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Effect of a Prophylactic Knee Brace on Leg Muscle Performance of Athletes

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EFFECTS OF A PROPHYLACTIC KNEE BRACE ON LEG MUSCLE PERFORMANCE OF ATHLETES

By

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An Abstract

of a thesis submitted in partial fulfillment
of the requirements for the degree of
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ABSTRACT

This study investigated the effect of prophylactic knee brace wearing on physical performance as measured by selected parameters. The 10 subjects were members of the 1985 Ithaca College women's lacrosse team. The Cybex II isokinetic dynamometer was used to assess the performance of the quadriceps at two angular velocities (60 and 120 deg/s), and the Wingate cycling test was administered to determine anaerobic capacity. Additionally, blood samples were taken to determine circulating lactate levels before and after exercise. Multivariate analysis of variance revealed physical performance was significantly better ($p < .05$) under the no brace condition compared to the brace wearing condition. It was concluded that performance, as described by blood lactate production, peak anaerobic power, peak torque output at 60 deg/s, rise time at 60 deg/s, and time to fatigue, was decreased significantly by prophylactic knee brace wearing. Rise time had the greatest influence upon the multivariate difference, but there was no statistical evidence to support a significant effect of this or any other single individual variable. However, there was a tendency for all variables to show slightly better performance under the no brace

condition. Given the lack of evidence from previous research to support a protective effect of prophylactic knee brace wearing and the current findings of impeded performance with brace wearing, there is little reason to support their use by athletes with stable knees.

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Requirements for the Degree
Master of Science

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

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

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

Thesis Advisor:

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DEDICATION

This thesis is dedicated to my parents. Your love, support, and encouragement has made it possible for me to come this far in pursuit of my academic goals. Your unwavering faith in my ability help me to endure and keep looking ahead.

TABLE OF CONTENTS

Chapter Page

Chapter Page

LIST OF TABLES

Chapter 1

INTRODUCTION

For many years, knee braces and tape were used to make it possible for an athlete with a knee impairment to return to activity during injury rehabilitation. Recently, prophylactic knee braces have been developed with the intention of decreasing the incidence and severity of joint injury. Many college and professional football teams have made prophylactic knee braces part of required equipment, and some high school football teams have also adopted this policy. Athletes in sports other than football (e.g., basketball and skiing) also use prophylactic knee braces. An effective knee brace could decrease medical costs and need for injury rehabilitation. However, the effectiveness of prophylactic knee braces now available is a controversial topic. Some reports from teams using the prophylactic knee braces have shown a dramatic decrease in serious knee injury (Hansen, Ward, & Diehl, 1985; Legwold, 1985), while other reports demonstrated no prophylactic effect of wearing knee braces (DeHaven, 1985; Legwold, 1985; Potera, 1985). Moreover, one study found increased incidence of knee injury as a result of prophylactic knee brace wearing (Potera, 1985). Most of these reports did not utilize scientific control or statistical analysis (Legwold, 1985). Furthermore, fewer scientific studies have been conducted to provide performance data during prophylactic knee brace wearing.

The most important function of the prophylactic knee brace is to protect the knee joint without impairing athletic performance. Houston and Goemans (1982) evaluated the performance of athletes wearing a knee brace and found performance to be impaired. Contrary results were noted by a group (Lysholm, Nordin, Ekstrand, & Gillquist, 1984) who examined a patellar knee brace and concluded performance was improved during knee brace use. These conflicting studies used subjects with knee impairment, and knee braces were prescribed to provide stability for the subject's injured knee. No study dealing with the effect of prophylactic knee brace use upon performance in the healthy knee joint has been reported. Whether an athlete with a prophylactic knee brace performs as well as without the knee brace is questionable. In order to further understand the potential effects of prophylactic knee brace use upon athletic performance, the influence of the brace upon the normal knee should be examined. The purpose of this study was to determine the effect of prophylactic knee brace use upon selected performance parameters of the healthy knee joint.

Scope of Problem

This study observed the effect of prophylactic knee brace use upon performance. Ten female athletes from the Ithaca College lacrosse team volunteered to take part as subjects. All subjects underwent tests of muscle strength and anaerobic power under two conditions: with a prophylactic knee brace and without a brace. The sequence of the two conditions was arranged randomly for each subject. Detailed explanations and demonstrations were provided to each subject before testing. All testing took place at the Ithaca College Physical Therapy Laboratory during morning hours. The data collected were analyzed to examine the effect of a prophylactic knee brace wearing upon performance. The data were subjected to multivariate analysis of variance (MANOVA) to determine if any difference existed between the conditions.

Statement of Problem

Do prophylactic knee braces affect leg performance, as measured by leg muscle strength, EMG activity of the rectus femoris muscle, blood lactate concentration, and anaerobic power in college-aged female athletes?

Null Hypothesis

There will be no differences in the selected parameters between the no brace and brace wearing conditions.

Assumptions of Study

The following were assumptions of this study:

1. The tests used were accurate measures of the abilities being tested.

2. All subjects were equally motivated throughout testing under the two different conditions.

Definition of Terms

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

1. Prophylactic Knee Brace: a brace designed and used to prevent or reduce the severity of knee injuries.

2. Healthy Knee Joint: a knee joint without any physical or functional impairment at the time this study was conducted.

Delimitations of Study

The delimitations of the study were as follows:

1. Athletes from the Ithaca College women's lacrosse team were recruited and asked to volunteer as

subjects.

2. Only subjects with healthy knee joints were used for testing.

3. Leg muscle performance was assessed using only the data gathered from Cybex II testing, electromyography, the Wingate anaerobic cycling test, and blood lactate level.

4. Only one prophylactic knee brace, the Stromgren Supporter (Stromgren-Scott, Inc., Hays, KS), was used in this study.

Limitations of Study

The limitations of the study were as follows:

1. The subjects were volunteers and might not be entirely representative of the total population of college-aged female athletes.

2. The physical activities and lifestyles of the individuals between the two tests were not controlled, and subjects may have altered their physical condition between tests.

3. The relatively small sample size may limit the generalization of statistical analysis.

4. The results of this study only apply when the selected leg muscle performance tests are used.

5. The results of this study only apply to the prophylactic knee brace used in this study.

Chapter 2

REVIEW OF RELATED LITERATURE

This chapter reviews literature related to the structure, function, and effectiveness of prophylactic knee braces. In addition, the relationship between knee braces and performance will be discussed.

