ABSTRACT

Background. Although it is common practice to administer pre-participation examinations (PPE) of athletes prior to training, there are no clearly established formats. Elements integral to the PPE fall within the scope of physical therapist practice, and are often categorized as a form of primary prevention for musculoskeletal disorders as defined in the Guide to Physical Therapist Practice.

Purpose. The purpose of this study is to describe the design and implementation of a PPE for a women's professional (gridiron) football team. The results and findings from this PPE provide one of the first musculoskeletal profiles and information about selected physical characteristics from members of a female professional football team.

Methods. Players from the Kentucky Karma women's football team, a member of the National Women's Football Association (NWFA), volunteered to participate in a PPE. Of twenty-five eligible team members, thirteen consented to participate. The PPE consisted of a health history questionnaire, a musculoskeletal screening, and a series of physical performance and agility tests.

Results. The players’ average (± SD) age, height, weight, body mass index (BMI), and body fat percentage were 29.6 (± 5.6) yrs., 1.66 (± .05) m, 66.8 (± 12.6) kg, 24.1 (± 3.7), and 27.4 (± 6.6) %, respectively. Commonly reported injuries were similar to those reported in men's collegiate football.

Conclusion. This is one of the first papers to report on a model PPE for a women's professional football team. Future research is needed to establish a standard PPE, recognize common injuries, and develop prevention strategies unique to women's professional football.

Key words: musculoskeletal screening, female athlete, performance testing

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INTRODUCTION
The pre-participation examination (PPE), also commonly referred to as a pre-season examination or physical, is often the first and sometimes the only opportunity to screen the comprehensive health of an athlete before training begins. The purposes of the PPE are to: (1) fulfill legal and/or insurance requirements, (2) ensure coaches and/or parents that players start the season with a baseline level of health and fitness, (3) provide medical personnel an opportunity to identify treatable conditions that might interfere with or be worsened by athletic participation, and (4) potentially aid in predicting/preventing future injuries. Team physicians, athletic trainers, physical therapists, and/or trained volunteers typically conduct the PPE. The PPE includes assessing the general health and fitness level, identifying biomechanical factors or pre-existing conditions that may predispose the athlete to injury, and detecting those athletes who may be at risk by participating in physical activity. PPEs have been in use for decades and there is an abundance of literature which discusses what components should be included, how those components should be arranged, and who should conduct the examinations. In 1984, the Sports Physical Therapy Section (SPTS) of American Physical Therapy Association (APTA) published Guidelines for Pre-season Athletic Participation Evaluation (2nd edition) which outlined recommendations for conducting PPEs.

Most PPEs include some form of medical history questionnaire, a musculoskeletal screening examination, and functional testing, either general, position or sport-specific. In 2005, one of the most comprehensive documents on the PPE, Pre-participation Physical Examination (3rd edition), was developed and published by several professional societies including the American Academy of Family Physicians (AAFP), American Academy of Pediatrics (AAP), American College of Sports Medicine (ACSM), American Medical Society for Sports Medicine (AMSSM), American Orthopaedic Society for Sports Medicine (AOSSM) and the American Osteopathic Academy of Sports Medicine (AOASM). Additionally, this document was endorsed by the National Athletic Trainer's Association (NATA) and the SPTS of the APTA, and was approved by the Special Olympics Medical Committee as meeting its standards for athletic participation. A recent clinical commentary by Maffey and Emery provides some rationale and evidence for a physical therapist delivered PPE to primarily address the musculoskeletal system. The musculoskeletal assessments are often the most emphasized part of the PPE. Physical therapists are trained to screen for musculoskeletal deficiencies such as joint hyper- or hypomobility, limited strength and flexibility, balance and coordination problems, and significant biomechanical or postural abnormalities that could be considered as potential risk factors for injury during athletic competition. Other aspects of the PPE often include screening for high blood pressure and assessing body composition and co-morbidities, such as diabetes or sex-specific issues such as the elements associated with the female athlete triad (e.g. abnormal menstruation, osteoporosis/decreased bone health, disordered eating).

Since the introduction of Title IX in 1972, participation in women’s sports has grown exponentially. Female athletes now have opportunities to participate in sports at every level – recreational leagues, club and select teams, scholastic and intramural teams, and professional leagues. Professional women’s leagues have been founded in sports from softball (WPSL-Women’s Professional Softball League), soccer (WUSA-Women’s United Soccer Association), golf (LPGA-Ladies Professional Golf Association), and to more traditionally “male predominant” sports like basketball (WNBA-Women’s National Basketball Association) and football (NWFA-National Women’s Football Association). The WNBA was started in 1996 and has been one of the most successful and long-running women’s professional leagues. Since its inception, the league has grown to 13 teams, some of which are still operated under the respective city’s NBA team. The WNBA currently does not have a league-mandated preparticipation examination, but allows each team and its staff to develop one that best suits their needs (According to B. Jacobs, strength coach for the WNBA Indiana Fever, personal communication, May 18, 2009). It is often difficult to conduct a true pre-season examination because a large percentage of the players participate in year-round international competition. The teams’ representatives perform an examination on the players prior to the WNBA season in order to identify any deficiencies in body composition, cardiovascular endurance, and limb asymmetries in balance, range of motion, and strength. This “pre-season” information may also be utilized to evaluate a player’s fitness when returning from an injury. The
team-specific PPE has become a vital tool in both monitoring and optimizing each athlete’s performance.

The Kentucky Karma, now a member of the Women's Football Alliance, was a member of the NWFA from 2003-2008.14 The NWFA was formed in 2000 and grew from two to as many as 40 teams. Teams typically maintained rosters with 25-55 players. In 2006, the NWFA's 34 teams were contacted regarding their use of the PPE. None of the contacted teams reported using formal PPE’s. Eight teams responded they were interested in incorporating a PPE into their programs, but reported financial constraints and a lack of qualified personnel to conduct PPEs.

The purpose of this report is to: 1) describe administration of a PPE for a professional women's football (gridiron) team, the Kentucky Karma, and 2) summarize and report the findings and results of this PPE. Currently, there is limited information reported in the literature about the physical and performance characteristics of the female professional football player.

METHODS

Subjects

Subjects were recruited from the official roster of the Kentucky Karma women’s professional football team. At the time of testing, there were 25 players eligible to participate in the PPE. Of these players, 13 (52%) agreed to participate in the questionnaire, musculoskeletal screening, and performance assessment. All players received a detailed description of the questionnaires and fitness testing protocols prior to the day of testing, and informed consent was obtained from all participants. The project was reviewed and approved by the University Institutional Review Board.

Health History Questionnaire

Prior to the testing, players completed a written questionnaire addressing personal and family medical history, issues specific to the female athlete such as menstrual and diet history, and any personal fitness/health goals (Figure 2). The health questionnaire was modeled after one developed by the University of Texas Fitness Institute.15 Patient history forms have been reported to have a sensitivity of 91.6%, while the sensitivity of the actual examination to be only 50.8% in identifying previous musculoskeletal injuries.6 Literature suggests the cardiovascular component of the PPE is one of the most important from a prevention standpoint.6,11,15 Recommendations state that screenings should be completed by a qualified healthcare practitioner trained to identify specific cardiovascular red flags, signs, and symptoms.14 The cardiovascular screens are suggested to be completed at least every two years with annual blood pressure checks and other updates when needed.16 A retrospective study by Wingfield et al17 reported the presence of cardiac symptoms in several athletes prior to their sudden deaths during competition. Players having three or more of the ACSM18 defined “Coronary Artery Disease Risk Factors,” as addressed in the questionnaire would have been excluded and referred to their primary care physician or team physician. The team physician reviewed the questionnaire and testing measures and found them to be safe and comprehensive. According to ACSM18 guidelines for physician-supervised exercise testing, all participants were categorized as “low risk” and physician presence was “not necessary” for testing (Tables 1-3).

