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The Relationship between Sun Exposure, Dietary Vitamin D and Muscle Soreness in Collegiate Football Players

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ACCEPTANCE

This thesis, The Relationship between Sun Exposure, Dietary Vitamin D and Muscle Soreness in Collegiate Football Players, by Emily Goodman was prepared under the direction of the Master's Thesis Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Master of Science in the Byrdine F. Lewis School of Nursing and Health Professions, Georgia State University. The Master's Thesis Advisory Committee, as representatives of the faculty, certify that this thesis has met all standards of excellence and scholarship as determined by the faculty.

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ABSTRACT

The Relationship between Sun Exposure, Dietary Vitamin D and Muscle Soreness in Collegiate Football Players

Emily Michelle Goodman

Background: A growing body of research is raising concern regarding the prevalence of poor vitamin D status among athletes. Besides it's well known association with low bone mineral density, an addition sign of vitamin D deficiency is muscular weakness and soreness, suggesting that deficiency in athletic populations may inhibit optimal physical performance and increase the risk of injury. It is difficult to achieve optimal vitamin D status through diet alone, so it is important to assess all sources of vitamin D, including dietary intake, supplementation, and amount and frequency of sun exposure to obtain a comprehensive profile of vitamin D risk. Currently, there are no studies that include such a complete profile of vitamin D risk in collegiate football players.

Purpose: The purpose of this study is to investigate the associations between sun exposure and diet, as markers of vitamin D status, and training-induced muscle soreness in collegiate football players. More specifically, this study assesses if total sun exposure and dietary vitamin D intake are related to muscle soreness.

Methods: Twenty-four male collegiate football players were recruited for this cross-sectional study in October 2015. Player body composition was measured using a multi-current bioelectrical impedance analyzer (BIA). Dietary intake, sun exposure, and muscle soreness data were collected via interview. The Sun Exposure Questionnaire and the Short Form McGill Pain Questionnaire (SF-MPQ) were used to assess weekly sun exposure and muscle soreness, respectively.

Results: The mean vitamin D intake (10.8±9.5 mcg) was below the RDA for vitamin D (15 mcg), with only 7 participants (29.2%) meeting or exceeding the RDA. Dietary vitamin D intake was inversely associated with portion of muscle sore ($r_s = -0.393$, $p = 0.029$). SF-MPQ total and affective scores were each inversely associated with weekly time outdoors ($r_s = -0.362$, $p = 0.041$; $r_s = -0.449$, $p = 0.014$, respectively). T-test analysis found that the mean SF-MPQ affective pain score was significantly lower for players with a time outdoors score above the mean ($p = 0.04$).

Conclusion: There is a high prevalence of insufficient dietary vitamin D intake (70.8%) identified in a collegiate football team. Our findings suggest that higher dietary vitamin D intake and more time spent outdoors are associated with a lower proportion of muscular soreness and decreased perceived pain. Thus, achieving a satisfactory vitamin D status, through a combination of diet and sun exposure, may reduce vitamin D deficiency associated risks, including lowering muscle soreness, thereby serving to enhance athletic performance.

The Relationship between Sun Exposure, Dietary Vitamin D and Muscle Soreness in Collegiate Football Players.

By:

Emily Goodman
A Thesis

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ABBREVIATIONS

25OHD – 25 Hydroxyvitamin D

$1,25OH_2D$ – Calcitriol

BIA – Bioelectrical Impedance Analyzer

IFN-ϒ – Interferon-gamma

IL-1β – Interleukin-1 beta

IL-6 – Interleukin-6

NCAA – National Collegiate Athletic Association

NSAIDS – Nonsteroidal Anti Inflammatory Drug

PPI – Present Pain Intensity

PTH – Parathyroid Hormone

RDA – Recommended Dietary Allowance

SES – Sun Exposure Score

SF-MPQ – Short Form McGill Pain Questionnaire

TNF-α – Tumor necrosis factor-alpha

UVB – Ultraviolet B

VDR – Vitamin D Receptor

Chapter I

Introduction

Research has shown adequate vitamin D is essential for a healthy body. The importance and versatility of vitamin D has called attention to the alarming prevalence of vitamin D deficiency, which affects about 1 billion people worldwide. A 2011 report found 42% of the general US population was vitamin D deficient (Forrest & Stuhldreher, 2011). Similar findings are evident in athletic populations; a recent meta-analysis of 2,313 athletes found 56% had inadequate serum vitamin D levels. (Farrokhyar et al., 2015).

As more evidence supporting the role of vitamin D in many essential biological processes emerges, a growing body of research is raising concern regarding the prevalence of poor vitamin D status among athletes. Vitamin D has biological functions beyond its role in bone metabolism, including supporting immune function, protein synthesis, muscle function and regulating the inflammatory response and cellular growth (Cannell et al., 2009; Todd et al., 2015). Additionally, a symptom of vitamin D deficiency is muscular weakness, suggesting that deficiency in athletic populations may inhibit optimal physical performance and increase the risk of injury (Cannell et al., 2009; Maroon et al., 2015; Scott et al., 2015). Poor vitamin D status has a wide range of adverse health effects that are important for athletes to consider, including low bone density, depressed immune system function, and poor skeletal muscle recovery from exercise (Todd et al., 2015).