Structure of Prophylactic Knee Braces

Many manufacturers of knee braces claim their product will protect the knee joint, especially knee ligaments. There are a variety of knee braces designed for this purpose. The classification of knee braces suggested by the Sports Medicine Committee of the American Academy of Orthopaedic Surgeons (1985) is as follows:

1. Prophylactic knee braces--those designed to prevent or reduce the severity of knee injuries.

2. Rehabilitation knee braces--those designed to allow protected motion of the injured knee, whether treated operatively or nonoperatively.

3. Functional knee braces--those designed to provide stability for unstable knees.

Most prophylactic knee braces are "off the shelf"; either one size fits all or three or four different sizes are expected to accommodate all athletes. This "off the shelf" design has brought about the concern that, often, the fit for each individual's knee may not be adequate to protect the joint and avoid brace slipping, a common problem with brace wearing. The general types of prophylactic knee braces are:

1. Lateral bars with hyperextension stops that are held in place by straps or taping.

2. Plastic cuffs, that can be custom fitted if desired, that are held in place by elastic wraps and taping.

Additionally, prophylactic knee braces are available with different hinge types: single, dual, and polycentric hinges. The research describing the structural differences in the designs of these hinges and their effect on the knee joint movement is limited. A disadvantage of the single hinge axis design is the difficulty fitting the brace to align with the anatomical axis of the knee. Furthermore, because the knee joint has a moving center of rotation, the single hinge becomes displaced in its effort to follow the moving anatomical center (Peizer, Lorenze, & Dixon, 1982). This displacement is transmitted to the cuff section of the brace, and produces an angular change that causes the cuff to shift along the limb, which leads to discomfort, slippage, and missed playing time to reposition the brace. Therefore, dual and polycentric hinges braces were designed to minimize the slipping movement (Peizer et al., 1982). However, more research is needed to determine if improvement is provided by this design.

Function of Prophylactic Knee Braces

Because the medial collateral ligament is the ligament most susceptible to injury, all prophylactic knee braces are designed to protect against valgus stress. By dispersing and distributing the impact load away from the medial collateral ligament, the brace increases joint resistance to valgus force (DeHaven, 1985). A cadaver study conducted by Paulos (cited in DeHaven, 1985) showed that prophylactic knee braces increased resistance to valgus stresses, and this protection was most effective at lower flexion angles.

The anterior cruciate ligament, the ligament preventing anterior tilt of the knee joint, is also very easily injured during sports activity. One study examined four popular prophylactic knee braces: McDavid Knee Guard, Losse Knee Defense, Iowa Knee Orthosis, and Anderson Knee Stabler. The results showed these braces had no effect on controlling anterior displacement (Daniel, cited in DeHaven, 1985). Even the Lenox Hill brace, a very popular functional knee brace that is designed to control varus and valgus instability, rotational laxities, and anterior/posterior translation, only improved anterior displacement under low force conditions (Bassett & Fleming, 1984). From these studies, it can be seen that little scientific support exists for manufacturer claims that knee braces are designed to decrease ligament injury. Furthermore, studies of medical record have not provided unequivocal support for use of prophylactic knee braces.

Effectiveness of Prophylactic Knee Braces

Studies from several teams that wore prophylactic knee braces have reported the rate and severity of knee joint injuries were decreased. A study from the University of Southern California at Los Angeles (USC) reviewed their football team's medical records and found the injury rate was 17% for the players not wearing a brace and 5% for players wearing the Anderson Knee Stabler. Of those injured and not wearing a brace, 5% had collateral ligament injury and needed surgery. Comparatively, less than 2% of players who wore the knee brace needed surgery to repair the collateral ligament. As a result of these findings, the Anderson Knee Stabler was recommended for linebackers and internal linemen at USC (Hansen, Ward, & Diehl, 1985).

DeHaven (1985) evaluated studies from Notre Dame University, University of North Carolina, University of Iowa, Iowa State University, University of Arizona, and University of Oregon. He found data from Notre Dame, North Carolina, Iowa, and Iowa State showed a trend toward reduced incidence of serious knee injuries with knee brace wearing; however, no statistically significant findings were reported. Moreover, studies from the Universities of Arizona and Oregon demonstrated no beneficial effect on the incidence or severity of medial collateral ligament injuries after using prophylactic knee braces for a 3-year period. None of these studies showed reduction in anterior cruciate ligament or meniscal injuries as a result of using prophylactic knee braces. Many reported the brace was bent out of shape after a blow, resulting in bruises on the lateral side of the leg. Considering the relatively mild nature of these injuries, most people believe prophylactic knee braces effectively protect the knee. However, it has been said in some cases the braces are weaker than the knee joint, suggesting a force strong enough to bend the knee brace might not be enough to hurt the knee joint (Potera, 1985). In addition, Haupt's study (cited in Legwold, 1985) has shown prophylactic knee braces may have the potential to lead to injury. In a 2-year study he found the rate and severity of injury were greater in players wearing prophylactic knee braces. Two possible explanations for these findings were given: (a) the braces were not custom made, and (b) the braces only protect against forces from the lateral side, which might stretch or "preload" the structures on the medial side. The same suggestions were made by DeHaven (1985), who proposed that individuals with varus alignment might be preloaded by wearing a prophylactic knee brace that had been designed for an anatomical valgus alignment. This may also occur in people whose valgus alignment of the legs is not matched well with the brace's designed alignment valgus. Thus, the amount of stress ligaments can absorb is decreased with this preload, which may increase susceptibility to injury. DeHaven (1985) also reviewed a case report from the University of North Carolina that found a player wearing a prophylactic knee brace suffered a severe hyperextension injury after sustaining a blow to the anterior lateral aspect of the knee joint. The concern raised was that the brace while preventing valgus deformity had allowed a more severe hyperextension injury. However, no conclusive data exist to imply increased susceptibility to injury as a result of a prophylactic knee brace wearing.

In summary, most studies report no statistically significant effectiveness of prophylactic knee brace wearing with regard to protective function. Many of these studies used subjective evaluation to determine effectiveness. A number of these subjective analyses concluded knee brace wearing did reduce the rate and the severity of knee joint injury. More well designed studies are needed to clarify the effectiveness of wearing prophylactic knee braces for injury prevention.