Additional questions addressed specific components of the female athlete triad – osteoporosis, amenorrhea, and disordered eating – all of which can be preceded by changes in diet. A 2007 ACSM position statement changed the structure of the triad to more of a continuum on which the athlete can be closer to some components but not necessarily to others.19 The ACSM also introduced an additional category of “low energy availability.” Energy availability is the difference between the energy intake and the energy spent – both for daily metabolic functions and for athletic training and competitions. Low energy availability can occur on a daily basis but have no effect for weeks or months. The ACSM feels that the triad can occur in any type of athlete and should be screened for at the PPE and at subsequent annual screenings.19 The following are recommendations of important information to obtain in the history specific to female athletes: 1) menstrual history- age at menarche and breast development, frequency/duration/regularity of periods, use of oral contraceptives, and significant events in obstetric history; 2) physical history- age at start of competitive physical training, frequency/intensity of current training, any menstrual changes occurring with changes in training intensity, and injury history specific to lower extremity stress fractures; 3) dietary history- adequacy of caloric intake, weight stability, perceived body image, history of dieting/binging/purging, use of diet pills/laxatives diuretics, dietary recall, and self-imposed restrictions; 4) family history- mother’s age at menarche/ menopause, osteo-
Figure 2. Health History Questionnaire

Fitness Screening Questionnaire

<table>
<thead>
<tr>
<th>Name:</th>
<th>Address:</th>
<th>Phone:</th>
<th>Email:</th>
<th>Age:</th>
</tr>
</thead>
</table>

Investigator Use Only:

/7
Cardiac Risk Factor

Please answer the following questions to the best of your knowledge by checking the appropriate answer. All answers will be confidential and will not be shared with anyone other than those directly involved in the research project.

1) Has a doctor ever told you that you have a heart condition and recommended only medically supervised physical activity? [ ] Yes [ ] No [ ] Unknown
2) Do you ever have chest pain brought on by physical activity? [ ] Yes [ ] No [ ] Unknown
3) Have you experienced chest pain in the last month when not participating in physical activity? [ ] Yes [ ] No [ ] Unknown
4) Have you experienced dizziness or lost consciousness? [ ] Yes [ ] No [ ] Unknown
5) Have you ever taken prescription medication for blood pressure or a heart condition? [ ] Yes [ ] No [ ] Unknown
6) Do you have any physical reason that would prohibit you from participating in physical activity? [ ] Yes [ ] No [ ] Unknown
7) *Do you smoke or have you quit in the last 6 months? [ ] Yes [ ] No [ ] Unknown
8) *Is your cholesterol greater than 240 mg/dl? [ ] Yes [ ] No [ ] Unknown
9) *Do you have a family history of heart disease, heart attack, or sudden death before the age of 50? [ ] Yes [ ] No [ ] Unknown
10) Are you physically inactive (less than 30 minutes of physical activity 3 days per week)? [ ] Yes [ ] No [ ] Unknown
11) Have you ever experienced pain or discomfort in the chest, neck, jaw, arm or other areas of your upper body? [ ] Yes [ ] No [ ] Unknown
12) Do you ever experience shortness of breath at rest or with mild physical activity? [ ] Yes [ ] No [ ] Unknown
13) Do you currently have swelling of your ankles? [ ] Yes [ ] No [ ] Unknown
14) Do you experience irregular beating of your heart or a very rapid heart rate with mild exertion? [ ] Yes [ ] No [ ] Unknown
15) Do you ever experience unusual fatigue or shortness of breath with usual daily activities? [ ] Yes [ ] No [ ] Unknown
16) Do you ever experience pain in your legs while exercising that is relieved by rest? [ ] Yes [ ] No [ ] Unknown
<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>17) Have you ever been hospitalized?</td>
<td></td>
<td></td>
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<tr>
<td>If yes, please describe</td>
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<tr>
<td>18) Have you ever had surgery?</td>
<td></td>
<td></td>
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<tr>
<td>If yes, please describe</td>
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<tr>
<td>19) Do you have a bone or joint problem that could be made worse by engaging in physical fitness testing?</td>
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<tr>
<td>20) Have you ever had a head injury/seizure, loss of consciousness, or other neurological problem?</td>
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<tr>
<td>If yes, please describe</td>
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<tr>
<td>21) Are you currently or have you recently experienced any joint or muscle pain?</td>
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<td>22) Do you attempt to control your weight?</td>
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<tr>
<td>If yes, please explain how &amp; how often</td>
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<tr>
<td>23) Do you now or have you ever had asthma?</td>
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<tr>
<td>24) Are you currently suffering from any orthopedic or musculoskeletal conditions that may affect your performance on the fitness screen?</td>
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<tr>
<td>Please explain</td>
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<tr>
<td>25) Do you require any protective equipment, for example knee or ankle braces, when being active?</td>
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<tr>
<td>If yes, please describe</td>
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<tr>
<td>26) Do you now or have you ever had:</td>
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<td></td>
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<tr>
<td>a) Coronary heart disease, heart attack, or heart surgery</td>
<td></td>
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<tr>
<td>b) Angina (chest pain)</td>
<td></td>
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<tr>
<td>*c) High blood pressure</td>
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<td></td>
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<tr>
<td>d) Peripheral vascular disease</td>
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<td></td>
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<tr>
<td>e) Stroke</td>
<td></td>
<td></td>
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<tr>
<td>*f) Diabetes or impaired fasting blood sugar</td>
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<td></td>
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<tr>
<td>g) Thyroid problems</td>
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<td></td>
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<tr>
<td>h) Hepatitis</td>
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<td></td>
<td></td>
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<tr>
<td>i) Arthritis</td>
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</tbody>
</table>
j) Gout
k) Headaches (chronic or severe)
l) Head injury or epilepsy
m) Abdominal pain, hernia, GI bleeding
n) Kidney problems or painful urination
o) Tendency to bleed or bruise easily
p) Anemia
q) Lung problems
r) Liver problems
s) Lack of or irregular menstruation
t) Gynecological issues requiring treatment
u) Stress fractures

27) Have you ever been diagnosed with a heart murmur?  
28) Have you donated blood or lost a significant amount of blood from an injury in the last month?  
29) Are you now or have you been pregnant in the last month?  
30) How old were you when you had your first menstruation?
31) Does the frequency or duration of your periods vary?  
   If so, please describe ______________________________

32) Have you recently been ill or injured?  
   If yes, please describe ______________________________

33) Have you ever had an orthopedic injury (sprains, tears, muscle/joint problems, etc)?
   If yes, please describe ______________________________

34) How satisfied are you with your current weight (select one)
   Very satisfied   Satisfied   Dissatisfied   Very dissatisfied
   Please briefly explain ______________________________

35) How would you classify your current diet? (select one)
   Always healthy   Sometimes healthy   Mostly fast food

36) Are you currently taking any prescription medications for the following conditions? Please name the medication.
   Name of medication
   a) Heart ______________________________  
   b) Blood pressure ______________________________  
   c) Hormones ______________________________  
   d) Lung condition ______________________________  
   e) Insulin ______________________________  
   f) Diabetes ______________________________  
   g) Arthritis ______________________________
h) Depression
i) Anxiety
j) Thyroid
k) Ulcers
l) Painkillers
m) Allergies
n) Birth control
n) Other

37) Are you currently taking any over the counter medications? 
Please list the medications ______________________

*Current level of physical activity – Please fill in the chart according to your activities in the last 3 months from most to least frequent.

