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Award Number: DAMD17-00-1-0515

TITLE: Biomechanical Factors in the Etiology of Tibial Stress Fractures

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REPORT DATE: August 2002

TYPE OF REPORT: Annual

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;
Distribution Unlimited

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 074-0188*

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 2002	Annual (21 Jul 01 - 20 Jul 02)

4. TITLE AND SUBTITLE
Biomechanical Factors in the Etiology of Tibial Stress Fractures

5. FUNDING NUMBERS
DAMD17-00-1-0515

6. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE

13. Abstract *(Maximum 200 Words)* *(abstract should contain no proprietary or confidential information)*

The overall aim of this research is to gain insight into the etiology of tibial stress fractures. Three dimensional motion analysis data along with structural data will be collected from 400 subjects (200 at each site) over a 3-year period. 30 of the subjects will have sustained a tibial stress fracture prior to the study and the other 370 will have not. Subjects will be recruited primarily from track teams, running clubs, and physicians local to the University of Delaware and University of Massachusetts. Within this Annual Report, information concerning adherence to work objectives, preliminary results with respect to the proposed hypotheses, and reportable outcomes are presented for the second year of the investigation. Overall, we have adhered to most work objectives and have proposed plans for rectifying any discrepancies. The preliminary analysis of the data demonstrates encouraging results and support of most hypotheses.

14. SUBJECT TERMS
tibial stress fractures, bone structure, running, etiology

15. NUMBER OF PAGES
59

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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INTRODUCTION

Stress fractures can be extremely costly to the military in terms of both time and medical expenses. The tibia is a common site for such injuries and has been most often associated with running, an activity common to all military training. Stress fractures are among the top 5 cited lower extremity injuries sustained by runners (Clement et al., 1981; Kowal, 1980; James et al., 1978; Jones et al., 1983; Pagliano et al., 1980; Reinker et al., 1979). They are among the most serious of running-related overuse injuries as they take long to heal and if untreated, can progress to a macrofracture. Females are a growing military contingency and appear to be particularly susceptible, as it has been noted that they are twice as likely to experience a stress fracture as their male counterparts (Brudvig et al, 1983; Pester & Smith, 1992; Reinker et al, 1979).

Structural and biomechanical factors have been suggested in the cause of stress fractures. However, these mechanisms are not well understood. Therefore, the purposes of this study are 1) to compare the structure and mechanics of runners who have sustained a tibial stress fracture to those who have not, 2) to gain an understanding of which combination of factors (structural and/or biomechanical) are predictive of tibial stress fractures, and 3) to assess whether mechanics are altered following a tibial stress fracture. Once the factors associated with stress fractures are identified, future work will focus on formation and testing of a simple screening tool to facilitate identification of those at risk.

This is a dual-site investigation (University of Delaware & University of Massachusetts, Amherst) which began on September 1, 2001 and has been under investigation for 2 years. This Annual Report will focus on preliminary results after the second year of the study.

BODY

Summary of Methodology

The overall aim of this research is to gain insight into the etiology of tibial stress fractures. Three dimensional motion analysis data along with structural data will be collected from 400 subjects (200 at each site) over a 3-year period. A minimum of 30 subjects will have sustained a tibial stress fracture prior to the study. Subjects will be recruited primarily from track teams, running clubs, and physicians local to the University of Delaware and University of Massachusetts. All subjects will be females between the ages of 18 and 45 and will be free of lower extremity injury at the time of testing. Lower extremity kinematics and kinetics will be collected during running. In addition, radiographs of both tibiae will be taken as well as clinical measures of lower extremity alignment. Subjects will then report their exposure data (mileage, intensity, terrain) as well as any injuries they have sustained each month via a custom developed webpage which will serve as a database for this information. If a subject reports a tibial stress fracture/reaction, the site coordinator will be notified automatically and the subject will be asked to return for a second running analysis once the fracture has healed and they are cleared to run by their physician. The structural and biomechanical factors leading up to a tibial stress fracture will be assessed. In addition, comparisons will be made of mechanics before and after the stress fracture to determine whether subjects revert back to their pre-injury mechanics.

Statement of Work

Between the two data collection sites, the following objectives were outlined in the approved Statement of Work for the second year. These objectives included:

1. Recruitment of an additional 75 subjects per site for a sub-total of 125 subjects per site.
2. Data recollected on those who have sustained a tibial stress fracture since the onset of the study.
3. Abstracts submitted to national meetings regarding structural and biomechanical data in subjects who have previously sustained a tibial stress fracture.
4. Continue with follow-up procedures on subjects.

Adherence to Work Objectives

1) Recruitment of Subjects

To date, data on 95 subjects have been collected at the University of Delaware and 50 subjects have been collected at the University of Massachusetts. Several local coaches and track teams have been contacted to recruit subjects and establish relationships for injury tracking. Additional contacts are continuing to be made to recruit the necessary subjects.

Of the 95 subjects collected at the University of Delaware, 75 have been collected in the past year which meets the requirement for this year. However, as of the end of year 1, the University of Delaware was 30 subjects short of meeting the objective of 50 subjects. Since the number of subjects for year 2 has already been met, we are confident that the remaining 30 subjects will be collected by December 2002 putting the University of Delaware back on schedule at that time.

The University of Massachusetts has had a difficult time recruiting subjects from the surrounding area of Amherst, MA. As such, the number of subjects collected does not reflect what was proposed and several circumstances exist to explain the discrepancy. First, one of the students intimately involved in recruiting and collecting data graduated in April of 2002 and thus a change of personal was necessary. With a new student involved in recruitment and data collection, time was lost to orient and train them. In addition, the new student who was recruited and trained decided to leave the PhD program only a few months after training. Thus, another student is will begin training at the end of the summer. In the mean time, summer students are working diligently to recruit and collect data. Second, the level of participation from surrounding colleges has been less than predicted. The status of local college recruitment is as follows:

- **Springfield College and Smith College:** The women's track and field and cross-country teams have been unavailable for the first 2 years of the study due to involvement in another research study. However, these teams will be able to participate in this study for the 2002/2003 school year.
- **Amherst College:** The coach was willing to include several of his runners in this study this past year but only during the fall. We expect to recruit several more subjects from this program in this coming fall.
- **Elms College:** This is a small program that is about 45 minutes away. We have had several subjects from this program and expect several more this coming fall.
- **Mt. Holyoke College:** We have had several subjects from this program and expect several more this coming fall.
- **Hampshire College:** This college does not have a cross-country team.
- **University of Massachusetts:** We have had ongoing data collections from incoming University of Massachusetts cross-country and track and field athletes.

Several actions have been implemented to increase University of Massachusetts recruitment. These actions include the following:

- Subject recruitment booths have been set up at local races. Brochures are given out and interested subjects are signed up at the event. A copy of the advertisements has been included in Appendix B.
- Presentations at several women's running groups have been given.
- Subject recruitment signs have been posted at local (Amherst, Northampton and Springfield) health clubs and running stores.
- Subject recruitment announcements have been printed in campus newspapers and in local running club bulletins.
- Subject recruitment announcements have been posted on local running club websites.

With these recent implementations, the University of Massachusetts has scheduled 28 subjects over the next two months. In addition, fall semester data collections of the surrounding colleges will begin with the return of the athletes. We believe that we will have the remaining subjects at each site collected by December 2002 putting each site on schedule.

2) Collection of Data on those who have sustained a tibial stress fracture

To date, 2 subjects have sustained lower extremity stress fractures since data was first collected on them. Data have been recollected on 1 of these subjects and we are waiting for the second subject to completely heal from the stress fracture before recollection. A summary of their pre-injury findings is included in the Reportable Outcomes section.

Unfortunately, 5 University of Delaware track athletes experienced stress fractures very early in the fall season and we were unable to collect their pre-injury data due to their scheduling conflicts. We have contacted the coach and are planning on collecting data on the new track team recruits prior to fall semester and the cross-country season in an effort to increase the number of prospective stress fracture injuries in our study. In addition, Delaware State, Widener University, West Chester University, and Lincoln University have all been contacted and a limited number of athletes have participated in the study to date. These Universities have shown limited involvement in the study most likely since they are 30-40 miles away from the University of Delaware. We will be contacting these teams early in the season in hopes of increasing the number of participants and thus the number of prospective stress fractures.

3) Abstract Submission

To date, three additional abstracts have been submitted and were accepted for presentation. These abstracts were presented at the American College of Sports Medicine National Meeting in St. Louis, Missouri and at the World Congress of Biomechanics in Calgary, Alberta, Canada. The references and a summary of the findings are provided in the Reportable Outcomes section and the complete abstracts are included in Appendix A.

4) Follow-up procedures

All subjects have been tracking their monthly running exposure and injuries since their initial visit and these data have been input into the database. The database continues to function properly and all subjects have been logging in on a monthly basis to record their mileage and injuries. A summary of the injuries reported has been summarized in the Reportable Outcomes section.

KEY RESEARCH ACCOMPLISHMENTS

Data collection and analysis of this 5-year project is still in the early stages. As defined by the Technical Reporting Requirements guidelines, there are no Key Research Accomplishments to report, nor were any expected at this stage of the project.

REPORTABLE OUTCOMES

This section contains a summary of the 3 abstracts presented on retrospective stress fractures, a summary of the data from the 2 prospective tibial stress fractures, a list of abstract publications, a summary degrees obtained that are supported from this award, and a summary of the information from the database.

1) Summary of the 3 abstracts presented on retrospective stress fractures

Subjects consisted of 10 females with a history of at least one lower extremity stress fracture (SF) and 10 females with no SF history who served as a control group. All subjects were between ages 18-35 and ran between 30-80 miles per week. Ground reaction force (GRF), kinematic data, and tibial acceleration data were recorded from 5 running trials. Three radiographs of the distal lower extremity were used to calculate the tibial area moment of inertia (Milgrom et al., 1989). Each subject underwent a structural evaluation by an experienced physical therapist.

1.1 It was hypothesized that runners who had sustained a previous SF would exhibit greater vertical loading rates (LR), vertical ground reaction forces (vGRF), and peak positive tibial acceleration (PPA).

Based on the results of these studies, subjects who had previously sustained a lower extremity stress fracture exhibited significantly greater vGRF, PPA, and LR values compared to non-injured subjects (Fig. 1-3). These results support those of Grimston et al. (1991) who also reported that higher vGRF values were associated with stress fractures in women runners. However, these results are in contrast to Crossley et al. (1999) who reported no differences in kinetic variables between SF and healthy runners. However, these authors used male runners who may exhibit different running mechanics compared to women runners.

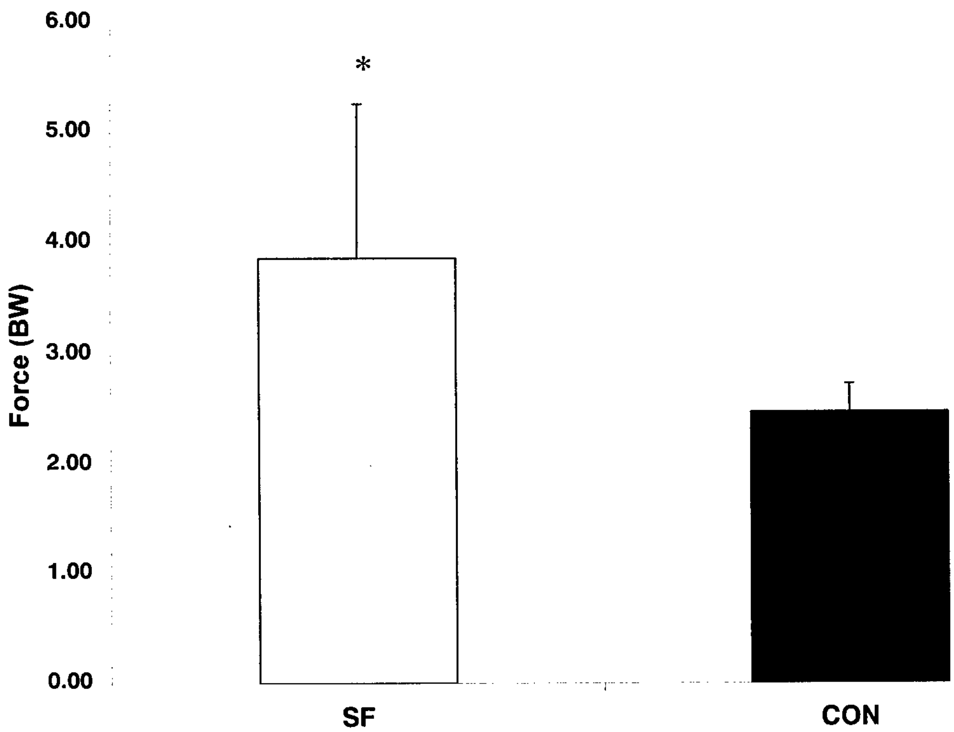

Figure 1: Vertical Ground Reaction Force for subjects who had previously experienced a stress fracture versus healthy controls. (* = significantly greater than controls)

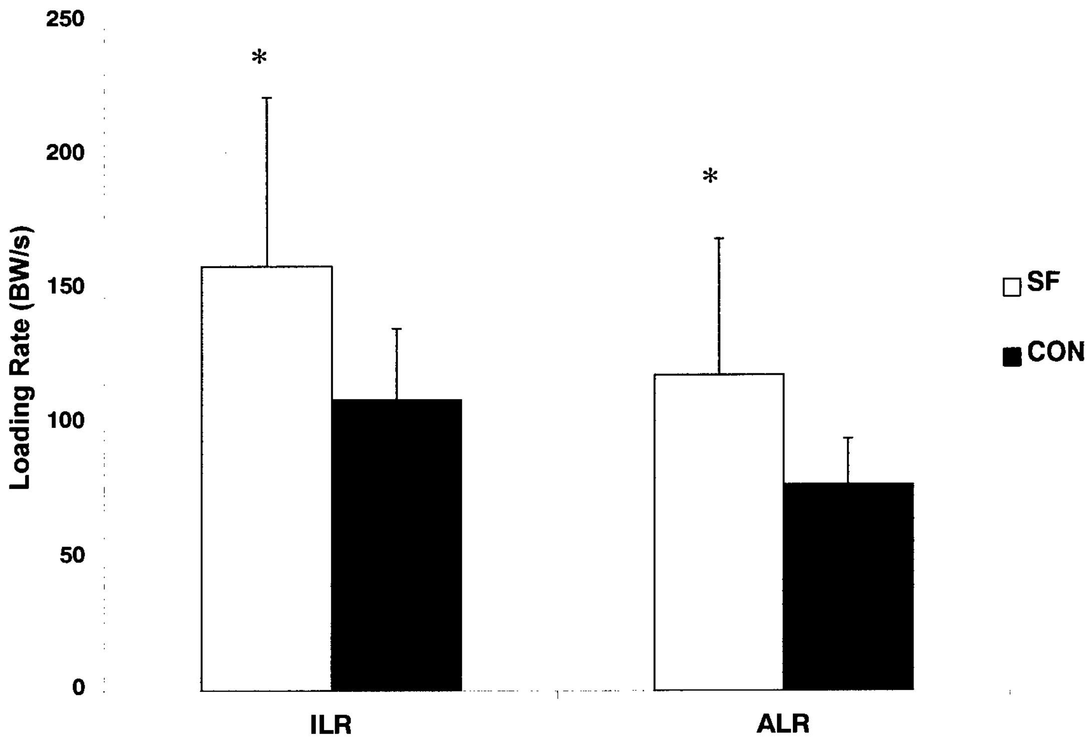

Figure 2: Instantaneous and average loading rates for subjects who had previously experienced a stress fracture versus controls. (* = significantly greater than controls)

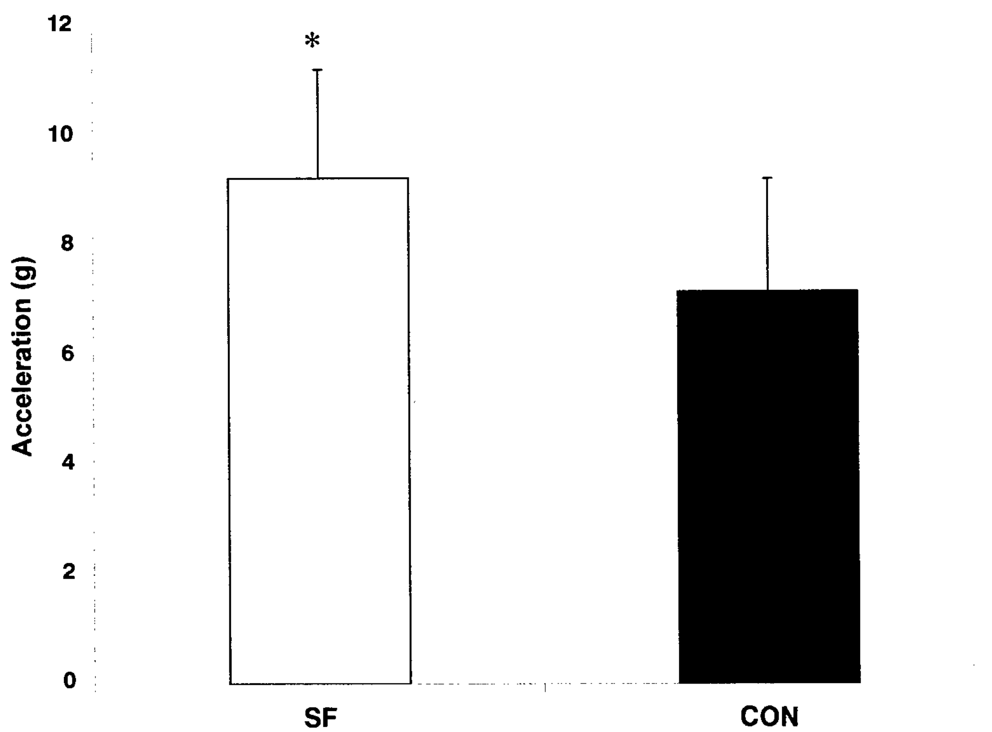

Figure 3: Peak positive acceleration for subjects who had previously experienced a stress fracture versus healthy controls. (* = significantly greater than controls)

1.2 It was hypothesized that runners who had sustained a previous SF would exhibit greater stiffness, and reduced knee flexion excursion compared to controls. .