Performance and Knee Braces

An important design function of prophylactic knee braces is not to interfere with normal joint action or impair performance. Thus, for the protection supplied by the braces, athletes should not have to sacrifice performance effectiveness. One study (Helfet, Manley, & Vaughan, 1983) has suggested that a variety of knee braces designed to support the knee have a great degree of rigidity that imposes restraints upon knee movement.

Houston and Goemans (1982) compared the leg performance of seven male athletes wearing prescribed knee support braces to protect their injured knees. This group found that dynamic peak torque values of knee extension, recorded during isokinetic exercise using the Cybex II dynamometer, were significantly higher and extension velocities faster in the no brace condition. Maximal power output and vertical velocity on a brief all-out stair run were also better under the no brace condition. Blood lactate concentrations were higher with brace wearing after a 15-minute ride on a bicycle ergometer at a workload eliciting a heart rate of 170 beats/min. Therefore, they concluded that the protective benefits of brace wearing come at the expense of exercise performance, at least for young injured athletes. Another study (Lysholm, Nordin, Ekstrand, & Gillquist, 1984) measured the effect of a patellar knee brace upon quadriceps peak muscle strength using the Cybex II dynamometer in patients with patellofemoral arthralgia. Contrary to the results of Houston and Goemans, they found 81% of the patients improved their performance by wearing the knee brace, 58% performed at more than 95% of the strength level of their control leg, and only 25% of the patients performed at that level without brace wearing. This group concluded that the patellar knee brace can prevent lateral slipping of the patella, which causes pain in patients with patellofemoral arthralgia. Thus, patients were able to perform better when the knee brace eliminated this painful slipping. The results of these two studies seem contradictory, but it should be noted that braces designed for different functions were used, and the joint impairment of the subjects was also different. In the study of Houston and Goemans, subjects wore knee braces to control medial collateral ligament instability, anterior cruciate ligament instability, or both. Thus, all the braces used were designed to provide stability to an unstable knee with weak, ruptured ligaments, or torn menisci. However, in the study of Lysholm et al., the braces used were designed to control patella position during movement. These functional differences might explain the discrepant results of the two studies. It should also be noted that the knee braces used in these studies were not prophylactic knee braces, as all subjects had knee impairments and were wearing a knee brace as a rehabilitative treatment.

One unpublished study (cited in American Academy of Orthopaedic Surgeons, 1985) of the C Ti brace, which is a functional knee brace, reported there was no statistical difference between brace wearing and no brace conditions, in terms of isokinetic performance of the quadriceps and hamstrings, vertical jumping, and an agility run. DeHaven (1985) reported the results of measuring speed and agility with and without wearing prophylactic knee braces. No statistically significant differences were found, but in almost every condition the times in the brace wearing trial were slightly slower than the no brace trial.

Summary

There are several different types of prophylactic knee braces with different designs. Prophylactic knee braces are created with the intention of protecting knee joints from common injury, especially medial collateral ligament injury and anterior cruciate ligament injury. Although studies that evaluated prophylactic knee brace wearing did not consistently support this claim, there is some evidence to show decreased rate and severity of injury with brace wearing.

Several studies have been done to investigate the relationship between knee brace wearing and leg performance. Contradictory results were found using different braces on specific patient populations. One study found that performance was reduced with knee brace wearing, while the other reported knee brace wearing improved leg performance. To date there has not been a study to examine any statistically significant changes that might occur in performance due to prophylactic knee brace wearing. Further study is needed to ascertain if these braces have any effect upon athletic performance. Moreover, greater understanding of the prophylactic knee braces currently available could lead to the development of improved braces in the future.

Chapter 3

METHODS AND PROCEDURES

This chapter outlines the methods and procedures used in this study. Specifically, this chapter deals with (a) selection of subjects, (b) testing instruments, (c) testing procedures, (d) data collection and scoring methods, and (e) treatment of data.

Selection of Subjects

Subjects for this study were 10 female athletes from the Ithaca College lacrosse team. After gaining the coach's permission, the subjects were contacted as a group to be informed of the nature of the study and to request voluntary participation. All participating subjects were asked individually to read and sign an informed contest form describing the testing procedure (Appendix A). Only individuals with healthy knee joints were used in this study.

Testing Instruments

The following instruments were used for data collection in this study:

Cybex II Dynamometer

This isokinetic exercise device utilizes the principle of constant speed and accommodating resistance to provide muscular exercise. It imposes a resistance to the muscle that is proportional to the amount of the force exerted by the muscle. This can be used to measure maximal muscle tension throughout the whole range of motion. Previous study has shown the measurement of contractile muscle strength and endurance by the Cybex II to be reliable and valid (Moffroid, Whipple, Hofkosh, Lowman, & Thistle, 1969). By varying the speed setting, this device can be used to test muscle strength (30-60 deg/s) or muscular endurance (120-240 deg/s). In this study, 60 deg/s and 120 deg/s speeds were used to test quadriceps strength and endurance, respectively. Paper speeds were 25 mm/s for 60 deg/s and 5 mm/s for 120 deg/s. A dual channel recorder was used to transcribe the torque (foot pounds), time to peak torque (seconds), and time to fatigue (seconds).

Electromyograph

By placing surface electrodes on the rectus femoris, electromyography was used to record the electrical activity of working muscles. One ground and two active electrodes were used for each muscle. The subjects sat on the Cybex II dynamometer with the speed set at 0 deg/s and the knee of their dominant leg flexed at 60 deg. A photo optic pen recorder was used to record the results. The subject was asked to do a maximal isometric contraction three times in order to determine a maximal reference value. All subsequent recordings were converted to a percentage of this maximal contraction.

Wingate Anaerobic Cycling Test

The Wingate anaerobic cycling test as described by Lamb (1984) was used to estimate anaerobic capacity of the subjects in the two conditions. The cycling test protocol was as follows:

1. Warm up: The subject cycled 4 min at an intensity sufficient to elicit a heart rate of 130-150 beats/min. Cycling was interspersed with all-out bursts for 5 s at the end of each minute.