<table>
<thead>
<tr>
<th>Type of activity (running, swimming, etc.)</th>
<th>How long have you participated in the Activity?</th>
<th>Avg. # of times per week</th>
<th>Avg. # of minutes each time</th>
<th>Intensity (see below)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Intensity: extremely light, very light, somewhat hard, hard, very hard, extremely hard

What are your primary fitness goals?
1) ______________________________________________________

2) ______________________________________________________

3) ______________________________________________________

The information I have provided is accurate and true to the best of my knowledge. I am willingly participating in this research/fitness project. All information I will provide to this project will be accurate. I understand the importance of being as honest as possible with my future answers. I understand there is no penalty for not participating.

Signature __________________________________________ Date _____________
<table>
<thead>
<tr>
<th>Risk Factors: (Positive)</th>
<th>Defining Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family History</td>
<td>Myocardial infarction, coronary revascularization, or sudden death before 55 years of age in father or other male first-degree relative (i.e., brother or son), or before 65 years of age in mother or other female first-degree relative (i.e., sister or daughter)</td>
</tr>
<tr>
<td>Cigarette Smoking</td>
<td>Current cigarette smoker or those who quit within the previous 6 months.</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Systolic blood pressure of $\geq 140$ mm Hg or diastolic $\geq 90$ mm Hg, confirmed by measurements on at least 2 separate occasions, or on antihypertensive medication.</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>Total serum cholesterol of $&gt;200$ mg/dL (5.2 mmol/L) or high-density lipoprotein cholesterol of $&lt;35$ mg/dL (0.9 mmol/L), or on lipid-lowering medication. If low-density lipoprotein cholesterol is available, use $&gt;130$ mg/dL (3.4 mmol/L) rather than total cholesterol of $&gt;200$ mg/dL.</td>
</tr>
<tr>
<td>Impaired Fasting Glucose</td>
<td>Fasting blood glucose of $\geq 110$ mg/dL (6.1 mmol/L) confirmed by measurements on at least 2 separate occasions</td>
</tr>
<tr>
<td>Obesity</td>
<td>Body Mass Index of $\geq 30$ kg/m$^2$, or waist girth of $&gt;100$ cm.</td>
</tr>
<tr>
<td>Sedentary Lifestyle</td>
<td>Persons not participating in a regular exercise program or meeting the minimal physical activity recommendations from the U.S. Surgeon Generals’ Report.</td>
</tr>
<tr>
<td>Risk Factors: (Negative)</td>
<td></td>
</tr>
<tr>
<td>High Serum</td>
<td>HDL Cholesterol $&gt;60$ mg/dL (1.6 mmol/L)</td>
</tr>
</tbody>
</table>

*Use with Initial ACSM (American College of Sportmedicine) Risk Stratification Table 2.

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<table>
<thead>
<tr>
<th>Table 2. Initial ACSM (American College of Sportmedicine) Risk Stratification.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Risk</strong></td>
</tr>
<tr>
<td><em>(≤ 1 risk factor)</em></td>
</tr>
<tr>
<td><strong>Moderate Risk</strong></td>
</tr>
<tr>
<td><em>(≥ 2 risk factors)</em></td>
</tr>
<tr>
<td><strong>High Risk</strong></td>
</tr>
<tr>
<td><em>(≥ 1 “Major” signs/symptoms)</em></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Table 3. ACSM Recommendations for: (A) Current Medical Examination &amp; Exercise Testing Prior to Participation and (B) Physician Supervision of Exercise Tests.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Risk</strong></td>
</tr>
<tr>
<td>A. Moderate exercise</td>
</tr>
<tr>
<td>Vigorous exercise</td>
</tr>
<tr>
<td>B. Submaximal test</td>
</tr>
<tr>
<td>Maximal test</td>
</tr>
</tbody>
</table>

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*North American Journal of Sports Physical Therapy | Volume 5, Number 1 | February 2010 | Page 8*
porosis, infertility, and thyroid disease; and 5) red flags—history of stress fractures, previous menstrual dysfunction, disordered eating, period frequency, and medication.9,19

**Testing Procedures**

**Musculoskeletal screening**

One of the primary goals of PPEs is to prevent injury or reinjury.1-4,6-8,10,12,13 Given the physical demand and relative high risk of collision sports such as football, it is essential that this PPE include a general orthopedic history and screen. The musculoskeletal portion of this PPE was modeled after those developed by Smith et al10 and Garrick et al.6 Strength and range of motion of all major joints were performed, and any asymmetries or deficiencies were noted. Additional orthopedic special tests were performed to screen for possible shoulder and elbow instability (load and shift, varus/valgus stress test), hip flexor and hamstring flexibility (Thomas and 90/90 test), knee and ankle ligament stability (knee varus/valgus, stress and anterior/posterior drawer tests; ankle anterior drawer and talar tilt tests, respectively), and general lower extremity mobility/function (squat and duck walk). All peripheral testing procedures were performed bilaterally with any significant findings noted and recorded. The previously mentioned joint assessment methods are well known and commonly used in musculoskeletal examinations and screenings.20

**Fitness and functional testing**

Prior to any fitness testing, cardiovascular clearance and subject questionnaires were reviewed, and significant findings were discussed according to the previously stated ACSM criteria.18 The fitness testing consisted of 10 stations addressing general vitals, body composition, speed, agility, upper extremity power, flexibility, aerobic capacity, lower extremity power, muscle endurance, and vertical jump. The functional agility, power, and endurance tests used in this current report are commonly employed in fitness assessments of athletes at many different levels of ability. All subjects progressed in a sequence through the circuit with a licensed physical therapist or physical therapy student supervised by a licensed physical therapist (Figure 1).

**RESULTS**

Thirteen players, ages 23 to 40, were screened on one of two testing days. Of these 13, four players were unable to complete all tests because of an existing injury that prevented safe participation. Average height and weight were 1.64 meters and 66.8 kilograms, respectively, yielding an average BMI of 25, which is considered borderline overweight.18 Body fat was measured using a commercially available bioelectrical impedance device (Tanita TBF-300GS, Tanita Corporation of America, Inc.), which has been reported to have an approximate margin of error of 3%.21,22 Average body fat was 27.4% (“above average” based on current ACSM guidelines).18

**Health History Questionnaire**

None of the participants were excluded from testing based on answers provided on the health history questionnaire (Figure 2). All athletes reported participating in regular (e.g. at least weekly) physical fitness activities in addition to their football training. Two players answered “yes” to questions that warranted further investigation of potential cardiac risk factors (Table 4). Upon further questioning, it was determined these responses were either related to previous musculoskeletal

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**Table 4. Significant past medical history as self-reported via questionnaire.**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Significant Past Medical History</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open Reduction Internal Fixation of right elbow, right wrist stress fracture, 2 concussions</td>
</tr>
<tr>
<td>2</td>
<td>rotator cuff tendonitis, chronic right ankle instability</td>
</tr>
<tr>
<td>3</td>
<td>none reported</td>
</tr>
<tr>
<td>4</td>
<td>rib contusion</td>
</tr>
<tr>
<td>5</td>
<td>family history of sudden death (myocardial infarction) before age 50, irregular menstruation</td>
</tr>
<tr>
<td>6</td>
<td>loose body in left knee</td>
</tr>
<tr>
<td>7</td>
<td>torn ligaments in right wrist</td>
</tr>
<tr>
<td>8</td>
<td>smoker, left knee surgery 1988, lower back pain since 16 years of age, cluster migraines, arm contusion</td>
</tr>
<tr>
<td>9</td>
<td>biceps tendonitis, right medial meniscus tear, heel spur, arthritis, irregular menstruation</td>
</tr>
<tr>
<td>10</td>
<td>smoker, shoulder tendonitis, wears ankle brace, tibial stress fracture 5 years ago</td>
</tr>
<tr>
<td>11</td>
<td>YES to #11, 12, 14, 15; second degree rheumatoid arthritis, osteoarthritis, left ankle sprain</td>
</tr>
<tr>
<td>12</td>
<td>heart murmur age 12, YES to #11, 12, 15, 16; ankle sprain, right ischial bursitis, displaced rib</td>
</tr>
<tr>
<td>13</td>
<td>umbilical hernia, hysterectomy, oophorectomy, torn right soleus</td>
</tr>
</tbody>
</table>
Figure 1. Setup of Testing Stations.