Although not significant, a trend towards greater stiffness and reduced knee flexion excursion in the SF group was also observed compared to controls (Fig. 4 & 5). The stiffness of elastic structures will control the kinematics of the runner. A "stiff" runner will spend less time in contact with the ground (Farley and Gonzalez, 1996) and will attenuate less shock between the leg and the head (McMahon, Valiant and Frederick, 1987). The results of these subjects who had previously experienced a SF are in agreement with Farley and Gonzalez (1996) and suggest that lower extremity stiffness and knee kinematics are highly correlated and may lead to SF.

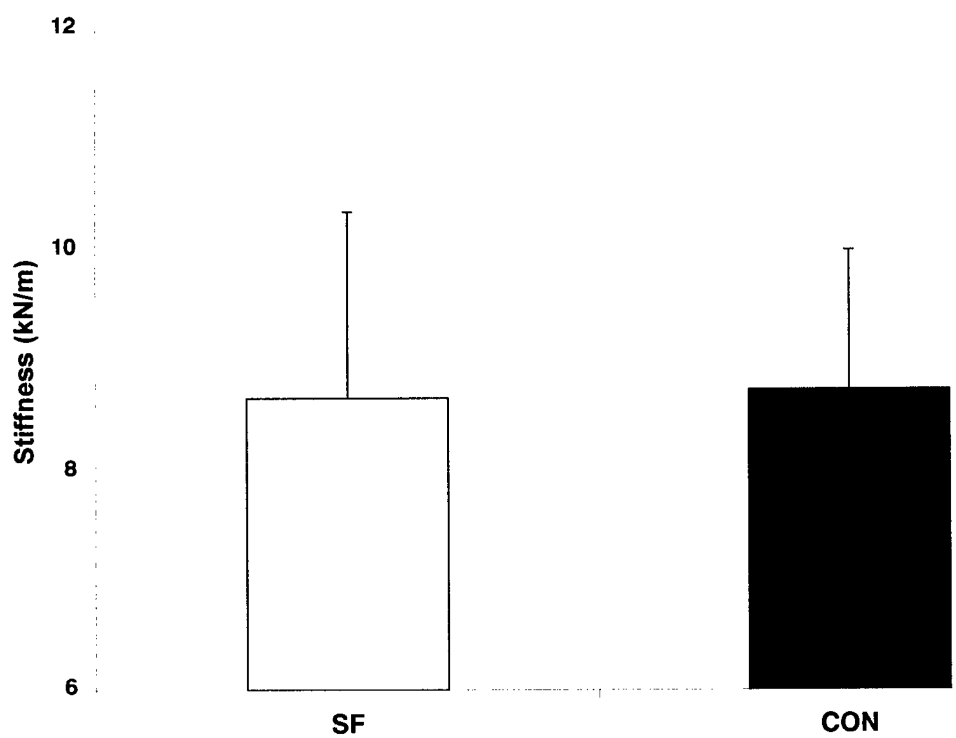

Figure 4: Lower extremity stiffness for subjects who had previously experienced a stress fracture versus healthy controls

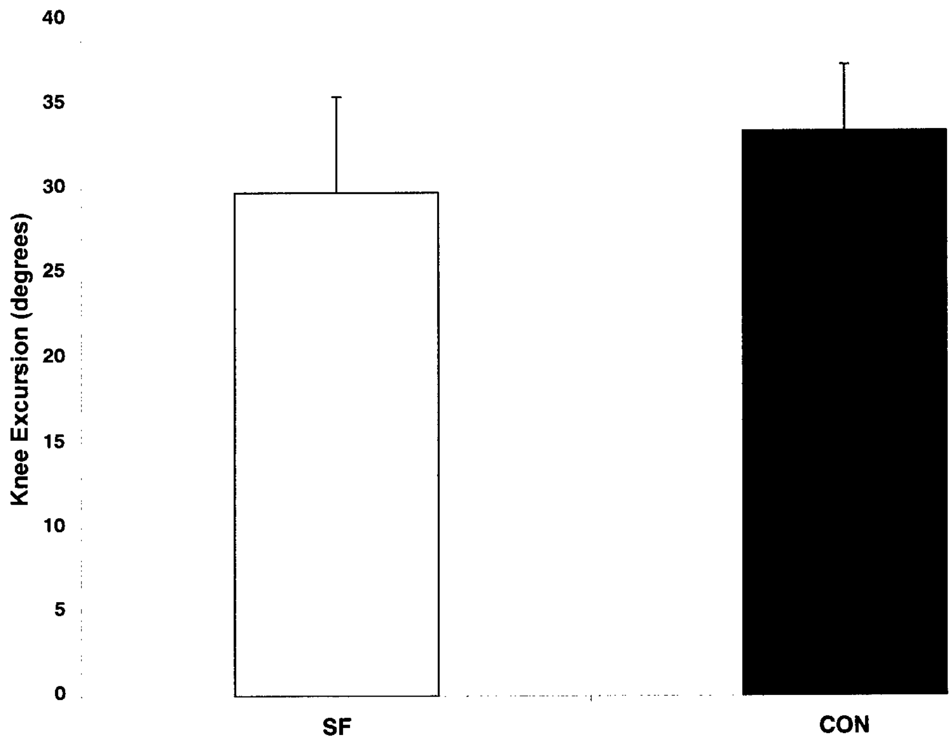

Figure 5: Knee flexion excursion for subjects who had previously experienced a stress fracture versus healthy controls

1.3 It was hypothesized that runners who had sustained a previous SF would exhibit greater tibial varum and reduced tibial area moment of inertia compared to healthy controls.

Although specific structural characteristics have been associated with stress fracture injuries (Crossley, 1999; Milgrom, 1989), these groups of female distance runners did not demonstrate this relationship. However, the SF group exhibited 30% less tibial area moment of inertia (M/L level 2) values compared with the control group (Fig. 6). No differences in tibial varum were observed between the two groups (Fig. 7). A small subject population may account for discrepancies between previous studies and the results of this investigation.

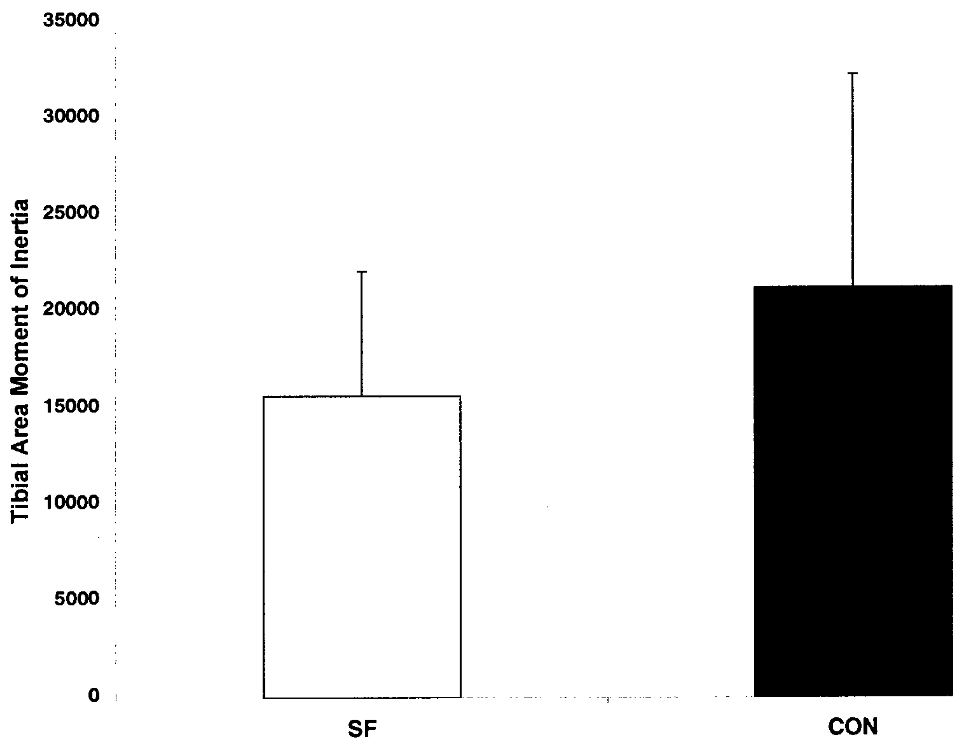

Figure 6: Tibial area moment of inertia (M/L level 2) for subjects who had previously experienced a stress fracture versus healthy controls

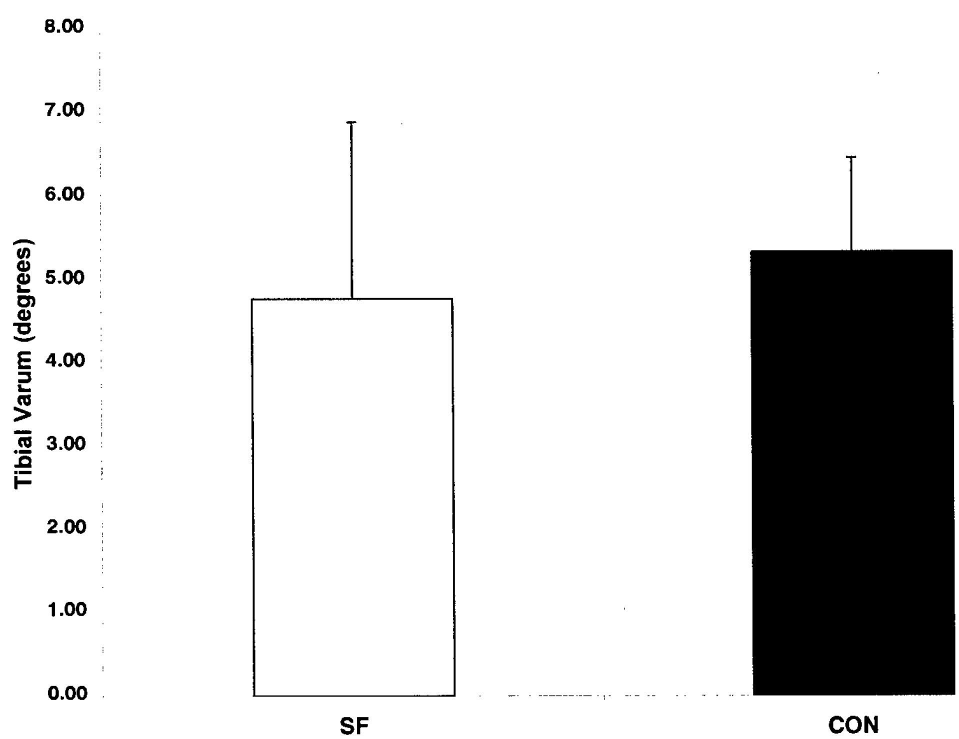

Figure 7: Tibial varum measurement for subjects who had previously experienced a stress fracture versus healthy controls

In conclusion, there may be numerous underlying mechanisms associated with these stress fracture injuries that are difficult to account for in a retrospective study. Potential underlying mechanisms could have included training mileage, training surface, nutrition and history of amenorrhea. In addition, prospective studies are essential to determine whether the observed increases in these kinetic variables were present prior to the stress injury. However, based on the summary of these 3 abstracts, several of the hypotheses were supported.

2) Summary of the 2 prospective tibial stress fractures

With the relatively small number of participants who have experienced tibial stress fractures (TSF), statistical analyses of the preliminary results have not been performed. Results for each of these variables will be discussed for each individual with respect to trends observed in the data. It was hypothesized that runners who had sustained a TSF would exhibit greater average and instantaneous loading rates (ALR/ILR), vertical ground reaction forces (vGRF), peak positive tibial acceleration (PPA), stiffness, and tibial varum. In addition, it was hypothesized that these subjects would also exhibit reduced knee flexion excursion and tibial area moment of inertia.

A summary of results for the respective hypotheses for the two TSF subjects and for a group of non-injured control subjects are presented in Table 1. Overall, the two TSF subjects collectively supported the majority of the hypotheses. For example, while Subject 1 exhibited only slightly greater ALR, ILR, vGRF, and tibial varum (Figs. 8, 9, & 12; Table 1), she demonstrated very high PPA and stiffness values compared to the control group (Figs. 10 & 11; Table 1). In addition, her tibial area moment of inertia was 31% less than controls (Fig.13; Table 1). On the other hand, while Subject 2 exhibited similar vGRF and stiffness values compared to controls (Figs. 9 & 11; Table 1), her ALR, ILR, and PPA were much higher compared to controls (Figs. 8 & 10; Table 1). In addition, Subject 2 demonstrated greater tibial varum alignment and 37% less tibial area moment of inertia (M/L level 2) compared to controls (Figs. 12 & 13; Table 1).

While only a slightly higher PPA and a lower tibial area moment of inertia were common between the 2 TSF subjects, several other variables were in support of the hypotheses. The etiology of a TSF is multifactorial in nature but is related, in part, to some combination of bone structure, peak forces, loading rates, as well as lower extremity running mechanics. These results suggest that each subject exhibited unique structural measures and running mechanics that may have predisposed them to a tibial stress fracture. Overall, these are encouraging results. As more subjects experience stress fractures, we are confident that a simple screening tool to facilitate identification of those at risk can be developed.

TABLE 1: Summary of variables for the 2 prospective tibial stress facture subjects in comparison with healthy controls.