2. Rest interval: A 3-min rest interval was allowed between the warm-up and the test.

3. The test: On command the subject pedaled the bicycle as fast as possible. Simultaneously, resistance was progressively increased to a predetermined load, determined by multiplying body weight by a constant (0.075) to find the optimum work load. At the moment the final load was reached, a count of the pedal revolutions began and continued for 30 s as the subject continued to pedal as fast as possible. Pedal count was recorded every 5 s.

4. Cool down: To minimize the risk of fainting, the subject was encouraged to continue pedaling at a light load for 2 to 3 min after the test.

Blood Analyzer

The YSI industrial blood chemistry analyzer (Yellow Springs Instrument Co., model 27) was used in this study for quantitative determination of the concentration of blood lactate. Calibration was done before each blood sample injection using 5-mM and 15-mM selected standards.

Testing Procedures

All subjects followed the same testing procedures. The knee brace used was the Stromgren Supporter, a dual hinge prophylactic brace. Subjects were asked to make two trips to laboratory; they wore the prophylactic knee brace during one visit and did not wear it during the other. These visits were assigned in random fashion. Testing procedures are described more fully below.

1. Upon arriving at the laboratory, the subject lay down while electrodes were applied on the rectus femoris muscle (about 25 cm inferior from the anterior superior iliac spine). At the same time, the finger to be used for blood sampling was bathed in warm water.

2. Blood was taken by the finger prick technique, which is a routine blood sampling procedure involving a minimum of discomfort. This blood sample was kept on ice for 40 min before being analyzed for resting blood lactate concentration.

3. Each subject walked on a level treadmill for 3 min at the speed of 3 miles/hr (4.8 km/hr). The purpose of this was to let the subject adapt to the knee brace. Treadmill walking was conducted during both trials.

4. Subjects were then placed on the Cybex II dynamometer in the sitting position. After proper fixation with belts on the chest, pelvis, and thigh, all electrodes were connected to the electromyograph. The subject was first asked to do three maximal isometric contraction with leg flexed at 60 deg and speed setting at 0 deg/s to determine the maximal reference value for electromyography. Then, at a speed of 60 deg/s, three trials were done by the subject to adapt to the exercise before eight maximal extension and flexion of the knee joint. Subsequently, at the speed of 120 deg/s, three trials were also done, and the subject was asked to continue maximal extension and flexion until the peak force produced was diminished to one-half its height.

5. After 2 min of rest, the Wingate anaerobic cycling test was administered using the protocol described.

6. Another blood sample was taken immediately after the 30-s cycling test.

Scoring of Data

Prior to each subject's testing, her weight, age, trial time (first trial or second trial), and brace condition (brace wearing or no brace) were recorded on a data sheet (Appendix B) by the researcher. Upon completion of the test the results for each variable were also recorded on the data sheet.

Scoring of Cybex Data

Peak torque was recorded using the Cybex II chart data card by matching the proper grid to the Cybex II recording chart. Two peak torques (one at the speed of 60 deg/s, the other at 120 deg/s) were recorded for each test trial. Rise time (time to peak torque), which is the time interval from the beginning of the torque curve to the point peak torque occurred, was recorded using the time scale of the Cybex II chart data card. The time scale is based upon a 25 mm/s chart speed, but during the 120 deg/s trial the paper speed was 5 mm/s. Therefore, rise times for these trials were recorded after multiplying the readings by

5. Time to fatigue, the elapsed time from the beginning of the torque curve (120 deg/s) to the time at which the torque output reached half of the peak torque, was also recorded by multiplying the reading from the time scale by 5.

Scoring of Electromyograph Data

The maximal reference value was recorded by measuring the height of the highest point of the three curves on the output recording chart for the maximal isometric contractions. The height of the highest point gained from each recording output at the speed of 60 deg/s was also measured. This value was then converted to the percentage of the maximal reference value.

Scoring of Wingate test

Results of each 5-s period were computed in watts according to the following equation:

$$\text{Watts} = \text{load(kg)} \times \text{revolutions} \times 11.765$$

The greatest power in a 5-s period was recorded as the peak anaerobic power. Average power was the mean value for the six 5-s periods. Power decline, which is an index of fatigue rate, was calculated by subtracting the lowest power evaluated in a 5-s period from the peak power and multiplying by 100.

Blood Lactate Concentration

Two blood lactate concentration readings were recorded for each trial. The blood lactate concentration difference was calculated by subtracting the blood lactate concentration at rest from the concentration determined from the sample taken following the testing procedures.

Treatment of Data

Multivariate analysis of variance (MANOVA) was computed to determine if any significant differences existed between brace wearing and no brace conditions. In a preliminary step, Pearson product-moment correlations revealed the interrelationships among five Cybex II variables (i.e., peak torque at 60 deg/s, peak torque at 120 deg/s, rise time at 60 deg/s, rise time at 120 deg/s, and time to fatigue) and among three Wingate test variables (i.e., peak power, average power, and power decline). Variables which did not have strong relationship (i.e., $r < \pm.5$) were selected for the MANOVA in order to minimize the possibility of multicollinearity affecting the results of the MANOVA. The chosen variables, combined with blood lactate concentration difference, were analyzed using MANOVA to estimate the significance of performance difference between the brace wearing condition and no brace conditions. A post hoc test was used to identify the relative contribution of each variable to a significant multivariate $\underline{F}$. A second post hoc test was used to identify on which individual variables (when analyzed separate from other dependent variables) differences under the two bracing conditions were significant. The .05 level of statistical significance was utilized to test the null hypotheses.

Chapter 4

ANALYSIS OF DATA

This study was conducted to investigate if wearing a prophylactic knee brace caused any significant difference in performance as measured by selected variables. A MANOVA was used to identify any significant differences that might exist in the performance related variables between the brace wearing and no brace conditions. A post hoc test identified the relative contribution of each variable to a significant multivariate $\underline{F}$. A second post hoc test was used to identify on which individual variables (when analyzed separately from other dependent variables) differences under the two bracing conditions were significant. Sections in this chapter include the following: (a) description of subjects, (b) intercorrelation of anaerobic power variables and Cybex II data, (c) multivariate analysis of variance (MANOVA), (d) repeated measures $\underline{t}$ tests of individual variables.