Station One: Intake and General Measures
- Review Health History Questionnaire
- Heart Rate
- Blood Pressure
- Height
- Weight
- Body Mass Index
- Body Fat (Bio-impedence)
- Triceps Skinfold

Station Two: Twenty Yard Dash

Station Three: Agility T-drill

Station Four: Ten Yard Dash

Station Five: Upper Extremity Power
(Medicine Ball Toss)

Station Six: Flexibility
Sit and Reach

Station Seven: Aerobic Capacity
YMCA Three Minute Step Test

Station Eight: Lower Extremity Power
- Triple Hop for distance
- Crossover Hop for distance

Station Nine: Muscle Endurance
- Push-up to fatigue
- Maximum half-sit up completed in one minute

Station Ten: Vertical Jump
- Standing counter-movement jump
- Plyometric/Drop jump (12 inches)
problems (e.g. muscle strain/joint sprain) or asthma for which they were being managed by a physician (e.g. inhaler for asthma).

Musculoskeletal and Functional Performance Testing

The following musculoskeletal injuries were reported by the players on the health history questionnaire at the time of the screening: loose body in knee, patellofemoral pain syndrome, C5-6 radiculopathy, grade II A-C sprain, medial meniscus tear, ankle sprain (two subjects), swan-neck deformity, and torn carpal ligaments (Table 5). Functional performance testing consisted of timed sprints (10 and 20 yards), seated 10-lb medicine ball toss, push-ups and sit-ups, and a series of hop tests (Figure 3). The summary scores (averages) of the agility and functional testing are reported in Table 6.

DISCUSSION

The purpose of this study was to describe a pre-participation physical screening/examination for members of a women’s professional football team. The study was also used to summarize the common injuries reported, identify any potential risk factors for future injury and gain a better understanding of the physical characteristics and performance profile of the female professional football player. Currently, there is very limited information available about the physical and injury characteristics, fitness level, and profile of

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**Table 5. Findings from musculoskeletal screening.**

<table>
<thead>
<tr>
<th>Test Performed</th>
<th># of occurrences</th>
<th>Test Performed</th>
<th># of occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Thomas test</td>
<td>12</td>
<td>↓ lateral flexion (cervical)</td>
<td>2</td>
</tr>
<tr>
<td>+ Anterior drawer (ankle)</td>
<td>6</td>
<td>UE muscular symmetry</td>
<td>1</td>
</tr>
<tr>
<td>+ Talar tilt</td>
<td>8</td>
<td>↓ lateral flexion (lumbar)</td>
<td>4</td>
</tr>
<tr>
<td>↓ rotation (lumbar)</td>
<td>1</td>
<td>Shoulder laxity</td>
<td>5</td>
</tr>
<tr>
<td>↓ wrist extension</td>
<td>3</td>
<td>+ FABER</td>
<td>4</td>
</tr>
<tr>
<td>+ 90-90 test</td>
<td>4</td>
<td>↓ shoulder rotation (IR &amp; ER)</td>
<td>2</td>
</tr>
<tr>
<td>↓ wrist flexion</td>
<td>1</td>
<td>+ Duck walk (full squat)</td>
<td>2</td>
</tr>
<tr>
<td>Capital flexor weakness</td>
<td>1</td>
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a. Positive if the patient’s straight leg does not reach down to the table or if there is increased lordinos  
b. Positive if a suction sign present in the area of the anterior talofibular ligament, pain, muscle spasm, or asymmetries noted  
c. Positive if patient reports pain or there are asymmetries  
d. Positive if the angle between the femur and tibia is < 150 degrees  
e. Positive if the knee of the testing leg remains above the straight leg  
f. Positive if asymmetrical or painful

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**Figure 3. An example of the functional and agility testing component (hop testing).**
female professional football athletes. The Kentucky Karma and other NWFA teams are independently owned and operated, and each team is responsible for its own fundraising, training, and staff. The Kentucky Karma was a new team in a relatively new league at the time this screening was conducted and, like many of the other NWFA teams, had limited financial and personnel resources. The development and administration of the PPE was the first for the team, and it is plausible that information obtained from this report may provide some direction for future PPEs for other female professional football teams. One of the authors (BN), a former NWFA player, was instrumental in recognizing the need for a PPE as she was familiar with and understood the demands of women’s professional football and was able to provide a unique perspective.

The current PPE consisted of a pre-participation health questionnaire, a musculoskeletal screening, body composition/body fat testing, heart rate and blood pressure, and selected physical performance/agility tests. As stated previously, there is currently very little information available or reported on about physical profiles, performance characteristics, or injury patterns of the female athlete involved in professional sports, especially women’s football. The importance of identifying pre-existing problems must be emphasized as prior injuries are often a good predictor of injury or re-injury and it has been documented that over 75% of medical and musculoskeletal conditions can be detected by the history alone.\textsuperscript{2,13,24} Based on NCAA injury surveillance data (1988-2004) for men's college football, the top injuries for men were knee sprains (ligament injury, complete or partial), ankle sprains, thigh muscle strains/contusions, and head injuries (concussion).\textsuperscript{25} The most common Kentucky Karma injuries reported (either by history or during the 2005-06 season) included shoulder sprain/strain (7 occurrences), ankle sprains (13 occurrences), and thigh muscle (hamstring/adductor/quadriceps) strains/contusions (6 occurrences). Other common injured regions reported with less frequency included: hand/wrist, fingers, ribs, and calf muscle strains (gastrocnemius/soleus). Based on the incidence of these specific injuries, recommendations were made to individual players and the coaching staff to implement specific prevention training programs. As examples, these programs included shoulder rotator cuff/scapular strengthening, ankle balance and proprioceptive training, and additional lower extremity strength and flexibility (e.g. hip flexor) exercises.

With increasing numbers of female athletes participating in competitive sports at all levels, there is a need for increasing awareness of sex-specific training, prevention, and health-related concerns (e.g. female triad: osteoporosis, amenorrhea/ dysmenorrhea, and disordered eating; stress fractures; ACL injury prevention). Although none of the players were identified as having any significant findings related to the female triad through self report or review of past medical history, and several athletes had BMIs that were significantly higher than is typically seen in the female triad, this was still considered an important component to include in the PPE.\textsuperscript{19}
While the findings presented here may be useful to sports medicine practitioners working with female professional athletes, there are several limitations to the current report. Inconsistencies while performing multiple examinations on different athletes by different examiners is a typical challenge when conducting large group or team screenings. In an attempt to limit the variability in testing procedures and the interpretation of these results, meetings were held prior to testing to discuss and establish uniform procedures to minimize inconsistency. Additionally, with only 53% of the players participating in the PPE, the results may not be a comprehensive or accurate representation of the team profile. Nearly half the players (48%) were unable to participate in the recommended but not mandatory testing because of other personal commitments (e.g. family, work, etc.). It is possible that variability in results of some of the testing was directly related to individual differences between athletes and their positions. For example, some of the skilled positions require an emphasis on speed and agility (e.g. running backs, receivers, special teams), while others require strength and power (e.g. linemen). However, many of the players, either by choice or necessity because of the team's small roster, played multiple positions (e.g. defense and offense) so any potential performance differences based on player position may be impossible to explain. Sport-specific and position-specific testing of female professional athletes would be an interesting area for future investigation.