Variable	Subject 1	Subject 2	Control
Vertical Loading Rates (ALR)	80.49	126.38	77.52 (17.03)
Vertical Loading Rates (ILR)	111.50	142.35	108.89 (26.44)
Peak vertical GRF (vGRF)	2.66	2.55	2.52 (0.23)
Peak Positive Tibial Acceleration (PPA)	10.68	9.80	7.52 (2.96)
Stiffness	9.78	7.93	8.7 (1.13)
Tibia Varum	6.00	8.00	5.25 (2.05)
Knee Flexion Excursion	36.03	35.12	33.40 (3.91)
Moment of Inertia (M/L level 2)	13991.14	12782.46	20322.50 (7819.56)

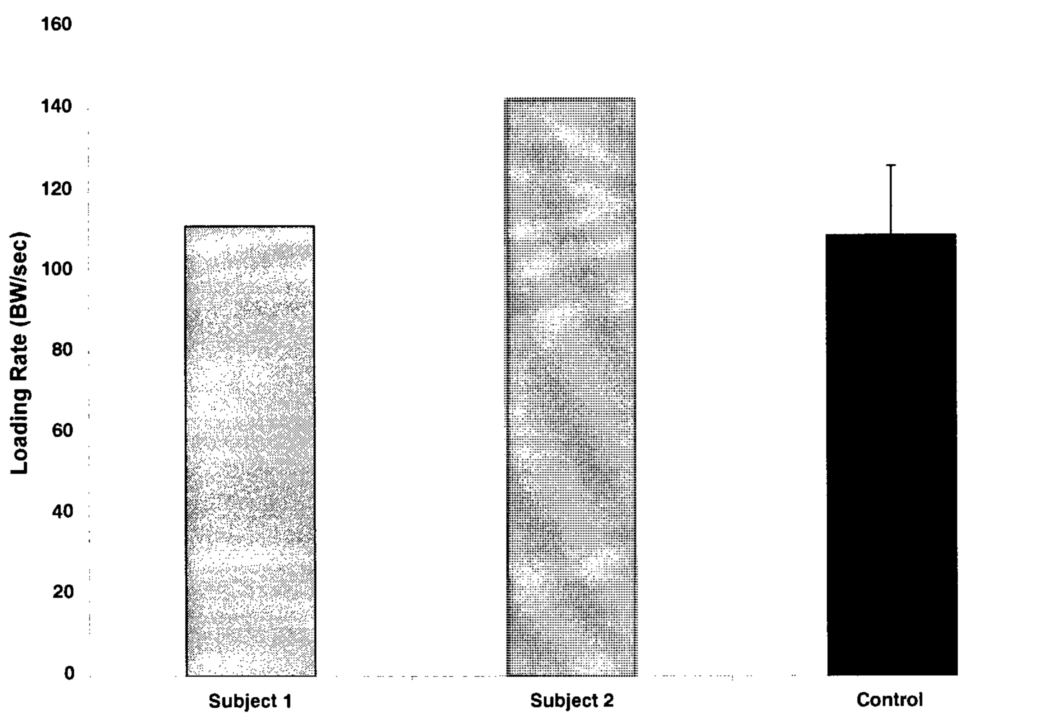

Figure 8: Instantaneous loading rate for the 2 prospective tibial stress fracture subjects and healthy controls

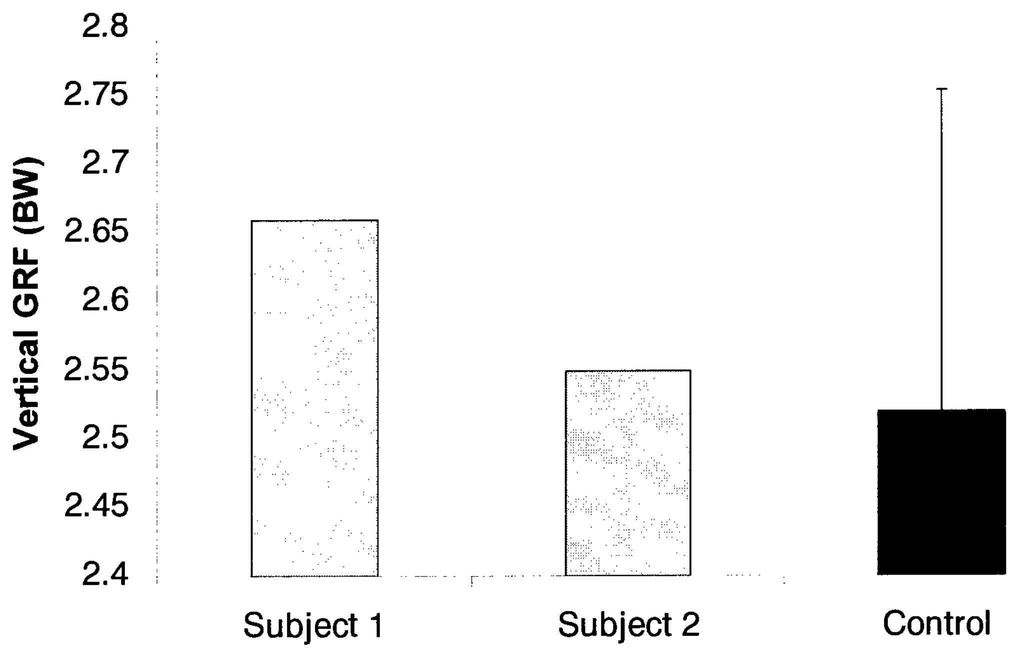

Figure 9: Peak vertical ground reaction force for the 2 prospective tibial stress fracture subjects and healthy controls

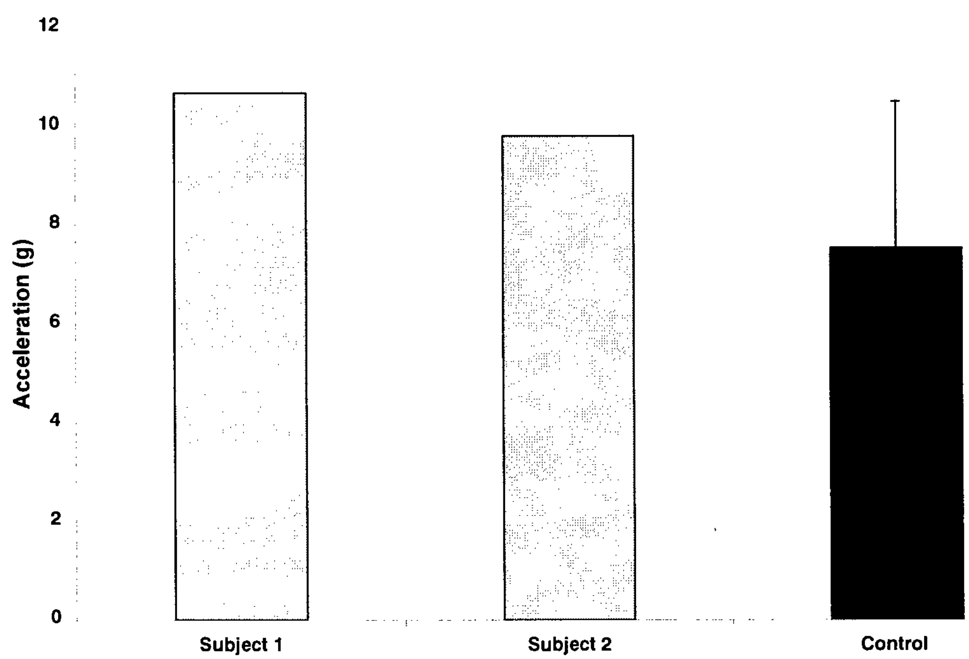

Figure 10: Peak positive acceleration for the 2 prospective tibial stress fracture subjects and healthy controls

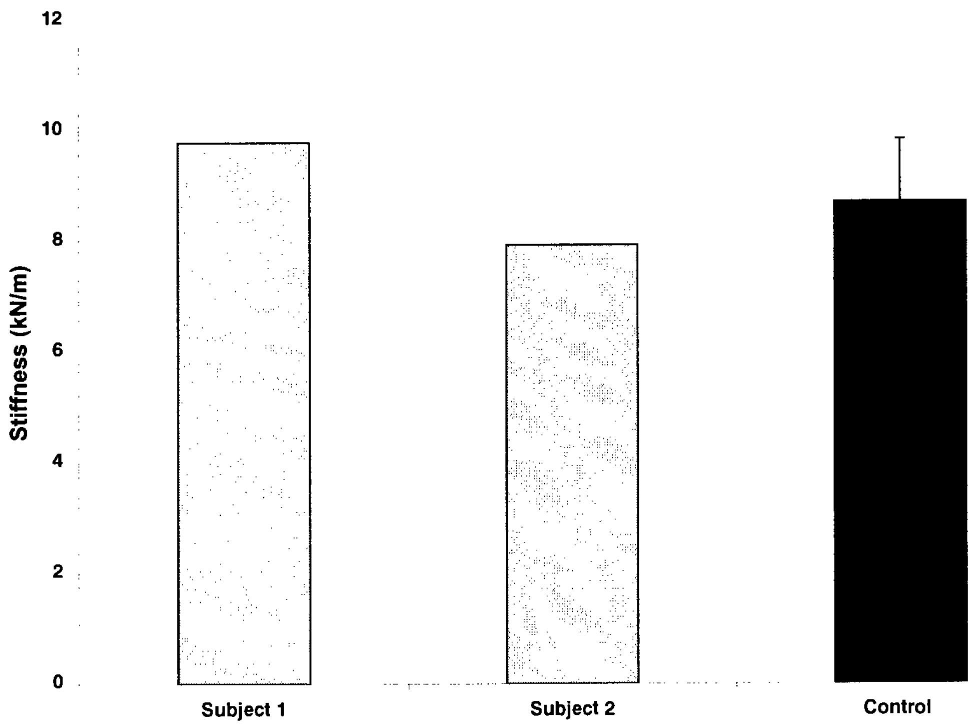

Figure 11: Lower extremity stiffness for the 2 prospective tibial stress fracture subjects and healthy controls

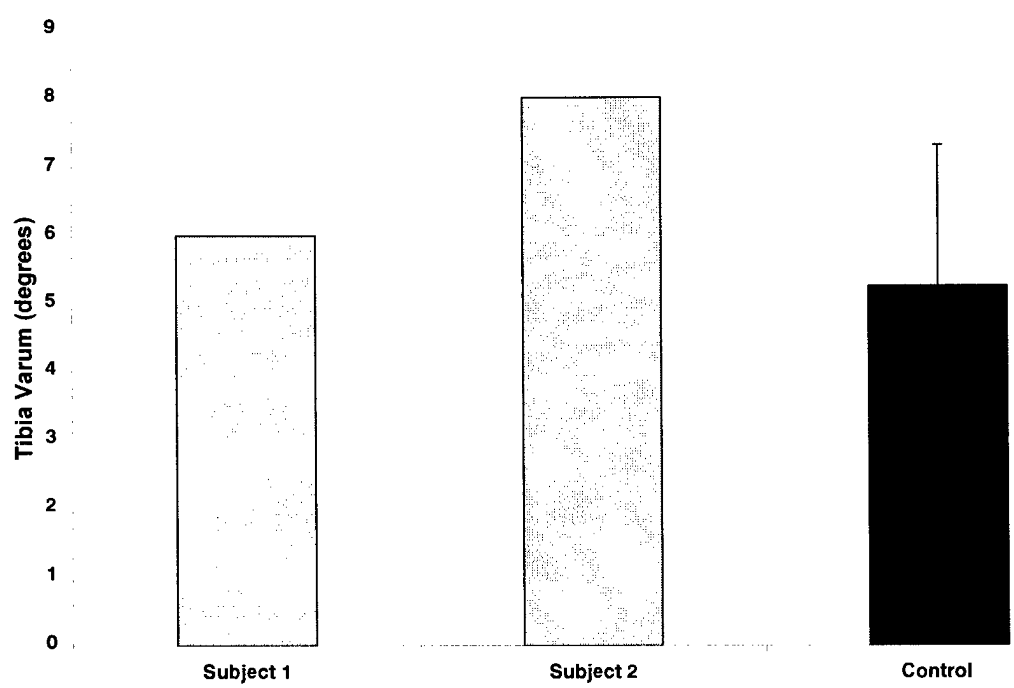

Figure 12: Tibial varum alignment for the 2 prospective tibial stress fracture subjects and healthy controls

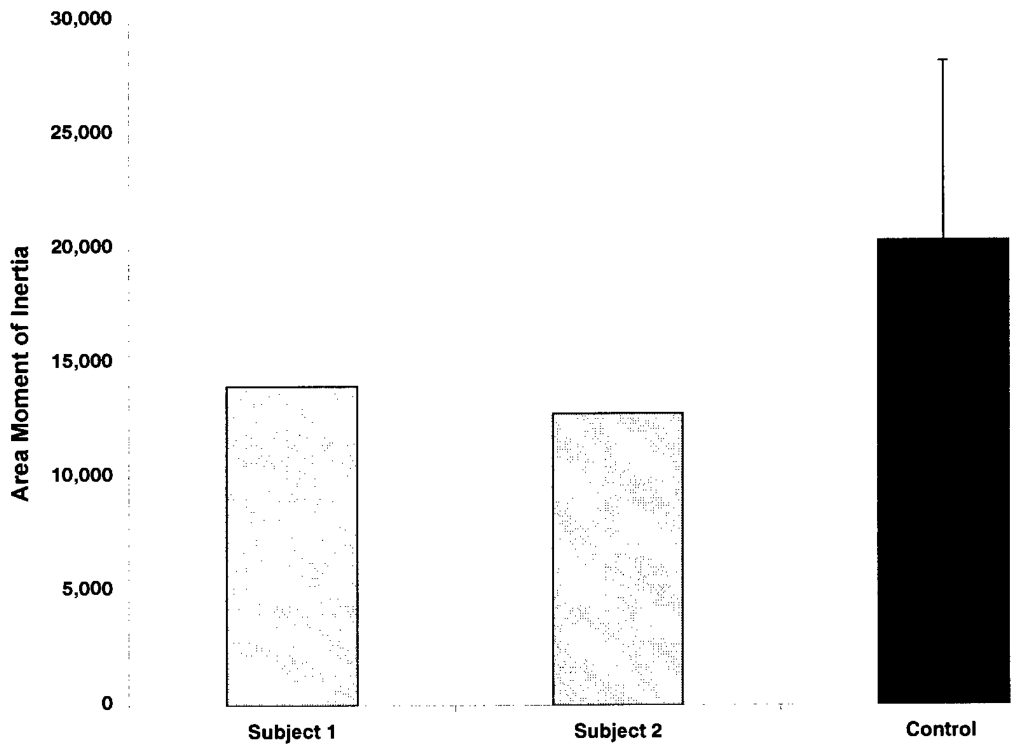

Figure 13: Tibial area moment of inertia (M/L level 2) for the 2 prospective tibial stress fracture subjects and healthy controls

3) List of Publications

From the data collected during year 1, one abstract was submitted and presented at the American Physical Therapists' Association Combined Sections Meeting in Boston, Massachusetts. In addition, information from this abstract is currently being used to prepare a manuscript for the Journal of Orthopaedic and Sports Physical Therapy journal. The reference is provided below.

Multiple Lower Extremity Stress Fractures In A Division I Cross Country Runner: A Case Study. Pollard C.D., McClay I.S., Hamill J. 2001 APTA Combined Sections Meeting, Boston, Massachusetts.

From the data collected during years 1 and 2, three additional abstracts have been submitted and presented at the American College of Sports Medicine National Meeting in St Louis, Missouri and at the World Congress of Biomechanics in Calgary Alberta, Canada. These abstracts are included in Appendix A and the references are provided below.

McClay Davis, I., Ferber, R., Dierks, T.A., Butler, R.J., & Hamill, J. (2002). Variables associated with the incidence of lower extremity stress fractures. Book of Abstracts 2002 World Congress of Biomechanics, Calgary, Alberta, Canada.

Ferber, R., McClay Davis, I., Hamill, J., Pollard, C.D., & McKeown, K.A. (2002). Kinetic variables in subjects with previous lower extremity stress fractures. Medicine and Science in Sports and Exercise, 34(1), s25.

Pollard, C.D., & McKeown, K.A. Hamill, J., Ferber, R., McClay Davis, I. (2002). Selected structural characteristics of female runners with and without lower extremity stress fractures. Medicine and Science in Sports and Exercise, 34(1), s991.

4) Degrees obtained that are supported by this award

Kelly Anne McKeown was funded on this award and graduated from the University of Massachusetts with a Masters of Science from the Department of Exercise Science in April of 2002.

5) Summary of information from the database

To date, a total of 473 entries have been recorded and there is a 96% compliance rate for subjects logging into the database on a monthly basis and recording their mileage and any injuries they may have sustained. Any subjects who do not log in on a monthly basis are contacted by telephone. Overall, we are very pleased with the compliance of the subjects involved in the study, the performance of the database program, and with the information we are continuing to collect. It is important to note that 2 subjects have dropped out of the study. One subject was in a near-fatal bicycle accident and is currently in a coma, and the other subject has decided to go on an extended vacation.