Description of Subjects

Subjects' physical characteristics are reported in Table 1. The subjects' ages varied from 18-22 years with the mean age being 19.7 $\pm$ 1.3 years. Their weights varied from 47.0 to 67.3 kg with a mean equal

Table 1

Physical Characteristics of Subjects

Subject	Age (years)	Weight (kg)
1	19	67.0
2	22	67.3
3	21	57.0
4	19	65.2
5	18	55.8
6	18	64.8
7	19	56.0
8	21	47.0
9	20	70.3
10	20	60.2
M	19.7	65.62
SD	1.3	15.83

to 65.62 $\pm$ 15.83 kg.

Intercorrelation of Anaerobic Power Variables and Cybex II Variables

Pearson product-moment correlations were used to examine the intercorrelation between two anaerobic power variables and among five Cybex II variables (see Appendix C and D for raw data), so that variables which had a strong relationship with each other (i.e., $r > .50$ or $r < -.50$) could be ruled out of the MANOVA analysis. This process was undertaken to minimize the possibility of multicollinearity affecting the MANOVA results. Power decline was not used for this analysis because it was always found to be significantly better at the second trial than the first. This will be discussed in chapter 5. It was found that peak power and average power had a high intercorrelation (r = .86, no brace; r = .74, brace wearing). Thus, only one variable (i.e., peak power) from the Wingate test was chosen for the MANOVA, in order to meet the assumption of independence of dependent variables. The correlations of the five Cybex II variables are reported in Table 2. It can be seen that peak torque at 120 deg/s has strong relationship with peak torque at 60 deg/s (r = .91, no brace; r = .59, brace wearing condition), therefore only peak torque at 60 deg/s was

Table 2

Intercorrelation of Cybex II Variables

	Peak Torque (120 deg/s)	Rise Time (60 deg/s)	Rise Time (120 deg/s)	Time to Fatigue
Peak Torque (60 deg/s)				
no brace	.91*	.48	-.28	-.26
brace	.59*	-.26	-.02	-.28
Peak Torque (120 deg/s)				
no brace		.46	-.02	.02
brace		-.23	.14	.37
Rise Time (60 deg/s)				
no brace			.07	.25
brace			-.57*	.47
Rise Time (120 deg/s)				
no brace				.63*
brace				.49

*$r > .50$ or $r < -.50$.

used in the MANOVA. Finally, rise time at 120 deg/s had a strong relationship with rise time at 60 deg/s (r = -.57 under brace wearing condition) and time to fatigue (r = .63 under no brace condition, r = .49 under brace wearing condition), so this variable was not included in the MANOVA.

Multivariate Analysis of Variance

Five variables were used for this analysis (i.e., blood lactate concentration difference, peak power, peak torque at 60 deg/s, rise time at 60 deg/s, and time to fatigue) to determine if a statistically significant difference existed between no brace and brace wearing conditions. Results of this analysis showed an approximate F value, with 5 and 5 df, of 5.85, which was significant at .05 level. Thus, the null hypothesis was rejected, and it was concluded that performance was significantly impaired under the knee brace wearing condition. From the raw discriminant function coefficients presented in Table 3, it can be seen that rise time at 60 deg/s had the greatest influence on this multivariate difference. Anaerobic peak power had the least influence. It should be noted that only one performance parameter, peak power, was positively affected by the brace wearing condition.

Table 3

Raw Discriminant Function Coefficients

Variables	Weighting
Lactate Concentration	.46
Peak Power	.07
Peak Torque(60 deg/s)	.29
Rise Time(60 deg/s)	-2.05
Time to Fatigue	.10

Repeated Measures *t* Tests of Individual Variable

Table 4 contains the results of the *t* tests for blood lactate concentration and electromyography scores (see Appendix E for raw data). Although the mean difference in blood lactate concentration was greater with brace wearing, no statistical significance was shown ($p > .05$). The electromyography recording during knee extension at the speed of 60 deg/s also had no statistically significant difference between the conditions.

The results of *t* tests for three anaerobic power variables determined during the Wingate anaerobic cycling test are presented in Table 5. In addition to the data describing the no brace and brace wearing conditions, the data describing the first and second trial difference is also presented. This was analyzed because there appeared to be an increase in performance on the Wingate test at the second trial, regardless of which bracing condition was being tested. It was seen that power decline was significantly smaller at the second trial ($p < .05$), indicating less fatigue occurred on this trial regardless of the bracing condition tested. No other significant differences were found.

Table 6 shows the *t* tests of five Cybex II

Table 4

Repeated Measures t Tests of Blood Lactate Concentration Difference and Electromyography Score

Variable	*M*	*SD*	*t*	*p*
Lactate[a]				
no brace	9.00	2.52	1.14	.28
brace	9.63	2.29		
EMG[b]				
no brace	99.90	19.05	0.29	.78
brace	100.60	22.54		

[a]Lactate are expressed in mM concentrations.

[b]EMG values are expressed as a percent of maximum contraction.

Table 5

Repeated Measures t Tests of Anaerobic Power Variables

Variable	M	SD	t	p
Peak Power				
no brace	207.00	48.43	0.58	.57
brace	216.10	49.40		
Average Power				
no brace	156.94	35.84	0.26	.80
brace	153.61	27.43		
Power Decline				
no brace	48.20	13.60	0.99	.35
brace	51.20	13.72		
Peak Power				
1st trial	213.10	52.96	0.16	.87
2nd trial	210.70	44.91		
Average Power				
1st trial	148.32	28.42	0.27	.27
2nd trial	162.23	33.52		

Table 5 (continued)

Variable	*M*	*SD*	*t*	*p*
Power Decline				
1st trial	53.60	12.53	7.42	.02
2nd trial	46.80	14.91		

Note. All power measurements are expressed in watts.

Table 6

Repeated Measures t Tests of Cybex II Variables

Variable	*M*	*SD*	*t*	*p*
Peak Torque (60 deg/s)				
no brace	99.70	20.46	0.52	.62
brace	97.60	16.37		
Peak Torque (120 deg/s)				
no brace	75.60	15.86	0.34	.74
brace	73.90	16.52		
Rise Time (60 deg/s)				
no brace	2.48	2.37	2.07	.07
brace	3.95	1.00		
Rise Time (120 deg/s)				
no brace	2.62	0.98	0.68	.51
brace	2.82	1.18		
Time to Fatigue				
no brace	39.06	17.74	0.06	.56
brace	37.34	14.69		

Note. All times are recorded in seconds, and peak torque is recorded in foot pounds.

variables. It can be seen that under the no brace condition, there were greater peak torques, shorter rise times, and longer times to fatigue were found, but again no statistically significant results were obtained from the *t* tests.