Confidentiality of the results obtained from the PPE is often an area of concern when dealing with health information. A few athletes with prior injuries expressed concern about the possibility that poor results or abnormal findings could limit their participation. It was explained to the players and coaches that this process was meant to be preventative and educational in its scope and not punitive or exclusionary. Individual results and normative comparisons (if available) of tests and performance were provided to each player, if and when requested. The results and findings were discussed with recommendations made for specific preventive measures such as bracing, exercise programs, and referrals to appropriate personnel if necessary (e.g. physical therapist, orthopaedic surgeon, or primary care physician). The success of this PPE and the effectiveness of the suggested individual and team injury prevention strategies is as yet unknown. PPEs need to be reviewed annually to audit, evaluate, and modify the process as deemed necessary and appropriate by the stakeholders (e.g. coaches, team physicians, physical therapists, athletic trainers, and even player representatives/team captains). Ideally, post-season testing of athletes should also be an area of future development to direct off-season training and conditioning programs.

Given the limitations, the authors believe this report offers useful information about potential risk factors for injury or team and individual training deficits. Additionally, and perhaps one of the most important components of the PPE is that this process allows players, coaches, and rehabilitation and medical staff to establish performance baselines from which to make sound and clinically evidence-based decisions about prevention strategies and/or when an athlete might safely return to competition following injury.

CONCLUSION

There is a need for an improved understanding about the PPE and physical performance of female athletes involved in professional sports, including women's professional football. The existing research and literature on the PPE with the female athlete has been based primarily on information from the collegiate or high school player. Future investigations are needed to establish more sport specific and, perhaps even more importantly, position-specific assessments and screenings related to women's professional football. Attention and research is needed in order to educate clinicians, players, coaches, and health care professionals about the unique characteristics of the female profession-
al athlete, including nutritional needs, injury prevention, training, and conditioning strategies.

REFERENCES
ABSTRACT

Observed gait abnormalities are often related to a variety of foot deformities such as the cavus foot, also known as pes cavus, cavovarus, uncompensated varus, and the high arched foot. When gait abnormalities related to cavus foot deformities produce symptoms or contribute to dysfunctional movement of the lower extremity, foot orthotics are commonly used to accommodate the deformity and optimize the function of the lower extremity. In more severe cases, surgical intervention is common. Hypomobility of the many joints of the foot and ankle may be mistaken as an idiopathic cavus foot deformity. As for any other limb segment suspected of musculoskeletal dysfunction, it is suggested that joint mobility testing and mobilization, if indicated, be attempted on the foot and ankle joints before assuming the presence of a bony cavus deformity. The purpose of this clinical suggestion is to describe the use of osteopathic manipulations of the foot and ankle in the context of an illustrative case of bilateral idiopathic cavus feet to demonstrate that apparent foot deformities may actually be joint hypomobility dysfunctions.

Keywords: manipulation, cavus foot, midfoot

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The Institutional Review Board of Columbia University Medical Center, New York, NY reviewed this single case report and found it not to be research on human subjects and thus did not require approval.
PROBLEM

Foot deformities are often associated with gait abnormalities that may contribute to dysfunction or pathology. One such deformity, the high arched or idiopathic cavus foot, has been associated with peroneal tendinopathy,1 lateral ankle sprains and instability,2,3 ankle arthritis,4 metatarsalgia or fracture,5 and up the kinetic chain to the knee,6 hip,7 and back.8 Characterized by a high medial longitudinal arch, plantarflexed first ray, claw toes, and callous over the 5th metatarsal base, the cavus foot is considered a varus foot deformity involving both the rear- and forefoot.5,9,10 The cavus foot ranges in severity from clubfoot to mild variants referred to as pes cavus or subtle cavus foot, and can be fixed or flexible.5,9 The fixed or flexible nature of the deformity is determined by whether the rearfoot joints are grossly mobile enough to compensate for the varus deformities to place the foot in a plantigrade position.10,11,12 Fixed varus deformities, isolated or both rear- and forefoot combined, are also referred to as uncompensated, while the flexible type are referred to as compensated.

Cavus foot deformities may lead to gait abnormalities that generate local or more proximal leg symptoms and dysfunction, and may require treatment.13,14 Limited evidence supports the use of orthotics in cases of idiopathic cavus feet.13,15,16 For many cases of idiopathic cavus foot, non-operative care including stretching, shoe modification, and foot orthotics have been recommended, but often been found to be inadequate.5,9 When non-operative care is not successful, a variety of surgical procedures can correct the bony cavus deformity.3,4,5,9,17

An idiopathic cavus foot may exist due to hypomobility of any combination of the many joints in the foot and ankle. Joint manipulation to the hypomobile foot or ankle joints, followed by soft tissue surgery and serial casting as described by Ponseti and Smoley,18 has become common in pediatric cases of idiopathic clubfoot. Compared to manipulation and surgical arthrodesis, the Ponseti and Smoley18 approach has resulted in greater parental satisfaction and ankle range-of-motion (ROM) outcomes.19 No known reports of joint manipulation changing the architecture of the idiopathic uncompensated varus foot in adults exist. This paper illustrates several osteopathic manipulations addressing specific joint hypomobility in the adult idiopathic cavus foot to demonstrate the importance of mobilizing specific hypomobile joints before determining that a fixed foot deformity exists and requires other treatment.

SOLUTION

Some cases of idiopathic cavus foot may be amenable to osteopathic manipulation, a term used here to refer to direct joint mobilization (grade I-V), mobilizations with movement and indirect mobilization via Strain Counterstrain. When specific joint mobility assessments of the foot and ankle joints indicate hypomobility, it is suggested that osteopathic manipulation be attempted. Clinically, the selection of appropriate techniques will depend on assessment of the individual. In this case, 5 techniques were applied: 1) high velocity low amplitude thrust (HVLAT) talocrural joint separation, 2) Strain Counterstrain (SCS) for the lateral calcaneus (LCA), 3) HVLAT of the navicular, 4) mobilizations with movement (MWM) of the cuboid, and 5) MWM of the first metatarsal phalangeal (MTP) joint.

Limited evidence exists to support some of these techniques, while other techniques have not been reported in the literature. Talocrural joint separation with HVLAT has been described20 and used to increase ankle dorsiflexion in cases of equinus8, diabetes21, plantar fasciitis22, and ankle sprains (Figure 1).24-27 Jones28 introduced SCS and described the application SCS for the lateral calcaneus, though not specifically for increasing rearfoot eversion as in this case (Figure 2). A HVLAT applied to the dorsal navicular for increased midfoot pronation has not been

Figure 1. Talocrural joint separation high velocity low amplitude thrust (HVLAT) With patient in supine, operator gently positions the ankle in slight dorsiflexion and grasps dorsal foot with both hands: thumbs on plantar aspect and 5th fingers over anterior talus. The operator applies an axial distraction force with HVLAT. Tibia can be stabilized to protect proximal joints.
reported in the literature (Figure 3). Mobilizations with movement (MWM) were introduced by Mulligan, and ankle MWM have been reported to increase ankle dorsiflexion. Open chain manipulation of the cuboid with the ankle plantarflexed for ankle sprains has been reported, but closed chain MWM of the cuboid to increase pronation with midfoot plantarflexion has not been described (Figure 4). MWM of the MTP joint to increase dorsiflexion after heel-off during gait (Figure 5) has also not been reported in the literature.