Table 2 and 3 are a summary of all retrospective and Table 4 is a summary of all prospective injuries we have collected. It is interesting to note the relatively large number of retrospective stress fractures compared to the other lower extremity injuries. We feel this is because we have been advertising this study as a stress fracture study and not as a running injury study.

TABLE 2: Summary of Retrospective Injury Information Collected from the Website Database

Injury Category		**Incidence of Injury**
Retrospective Injuries		
Tibial Stress Syndrome		6
Previous Tibial Stress Fracture		21
Plantar Fasciitis		21
Patellofemoral Pain Syndrome		7
Other stress fractures	pelvic	2
	femur	2
	fibula	4
	metatarsal	1
Patellar Tendinitis		6
Metatarsal Stress Syndrome		10
Lateral Ankle Sprain		14
Iliotibial Band Syndrome		23
Anterior Compartment Syndrome		4
	TOTAL	**121**

TABLE 3: Summary of Prospective Injury Information Collected from the Website Database

Injury Category	**Incidence of Injury**
Prospective Injuries	
Tibial Stress Fracture	2
Femoral Stress Fracture	1
Pelvic Stress Fracture	1
Metatarsal Stress Fracture	1
Gastrocnemius/Soleus strain	7
Anterior Compartment Syndrome	5
Achilles tendonitis	4
Back Strain	5
Iliotibial Band Syndrome	6
Hamstring Strain	2
Quadriceps Strain	2
Plantar Fasciitis	3
Patellofemoral Pain Syndrome	2
Ankle Sprain	3
Foot/Ankle Muscle Strain	4
Hip/Groin Muscle Strain	4
TOTAL	**52**

CONCLUSIONS

The overall aim of this research is to gain insight into the etiology of tibial stress fractures using 3-D motion analysis and structural data. Data from 400 subjects will be collected at the University of Delaware and University of Massachusetts (200 at each site) over a 3-year period. 30 of the subjects will have sustained a tibial stress fracture prior to the study and the other 370 will have not. The structural and biomechanical factors leading up to a tibial stress fracture will be assessed. In addition, comparisons will be made of mechanics before and after the stress fracture to determine whether subjects revert back to their pre-injury mechanics.

This Annual Report focused on the second-year status of this investigation. Four specific work objectives were outlined and discussed with respect to adherence and methods used to meet all objectives in a timely manner. While the University of Massachusetts is still behind in the number of subjects, measures have been taken to increase recruitment efforts. We are confident that by December of 2002, we will be very close to achieving all work objectives.

To date, data on 143 subjects were collected and an analysis was performed on 2 subjects who had experienced a tibial stress fracture. In addition, 3 additional abstracts were presented at two conferences on subjects who had previously experienced a lower extremity stress fracture. Overall, the primary hypotheses were supported by the data after analysis. These are encouraging results. We are confident that additional data will provide valuable information regarding mechanics and etiology of tibial stress fractures.

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APPENDICES

Appendix A: Abstracts

1) Presented at the American College of Sports Medicine National Meeting

KINETIC VARIABLES IN SUBJECTS WITH PREVIOUS LOWER EXTREMITY STRESS FRACTURES

R. Ferber, I. McClay Davis, FACSM, J. Hamill, FACSM, C.D. Pollard, K.A. McKeown

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Overuse injuries are common among competitive runners with stress fractures being one of the most serious injuries runners sustain. Females are twice as likely to experience a stress fracture as their male counterparts. The etiology of stress fractures is multifactorial in nature but is related, in part, to some combination of peak forces and loading rate as well as shock experienced by the lower extremity. However, few studies have quantified these factors in competitive female distance runners. PURPOSE: To examine differences in ground reaction force (GRF) variables and tibial acceleration between competitive female distance runners who had sustained a previous lower extremity stress fracture (SF) and uninjured control subjects (CON). METHODS: Ten CON and 10 SF subjects ran along a 25m runway at a speed of 3.7 (±0.2) m/s. GRF and tibial acceleration data were recorded from 5 trials. Peak positive tibial acceleration (PPA), peak to peak acceleration (PTP), peak vertical GRF (VGRF), stiffness, and instantaneous and average loading rate (ILR/ALR) were determined. RESULTS: SF subjects exhibited 22% greater PPA (9.24g vs 7.16g; p=0.05), 26% greater PTP (13.43g vs 9.97g; p=0.03), 36% greater VGRF (3.87BW vs 2.48BW; p=0.01), 32% greater ILR (158.61BW/s vs 108.89BW/s; p=0.03), and 34% greater ALR (117.93BW/s vs 77.52BW/s; p=0.03) as compared to CON. No differences in stiffness (8.67kN/m vs 8.74kN/m; p=0.62) were observed between the two groups. CONCLUSION: Based on the results of this study, subjects who had previously sustained a lower extremity stress fracture exhibited significantly greater GRF values and tibial acceleration. Repetitive exposure to these forces may have predisposed these subjects to overuse-related stress fracture injuries. However, prospective studies are essential to determine whether the observed increases in these kinetic variables were present prior to the stress injury.

This study was funded by the Department of the Army (#17-00-1-0515)

SELECTED STRUCTUAL CHARACTERISTICS OF FEMALE RUNNERS WITH AND WITHOUT LOWER EXTREMITY STRESS FRACTURES

C. D. Pollard, K.A. McKeown, R. Ferber, I. McClay Davis FACSM, J. Hamill FACSM, University of Massachusetts, Amherst, MA

Lower extremity stress fractures are a common injury among female distance runners. Stress fractures are thought to occur when tissues adapt abnormally to repetitive stress and may be a result of this abnormal adaptation. Selected static anthropometric measures have been implicated as a predictor of lower extremity stress fractures. PURPOSE: The aim of this investigation was to examine selected structural characteristics of female runners with and without a history of lower extremity stress fractures to gain insight into the etiology of these injuries. METHODS: Subjects consisted of 9 females with a confirmed history of at least one lower extremity stress fracture and 9 females with no stress fracture history. All subjects were between ages 18-35 and ran an average of 20 miles per week. Each subject underwent a structural evaluation by a licensed physical therapist that included measurement of tibial varum, static rearfoot angle, and arch height. Three radiographs of the distal lower extremity were used to calculate the area moments of inertia (Milgrom et al., 1989). RESULTS: There were no significant differences in the selected structural characteristics between the two groups. However, mean area moments of inertia were 30\% less for the stress fracture group ($p<.10$). CONCLUSION: There may be numerous underlying mechanisms associated with these stress fracture injuries that are difficult to account for in a retrospective study. Potential underlying mechanisms could have included training mileage, training surface, nutrition and history of amenorrhea. Although specific structural characteristics have been associated with stress fracture injuries, these groups of female distance runners did not demonstrate this relationship. However, the observed trend towards decreased tibial area moments of inertia in the stress fracture group were consistent with previous investigations that have suggested stress fractures occur where high bending loads are found.

This study was funded by the Department of the Army (\#17-00-1-0515).

2) Presented at the World Congress of Biomechanics International Meeting

VARIABLES ASSOCIATED WITH THE INCIDENCE OF LOWER EXTREMITY STRESS FRACTURES

I. McClay Davis [1,2], R. Ferber[1], T.A. Dierks[1], R.J. Butler[1], J. Hamill [3]

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[2]Joyner Sportsmedicine Institute, Harrisburg, PA
[3] Department of Exercise Science, University of Massachusetts, Amherst, MA

INTRODUCTION

Overuse injuries are common among competitive runners with stress fractures (SF) being one of the most serious overuse injuries. SF are among the top 5 cited running-related injuries and females are twice as likely to experience a SF as their male counterparts. The etiology of SF is multifactorial in nature but is related, in part, to some combination of bone structure, peak forces, loading rates, as well as lower extremity running mechanics. Therefore, the purpose of this investigation was to examine differences in ground reaction force (GRF), tibial acceleration, bone structure, and kinematic variables between competitive female distance runners who had sustained a previous lower extremity SF and uninjured control subjects. It was hypothesized that peak tibial acceleration, vertical GRF loading rates, and lower extremity stiffness would be greater in the injured runners and area moment of inertia of the tibia and knee flexion excursion would be lower. In addition, those variables which were different would contribute significantly to the prediction of which runners had sustained a SF.

METHODS

Subjects consisted of 8 females with a history of at least one lower extremity SF and 8 females with no SF history who served as a control group (CON). All subjects were between ages 18-35 and ran between 30-80 miles per week. These subjects are part of a larger ongoing study investigating factors associated with SF in women runners. GRF and tibial acceleration data were recorded from 5 running trials. Three radiographs of the distal lower extremity were used to calculate the tibial area moment of inertia (Milgrom et al., 1989). Variables of interest included peak positive tibial acceleration (PPA), peak vertical GRF (VGRF), instantaneous loading rate (ILR), stiffness (STF), knee flexion excursion (KFlex) and tibial area moment of inertia in the anterior/posterior plane (I_{AP}). Independent t-tests were used to assess differences between groups. A backward, stepwise statistical regression analysis was used to determine the factors that best predicted which subjects had previously suffered a SF.

RESULTS AND DISCUSSION

Of the 8 total SF, 5 were tibial, 2 were fibular and 1 was metatarsal. Results indicated that both PPA and ILR were significantly ($p<0.05$) greater in the SF group (Table 1). Although not significant ($p>0.05$), a trend towards greater stiffness and reduced knee flexion excursion in the SF group was also observed (Table 1). Williams et al. (2001) also reported a significantly higher load rate and great stiffness in a group of runners with high arch feet and a greater incidence of stress injuries. However, Crossley et al. (1999) reported no significant differences in GRF variables between SF and control subjects.

Other investigations have reported that bone geometry was significantly different between SF and control groups (Crossley, 1999; Milgrom, 1989). However, in the present investigation, the SF group exhibited similar tibial I_{AP} values as compared with the control group (Table 1). A small subject population may account for discrepancies between previous studies and the results of this investigation.

The results indicate that PPA and ILR explained 46% of the variance ($p=0.01$) in predicting subjects who had previously suffered a SF. ($y = 3.50 + -0.12PPA + -0.01ILR$). None of the remaining variables entered into the regression equation. However, it is possible that these results may change as more subjects are analyzed during this ongoing study.

SUMMARY

These data suggest that 1) subjects who had previously suffered a lower extremity SF demonstrated greater GRF loading rates, shock, and stiffness and reduced knee flexion excursion as compared with noninjured controls and 2) kinetic measures can be used to predict which subjects had previously sustained a SF.

ACKNOWLEDGEMENTS

This study was funded by the Department of the Army (#17-00-1-0515).

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Table 1: Mean (SD) and p-values of selected variables for SF and CON groups.

	PPA (g)	ILR (BW/s)	STF(kN/m)	KFlex (°)	I_{AP}
SF	8.23 (1.08)	119.20 (27.97)	9.32 (1.53)	29.76 (5.70)	11016 (3175)
CON	6.50 (1.56)	90.44 (15.28)	8.30 (0.54)	33.40 (3.91)	11457 (4098)
p value	0.02	0.04	0.09	0.14	0.81

Appendix B: Advertisement Flyer

FREE BIOMECHANICAL ANALYSIS

♦ **We are looking for Female Distance Runners who meet the criterion below to help better understand the mechanisms involved in Lower Extremity Stress Fractures** (we are interested in evaluating both those individuals who have never had a stress fracture as well as those who have had a stress fracture).

♦ As you may know, female runners are at a higher risk of sustaining a lower extremity stress fracture than their male counterparts.

♦ As a subject you will be making a significant contribution to this area of research and will gain better understanding of your own lower extremity structure and mechanics. You will also receive **$50.00** upon completion of the study.

Inclusion Criteria:

- **Ages 18-45**
- **Average 20 miles per week**

Requirements: One two-hour data collection will occur at the University of Massachusetts, Amherst and will include a lower extremity evaluation by a licensed physical therapist, 3-D motion analysis of your running gait, and an x-ray of your lower extremities.

Appendix C: Curriculum Vitae for Irene S. McClay

Irene McClay Davis

Curriculum Vitae

PII Redacted [redacted]

[redacted]

EDUCATION

PhD	1990	Pennsylvania State University	Biomechanics
MEd	1984	University of Virginia	Biomechanics
BS	1978	University of Florida	Physical Therapy
BS	1977	University of Mass.	Exercise Science

EMPLOYMENT

Director of Research, Joyner Sportsmedicine Institute, (6/97 - present)
Development of research within the Joyner Sportsmedicine Institute aimed at advancing the science of sportsmedicine and improving prevention, diagnosis and treatment of sports-related injuries.

Associate Professor, Program in Physical Therapy, University of Delaware. (5/97 - present)

Assistant Professor, Program in Physical Therapy, University of Delaware. (9/89 - 5/97)
Instruction of graduate students in physical therapy. Research in clinical biomechanics with specific interest in lower extremity mechanics and injury. Director, Running Injury Clinic.

Research Assistant, Pennsylvania State University, Center for Locomotion Studies. (8/85 - 6/89)
Responsible for the development and coordination of the Running Injury Clinic and Orthopedic Clinic. Research activities in locomotor biomechanics. Consultant to the Distance Runner's Camp at US Olympic Training Center.

Research and Teaching Assistant, University of Virginia, Rehabilitation Engineering Center. (8/82-8/85)
Research activities in wheelchair ergonomics. Instructor of graduate courses in biomechanics and human dissection. Co-coordinator of the Arts and Science of Sports Medicine Conference held annually at the University of Virginia (6/84, 6/85)

Physical Therapist, Blue Ridge Rehabilitation Associates, Charlottesville, VA (1/83 - 7/85)
Part time home health and private practice physical therapy.

Physical Therapist, Woodrow Wilson Rehabilitation Center, Fishersville, VA (2/79 - 6/82)
Patient treatment, supervision of physical therapy students, inservice training and Coordinator of the Amputee Clinic. Instructor in continuing education course in Management of the Spinal Cord Injured Patient.

GRANTS

The Effect of Wedged Foot Orthoses on Lower Extremity Mechanics and Function in Patients with Knee Osteoarthritis. Submitted to the National Institutes of Health (COBRE Grant) $932,815 for 5 years (funded)

A Comparison of Custom and Semicustom Foot Orthotic Devices on Lower Extremity Mechanics and Comfort. The Pauline Marshall Research and Education Foundation, $15,000 for one year grant period beginning 9/2001.

Biomechanical Factors Associated with the Etiology of Stress Fractures in Runners. The Department of the Army. $1.05 million for 5 yr grant period beginning 9/2000.

2 Doctoral Scholarship. $20,000. Joyner Sportsmedicine Institute, 1998, 1999, 2000, 2001

Undergraduate Summer Scholarship. $4,000. Joyner Sportsmedicine Institute, 1997 and 1998, 1999, 2000, 2001

A Comparison of Four Methods to Obtain a Negative Impression of the Foot, $3,250, Foot Management, Inc, 1998-1999

The Effect of Different Orthotic Devices on Lower Extremity Mechanics of Rearfoot and Forefoot Strikers, $3,500. Foot Management, Inc, 1999-2000.

The Effect of the Protonics System on Patellar Aligment and Gait in Patients with Patellofemoral Joint Pain. $18,000. Funded by Inverse Technology, 1998-1999

Clinical Efficacy of the Protonics System in Patients with Patellofemoral Joint Pain. $3,000. Funded by Inverse Technology, 1998-1999

A Comparison of Strengthening vs. Orthotics on Pronation and Pronation Velocity. Funded by the Physical Therapy Foundation **$60,000**, 1993-1995

Lower Extremity Mechanics and Injury. Funded by the Whitaker Foundation **$180,000**, 1993-1996.

The Relationship between Subtalar Joint Axis Orientation, Joint Motion and Injuries in Runners. Funded by the Biomedical Research Support Grant. **$2550,** 1992

The Relationship between Subtalar Joint and Knee Joint Motion in Runners. Funded by the University of Delaware Research Foundation. **$16,000,** 1990.

A Comparison of Patellofemoral 3-D Kinematics in Runners with and without Patellofemoral Pain. Doctoral Dissertation. Foundation for Physical Therapy. **$8500,** 1988.

