medicine at Spartanburg Regional Medical Center.