As a result of the MANOVA, the null hypothesis was rejected. Therefore this study failed to support the idea that there will be no difference in the selected parameters between the no brace and brace wearing conditions. However, no statistical significance was found for any individual variable examined by *t* tests.

Chapter 5

DISCUSSION

The purpose of this study was to investigate the effect of a prophylactic knee brace on the motor performance of the knee as described by selected variables in young female athletes. A MANOVA was computed to examine any overall differences in performance between the brace wearing and no brace conditions. Additionally, repeated measures _t_ tests were computed to search for specific differences for each individual variable between the two conditions. This chapter contains a discussion and interpretation of the results reported in chapter 4.

MANOVA revealed that exercise performance, as described by blood lactate concentration difference, peak anaerobic power, Cybex II variables (peak torque at 60 deg/s, rise times at 60 deg/s, and time to fatigue), was significantly different between the brace wearing and no brace conditions. The analysis revealed that rise time at 60 deg/s had the greatest influence on this difference. Other performance variables influenced the difference between conditions in the following order of importance: blood lactate, peak torque at 60 deg/s, time to fatigue, and peak anaerobic power. As far as performance was concerned, it was significantly better under the no brace condition. Under the brace wearing condition, rise time was longer, peak torque smaller, time to fatigue shorter, and blood lactate production greater. Accordingly, brace wearing may inhibit speed of contraction, decrease force output with equivalent muscular effort, and foster greater anaerobic metabolism leading to earlier fatigue. Houston and Goemans (1982) reported similar findings in their study of functional knee braces. Their subjects demonstrated significantly slower knee extension velocity, lower peak torque, and greater blood lactate concentration under the brace wearing condition. Contrary to these findings, DeHaven (1985) reported no significant effect of prophylactic knee brace wearing upon speed and agility, although most subjects presented slower speed and reduced agility the under brace wearing condition. In this regard, DeHaven's report is consistent with the present study (i.e., rise time was slower with brace wearing). One unpublished study (cited in American Academy of Orthopaedic Surgeons, 1985) of the C Ti brace, which is a functional knee brace, reported there was no statistical difference between brace wearing and no brace conditions. This study examined isokinetic performance of the quadriceps and hamstrings, vertical jumping, and an agility running. Unfortunately, detailed information of the procedures, data, and statistical methods were not available for a comprehensive comparison with the present study. In summary, considering the results of the present study and some previous studies, knee brace wearing may interfere with physical performance by causing decreased speed and force of contraction and promoting fatigue. Individual variables examined are discussed below to provide a more detailed account of how brace wearing affected performance.

Five Cybex II variables (i.e., peak torque and rise time at two different angular speeds, and time to fatigue) were measured during knee extension under brace wearing and no brace conditions. Dibrezzo, Gench, Hinson, and King (1985) studied peak torque and rise time at 60 deg/s in young healthy female subjects (ages from 18-28 years) and reported peak torque and rise time means of 96.47 ft-lb and 2.77 s, respectively. Comparing these data with the present study (99.70 ft-lb and 2.50 s under no brace condition), slightly better performance was evidenced by the subjects used in this study. These minor differences were probably related to the fact that these subjects were slightly younger and competitive athletes.

The results of the repeated measures _t_ tests did not reveal any statistically significant differences in any single Cybex II variable between the experimental and control conditions. However, the absolute means for each variable represented poorer test performance with prophylactic knee brace wearing. The peak torque at both speeds was reduced, rise time was longer, and time to fatigue was shorter under the brace wearing condition. Houston and Goemans (1982) also reported that subjects' peak torques were significantly lower with knee brace wearing when compared to a control trial. However, it should be noted that these were male subjects with unstable knees, rather than the healthy female subjects as used in the present study. Moreover, these investigators made use of functional knee braces rather than a prophylactic type; the rigidity of a functional knee brace may interfere to a greater extent with normal knee function. However, results of the present study supported the conclusion of Houston and Goemans in that output torque of the knee muscles was reduced with knee brace wearing. These authors suggested that reduced torque output resulted from the damping effect of the knee brace, which absorbs output force of the knee joint muscles. In the present study, electromyographic activity of the quadriceps was recorded to examine this possible damping effect.

Electromyographic data collected showed no significant difference between the conditions, indicating that subjects made equivalent efforts during both brace wearing and no brace conditions. Unfortunately, significant electromyographic signal artifact was observed during the testing, and test scores greater than maximal reference values were recorded. (Indeed, one subject scored 170% of her reference value.) Artifact may have resulted from two factors: (a) the wire from the amplifier may have moved while subjects extended and flexed their knees, which affected input impedance of the amplifier (Soderberg & Cook, 1984), or (b) the Cybex II dynamometer's electrical operation interfered with the signals. Further study is needed to detect and eliminate the source of signal artifacts.

Cybex II variables and electromyography were measured during knee extension. Combining the results of these variables, it can be noted that although no statistically significant difference was observed for either individual variable, output force tended to be diminished although equivalent efforts between trials probably occurred.

In this study, anaerobic performance was estimated by the Wingate anaerobic cycling test and blood lactate concentration. Three variables were observed during the Wingate test. No statistically significant difference was found in any of these individual variables between the knee brace wearing and no brace conditions. However, power decline and average power (calculated from the results of the Wingate test) revealed higher mean scores under the no brace condition. Therefore, less fatigue and greater power output were seen in the subjects under the no brace condition. Houston and Goemans (1982) reported the maximal power output, measured by a short stair run, was significantly greater under the no brace condition. In the present study, peak power failed to show any remarkable difference between the two conditions, although a lower mean was seen under the no brace condition.

It was interesting to note, without regard to treatment or control trial, subjects always performed better during their second Wingate test. (Half the subjects wore the brace during the first trial, half during the second trial.) The results of repeated measures *t* test showed that power decline, which is an index of fatigue rate, was significantly less for the second trial ($p < .05$). This smaller power decline indicated that subjects were less fatigued. Although the average power did not show significant difference, the mean value for this variable did represent a greater average power at the second trial. As a result, it can be concluded that subjects consistently performed better at the second trial. This implied that a learning effect, unanticipated in the present study, influenced test results. Several sources (Lamb, 1984; Tharp, Newhouse, Uffelman, Thorland, & Johnson, 1985) have reported that the Wingate test can serve as a predictor of anaerobic capacity, but fail to mention that an individual's familiarity with the test should be considered. However, it is not believed results of this study were strongly affected, because learning was at least partially controlled by random assignment of the condition. Exactly half of the subjects wore the brace on the first trial, and the other half wore the brace during the second trial.