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ABSTRACTS

Pollard CD, McClay IS, Hamill J. Multiple Lower Extremity Stress Fractures in a Female Division I Cross-Country Runner: A Case Study. Presented at the Combined Sections Meeting of the APTA, Boston, MA, February 2002.

McCrory, JL, Quick' NE, Ballantyne, BT, and McClay Davis, I. Effects of a Dynamic Knee Othosis on Subject Kinematics during the Lateral Step-Up Exercise. To be presented at the American College of Sports Medicine Meeting in St. Louis, MO, June, 2002.

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Shapiro, R, Yates, J, McClay, I, and Ireland, ML. Male-Female Biomechanical Differences in Selected Landing Maneuvers. Presented at the ACL Research Retreat, Lexington, KY, April, 2001

Laughton, CA, McClay, IS, Hamill, J Effect of Orthotic Intervention and Strike Pattern on Tibial Shock in Runners. Presented at the International Society of Biomechanics, Zurich, Switzerland, July, 2001

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Sahte, V, Ireland, ML, Ballantyne BT and McClay, IS. Acute Effect of the Protonics System on Patellofemoral Alignment. Presented at the ACSM National Mtg in Indianapolis, IN, 6/00.

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McClay, IS & Manal, KT Lower Extremity Kinetic Comparisons between Forefoot and Rearfoot Strikers. Presented at the American Society of Biomechanics Meeting, Stanford, CA 8/95

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Brubaker, CE, McClay, IS, & McLaurin, CA: "The Effect of Mechanical Advantage on Lever Propulsion Efficiency". Proceedings of the 6th Annual Conference on Rehabilitation Technology, 1983, pp. 122-124.

SELECTED INVITED PRESENTATIONS

"An Update on the Mechanics behind the Success of Orthotic Intervention" Presented at Temple University School of Podiatric Medicine evening seminar series, Philadelphia, PA, February 2002.

"Core Instability and Lower Extremity Mechanics: Implications for Injury." Presented at the Combined Sections Meeting of the APTA, Boston, MA, February, 2002.

"The Application of Biomechanics to Sports Medicine: Focus on Running Injuries" Keynote presentation at the Midwest Student Biomechanics Symposium, Normal, IL, March, 2002.

"The Effect of the Inverted Orthotic on Lower Extremity Mechanics: An Update" Presented at the Prescription Foot Orthotic Laboratory Association Annual Meeting, Miami, FL, November, 2001

"How Do Foot Orthotic Devices Influence Lower Extremity Mechanics: Evidence from the Literature. Presented at the Prescription Foot Orthotic Laboratory Association Annual Meeting, Miami, FL, November, 2001

"Selected Case Studies in Running Injuries" Presented at the Combined Sections Meeting of the APTA, San Antonio, TX, Feb, 2001.

"Developing Standards in Epidemiological Research" Presented at the National ACSM Mtg in Indianapolis, June, 2000

"Lower Extremity Mechanics and Injury Patterns in High and Low Arch Runners". Keynote Presented at the Foot and Ankle Research Retreat, Annapolis, MD, May,2000

"Effect of the Inverted Orthotic on Rearfoot and Knee Mechanics" Presented at the 4th Annual John Weed Seminar, Palm Springs, CA, March, 2000 and the PFOLA meeting in Vancouver, BC, November 2000

"Influence of foot, knee and hip coupling on patellofemoral mechanics" Symposium at the Combined Sections Meeting of the APTA, New Orleans, LA, February, 2000 and at the National ACSM Mtg in Indianapolis, June, 2000, and the Arts and Science of Sports Medicine, Charlottesville, VA, June, 2000.

"Visual Gait Analysis in Runners" Presented at the Arts and Science of Sports Medicine, Charlottesville, VA, June, 2000.

"Injury Mechanisms in Runners" Keynote speaker at the Fifth IOC Congress on Sport Sciences, Sydney, Australia, November, 1999

"Clinical Gait Analysis" Keynote speaker at the Fifth IOC Congress on Sport Sciences, Sydney, Australia, November, 1999.

"Risk Factors in Anterior Cruciate Ligament Injuries" Clinical Colloqium presented at the National ACSM Mtg, in Seattle, WA, 6/99

"Problem Solving the Injured Runner" Clinical Colloqium presented at the National ACSM Mtg, in Seattle, WA, 6/99

"Coupling between the Foot and the Knee in Runners" Presented at Joyner Sportsmedicine Institute National Conference, Hilton Head, SC, 10/99

"Biomechanics of the Knee" Presented at Joyner Sportsmedicine Institute National Conference, Hilton Head, SC, 10/99

"Physical Therapist to Marathoner - A Classical Tale of Overuse." Presented at the Case Conference Seminar at the Annual Conference of the American Physical Therapy Association, Minneapolis, MN, 6/98.

Eugene Michels Research Forum - "Instrumented versus Visual Gait Analysis in Clinical Assessments" Presented at the Combined Sections Meeting in Dallas, TX, 2/97.

"Biomechanical Differences between Forefoot and Rearfoot Strikers" presented at the Joyner Sportsmedicine Institute 1996 National Conference, Hilton Head, SC, 11/96.

"Plantar Fasciitis:A Case Study" Presented at the Case Conference Seminar at the Annual Conference of the American Physical Therapy Association, Minneapolis, MN, 6/96.

"The Use of Motion Analysis in Physical Therapy". University of PA, Philadelphia, 10/95.

"The Patellofemoral Joint - Implications of the study of three-dimensional kinematics". Grand Rounds, Dept. of Orthopedic Surgery, Hershey Medical Center, 1/95.

"What is Clinical Research". Keynote Address at Research Symposium, Shenandoah University, 4/94 .

"Research in Foot and Ankle Biomechanics". Presented at the Combined Sections Meeting of the American Physical Therapy Association, New Orleans, LA, 2/94

"Biomechanical Assessment of Gait" Presented at the Arts and Science of Sports Medicine Conference, Charlottesville, Va., 6/93

"Closed Kinetic Chain Activities for the Foot and Ankle" Presented at the Foot and Ankle Seminar for HealthSouth in Orlando, FL, 2/93, Phoenix, AZ, 3/93, St. Louis, MO, 4/93 and for Foot Mgt, Inc in Ocean City, MD in 10/94 and 4/96.

"Normal Structure and Gait". Presented at the Arts and Science of Sports Medicine Conference, Charlottesville, Va., 6/92, and at the Symposium on the Biomechanics of the Lower Extremity, NATA, Denver, CO, 2/92.

"Abnormal Structure and Gait". Presented at the Arts and Science of Sports Medicine Conference, Charlottesville, Va., 6/92, and at the Symposium on the Biomechanics of the Lower Extremity, NATA, Denver, CO, 2/92 and for Foot Mgt, Inc in Ocean City, MD in 10/94 and 4/96.

"The Biomechanical Evaluation of the Injured Runner". Presented at the Medical Symposium of the Penn Relays, 4/92, The Arts and Science of Sports Medicine Conference, Charlottesville, Va., 6/88 and the East Coast Gait Conference, Bethesda, Md, 11/87

"Biomechanics of the Foot and Ankle". Presented at the Arts and Science of Sports Medicine Conference, Charlottesville, Va., 6/91.

"Relationship between Mechanics and Running Injuries". Presented at the Arts and Science of Sports Medicine Conference, Charlottesville, Va., 6/91.

"Anatomy and Biomechanics of the Patellofemoral Joint". Presented at the Sports Physical Therapy Meeting, Orlando, Fla. 12/90.

"Relationship between Structure and Function in Patellofemoral Disorders". Presented at the Sports Physical Therapy Meeting, Orlando, Fla. 12/90.

"Normal and Abnormal Running Mechanics". Presented at the Arts and Science of Sports Medicine Conference, Charlottesville, Va. 6/90.

"Biomechanical Perspective of Stress Fractures in Professional Basketball Players". Presented at the Annual Meeting of the NBA Physicians, West Palm Beach, Fl, 11/88.

"The Biomechanics of Patellofemoral Disorders". Presented at the Arts and Science of Sports Medicine Conference, Charlottesville, Va., 6/88.

"Biomechanical Profile of Elite Woman Distance Runners". Presented at the Dogwood Festival Pre-race Conference, Atlanta, GA, 7/88.

HONORS

Physical Therapy Foundation Scholar	1988
Recipient of Zipser Scholarship, The Penn State University	1988
Outstanding Masters Student Award, University of Virginia	1984
Nominee for Mary McMillan Scholarship Award, APTA	1978
Magna Cum Laude Graduate, University of Florida	1978
Magna Cum Laude Graduate, University of Massachusetts	1977

PROFESSIONAL ACTIVITIES

Societies

American Society of Biomechanics
- Organizing Committee, Annual ASB Mtg, Chicago, IL, July 2000
- Membership Committee (1997-2001)
- Scientific Committee for the Third International Symposium on 3-D Analysis of Human Movement, Stockholm, Sweden, 1994

American College of Sports Medicine, Fellow

American Physical Therapy Association (APTA)
- Orthopedic and Research Sections Member
- Chairperson of Research Committee of the Foot and Ankle Special Interest Group (1997-present)

International Society of Biomechanics

Advisory

Invited Participant to the "Working Conference on Gait Analysis in Rehabilitation Medicine" National Institutes for Health, September, 1996

Doctoral Research Advisory Committee, American Physical Therapy Association (1995-1997)

Medical Consultant for Runners World (1995-present)

Ed. Board

Clinical Biomechanics (1999-present)

Journal of Orthopedic and Sports Physical Therapy (1996-1997)

Journal of Applied Biomechanics (1997-1999)

Reviewer

Journal of Biomechanics

Medicine and Science in Sports and Exercise

Foot and Ankle, International

Journal of the American Podiatric Medical Association

Journal of Applied Biomechanics

Other Organizing Chair for Research Retreat - Static and Dynamic Classification of the Foot. Annapolis, MD, May, 2000.
Organizing Chair for Research Retreat - ACL Injuries: The Gender Bias. Lexington, KY, April 2001.

Licensure Licensed Physical Therapist, State of Delaware

Appendix D: Curriculum Vitae for Joseph Hamill

<u>CURRICULUM VITA</u>

Joseph Hamill, Ph.D.

Professor and Chair
Department of Exercise Science
University of Massachusetts Amherst
Director, Biomechanics Laboratory
University of Massachusetts Amherst

BUSINESS ADDRESS: Biomechanics Laboratory
Department of Exercise Science
University of Massachusetts
Amherst, MA 01003
(413) 545-2245
(413) 545-2906 Fax

E-MAIL ADDRESS: jhamill@excsci.umass.edu

PII Redacted [redacted] [redacted]

EDUCATION

1967	Teaching Certificate	Lakeshore Teacher's College, Toronto, Canada
1972	B.A.	York University, Toronto, Canada
1977	B.S. (magna cum laude)	Concordia University, Montreal, Canada
1978	M.S.	University of Oregon, Eugene, Oregon
1981	Ph.D.	University of Oregon, Eugene, Oregon

Undergraduate Areas of Study: Political Science
General Science
Graduate Area of Study: Biomechanics

RESEARCH INTERESTS

Mechanics of lower extremity function
Mechanical Analysis of normal and pathological gait.
Modeling the lower extremity in gait.
Optimality criteria in human locomotion
Dynamical Systems

EMPLOYMENT EXPERIENCE

1977-1979	Graduate Teaching Fellow Biomechanics Laboratory, University of Oregon
1979-1981	Graduate Research Fellow Biomechanics Laboratory, University of Oregon
1981-1982	Post-doctoral Fellow Biomechanics Laboratory, University of Oregon
1982-1985	Assistant. Professor (Biomechanics) Department of Physical Education, Southern Illinois University
1985-1986	Assistant Professor (Biomechanics) and Graduate Program Director Department of Physical Education, Southern Illinois University
1986-1988	Assistant Professor (Biomechanics) Department of Exercise Science, University of Massachusetts
1989-1995	Associate Professor (Biomechanics) and Graduate Program Director Department of Exercise Science, University of Massachusetts
1990-1995	Adjunct Professor Department of Medicine, University of Massachusetts Medical Center
1995-1996	Associate Professor (Biomechanics) and Department Chair Department of Exercise Science, University of Massachusetts
1996-present	Professor (Biomechanics) and Department Chair Department of Exercise Science, University of Massachusetts

RESPONSIBILITIES OF PRESENT POSITION

Department Chair
Director of the Biomechanics Laboratory
Teach graduate and undergraduate courses in Biomechanics
Advise undergraduate and graduate students
Chair graduate theses and dissertations in the Department
Conduct research in the area of Biomechanics
Secure external funding for the Biomechanics Laboratory

TEACHING RESPONSIBILITIES

At Southern Illinois University

Undergraduate

P.E. 302	Kinesiology for Physical Therapy
P.E. 370	Tests and Measurements

Graduate

P.E. 511	Mechanical Analysis
P.E. 512	Biomechanics of Sport
P.E. 505A	Biomechanics Instrumentation
P.E. 505B	Computer Applications
P.E. 505C	Biomechanics of the Musculo-skeletal System
P.E. 561	Doctoral Seminar

At University of Massachusetts

Undergraduate

Ex Sc 300	Writing Seminar for Exercise Science
Ex Sc 305	Kinesiology
Ex Sc 304	Human Anatomy
Ex Sc 311	Anatomy of Human Motion
Ex Sc 474	Tests and Measurements

Graduate

Ex Sc 531	Mechanical Analysis of Human Motion
Ex Sc 611	Introduction to Research
Ex Sc 732	Advanced Biomechanics
Ex Sc 892	Doctoral Seminar
Ex Sc 895	Clinical Biomechanics Seminar

UNIVERSITY SERVICE

Department Committees

- Master's Thesis Review Committee, 1982-1983
- Comprehensive Examination Review Committee, 1983-1984
- Chair, Graduate Faculty, 1982-1986
- Chair, Search Committee for Department Chairperson, 1986
- Graduate Committee, 1986-
- Telecommunications Committee, 1988-1990
- Chair, Department Personnel Committee, 1994-1995
- Chair, Motor Control Search Committee, 1994-1995

College Committees

- College Computer Advisory Committee, 1982-1986
- School Personnel Committee, 1994-1995
- School Executive Committee, 1995-
- Member, School Development Officer Search Committee, 1997.

University Committees

- Graduate Council, 1991
- Recruitment and Retention Committee, 1991-92
- Research Council, 1992-1995

PROFESSIONAL ORGANIZATIONS

American Alliance for Health, Physical Education, Recreation and Dance
Biomechanics Academy of the Research Consortium
International Society of Biomechanics
Canadian Society of Biomechanics
American Society of Biomechanics
American College of Sports Medicine
New England College of Sports Medicine
International Society of Biomechanics in Sport
ASTM

RESEARCH AFFILIATIONS

Scientific Advisory Board, Rockport Walking Institute, 1986-1992.
Scientific Advisory Board, LifeFitness, Inc., 1993-
Scientific Advisory Board, USA Field Hockey, 1995-1998
USA Volleyball Sports Medicine and Performance Commission's Resource Advisory Committee, 1996-1999

ACADEMIC HONORS

Fellow, Research Consortium of the AAHPERD, 1984
Fellow, American College of Sports Medicine, 1986
Fellow, American Academy of Kinesiology and Physical Education, 1997

OFFICES IN PROFESSIONAL ORGANIZATIONS

1. Chair-elect, Kinesiology Academy, 1990-91.
2. Board Member, International Society of Biomechanics in Sports, 1992-94.
3. Chair, Biomechanics Interest Group of the American College of Sports Medicine, 1996-97.
4. Member-at-large, Executive Committee of the New England Chapter of the American College of Sports Medicine, 1995-
6. Board Member, International Society of Biomechanics Technical Group on Footwear, 1998-2000
7. Member, Credentials Committee, American College of Sports Medicine, 2000-
8. Member-at-Large, Executive Board of Canadian Society of Biomechanics, 2000-

PROFESSIONAL SERVICE

Review Committees For Professional Meetings

1) Abstract Review Committee, American College of Sports Medicine Annual Meeting, 1989.
2) Abstract Review Committee, American College of Sports Medicine Annual Meeting, 1990.
3) Program Committee, combined meeting of the 9th International Symposium on Biomechanics in Sports
4) and the Kinesiology Academy, June 29 - July 7, 1991.
5) Abstract Review Committee, American College of Sports Medicine Annual Meeting, 1991.
6) Review Panel Chair for Research Consortium, AAHPERD Convention, 1991-92.
7) Abstract Review Committee, American College of Sports Medicine Annual Meeting, 1992.
8) Review Panel Chair for Research Consortium, AAHPERD Convention, 1992-93.
9) Abstract Review Committee, American College of Sports Medicine Annual Meeting, 1993.
10) Abstract Review Committee, American College of Sports Medicine Annual Meeting, 1994.
11) Scientific Committee, International Society of Biomechanics in Sports Annual Meeting, Budapest, Hungary, June 1-6, 1994.
12) Abstract Review Committee, American College of Sports Medicine Annual Meeting, 1995.
13) Member, Scientific Review Committee, International Society of Biomechanics in Sports Annual Meeting, Madiera, Portugal, 1995-96.
14) Program Committee, New England American College of Sports Medicine Annual Meeting, Providence, RI, 1999.
15) Program Committee, New England American College of Sports Medicine Annual Meeting, Providence, RI, 2000.
16) Abstract Reviewer, XVIIIth Congress of the International Society of Biomechanics, ETH Zurich, Switzerland, July, 2001.
17) Abstract Reviewer, Vth Symposium of the Footwear Working Group Symposium of the International Society of Biomechanics, July, 2001.
18) Abstract Reviewer, International Society of Biomechanics in Sports Annual Meeting, Caceres, Spain, July, 2002.