USE IN PHYSICAL THERAPY
The subject is a 27-year-old woman who presented with bilateral idiopathic cavus feet. Both feet appeared to have uncompensated rear- and forefoot varus deformities such that her first rays were atypically not plantarflexed and she bore no weight on the medial side of her foot in standing and walking. The subject’s mother, who reportedly has similar but less severe cavus feet, reported that the subject’s feet had always appeared the same since beginning to walk at eight months old. The subject’s parents sought medical intervention at two years of age to address her bow-legged and hyper-lordotic posture. The physician assured them, however, that any deformity would correct as she developed without treatment or orthoses. Although the subject always walked on the lateral border of both feet, she had no other medical issues other than an ankle sprain from a car accident when nine years old. She never limited her activities and as an adult has exercised four to five times per week. Over the past five years, however, the subject reported insidious low back pain and bilateral
hip pain ranging in intensity from three to seven on a scale with ten being the worst pain. She also reported bilateral clicking heel pain and overall discomfort in both feet. Pain on her left side had progressed in the past year leading her to consult a physical therapist.

At the time of consultation, the subject stood on the lateral borders of both feet with uncompensated cavus feet apparent. Her bilateral hip, knee, and ankle ROM were grossly normal except ankle dorsiflexion at approximately 10 degrees, rearfoot eversion less than neutral, and first MTP dorsiflexion at approximately 45 degrees. Mobility testing of the talocrural, subtalar, midtarsal, and first MTP joints revealed bilateral hypomobility throughout. Her gait was marked by a loud impact upon heel-strikes with lateral weight bearing throughout the stance phase. Pronation of the subtalar and midtarsal joints were insufficient for her feet to achieve medial plantigrade.

It was agreed upon to attempt to reduce the cavus foot architecture with osteopathic manipulation, starting with her right foot. Mortise separation with HVLAT increased ankle dorsiflexion by approximately 5 degrees. Strain counterstrain for LCA resulted in rearfoot eversion past neutral, but did not alter the cavus shape of her foot. The HVLAT to the navicular resulted in dramatic lowering of her medial foot to plantigrade in standing, though she exhibited minimal first toe weight bearing during the terminal stance phase of gait. Closed chain MWM of the cuboid was used to increase midtarsal joint pronation and enhance medial weight bearing in both standing and gait.

Closed chain MWM of the first MTP joint to increase dorsiflexion in terminal stance was applied once medial weight bearing was achieved. The net result was normalized standing posture and gait (Figures 6 & 7).

After the first consultation, a home exercise program was provided including ankle and hip stretching, active closed chain ankle and toe dorsiflexion, and unilateral bridging for hip strength. Between the first and second consultation, the subject experienced general leg soreness, period ic lateral ankle and medial knee pain after walking several blocks, increased pressure around the lateral malleolus, numbness and tingling at the distal lateral lower leg, and disruption of her balance experienced as a veering limp to the left and occasional trip on sidewalk cracks. The manipulation sequence was repeated on her left foot at the second consultation, three weeks later, when her feet did not exhibit signs of cavus deformity (Figure 8), except for lateral claw toes due to residual soft tissue contracture (Figure 9). Her back, hip, knee, and heel pain were completely relieved. Her gait was normalized, and she reported quieter, more comfortable bilateral heel strike two weeks after the second consultation. However, occasional loss of balance to her left occurred when walking fast. Residual numbness and tingling extended from the anterior ankle proximally to the lower leg. In short, the apparent uncompensated cavus foot deformities were actually multi-joint hypomobility-related dysfunctions.
DISCUSSION

The foot and ankle complex includes many joints, all of which can become hypomobile independently or as a group. This case of idiopathic cavus foot corrected with osteopathic manipulation is presented to provoke the consideration of whether observed foot abnormalities are bony deformities or dysfunctional joint hypomobility. As in this case, some idiopathic cavus foot abnormalities may be corrected with osteopathic manipulation. The patient/client should be advised to prepare for potential post-treatment lower extremity discomfort as the region adapts to the new available joint motions. In cases of bilateral abnormalities, treatment of both feet on the same day can minimize asymmetry-related discomfort, although in this case scheduling precluded this approach. Before assuming the presence of immutable bony deformity that may require orthoses or surgery, clinicians are suggested to assess the specific joint mobility of all foot and ankle joints and mobilize if hypomobility is indicated.

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ABSTRACT

Background and Purpose. Limited research suggests that an effect of whole body vibration (WBV) on the central nervous system (CNS) is suppression. An indirect measure used to assess CNS level of activation is the Soleus H-reflex. If true suppression does occur, other factors such as range of motion may be impacted. The purpose of this study was to examine the impact of WBV on H-reflex amplitude and passive ankle dorsiflexion.

Subjects and Methods. Twenty-seven healthy volunteers between the ages of 21-41 participated. Subjects were randomly assigned to a control group (n=13) or WBV group (n=14). H-reflex and ankle dorsiflexion measures were assessed before and after a three minute WBV perturbation (40 µHz, amplitude 2-4 mm). These measurements were repeated every five minutes up to twenty minutes following the intervention.

Results. The H-reflex amplitude showed a significant decrease (p<.05) between pre-test and initial post-test for both groups. The H-reflex returned to baseline within five minutes following the intervention. The dorsiflexion range of motion showed significant interaction (p<.05). All changes were less than 5 degrees; therefore, no clear clinical impact was evident.

Results. The observed decrease in H-reflex amplitude immediately following WBV agreed with previous research indicating a lower level of CNS activation. However, since the control group also showed this change, WBV does not appear to be a key cause of suppression. Range of motion was not clinically significant for either group.

Key Words. Whole body vibration, H-reflex, Soleus muscle

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INTRODUCTION
Enhancing athletic performance, at both the elite and recreational levels, requires the coordinated efforts of athletes, coaches, scientists, health care professionals, and exercise specialists. One of the primary trends in the sports industry today is analyzing the anatomical and physiological needs of athletes in their respective sports in order to locate possible methods or tools for sports performance improvement. Similarly, in a time where athletes are under great scrutiny, it is imperative to identify means to augment sport-specific skills without the use of ergogenic aids. One such aid that has recently been in the forefront of research is whole body vibration (WBV). Research regarding tools to enhance athletic performance is pertinent and crucial for not only for assessing athletes' current physical capacities or locating deficits in performance, but also decisions whether to apply interventions in order to improve the athletes' performance. Ultimately, athletes seek interventions that provide the most effective and efficient improvements that are achieved safely and noninvasively.