Lactate, the product of anaerobic metabolism, is regarded as a fatigue-inducing substance produced during intense physical exercise. Excessive lactate accumulation in skeletal muscle inhibits phosphorylase and phosphofructokinase activity, and thereby promotes fatigue (Lamb, 1984). Anaerobic metabolism occurs in two situations: (a) the beginning of relatively high intensity exercise, before aerobic metabolism can meet the total energy demand, and (b) when the aerobic metabolism pathway of carbohydrates is over stimulated and certain key enzymes are not able to keep up with the required pace (Jacobs, 1983). Houston and Goemans (1982) reported that after completing a 15-min endurance bicycle ride, blood lactate concentrations were significantly higher under the brace wearing condition. They suggested the knee braces might interfere with blood flow and hence oxygen delivery. In the present study, subjects rode on the bicycle for only 4.5 min, but for the last 30 s their efforts were very intense. Results showed that mean values of lactate concentration were higher under the brace wearing condition, but this was not statistically significant. If Houston and Goemans' interpretation was correct, the riding time in the present study may not have been long enough to produce a significant difference. Despite the lack of a significant difference, data trends indicated increased lactate under the brace wearing condition. This increased lactate concentration may have contributed to the earlier fatigue indicated by a greater power decline found in the present study.

The results of the present study showed decreased speed, force of contraction, and early fatigue occurred under the brace wearing condition. It can be concluded that physical performance of young female athletes was impeded under these circumstances. Although individual aspects of performance were affected only slightly, the overall physical performance of the brace wearing leg was reduced significantly as indicated by the MANOVA. The failure of previous studies to use multivariate procedures could explain why most failed to find any significant decline in performance with brace wearing. Impeded performance probably resulted from the restriction and damping effect caused by the brace, which promoted lactate accumulation and decreased the output force of muscle contraction. Further studies are needed to elaborate the reasons for the performance decline observed.

It is still controversial whether a prophylactic knee brace can really protect the knee joint from severe injury. Reports from some universities claimed that injuries are reduced with brace wearing, but others reported no significant difference between two conditions. Potera (1985) suggested that it is possible that a prophylactic knee brace is not strong enough to really prevent severe injury. Furthermore, Legwold (1985) and DeHaven (1984) stated that the structural design of a prophylactic knee brace may lead to a greater injury rate and severity. Considering the results of the present study, reduced performance with brace wearing may be related to increased injury rate, although this speculation can not be confirmed. Future studies should be done to examine this possibility.

At this time, no protective effectiveness of the prophylactic knee brace has been proven. Considering the results presented by this study, it is important to question whether the protection offered will counterbalance the reduced performance ability apparently caused by brace wearing. However, it should be noted that the present study was conducted in a laboratory setting, and a field study should be done to further observe the effects of brace wearing upon performance.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate the effect of a prophylactic knee brace on athletic performance as described by selected variables. The subjects were 10 female athletes ranging in age from 18 to 22 years. All subjects were students and members of the 1985 Ithaca College women's lacrosse team.

The study consisted of two testing sessions for each subject. The procedures for each session were the same except that during one trial subjects wore a prophylactic knee brace. Independent variables measured under the two conditions were blood lactate concentration, Cybex II variables, and anaerobic power. All tests were performed at the Ithaca College Physical Therapy Laboratory. Knee extension performance was also quantified by electromyographic data. A MANOVA was computed to test for significance between the two conditions when the combined effect of all independent variables were considered. Results revealed that the performance of young female athletes was significantly reduced in the brace wearing condition ($p < .05$). Repeated measures t tests were utilized to determine if significant differences existed in the independent variables under the two conditions. No statistically significant differences were found for any individual variable. However, most data supported the idea that brace wearing can impede physical performance.

Conclusions

The results of the this study support the following conclusions:

1. The overall performance as described by blood lactate concentration, peak power, peak torque at 60 deg/s, rise time at 60 deg/s, and time to fatigue is decreased significantly by prophylactic knee brace wearing.

2. There is not enough statistical evidence to support decreased performance for individual variables (contraction speed, output torque, anaerobic power, and lactate production), although there was a tendency for all variables to indicate slightly worse performance under the brace wearing condition.

Recommendations

The findings of this investigation lead to these recommendations:

1. A study should be conducted involving a larger number of subjects.

2. A study should be conducted to involve different prophylactic knee braces to assess the effect of various structural designs.

3. A study should be conducted in which the electromyograph's artifact observed in this study is controlled to determine if equivalent contraction effort really occurs under the no brace and brace wearing conditions.

4. A study should be undertaken to assess the effect of learning on the Wingate anaerobic cycling test and establish a reliable administration schedule.

5. Another study should be conducted to examine the effect of prophylactic knee brace wearing during field activity.

Appendix A

INFORMED CONSENT FORM

1. (a) Purpose of the study. To assess the effect of a protective knee brace on leg performance (i.e., muscle strength, muscle activity pattern, velocity, and the degree of fatigue).

   (b) This study will attempt to provide information about the influence of a protective knee brace on leg performance. It is hoped the results of this study will provide useful information to encourage or discourage the further use of protective knee braces in physical activity. As a subject, a direct benefit you will receive is a free evaluation of your knee function. This explanation will include how the knee brace affects your work capacity.

2. Method.

   You will be asked to fill out a personal medical history questionnaire (see attached). You will need to visit the Ithaca College Physical Therapy Laboratory two times. One hour will be needed for each visit. The procedures you will be asked to do on each visit are as follows:

Appendix A (continued)

(a) Allow two small blood samples to be taken by the finger pricking technique.

(b) Walk on a level treadmill for 3 min.

(c) Ride a bicycle at maximal effort for 30 s.