External Reviewer for Theses and Dissertations

1. External Dissertation Reviewer, McMaster University, Hamilton, Ontario, Canada, June, 1995.
2. External Thesis Reviewer, Lakehead University, Thunder Bay, Ontario, Canada, June, 1995.

3.External Dissertation Reviewer, University of Guelph, Guelph, Ontario, Canada, January, 1997.
4.External Dissertation Reviewer, University of Connecticut, Storrs, Connecticut, December, 1998.
5.External Dissertation Reviewer, University of Delaware, Newark, Delaware, March, 2000.
6.External Thesis Reviewer, University of Delaware, Newark, Delaware, November, 2000.

External Grant Reviewer

1.External Reviewer for internal grants at University of Texas at Tyler, 1991.
2.Grant Reviewer, Natural Sciences and Engineering Council of Canada, 1993.
3.External Grant Reviewer, University Grants Committee, Hong Kong, February, 1998.
4.External Grant Reviewer, Natural Sciences and Engineering Council of Canada, May, 2000.

Committee Member

1. Biomechanics Model Research Laboratory, Olympic Scientific Congress, University of Oregon, July, 1984.
2. Completed Research in Health, Physical Education, Recreation and Dance, 1986.
3. Research Consortium Program Review Committee, AAHPERD Annual Convention, April, 1987.
4. Kinesiology Academy, Nominating Board for Officers, 1987.
5. Completed Research in Health, Physical Education, Recreation and Dance, 1988.
6. Nominating Committee for Kinesiology Academy Chair, 1991.
7. Delegate to American Alliance Assembly, January 1, 1991 to December 31, 1991.
8. ASTM Committee F-8 on Sports Equipment and Facilities, June, 1992.
9. .Conference Chair, International Society of Biomechanics in Sport Annual Meeting, University of Massachusetts Amherst, June 23-26, 1993.
10. Doctoral Program Evaluation Committee, American Academy of Kinesiology and Physical Education, 1997.
11. Program Review Committee for Biomechanics, Michigan State University, East Lansing, MI, January, 2000.
12. Continuing Committee for Doctoral Program Review, American Academy of Kinesiology and Physical Education, 2001-
13. Member, Research Consortium Research Writing Award Committee, 2001.
14. Member, AAHPERD Grant Proposal Committee, 2001.
15. Member, Holyoke Community College Department of Health and Fitness Advisory Board, 2001-

EDITORIAL BOARD OF PROFESSIONAL JOURNALS

1. Member, Editorial Review Board, Pediatric Exercise Science, 1988-
2. Member, Editorial Review Board, Medicine, Exercise, Nutrition, and Health, 1991-1995
3. Guest Editor, Special Issue of Pediatric Exercise Science, The Physically Challenged Child, May, 1992.
4. Section Editor, Biomechanics, Research Quarterly for Exercise and Sport, 1993-96
5. Member, Editorial Review Board, Journal of Applied Biomechanics, 1996-1999
6. Member, Research Quarterly for Exercise and Sport Editorial Board, 1998-2002
7. Chair, Research Quarterly for Exercise and Sport Editorial Board, 2001-2002
8. Associate Editor, Medicine and Science in Sports and Exercise, 2000-2002
9. Member, Editorial Review Board, Sports Biomechanics, 2000-
10. Member, Editorial Board, Journal of Sports Sciences, 2001-

REVIEWER FOR PROFESSIONAL JOURNALS

1. Reviewer, Medicine and Science in Sports and Exercise, 1985-
2. Reviewer, International Journal of Sports Biomechanics, 1986-
3. Reviewer, Research Quarterly for Exercise and Sport, 1989-
4. Reviewer, Sports Medicine, 1991-
5. Reviewer, Journal of Gerontology, 1991-
6. Reviewer, Journal of Orthopedic and Sports Physical Therapy, 1991-
7. Reviewer, Journal of Applied Biomechanics, 1993-

8. Reviewer, Journal of Applied Physiology, 1993-
9. Reviewer, Journal of Biomechanics, 1993-
10. Reviewer, Clinical Journal of Sports Medicine, 1996-
11. Reviewer, British Journal of Sports Medicine, 1996-
12. Reviewer, Clinical Biomechanics, 1999-
13. Reviewer, Exercise and Sports Science Review, 2000-
14. Reviewer, European Journal of Applied Physiology, 2000-

PUBLICATIONS

1. Osternig, L. R., Sawhill, J. A., Bates, B. T., **Hamill, J.** A method for rapid collection and processing of isokinetic data. *Research Quarterly for Exercise and Sport* 53(3):252-257, 1982.
2. Knutzen, K. M., Bates, B. T., **Hamill, J.** Electrogoniometry of post surgical knee bracing in running. *American Journal of Physical Medicine* 62(4):172-181, 1983.
3. Osternig, L. R., **Hamill, J.**, Sawhill, J. A., Bates, B. T. Influence of torque and joint speed on power production. *American Journal of Physical Medicine* 62(4): 163-171, 1983.
4. **Hamill, J.**, Bates, B. T., Sawhill, J. A., Knutzen, K. M. Variations in ground reaction force parameters at different running speeds. *Human Movement Sciences* 2:47-56, 1983.
5. **Hamill, J.**, Bates, B. T., Knutzen, K. M. Ground reaction force symmetry during walking and running. *Research Quarterly for Exercise and Sport* 55(3):289-293, 1984.
6. Knutzen, K. M., Bates, B. T., **Hamill, J.** Knee brace influences on the tibial rotation and torque patterns of the surgical limb. *Journal of Orthopaedic and Sports Physical Therapy* 6(2):116-122, 1984.
7. Osternig, L. R., **Hamill, J.**, Corcos, D. M., Lander, J. E. Electromyographic patterns accompanying isokinetic exercise under varying speed and sequencing conditions. *American Journal of Physical Medicine* 63(6):289-297, 1984.
8. Knutzen, K. M., **Hamill, J.**, Bates, B. T. Ambulatory characteristics of the visually disabled. *Human Movement Sciences* 4:55-66, 1985.
9. Lander, J. E., Bates, B. T., Sawhill, J. A., **Hamill, J.** A comparison between free-weight and isokinetic bench pressing. *Medicine and Science in Sports and Exercise* 17(3): 344-353, 1985.
10. Smith, P. K., **Hamill, J.** The effect of punching glove type and skill level on momentum transfer. *Human Movement Studies* 12(3):153-161, 1986.
11. **Hamill, J.**, Knutzen, K. M., Bates, B. T., Kirkpatrick, G. M. Evaluation of two ankle appliances using ground reaction force data. *Journal of Orthopaedic and Sports Physical Therapy* 7(5):244-249, 1986.
12. Osternig, L. R., **Hamill, J.**, Lander, J. E., Robertson, R. Coactivation of sprinter and distance runner agonist/antagonist muscles in isokinetic exercise. *Medicine and Science in Sports and Exercise* 18(4):431-435, 1986.
13. **Hamill, J.**, Ricard, M. D., Golden, D. M. Angular momentum in multiple rotation non-twisting platform dives. *International Journal of Sport Biomechanics* 2(2): 78-87, 1986.
14. Knutzen, K. M., Bates, B. T., Schot, P., **Hamill, J.** Knee brace evaluation. *Medicine and Science in Sports and Exercise* 19(3):303-309, 1987.
15. **Hamill, J.**, Murphy, M. V., Sussman, D. H. The effects of track turns on lower extremity function. *International Journal of Sport Biomechanics* 3(3):276-286, 1987.
16. **Hamill, J.**, Morin, G., Clarkson, P. M., Andres, R. O. Exercise moderation of foot function during walking with a re-usable semirigid ankle orthosis. *Clinical Biomechanics* 3(3):153-158, 1988.
17. **Hamill, J.**, Bates, B. T. A kinetic evaluation of the effects of in vivo loading on running shoes. *Journal of Orthopaedic and Sports Physical Therapy* 10(2):47-53, 1988.
18. **Hamill, J.**, Freedson, P. S., Boda, W., Reichsman, F. Effects of shoe type and cardiorespiratory responses and rearfoot motion during treadmill running. *Medicine and Science in Sports and Exercise* 20(5):515-521, 1988.
19. Greer, N. L., **Hamill, J.**, Campbell, K. R. Ground reaction forces in children's gait. *Pediatric Exercise Science* 1(1):45-53, 1989.
20. **Hamill, J.**, Knutzen, K. M., Bates, B. T., Kirkpatrick, G. M. Relationship of static and dynamic measures of the lower extremity. *Clinical Biomechanics* 4(4):217-225, 1989.
21. Greer, N. L., **Hamill, J.**, Campbell, K. R. Dynamics of children's gait. *Human Movement Sciences* 8:465-480, 1989.

22. Brown, D. B., Knowlton, R. G., **Hamill, J.**, Schneider, T. L., Hetzler, R. K. Physiological and biomechanical differences between wheelchair-dependent and able-bodied subjects during wheelchair ergometry. *European Journal of Applied Physiology* 60:179-182, 1990.
23. Holt, K. G., **Hamill, J.**, Andres, R. O. The force driven harmonic oscillator as a model for human locomotion. *Human Movement Science* 9:55-68, 1990.
24. **Hamill, J.**, McNiven, S. L. Reliability of ground reaction force parameters during walking. *Human Movement Science* 9:117-131, 1990.
25. Robertson, R. N., Osternig, L. R., **Hamill, J.**, DeVita, P. EMG-torque relationships during isokinetic dynamometer exercise. *Sports Training, Medicine and Rehabilitation* 2:1-10,1990.
26. Holt, K. G., **Hamill, J.**, Andres, R. O. Predicting the minimal energy cost of human walking. *Medicine and Science in Sports and Exercise* 23(4):491-498, 1991.
27. **Hamill, J.**, Freedson, P. S., Clarkson, P. M., Braun, B. Muscle soreness during running: biomechanical and physiological implications. *International Journal of Sports Biomechanics* 7(2):125-137, 1991.
28. Devita, P., Hong, D. M., **Hamill, J.** Effects of asymmetric load carrying on the biomechanics of walking. *Journal of Biomechanics* 24(12):1119-1129, 1991.
29. Ebbeling, C. J., **Hamill, J.**, Freedson, P. S., Rowland, T. W. Efficiency in Children's Gait. *Pediatric Exercise Science.* 4(1):36-49, 1992.
30. Widrick, J., Freedson, P. S., **Hamill, J.** Effect of internal work on the calculation of optimal pedalling rates. *Medicine and Science in Sports and Exercise* 24(3): 376-382, 1992.
31. **Hamill, J.**, Bates, B. T., Holt, K. G. Timing of lower extremity joint actions during treadmill running. *Medicine and Science in Sports and Exercise* 24(7):807-813 1992.
32. Foti, T., Ebbeling, C. J., **Hamill, J.**, Ward, A., Rippe, J. Stair climbing machines: Lower extremity kinematics and exercise intensity comparisons. *Medicine, Exercise, Nutrition, and Health* 2:162-169, 1993.
33. Ebbeling, C. J., **Hamill, J.**, Crussemeyer, J. A. Lower extremity mechanics and the energy cost of walking in high-heeled shoes. *Journal of Orthopaedic and Sports Physical Therapy* 19 (4):190-196, 1994.
34. Holt, K. G., Jeng, S. F., Ratcliffe, R., **Hamill, J.** Energetic cost and stability during human walking at the preferred stride frequency. *Journal of Motor Behavior* 27(2): 164-178, 1994.
35. **Hamill, J.**, Derrick, T. R., Holt, K. G. Shock attenuation and stride frequency during running. *Human Movement Science* 14:45-60, 1995.
36. Whittlesey, S. N., **Hamill, J.** An alternative model of the lower extremity during locomotion. *Journal of Applied Biomechanics* 12(2):269-279, 1996.
37. Jensen, R. L., Freedson, P. S., **Hamill, J.** The prediction of power and efficiency during near-maximal rowing. *European Journal of Applied Physiology* 73:98-104, 1996.
38. **Hamill, J.**, Caldwell, G. E., Derrick, T. R. Reconstructing digital signals using Shannon's Sampling Theorem. *Journal of Applied Biomechanics* 13:226-238, 1997.
39. Mahar, A. T., Derrick, T. R., **Hamill, J.**, Caldwell, G. E. Impact shock and attenuation during in-line skating. *Medicine and Science in Sports and Exercise* 29(8):1069-1075, 1997.
40. Derrick, T. R., **Hamill, J.**, Caldwell, G. E. Energy absorption in conditions of various stride frequencies. *Medicine and Science in Sports and Exercise* 30(1):128-135, 1998.
41. **Hamill, J.**, van Emmerik, R. E. A., Heiderscheit, B. C., Li, L. A dynamical systems approach to the investigation of lower extremity running injuries. *Clinical Biomechanics* 14(5):297-308, 1999.
42. Li, L., Hardin, E. C., Caldwell, G. E., Van Emmerik, R. E. A., **Hamill, J.** Coordination patterns of walking and running at similar speed and stride frequency. *Human Movement Science* 18:67-85, 1999.
43. Heiderscheit, B. C., **Hamill, J.**, Van Emmerik, R. E. A. Influence on Q-angle on the variability of lower extremity segment coordination during running. *Medicine and Science in Sport and Exercise* 31(9):1313-1319, 1999.
44. Derrick, T. R., Caldwell, G. E., **Hamill, J.** Modeling the stiffness characteristics of the human body while running at various stride frequencies. *Journal of Applied Biomechanics* 16:36-51, 2000.
45. Heiderscheit, B. C., **Hamill, J.**, Caldwell, G. E. Influence on Q-angle on lower extremity kinematics during running. *Journal of Orthopedic and Sports Physical Therapy*, 30(5):271-278, 2000.
46. McCaw, S. T., Heil, M. E., **Hamill, J.** The effect of comments about shoe construction on impact forces during walking. *Medicine and Science in Sport and Exercise* 32(7):1258-1264, 2000.
47. Whittlesey, S. N., Van Emerik, R. E. A., **Hamill, J.** The swing phase of human walking in not a passive movement. *Motor Control*, 4(3):273-292 2000.