WBV is a neuromuscular training method that has sparked new research interest as an intervention useful for many populations in the field of physical therapy. In this form of training, the entire body is exposed to oscillating motions through the use of a vibrating platform upon which exercises can be performed.1 WBV has the potential to create short term gains in both flexibility and power that most athletes desire as described in a meta-analysis by Cardinale and Bosco as well as by Armstrong et al.2-3 Research on the effects of WBV has been predominantly focused on muscle power and strength, body composition, electromyography, and balance and functional mobility in all age distributions.4 Results of current research indicate that WBV acts as a positive feedback mechanism serving to increase the contractile force of the muscle. Delecluse et al determined that a 12-week WBV protocol produced significant strength gains in the knee extensors in addition to increases in power.5 Results from a study by Bosco et al demonstrated that an increase in neural activity during vibration played an important role in muscle performance, specifically power gains after WBV on an explosive power training regimen.6 An understanding of how WBV may affect performance is important in order to optimally apply this technique in clinical and athletic practices. To date, however, there is little research focusing on the effects of vibration on a single muscle group from a single exposure. Results of studies support that there is an increase in range of motion following exposure to WBV, but do not describe a hypothesis to explain how this occurs.7 The decrease in motor neuron pool excitability at the level of the spinal cord after using WBV is one possible hypothesis.8 A decrease in motor neuron pool excitability provides concurrent suppression of the central nervous system, which may allow for short-term gains in ROM.

Subsequently, there is an explicit demand for a method by which to objectify the effects of WBV. The Hoffman Reflex (H-reflex) is an important electrophysiological measure that enables better understanding of muscular activation patterns through assessment of spinal reflexes of key muscles. Specifically, it is a monosynaptic reflex that is elicited by stimulating a nerve and is analogous to a spinal stretch reflex. The H-reflex allows researchers to compare muscle activity of individuals using latency and amplitude measurements of the electrical activity associated with a muscle contraction. In adults, the "H-reflex is an estimate of alpha motor neuron excitability when presynaptic inhibition and intrinsic excitability of the alpha motor neurons remain constant. This measurement can be used to assess the response of the nervous system to various neurologic conditions, musculoskeletal injuries, application of therapeutic modalities, pain, exercise training and performance of motor tasks (p 268)."7 Armstrong et al used the H-reflex as a measure of motor neuron excitability in the soleus muscle.8 "It is a measure of the efficacy of synaptic transmission as the stimulus travels in the afferent (1a sensory) fibers through the motor-neuron pool of the corresponding muscle to the efferent (motor) fibers (p 268)."7 To elicit the H-reflex in the soleus muscle, an electrical pulse is applied to the tibial nerve in the popliteal fossa. If the motor neuron excitability is decreased and the muscle remains relaxed, it is reasonable to assume that range of motion (ROM), both passive and active, could increase due to less resistance to stretch. Specifically, the inhibition of the tibial nerve excitability may allow an increase in the passive movement of dorsiflexion, which may influence motor control relative to gait patterns, functional activities and athletic performance.

Two proposed mechanisms exist that attempt to describe how WBV may cause muscle adaptation. Researchers have theorized that one such mechanism is a tonic vibration reflex, which may be the physiological response that is mediated by muscle through the utilization of interven-
tions that use vibration. In addition, the tonic vibration reflex may cause repeated elongation of activated muscles which in turn elicits Ia afferent activity, leading to reflexive muscle contractions. Another suggested mechanism describes how an increased load applied to muscles during vibration facilitates a neuromuscular response. During the sinusoidal displacements provided by the WBV platform high accelerations, up to 15 g delivered at the equivalent of 147 m/s² are generated. Ultimately, WBV seems to have a direct impact on both elicitation and consequent suppression of H-reflex activity, making the H-reflex a sound, objective method for exploration of the physiological effects of WBV.

While manual stretching is a typical method used to promote functional gains in muscle and tendon length, it requires consistent active effort from the individual or an outside source (i.e., a physical therapist). As noted in the stress-strain curve (Figure 1) there is a necessary and crucial threshold that must be attained and maintained in order to achieve permanent deformation and gains in extensibility of the musculotendinous unit.

In order to achieve success in athletic performance, individuals may stretch muscle groups regularly, but perhaps there is a means by which functional gains in ranges of motion can be promoted and maintained by other interventions. Suppression of antagonistic muscle activity that would otherwise be inhibiting passive range of motion could be such an intervention. “The stretch reflex is a pathway with one central nervous synapse, relaying information about length changes to the alpha motoneuron. Within this pathway the Ia-afferent nerve fibers have a predominant effect on large motor units containing predominantly fast twitch muscle fibers. After demanding exercise the reflex amplitude is typically decreased (p 82).” It would seem that a stretch reflex, such as the H-reflex, may be inhibited by exercise, and therefore the effects of WBV would potentially suffice to fatigue muscle in the same fashion that other types of exercise otherwise would. Rittweger et al found in 2003, “…vibration frequency below 20Hz induces muscular relaxation whereas there are reports that at frequencies above 50 Hz severe muscle soreness and even hematoma may emerge in untrained subjects (p 82).” Additionally, mechanical vibration, administered to tendons or muscles, at frequencies between 10-200 Hz can cause a reflex response or contraction of the muscle belly.

Armstrong et al suggested that whole body vibration may suppress the central nervous system which is observed as a decreased or inhibited H-reflex. The WBV induced inhibition of the monosynaptic reflex pathway of the plantarflexors may provide an increase in range of motion into dorsiflexion at the ankle joint. Armstrong et al studied the effects of WBV on 19 subjects implementing a one minute whole body vibration period followed by measurements of the H-reflex every 30 seconds up to 30 minutes following the intervention. All subjects “displayed a significant suppression of the H-reflex during the first minute post-WBV.” Jacobs and Burns demonstrated a significant increase in range of motion of knee extension between subjects who had utilized the WBV compared to those who had used a cycle ergometer. Therefore, it is possible that CNS suppression as reflected by H-reflex amplitude measured after WBV interventions coincides with concurrent gains in ROM. The purpose of this study was to examine the impact of WBV on H-reflex amplitude and passive ankle dorsiflexion range of motion.

Methodology

Approval was granted from Belmont University’s Institutional Review Board for the study. Flyers were posted to attract a sample of convenience from the Belmont University School of Physical Therapy. To be included in the study a participant had to be a healthy individual over the age of twenty-one without any of the following: having participated in strenuous activity in the past four hours, recent (in the past 5 years) lower extremity or spinal surgery, presence of leg, ankle, or foot pathology, pregnancy, or any other disorders that could potentially affect sensation or musculoskeletal performance. Prior to data collection, the purpose and procedures of the study were explained to the subjects, and each subject signed an informed consent form. Each subject then completed a medical history form, followed by a nonin-
vasive lower quarter screen of leg strength, range of motion, and sensation to ensure each subject's eligibility to participate in the study. If the subject met the study eligibility criteria, the dominant leg of the subject was determined by kicking a gym ball. They were then randomly assigned to one of two groups, whole body vibration plate intervention or control.

Each participant was positioned prone over a pillow with the knee of the dominant leg slightly flexed over a pillow. The back of the knee and lower leg was cleaned with alcohol swabs. The tibial nerve was marked in the popliteal fossa indicating where the stimulating electrode was to be placed. A measurement was taken on the medial aspect of the leg from the marker in the popliteal fossa to the medial malleolus. This distance was divided in half, and a marker was placed at this location. The recording electrode was placed at this halfway marker with the reference electrode placed 2 cm distally. The ground electrode was placed on the lateral aspect of the calf. Two alligator clips were used to connect the two adhesive electrodes to the EMG unit. A gel medium was placed on the tip of the stimulating and dispersive electrodes. The stimulating bar electrode was placed on the marked location in the popliteal fossa with the dispersive electrode distal and the reference electrode proximal. The bar electrode was taped to the skin, the wrapped with a Nylatex band to create a constant pressure and prevent movement of the electrode (Figure 2). Normalization procedures as well as subject positioning is “crucial during H-Reflex testing because factors such as eye closure, head position, joint position and angle, and muscles length affect the H-reflex amplitude. (p 271)” Therefore, participants wore acoustic noise cancelling headphones to decrease perceived noise in the room that may otherwise stimulate or excite them, possibly affecting the elicited H-reflex amplitude and not allowing measurement of a true baseline H-reflex. To attain the pre-exercise values, all participants had his/her tibial H-reflex amplitudes measured using the Cadwell® Wave® EMG unit. The amplitude was increased to stimulate a supramaximal M wave. This created a baseline measurement for the participant. Once a supramaximal M wave was recorded, the amplitude was decreased to 30 percent of the amplitude used to obtain the appropriate H reflex wave. The H reflex was elicited at this amplitude 5 times consecutively, and recorded to be averaged for later data entry.