(d) Sit at the Cybex II dynamometer, which is a machine used to measure muscle strength. Three surface recording electrodes (sticker tape electrodes) will be put on the thigh to monitor the muscle activity. You will maximally extend and flex the knee joint eight times at a slower speed followed by several efforts at a faster speed.

The same procedures will be repeated during the second visit. The only difference between the two visits is you will be asked to wear a knee brace during only one of the visits.

3. Will this hurt? No lasting physical or psychological pain will result from this experimentation. Some muscle ache may be experienced as fatigue approaches at the end of exercise, and some minor discomfort may be felt after finger pricking. Additionally, some delayed muscle soreness may be present in the 24-72 hours subsequent to each test day.

Appendix A (continued)

4. <u>Need more information?</u> Additional information may be obtained from either Nih-Mey Chen (257-6568) or Dr. G. Sforzo (274-3359). All questions are welcome and will be answered.
5. <u>Withdraw from the study.</u> Participation is voluntary. You are free to withdraw your consent and discontinue at any time during this study without prejudice of any kind.
6. <u>Will data be maintained in confidence?</u> All of the data will be confidential. Once data are collected, names of subjects will be discarded and replaced by numbers in subsequent reports. Only group data will be reported.
7. Please initial either (a) or (b) below, as appropriate:
   (a) I have NOT experienced any knee injury and have no physical condition which might be aggravated by participation in this study.________________
   (b) I have experienced a knee injury and/or I have a physical impairment of the knees (circle as applicable), but medical clearance to participate in this study is attached.

   ____

Appendix A (continued)

8. I have read the above and I understand its contents and I agree to participate in the study. I acknowledge that I am 18 years of age or older.

Signature:__________________________Date:_____________

Appendix A (continued)

PERSONAL MEDICAL HISTORY

Please Print

Name:______________________ Date of birth:_________

Home Address:______________________________________

Phone:______________

General Information

Do you do any physical training program regularly? Y N

If yes, please list type and intensity:

____

number of times:

Have you worn a knee brace before? Y N

If yes, please give the name of brace:

____

When did you wear it?

____

How long did you wear it?

____

Why did you wear it?

____

Do you currently wear a knee brace?

If yes, please give the name of brace:

____

Appendix A (continued)

When do you wear it?

____

How long have you worn it?

____

Why do you wear it?

____

On which leg do you wear it?

____

Appendix A (continued)

General Medical History

Do you have any systemic disease? Y N

If yes, please specify:________________________

Have you ever received any treatment for the knee joint? Y N

If yes, please write down the reason:

____

When?____

Which knee?____________________________________

Do you have any muscular injuries or illness now? Y N

If yes, please specify:________________________

Do you have any muscular pain at rest? Y N

If yes, please describe:_______________________

Do you feel any muscular pain with exertion? Y N

If yes, please describe:_______________________

Do you have any knee injury before? Y N

If yes, please describe:_______________________

Which leg:_______________________

When:_______________________

Do you feel any knee joint pain after exercise? Y N

If yes, please describe:_______________________

Appendix B

DATA SHEET

Subject:___________________________ Date:_______________

Bracing Condition: brace wearing no brace

Body weight:__________________ Age:_______________

Cybex II	60 deg/s	120 deg/s
peak torque	_______________	_______________
rise time	_______________	_______________
time to fatigue	_______________	_______________

EMG	max. value	60 deg/s	%
	____________	_______________	_____

Wingate test	5	10	15	20	25	30

peak power:____________________

average power:_________________

power decline:_________________

Lactate concentration	before	after

Difference:_______________________

Appendix C

SUBJECTS' RAW DATA:

WINGATE ANAEROBIC CYCLING TEST

Subject	Peak power		Average power		Power decline	
	no brace	brace	no brace	brace	no brace	brace
1	529.42	352.95	435.52	225.23	57%	60%
2	588.25	588.25	392.36	392.26	33%	50%
3	317.66	423.54	238.24	273.71	33%	50%
4	337.26	282.36	197.65	254.12	67%	60%
5	370.60	423.54	308.65	379.60	29%	25%
6	370.60	337.26	320.20	282.36	44%	44%
7	376.48	470.60	268.24	282.36	43%	33%
8	370.60	370.60	301.83	281.24	56%	67%
9	494.13	564.72	340.95	340.80	63%	60%
10	317.65	423.54	273.71	301.16	57%	63%

Note. All power measured in watts.

Appendix D

SUBJECTS' RAW DATA: CYBEX TEST

Subject	Peak torque				Rise time	
	60 deg/s		120 deg/s		60 deg/s	
	no brace	brace	no brace	brace	no brace	brace
1	100	114	90	99	3.00	3.56
2	135	106	96	50	6.20	3.40
3	77	80	66	69	3.11	5.64
4	93	84	72	75	4.00	3.92
5	99	98	74	82	0.72	2.80
6	114	111	82	84	6.20	5.28
7	87	75	66	66	0.44	3.14
8	68	84	42	48	0.40	5.04
9	124	124	92	92	0.48	3.30
10	100	100	76	74	0.42	3.40

Note. All times are recorded in seconds, and peak torque is recorded in foot pounds.

Appendix D (continued)

Subject	Rise Time 120 deg/s		Time to Fatigue	
	no brace	brace	no brace	brace
1	2.8	2.30	43.3	40.00
2	2.2	6.20	19.2	12.00
3	4.1	4.80	78.8	63.00
4	4.4	4.80	46.0	32.40
5	2.3	2.40	37.2	24.40
6	1.4	3.70	49.8	52.80
7	2.9	1.70	36.5	49.40
8	1.5	1.80	15.0	24.40
9	2.4	2.20	32.6	31.20
10	2.2	2.26	32.2	33.76

Note. All times are recorded in seconds.

Appendix E

SUBJECTS' RAW DATA:

ELECTROMYOGRAPHY AND LACTATE CONCENTRATION

Subject	EMG		Lactate	
	no brace	brace	no brace	brace
1	96	100	10.50	12.28
2	150	160	10.96	13.00
3	83	103	10.50	8.21
4	107	108	6.19	7.20
5	92	90	10.20	11.85
6	93	85	13.30	10.73
7	98	95	6.67	7.01
8	83	80	6.99	9.58
9	98	92	5.64	6.80
10	98	93	9.00	9.60

Note. EMG values represent a percent of maximal contraction, and lactate is the concentration difference between resting and post-exercise in millimolar.

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