48. **Hamill, J.**, Haddad, J.M., McDermott, W.J. Issues in quantifying varaibility from a dynamical systems perspective. *Journal of Applied Biomechanics*, 16:409-420, 2000.
49. Williams, D. S., McClay, I. S., **Hamill, J.**, Buchanan, T. S. Lower extremity kinematic and kinetic differences in runners. *Journal of Applied Biomechanics* 17:153-163, 2001.
50. Williams, D. S., McClay, I. S., **Hamill, J.** Arch structure and injury patterns in runners. *Clinical Biomechanics* 16(4):341-347, 2001
51. O'Connor, K. M., **Hamill, J.** Does running on a cambered road predispose a runner to injury? *Journal of Applied Biomechanics* 18(1):3-14, 2002.
52. Heiderscehit, B. C., **Hamill, J.**, Van Emmerik, R. E. A. Locomotion variability and patellofemoral pain. *Journal of Applied Biomechanics* 18(2):110-121, 2002.
53. Hardin, E. C., **Hamill, J.** The influence of midsole cushioning on mechanical and hematological responses during a prolonged downhill run. *Research Quarterly for Exercise and Sport* (in press), 2002.
54. Li, L., **Hamill, J.** Characteristics of the vertical ground reaction force component prior to gait transition. *Research Quarterly for Exercise and Sport* (in press), 2002.
55. Mercer. J. A., Vance, J., Hreljac, A., **Hamill, J.** Relationship between shock attenuation and stride length during running at different velocities. *European Journal of Applied Physiology* (in press), 2002.

MANUSCRIPTS UNDER REVIEW

Hardin, E., **Hamill, J.** The influence of shoe/surface interactions on impact shock attenuation. *Journal of Applied Biomechanics*, 1999.

Laughton, C., McClay, I., **Hamill, J.** Orthotic intervention and rearfoot motion in forefoot and rearfoot strike running patterns. *Clinical Biomechanics*, 2001.

MANUSCRIPTS IN PREPARATION

Derrick, T. R., Caldwell, G. E., **Hamill, J.** The effect of simulated MUAP shape, rate and variability on the power spectrum.

Hamill, J., Derrick, T. R. Co-contraction of lower extremity muscles under varying stride frequency conditions.

Hamill, J., Derrick, T.R., McClay, I. Joint stiffness during running with different footfall patterns.

PROCEEDINGS

1. Bates, B. T., Sawhill, J. A., **Hamill, J.** Dynamic running shoe evaluation. In Proceedings of Human Locomotion, Special Conference of the Canadian Society of Biomechanics, 122-124, London, Ontario, October, 1980.
2. **Hamill, J.**, Bates, B. T., White, C. A. Evaluation of foot orthotic appliances using ground reaction force data. In Proceedings of Human Locomotion II, Special Conference of the Canadian Society of Biomechanics, 74-76, Kingston, Ontario, September, 1982.
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5. **Hamill, J.** Mechanical load on the body. In *American College of Sports Medicine Resource Manual (3rd Edition)*. pp. 103-108. Baltimore, MD: Williams and Wilkins, 1998.
6. Caldwell, G. E., Van Emmerik, R E. A., **Hamill, J.** Movement Proficiency: Incorporating Task Demands and Constraints in Assessing Human Movement. In W. A. Sparrow (ed.). *Energetics of Human Activity*. pp. 66-95. Champaign, IL: Human Kinetics Publishers, 2000.
7. **Hamill, J.**, Caldwell, G. E. Mechanical load on the body. In *American College of Sports Medicine Resource Manual (4th Edition)*. pp. 107-1012. Baltimore, MD: Williams and Wilkins, 2001.
8. **Hamill, J.**, Hardin, E. C. Special Topics In Biomechanics. In G. Kamen (ed.). Foundations of *Exercise Science*. pp. 177-189. Baltimore: Lippincott, Williams & Wilkins, 2001.
9. Hardin, E. C., **Hamill, J.** Exercise, Sport and Materials Science. In G. Kamen (ed.). Foundations of *Exercise Science*. pp. 191-214. Baltimore: Lippincott, Williams & Wilkins, 2001.

NON-REFEREED PUBLICATIONS

1. **Hamill, J.**, Golden, D. M. Mechanics of tower dive take-offs. Proceedings of the United States Diving Association Annual Convention, D. M. Golden (ed.). pp. 45-66, U.S. Diving Sports Science, Phoenix, AR, September, 1985.
2. **Hamill, J.** All about athletic shoes. *Popular Mechanics*. pp. 71-75, September, 1986.

3. **Hamill, J.** Choosing the appropriate running shoe. *Scholastic Coach*, December, 1989.
4. **Hamill, J.** Design of athletic shoes: Biomechanical considerations. *Kinesiology Academy Newsletter*, Fall, 1990.
5. **Hamill, J.**, Clarkson, P. M., Holt, K. G., Freedson, P. S. Muscle Soreness. *Nike Sport Research Review*, December/March, 1991.
6. **Hamill, J.** Is biomechanics an atheoretical discipline? In J. D. Wilkerson, E. Kreighbaum, C. L. Tant. (eds.). *Teaching Kinesiology and Biomechanics in Sports*. pp. 119-121, Iowa State University, Ames, Iowa, 1992.
7. **Hamill, J.**, Foti, T., Crussemeyer, J. A. Annotated bibliography: Biomechanics of the lower extremity during running 1987-1992. *Medicine, Exercise, Nutrition, and Health* 4(1):245-252, 1992.
8. **Hamill, J.**, Holt, K. G. Running injuries and treatment. In A. Barabas and G. Fabian, (eds.). *Biomechanics In Sports XII*. pp. 121-127, 1994.
9. **Hamill, J.** Understanding rearfoot motion. *Biomechanics.* II(3):87-90, 1995.
10. Derrick, T. R., **Hamill, J.** Riding the shock wave. *Biomechanics*. II(9):75-77, 1995.
11. **Hamill, J.**, Derrick, T. R. The mechanics of foot orthoses during running. *Biomechanics.* III(2):123-126, 1996.
12. **Hamill, J.** Evaluation of sport shoes using ground reaction force data. In J. M. C. S. Abrantes (ed.). *Biomechanics in Sports XIV*. Universidade Tecnica de Lisboa, pp. 111-119, 1996.
13. **Hamill, J.** Biomechanics of distance running. *Proceedings of the 1997 International Symposium for the Improvement of Athletic Performance*. pp. 91-108. Research Institute of Sports Science, Korean National University, Seoul, Korea.
14. Heiderscheit, B., **Hamill, J.**, Tiberio, D. Current research in foot orthoses. British Journal of Sports Medicine, 1(1):4-5, 2001.
15. **Hamill, J.**, Heiderscheit, B., Tiberio, D. Do foot orthoses work?. Western Journal of Medicine, 176:4-5, Januray, 2002.

PUBLISHED RESEARCH REPORTS

1. Sawhill, J. A., McIntyre, D. R., **Hamill, J.** Dynamic human performance analysis. Isotechnologies, Inc., Research Report, May, 1982.
2. Sawhill, J. A., McIntyre, D. R., **Hamill, J.** What are you really measuring? Isotechnologies, Inc., Research Report, May, 1983.
3. **Hamill, J.**, Bensel, C. K. Biomechanical Analysis of Military Boots. Phase I: Materials Testing of Military and Commercial Footwear. Technical Report - Natick/TR-93/006. Natick, MA: US Army Natick Reserach, Development and Engineering Center, October, 1992.
4. **Hamill, J.**, Bensel, C. K. Biomechanical Analysis of Military Boots. Phase II: Human User testing of Military and Commercial Footwear (Volume I). Technical Report - Natick/TR-96/011. Natick, MA: US Army Natick Reserach, Development and Engineering Center, February, 1996.
5. **Hamill, J.**, Bensel, C. K. Biomechanical Analysis of Military Boots. Phase II: Human User testing of Military and Commercial Footwear (Volume II). Technical Report - Natick/TR-96/012. Natick, MA: US Army Natick Reserach, Development and Engineering Center, February, 1996.
6. **Hamill, J.**, Bensel, C. K. Biomechanical Analysis of Military Boots. Phase III: Recommendations for the Design of Future Military Boots. Technical Report - Natick/TR-96/013. Natick, MA: US Army Natick Reserach, Development and Engineering Center, February, 1996.

PUBLISHED BOOK REVIEWS

1. A Primer of Orthopaedic Biomechanics. American College of Sports Medicine Bulletin, Vol. 20, No. 2, April, 1985.
2. Sports Shoes and Playing Surfaces. American College of Sports Medicine Bulletin, Vol. 20, No. 2, April, 1985.

PRESENTATIONS

International:

1. Holt, K. G., **Hamill, J.**, Certo, C., Fitzgerald, M. Tuning the novice runner to resonance. Xth Meeting of the International Society for Biomechanics in Sports, Milan, Italy, June, 1992.
2. **Hamill, J.**, Bates, B. T., Holt, K. G., Davis, H. Influence of shoe-surface interactions on rearfoot motion during running. Xth Meeting of the International Society for Biomechanics in Sports, Milan, Italy, June, 1992.
3. Bates, B. T., **Hamill, J.**, Davis, H. P., Stergiou, N. Surface and shoe effects on lower extremity impact characteristics. European Society for Biomechanics Annual Meeting, Rome, Italy, June, 1992.
4. Mahar, A. T., Derrick, T. R., **Hamill, J.**, Caldwell, G. E. Evaluation of in-line skating for rehabilitation: impact shock considerations. North American Clinical Gait Laboratory Conference, Waterloo, Ontario, Canada, June, 1995.
5. Laughton, C., McClay, I. S., **Hamill, J.** The effect of orthotic intervention and strike pattern on tibial acceleration. XVIIIth Congress of the International Society for Biomechanics in Sports, ETH Zurich, Switzerland, July, 2001.
6. Countryman, M., O'Conner, K., **Hamill, J.** Alterations in rearfoot motion across locomotor speeds. XVIIIth Congress of the International Society for Biomechanics in Sports, ETH Zurich, Switzerland, July, 2001.
7. McKeown, K. A., Brown, C. D., Chu, J., **Hamill, J.** Lower extremity coordination changes during a fatiguing run. XVIIIth Congress of the International Society for Biomechanics in Sports, ETH Zurich, Switzerland, July, 2001.
8. McDermott, W. J., Chu, J. J., **Hamill, J.**, Caldwell, G. E., van Emmerik, R. The influence of step-related mechanical constraints on the coordination between locomotory and breathing rhythms. XVIIIth Congress of the International Society for Biomechanics in Sports, ETH Zurich, Switzerland, July, 2001.
9. Heiderscheit, B., **Hamill, J.**, van Emmerik, R. Patellofemoral pain and knee interlimb coordination asymmetry during running. XVIIIth Congress of the International Society for Biomechanics in Sports, ETH Zurich, Switzerland, July, 2001.
10. Chu, J., **Hamill, J.**, Caldwell, G. E. Quantifying stiffness during downhill running. XVIIIth Congress of the International Society for Biomechanics in Sports, ETH Zurich, Switzerland, July, 2001.
11. Kandle, R., Whittlesey, S. N., **Hamill, J.** Gait adaptations in ACL-reconstructed patients before and after operative reconstruction. XVIIIth Congress of the International Society for Biomechanics in Sports, ETH Zurich, Switzerland, July, 2001.

National:

1. Knutzen, K. M., Bates, B. T., **Hamill, J.** Electrogoniometric evaluation of knee brace influences on the surgically repaired knee during overground running. American Alliance for Health, Physical Education, Recreation and Dance Annual Meeting, Minneapolis, MN, April, 1982.
2. **Hamill, J.**, Knutzen, K. M. Evaluation of strapping techniques using ground reaction force data. American Alliance for Health, Physical Education, Recreation and Dance Annual Meeting, Anaheim, CA, April, 1984.
3. Sussman, D. H., **Hamill, J.** Effect of high and low top basketball shoes on sub-talar pronation. American Alliance for Health, Physical Education, Recreation and Dance Annual Meeting, Cincinnati, OH, April, 1986.
4. Hetzler, R., Knowlton, R. G., **Hamill, J.**, Noakes, T., Schneider, T. Physiological and biomechanical comparison of able-bodied persons to wheel-chair dependent persons during wheelchair ergometry. American Alliance for Health, Physical Education, Recreation and Dance Annual Meeting, Cincinnati, OH, April, 1986.
5. Sussman, D. H., **Hamill, J.**, Miller, M., Hong, T. Effect of shoe height and athletic taping on sub-talar joint supination during lateral movement. Annual Meeting of American Alliance for Health, Physical Education, Recreation and Dance, Las Vegas, NV, April, 1987.
6. Ricard, M. D., **Hamill, J.** Mechanical energy in the front handspring-front salto vault. American Alliance for Health, Physical Education, Recreation and Dance Annual Meeting, Kansas City, MO, April, 1988.
7. Greer, N. L., **Hamill, J.**, Campbell, K. R. Ground reaction forces in children's gait. American Society of Biomechanics Annual Meeting, Champaign-Urbana, IL, September, 1988.

8. Ebbeling, C. J., Foti, T. A., **Hamill, J.**, Ward, A., Rippe, J. Comparison of energy cost and lower extremity mechanics of three stair-stepping machines. American Alliance for Health, Physical Education, Recreation and Dance Annual Meeting, San Francisco, CA, April, 1991.
9. Holt, K. G., Jeng, S. F., Ratcliffe, R., **Hamill, J.** Optimality criteria in walking. Tenth Annual Meeting, International Society for Ecological Psychology, Hartford, CT, October, 1991.
10. **Hamill, J.**, Bates, B. T., Holt, K. G. Timing of the knee and sub-talar joint actions during treadmill running. American Society of Biomechanics Annual Meeting, Phoenix, AZ, October, 1991.
11. Holt, K. G., Jeng, S. F., Ratcliffe, R., **Hamill, J.** Exploring the use of non-linear dynamics in the assessment of stability of human walking. 13th Annual Conference IEEE, Engineering in Medicine and Biology, Orlando, FL, November, 1991.
12. Holt, K. G., Jeng, S. F., Ratcliffe, R., Thompson, S., **Hamill, J.** Stability and the metabolic cost of human walking. XIth International Symposium on Posture and Gait: Control Mechanisms, Portland, OR, May, 1992.
13. Li, L., Hardin, E. C., Caldwell, G. E., **Hamill, J.** Comparison of walking and running at the same speed. American Alliance for Health, Physical Education, Recreation and Dance Annual Meeting, Atlanta, GA, April, 1996.
14. Li, L., Hardin, E. C., Van Emmerik, R. E. A., Caldwell, G. E., **Hamill, J.** Change in variability during prolonged downhill running. Biomechanics and Neural Control of Movement IX, Engineering Foundation Conference, Mt. Sterling, OH, June, 1996.
15. Worthen, L., **Hamill, J.** Biomechanical issues in ballet: ankle alignment in pointe shoes. 15th Annual Symposium on Medical Problems of Musicians and Dancers, Aspen, CO, June, 1997.
16. Li, L., Heiderscheit, B. C, Caldwell, G. E., **Hamill, J.** Knee joint stiffness during the stance phase of level running. Annual Meeting of the Combined Sections of the American Physical Therapy Association, Boston, MA, February, 1998.
17. Heiderscheit, B. C., **Hamill, J.**, van Emmerik, R. E. A. Influence of Q-angle on lower extremity segment interactions during ruuning. Annual Meeting of the North American Society of Gait and Clinical Movement Analysis, San Diego, CA, April, 1998.
18. Kandle, R., Heiderscheit, B.C., **Hamill, J.** Interjoint coordination following ACL reconstruction. Annual Meeting of the Combined Sections of the American Physical Therapy Association, New Orleans, LA, February, 2000.
19. Haddad, J., van Emmerik, R. E. A., Whittelsey, S.N., **Hamill, J.** Inter- and intra-limb coordination under asymmetrical loading. American Alliance for Health, Physical Education, Recreation and Dance Annual Meeting, Orlanda, FL, March, 2000.