The participant remained prone with the knee slightly flexed for measurement of passive dorsiflexion of the ankle. The foot on the dominant leg was off the edge of the plinth while 30 pounds of force was applied at the metatarsal heads through the Lafayette Instrument® Manual Muscle Test System digital hand dynamometer to

![Figure 2. H-Reflex electrode placement.](image2)
![Figure 3. Testing position for ankle range of motion with standardized force application.](image3)
![Figure 4. Standardized placement on the WBV device.](image4)
determine a consistent, standardized force. A Baseline® Digital Absolute Axis® Goniometer was used to measure ankle dorsiflexion simultaneously (Figure 3).

After the data was collected, the alligator clips were removed from the electrodes on the calf, allowing the participant to walk to the vibration platform. The participants of both groups stood on the Pneumex Vibration Plate® for the three minute intervention, in the standardized position of feet shoulder-width apart and knees slightly flexed, with the vibration plate turned on (intervention) or off (control). (Figure 4) The vibration plate was set to 40 µHz with amplitude of 2-4 mm as seen previously in the Armstrong et al research.3 All participants returned to the prone position on the table immediately following the WBV intervention or sham intervention in order to collect post-intervention H-reflex and dorsiflexion PROM measures using the same methods as pre-intervention data collection. H-reflex and dorsiflexion PROM measures were subsequently collected at 5, 10, 15, and 20 minutes post intervention.

**Results**

The research study had thirteen control subjects and fourteen whole body vibration subjects. The average age of the control group was 23.92 years, and the average age of the WBV group was 25.93 years. The percentage of females in the control and WBV groups, respectively, were 76.92% and 64.29%. All subjects were right leg dominant except for one control group subject.

Data were analyzed using two mixed 2-way ANOVAs, utilizing SPSS version 16.0. A pre-determined alpha level of p<0.05 was utilized to determine if statistically significant differences existed between groups or conditions. One analysis compared the H-reflex amplitude over time of the between the control group and the vibration group. (Figure 5) There was no significant interaction between H-reflex amplitude and group (p=0.876). There was a significant difference in H-reflex amplitude over time (p=0.001) for all subjects.

A post hoc analysis using a paired t-test with a Bonferroni correction was necessary (p<0.0033). The post-test amplitude was significantly different (p<0.0033) when compared to pretest and 5, 10, 15 and 20 minute intervals. After the decreased post-test amplitudes were collected, a trend became evident across all times with a return to similar pre-test values. (Figure 6)
No significant differences in range of motion existed across the repeated trials (p = 0.934) for all subjects. Additionally, no significant interaction (p = 0.077) between dorsiflexion range of motion and group was demonstrated. (Figure 7)

Discussion
This investigation has several key findings that need to be discussed. First, the post-test H-reflex values significantly decreased from pre-test values, in both groups. This finding suggests that WBV is not the primary reason for the decrease in H-reflex amplitude. The researchers theorize that there was something inherent to the protocol that created this suppression in the immediate post-test time. Plausible factors for the change in H-reflex include anything that occurred during the time that the participant stood up from the table to the time that he/she took to return to the prone position. These factors include the transitions between prone and standing, ambulation to and from the vibration platform, removal of headphones upon standing, or prolonged static positioning used during the intervention or sham intervention. Despite the fact that the H-reflex amplitude of both groups decreased in the posttest time, the results of the WBV group were consistent with similar studies such as Armstrong et al who demonstrated “all subjects displayed a significant suppression of the H-reflex during the first minute post-WBV.” Notably, this study employed a sample size and achieved power values consistent with previous studies of the same nature. Unique to the current study was the inclusion of a control group which provides additional information to the previous studies that did not have a control group. Therefore, it is not that the WBV group results are different from results of similar studies but the implications of the results vary due to the inclusion of a control group, which was previously unused.

Another point of interest is that H-reflex amplitudes are highly variable within the general population. H-reflex amplitudes have been documented to vary due to variations in skin resistance, different amounts of subcutaneous fat and locations of the nerve relative to the stimulus (p 271). Even with a wide range of variability of H-reflex amplitudes among subjects, the results of the current study are unable to demonstrate that WBV as an intervention is a significant source of CNS suppression and increase in ankle ROM. Other researchers such as Sands et al and Jacobs and Burns, have found range of motion gains in the hamstrings and low-back/hamstrings using WBV respectively. However these researchers used elite athletes who also performed ballistic stretching on the vibration plate. They also employed different vibration techniques to the muscle bellies. Sands et al “did not use the general WBV platform axial loading strategy; instead, they use an experimental apparatus to apply an oscillatory stimulus oblique to muscle fibers elongated without the mechanical loading associated with upright stance, thus without the respective level of muscle tension” (p 55). Therefore, it is inappropriate to directly compare the results of the current study to their findings as protocols and subjects were drastically different.

In order to look at the relevance of the findings of the current study, limitations need to be addressed. Notably, an initial dorsiflexion range to qualify or exclude the participants was not specified. Since most participants had PROM dorsiflexion values near 20 degrees, which is considered normal according to the AAOS and AMA, it is possible that there was limited room for improvement of ROM or a ceiling effect for range of motion. An anatomical bony block should have occurred between the talus and the distal tibia and fibula, which would have prevented additional gains in ROM. The ankle joint and its surrounding musculature may not be optimal to examine the effects of WBV on ROM because of its anatomical design. Research examining WBV effects on a joint or muscular region may be better studied in a joint or muscle with a greater ROM or with a different anatomical design (i.e. the knee and the hamstrings).

Conclusion
Since a decrease in H-reflex occurred in both the control and WBV groups, new hypotheses need to be generated to determine the cause of this change. Additional studies should use participants with limited dorsiflexion ROM in order to provide a greater window for possible range of motion improvement. In examining a population with limited range in dorsiflexion, the researchers should investigate trends in response to whole body vibration interventions as based on two factors: 1) the pathology or cause of the dorsiflexion limitation (e.g., do participants with limited dorsiflexion secondary to tight heel cords respond better to WBV interventions than do participants with limited dorsiflexion secondary to Cerebral Palsy), and 2) how long the source of limited dorsiflexion, be it pathology or other impairment, has been present in the participants. Although the WBV parameters used in the current study were gleaned from similar previous studies, no
consistent parameters for this intervention were present in those previous investigations. A standard WBV protocol for intervention would allow for more consistency in studies regarding the efficacy and mechanism of action of this intervention. In conclusion, the current study does not support the hypothesis that WBV creates a suppression of the CNS, as measured by H reflex. Ankle PROM was not significantly affected by WBV. Further investigation is needed to identify the cause of the decreased H-reflex that occurred post WBV in both groups. Finally, additional research is needed to standardize a WBV intervention protocol.

REFERENCES