Regional, State, and Local:

1. **Hamill, J.** A comparison of selected kinematic parameters in the support phase of running on various inclinations. Conference of the Oregon Alliance for Health, Physical Education, Recreation and Dance, October, 1980.
2. **Hamill, J.**, Knutzen, K. M., Sawhill, J. A. Accuracy for center of gravity estimates. Conference of the Oregon Alliance for Health, Physical Education, Recreation and Dance, October, 1980.
3. **Hamill, J.**, Bates, B. T. Effects of shoe-orthotic interactions. New England Chapter of the American College of Sports Medicine Annual Meeting, Foxboro, MA, November, 1986.
4. Boda, W. L., **Hamill, J.**, Homa, K. Shoe type and lower extremity kinematics during walking. New England Chapter of the American College of Sports Medicine Annual Meeting, Worcester, MA, November, 1988.
5. Holt, K. G., **Hamill, J.**, O'Connor, D. Perceived and biomechanical evaluation of orthotic inserts. New England College Chapter of the American of Sports Medicine Annual Meeting, Worcester, MA, November, 1988.
6. Ebbeling, C. J., **Hamill, J.**, Foti, T., Ward, A, Rippe, J. Kinematics of the lower extremity on stair-stepping machines. New England Chapter of the American College of Sports Medicine Annual Meeting, Marlborough, MA, November, 1990.
7. Hintermeister, R. A., **Hamill, J.** Is symmetry valid in running? New England Chapter of the American College of Sports Medicine Annual Meeting, Marlborough, MA, November, 1990.
8. Boda, W. L., **Hamill, J.** Kinematic variations in three different backward presses in springboard diving. New England Chapter of the American College of Sports Medicine Annual Meeting, Marlborough, MA, November, 1990.

9. Elliott, E. H., **Hamill, J.**, Derrick, T. R. Reliability of the LiftStation measurement system. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November, 1993.
10. Derrick, T. R., **Hamill, J.**, Foti, T. Spectral analysis of EMG during running in orthotic/non-orthotic conditions. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November, 1993.
11. Elliott, E. H., **Hamill, J.**, Derrick, T. R. The influence of multiple lifts on load kinematics in males and females. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November, 1994.
12. Mahar, A., **Hamill, J.**, Derrick, T. R. Impact attenuation during running. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November, 1994.
13. Li, L., Swanson, S. C., Caldwell, G. E., **Hamill, J.** Measurement of lower extremity stiffness during the stance phase of level and downhill walking. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November, 1995.
14. Swanson, S. C., Derrick, T. R., **Hamill, J.** Impact attenuation and forefoot stiffness in hiking boots. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November, 1995.
15. Hardin, E. C., **Hamill, J.**, Taylor, J. M. The influence of midsole durometer on leg shock, hemocrit and muscle damage during downhill running. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November, 1995.
16. Heiderscheit, B. C., **Hamill, J.**, Derrick, T. R. Relationship between Q-angle and lower extremity kinematics during running. Annual Conference of the Massachusetts Chapter of the APTA, Danvers, MA, October, 1996.
17. Busconi, K., Gore, M., **Hamill, J.**, Freedson, P. Time motion profile of U. S. Olympic field hockey players during game conditions. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November, 1996.
18. Heiderscheit, B. C., **Hamill, J.**, Derrick, T. R. Relationships between Q-angle and lower extremity kinematics. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November, 1996.
19. Goff, D., **Hamill J.**, Clarkson, P. Biomechanical and biochemical changes after downhill running. New England Chapter of the American College of Sports Medicine Annual Meeting, Providence, RI, September, 1997.

KEYNOTE PRESENTATIONS

1. Mechanics of tower dive take-offs. United States Diving Association Annual Convention, Phoenix, AR, September, 1985.
2. Mechanics of walking. National Prescription Footwear Association, New York, NY, November, 1987.
3. Athletic Footwear and Injury. American Public Health Annual Meeting, Boston, Massachusetts, November 15, 1988.
4. Biomechanics of the lower extremity. Southeast Chapter of the American College of Sports Medicine Annual Meeting, Louisville, Kentucky, February 2, 1991.
5. Timing of lower extremity joint actions: A mechanism for knee injury? Northwest Chapter of the American College of Sports Medicine Annual Meeting, Eugene, OR, February 11, 1993.
6. Running injuries and rehabilitation. International Society of Biomechanics in Sports Annual Meeting, Budapest, Hungary, June 5, 1994.
7. Biomechanical aspects of exercise in children. IXth Annual NASPEM Conference, Pittsburg, PA, August 12, 1994.
8. Evaluation of athletic footwear using ground reaction force data. International Society of Biomechanics in Sports Annual Meeting, Madiera, Portugal, June, 1996.
9. Biomechanics of distance running. International Symposium of the Research Institute of Sports Science at Korean National University, Seoul, Korea, October 17, 1997.
10. Evaluation of shock attenuation. Fourth Symposium of the Technical Group on Footwear Biomechanics, Canmore, Alberta, Canada, August 6, 1999.

11. Segment coupling and running injuries. University of Nevada-Las Vegas Distinguished Lecture Series, Las Vegas, Nevada, March 1, 2002.

INVITED PRESENTATIONS

1. Effects of running shoes on foot function. Y.M.C.A., Eugene, OR, October, 1981.
2. Medio-lateral foot function during locomotion. University of Illinois Graduate Faculty and students, Champaign, IL, February, 1983.
3. Biomechanics of walking. American Heart Association Walk for Life, St. Louis, MO, May, 1987.
4. Biomechanics of walking and running shoes. New Mexico Race Walkers Association, Albuquerque, New Mexico, June, 1987.
5. Biomechanics of fitness walking. American Diabetes Association, St. Louis, Missouri, September, 1987.
6. Orthotics and lower extremity function. Athletic Training Symposium, American Alliance for Health, Physical Education, Recreation and Dance Annual Meeting, Kansas City, Missouri, April, 1988.
7. Running analysis from both a biomechanical and physiological perspective. Symposium, New England College of Sports Medicine Annual Meeting, Worcester, MA, November 4, 1988.
8. If the shoe fits: A biomechanical analysis of locomotion. Sigma Xi Society, University of Massachusetts, Amherst, MA, November 16, 1988.
9. Muscle soreness during running: Biomechanical and physiological considerations. Neuromuscular Research Center Seminar, Boston University, September 20, 1989.
10. Design of athletic shoes : Biomechanical considerations. Kinesiology Academy Meeting at the American Alliance of Health, Physical Education, Recreation, and Dance Annual Meeting, New Orleans, LA, April 28, 1990.
11. Biomechanical implications of the design of running shoes. Physical Therapy Department, Boston University, April 18, 1990.
12. Biomechanics of running. Physical Therapy Department, Boston University, November 6, 1990.
13. Is biomechanics an atheoretical discipline? Kinesiology Academy Teaching Conference, Ames, Iowa, July 5, 1991.
14. Biomechanics of Running. Education Resources Inc. Conference, Framingham, MA, September 27, 1991.
15. Optimality criteria for human locomotion. Motor Control/Biomechanics Seminar, Department of Exercise and Human Movement Studies, University of Oregon, January, 1992.
16. Biomechanical considerations for equipment design in children's sports. Seminar on Children's Activities, United Hospital Medical Center, Port Chester, NY, March 28, 1992.
17. Effficency of children's gait. (with C. J. Ebbeling). Kinesiology Academy Symposium at the American Alliance of Health, Physical Education, Recreation, and Dance Annual Meeting, Indianapolis, IN, April 13, 1992.
18. Optimality criteria for human locomotion. (with Holt, K. G., Maliszewski, A. F.) Invited Symposium at the Annual Meeting of the American College of Sports Medicine, May, 1992.
19. Optimality criteria for human locomotion. (with K. G. Holt and A.F. Maliszewski). Symposium at the American College of Sports Medicine Annual Meeting, Seattle, Washington, June 5, 1993.
20. The influence of step aerobics on knee angle. Research Symposium at the IDEA Annual Conference, New Orleans, Louisiana, June 21, 1993.
21. Rearfoot motion in running. (with K. G. Holt and C. J. Edington). Symposium at the New England College of Sports Medicine Annual Meeting, Boxborough, MA, November 5, 1993.
22. Controversies in the calculation of mechanical energy. (with K. D. Browder and L. Darby). Biomechanics Academy Symposium at the American Alliance of Health, Physical Education, Recreation, and Dance Annual Meeting, Denver, CO, April 13, 1994.
23. Stability and rearfoot motion testing: A proposed standard. (with M. Milliron and J. Healy). VIIIth Biennial Meeting of the Canadian Society for Biomechanics, Calgary, Canada, August, 1994.
24. Stride Frequency and Foot Strike Impact. Dept. of Exercise and Sports Science. Arizona State University, December 8, 1994.
25. Biomechanics of functional footwear. (with M. Shorten). Pre-Conference Symposium at the International Society of Biomechanics Biannual Meeting, Jyvaskyla, Finland, June, 1995.

26. Impact shock attenuation during conditions of altered stride frequencies in running. (with T. R. Derrick and K. G. Holt). Biomedical Engineering Society Meeting, Boston, MA, October, 1995.
27. Shoe and surface influences on ACL injuries. (with B. Busconi). American Volleyball Coaches Annual Meeting, Springfield, MA, December 15, 1995.
28. A force-driven harmonic oscillator model of human locomotion. German Sports University, Cologne, Germany, February 29, 1996.
29. If the shoe fits: the biomechanics of running shoes. American Medical Athletic Association, Boston, MA, April 12, 1996.
30. Biomechanics of athletic footwear. (with Martyn Shorten). American Alliance of Health, Physical Education, Recreation, and Dance Annual Meeting, Atlanta, GA, April, 1996.
31. An oscillator model of locomotion. University of Massachusetts Physics Department Seminar, Amherst, MA, May 1, 1996.
32. The mechanics of orthotics. New England Chapter of the American College of Sports Medicine Annual Meeting, Boxborough, MA, November 7, 1996.
33. A case study of a patient with patellofemoral pain. Eugene Michaels Lecture at the Combined Sections Meeting of the American Physical Therapy Association Annual Meeting, Dallas, Texas, February 14, 1997.
34. Oscillator Models of Human Locomotion. Korean Sports Science Institute, Seoul, Korea, October 15, 1997.
35. Lower extremity variability during running. Physical Therapy Department Seminar, University of Delaware, February 20, 1998.
36. Shock attenuation and transmission during running. (with T. R. Derrick). XVIIth Congress of the International Society of Biomechanics, Calgary, Alberta, Canada, August 12, 1999.
37. Variability and Stability: A Dynamical Systems Perspective. (with Van Emmerik, R. E. A., Heiderscheit, B., Li, L). Invited Symposium at the Annual Meeting of the American College of Sports Medicine, Indianapolis, IN, June, 2000.
38. From a Pendulum to a Spring. Department of Kinesiology, Louisiana State University, Baton Rouge, LA, October 24, 2000.
39. Oscillators and Springs. The Gladys Garrett Honor Lecture, Department of Exercise Science, University of Connecticut, Storrs, CT, May, 2001.
40. Joint Coupling variability and knee pain during running. (with B. Heiderscheit, R. Van Emmerik, J. Haddad). XVIIIth Congress of the International Society of Biomechanics, ETH Zurich, Switzerland, July, 2001.
41. Current Issues in Biomechanics. Beijing University, China, October 16, 2001.
42. Mechanical models and human locomotion. Beijing University, China, October 18, 2001.
43. A primer in 3-D: Considerations for biomechanical research. University of Las Vegas-Nevada, Las Vegas, Nevada, February 28, 2002.
44. Biomechanics Curriculum for Exercise Science programs. Biomechanics Academy, AAHPERD Annual Conference, San Diego, CA, April 11, 2002.
45. The role of variability in running injuries.). Invited Symposium at the Annual Meeting of the American College of Sports Medicine, St. Louis, MO, June, 2002.

GRANTS AND GIFTS

1. Mechanics of lower extremity function, Isotechnologies, Inc., $12,000, 9/1982 - 6/1984.
2. Dynamics of platform diving, United States Diving Association, $3,000, 1/1984 - 12/1984.
3. Effects of anatomically variant foot-types on walking gait, ORDA, Southern Illinois University, $6,000, 9/1985 - 6/1986.
4. Ergonomics of lower extremity function, KangaROOS, USA, $58,000, 9/1986 - 9/1989.
5. Effect of orthotic inserts on walkers with rearfoot and forefoot dysfunctions. Biomedical Research Support Grant, $6,000, 1/1987 - 1/1989.
6. Activity in later life: effects on posture and gait. National Institute of Aging, co-principal investigator, resubmitted January 28, 1988 (approved but not funded).
7. Musculoskeletal fitness norms for individuals aged 45-75. National Institute of Health, submitted February 1, 1988 (approved but not funded).
8. Prophylactic Knee and Ankle Bracing, AirCast Corp., $20,000, 9/1988 - 9/1989.

9. Mechanics of springboard diving : modeling the diver-board system, United States Diving Association, $15,000, l/1989 - l/1991.
10. Lower extremity action during exercise, Life-Fitness Group, $6,000, 7/1990 - 7/1992.
11. Biomechanical analysis of military boots, (Contract #DAAK60-91-C-0102) U.S. Army, Natick, MA, $183,000, 7/1991 - 12/1992.
12. Lower extremity mechanics, Hyde Athletic Shoe Company, $279,000, 1/1989 - 1/1997.
13. Biomechanical analysis of golf equipment, Titlest and Footjoy Worldwide, $283,000, 6/1992-12/1997.
14. Biomechanical analysis of hiking gait, The Timberland Company, $15,000, 3/1995 - 10/1995.
15. Biomechanical analysis of military boots, (Contract #DAAK60-95-R-8010) U.S. Army, Natick, MA, (sub-contract from Wellco Industries, North Carolina, $51,436, 9/1995 - 12/1997.
16. A physiological profile of the game of field hockey. (with P. S. Freedson). United States Olympic Committee, Colorado Springs, Colorado, $35,132, 1/1996 - 12/1996.
17. Locomotor patterns on running machines. NordicTrak, $10,000, 9/1997-3/1998.
18. A prospective study of running injuries: variability in movement coordination. (with R. van Emmerik). National Institute of Health, submitted October 1, 1997.
19. Plantar pressure patterns during hiking gait. The Timberland Company, $42,000, 3/1998 - 5/1999.
20. Investigation of foot scaling using a 3-D laser measurement system. Titleist and FootJoy Worldwide, $50,000, 1/1999 – 12/2000
21. Biomechanical analysis of golf footwear, Titleist and FootJoy Worldwide, $63,000, 1/1999-12/1999.
22. Walking and running mechanics and their effect on footwear, Hyde Athletic Shoe Company, $33,000, 1/1999 - 12/1999.
23. In-shoe temperatures during hiking, The Timberland Company, $15,000, 1/1999-3/1999.
24. Plantar forces during basketball movements, And1 Company, $15,000, 1/1999-3/1999.
25. Rearfoot motion and shock attenuation in trial running footwear, The Timberland Company, $10,000, 6/1999-7/1999.
26. Biomechanical analysis of military boots: Phase III, (Contract #DAAK60-95-R-8010) U.S. Army, Natick, MA, (sub-contract from Wellco Industries, North Carolina, $5,000, 9/1999 - 12/1999.
27. Biomechanical analysis of military boots. (Contract #DAAK16-00-P-0112) U.S. Army Soldier Systems Center, Natick, MA, $25,000, 1/2000 - 6/2000.
28. Running mechanics and their effect on footwear. Hyde Athletic Shoe Company, $33,000, 1/2000 - 12/2000.
29. Implementation of a 3-D laser measurement system. Titleist and FootJoy Worldwide, $89,000, 1/2000 – 12/2000.
30. Shock attenuation in hiking footwear. The Timberland Company, $18,000, 1/2000 - 6/2000.
31. Traction analysis of golf footwear. Titleist and FootJoy Worldwide, $48,000, 1/2000 - 12/2000.
32. Prospective study on tibial stress fractures. (with Irene McClay). US Army, $1,050,000, 8/1/2000 – 8/1/2004.
33.Footwear Testing. Titleist and FootJoy Worldwide. $50,000, 1/2001 - 12/2001.
34.3-D laser measurement system. Titleist and FootJoy Worldwide, $89,000, 1/2001 – 12/2001.
35.Walking mechanics and their effect on footwear. Hyde Athletic Shoe Company, $33,000, 1/2001 - 12/2001.
36.Parachute Landing Falls. Sub-contract from Foster-Miller, Inc., Waltham, MA, $60,000, 1/2001 – 12/2002.
37.A new 3-D laser measurement system. Titleist and FootJoy Worldwide, $69,000, 1/2002 – 12/2002.
38.Footwear Testing. Titleist and FootJoy Worldwide, $50,000, 1/2002 - 12/2002.
39.Footwear Testing. Hyde Athletic Shoe Company, $16,500, 1/2002 - 6/2002.
40.Hiking and Workboot Design. Timberland Company, $24,000, 1/2002 – 12/2002.