Past studies have identified indoor athletes, including gymnasts, swimmers, basketball and hockey players, as being in particularly high risk for vitamin D deficiency because of inadequate exposure to sunlight, which is a primary source of vitamin D (Cannell et al., 2009; Gunton et al., 2015). However, several recent studies have reported poor vitamin D status in athletic populations, regardless of indoor or outdoor training environments (Bescós García et al., 2011; He et al., 2013; Maroon et al., 2015). These researchers have examined serum vitamin D levels in athletes involved in different sports, including basketball, soccer, hockey, swimming, running, and also ballet dancing. Many of the assessed athletes participated at a college or professional level. (Bescós García et al., 2011; Fitzgerald et al., 2015; Koundourakis et al., 2014; Morton et al., 2012; Villacis et al., 2014; Willis et al., 2012; Wyon et al., 2014).

One study reported on vitamin D levels in American professional football players, a high-impact, contact sport (Maroon et al., 2015). The study found a high prevalence of poor vitamin D status in these players, which is consistent with findings in other athletes (Maroon et al., 2015; Todd et al., 2015; Villacis et al., 2014). Collegiate football players are likely to be at a similar risk of vitamin D inadequacy, perhaps the result of the amount of protective equipment and clothing required as a part of the uniform, which can inhibit ultraviolet skin exposure and vitamin D synthesis. Additionally, the contact nature of American football increases risk for injury regardless of vitamin D status (Maroon et al., 2015). The Maroon et al. (2015) study also found an association between vitamin D levels and performance indicators; players with poor vitamin D statuses were more likely to become injured and, therefore, less likely to make the team and secure a professional contract.

Intense and frequent training can elicit an inflammatory response through the production of pro-inflammatory cytokines, which initiate a process that promotes muscle repair. However, excessive production of these cytokines can have an inhibitory effect on the repair process and has been associated with excess muscle soreness, decreased muscular strength, and prolonged recovery time (Barker et al., 2013; Barker et al., 2014). There is typically a natural balance between the production of anti- and pro-inflammatory cytokines that usually prevents excess muscle soreness. Research has shown, however, that poor vitamin D status up-regulates pro-inflammatory cytokine activity and prolongs recovery time after injury (Barker et al., 2013; Willis et al., 2012).

Muscle soreness and weakness is common in athletic populations, but ignoring symptoms could cause a predisposition to a severe injury (Barker et al., 2015). Both muscle soreness and injury have negative effects on athletic performance due to the pain associated with a decreased range of motion and muscular strength (Lewis et al., 2012). Adequate vitamin D may contribute to immune processes by preserving the balance of pro- and anti-inflammatory cytokines. This balance may indirectly influence athletic performance by protecting athletes from excessive muscle soreness and decreasing the risk or severity of muscular injury. However, there is a lack of research specifically connecting poor vitamin D status with increased risk for excessive muscle soreness in American collegiate football players. The primary objective of this study is to investigate the associations between sun exposure and diet, as markers of vitamin D risk, and training-induced muscle soreness in collegiate football athletes.

Purpose

The purpose of this study was to investigate the association between exposure to sunlight, vitamin D in the diet, and training-induced muscle soreness. More specifically, this study assessed if total sun exposure and dietary vitamin D intake were associated with muscle soreness. Based on previous studies, it is a primary hypothesis of this study that higher total vitamin D from the combination of greater total weekly sun exposure and dietary intake is correlated with decreased muscle soreness.

Hypotheses

1. The weekly sun exposure score is inversely associated with muscle soreness.

   [1-0] The weekly sun exposure is not inversely associated with muscle soreness.

   a. The weekly time outdoors score is inversely associated with muscle soreness.

      [1a-0] The weekly time outdoors score is not inversely associated with muscle soreness.

   b. The weekly skin exposure score is inversely associated with muscle soreness.

[1b-0] The weekly skin exposure score is not inversely associated with muscle soreness.

2. Dietary intake of vitamin D is inversely associated with muscle soreness.

    [2-0] Dietary intake of vitamin D is not inversely associated with muscle soreness.

Chapter II

Review of Literature

Introduction

Vitamin D is critically important to health and may specifically impact athletic performance. Several studies have demonstrated the effect of vitamin D on exercise-induced inflammation, bone health and skeletal muscle performance. However, the literature which includes the sources of vitamin D in the analysis is scarce. To more completely identify the role of vitamin D in athletic performance it is necessary to include these primary sources of vitamin D. The following review will cover how vitamin D is metabolized in the body, its relationship to immune system, muscle function, and the two main sources of vitamin D: diet and sunlight.

Vitamin D Metabolism

Vitamin D is a fat-soluble vitamin produced in the skin through exposure to Ultraviolet B (UVB) radiation. In the dermis layer, vitamin D_3 (cholecalciferol) is produced and then converted to 25-hydroxyvitamin D (25OHD) by hydroxylation in the liver. The hormonally active form of vitamin D, calcitriol (1,25OH_2D) is formed in the kidneys by a second hydroxylation (Gunton et al., 2015). Calcitriol is a subclass of secosteroid hormones; it is a ligand that acts through binding the vitamin D receptor (VDR). VDR is ubiquitous, as it is expressed in virtually all body tissues (Issa et al., 1998). Calcitriol, bound to VDR, has both endocrine and autocrine functions. Its endocrine function stimulates calcium absorption in the small intestine and works with parathyroid hormone (PTH) to regulate calcium homeostasis and bone mineralization (Takahashi et al., 2014). Calcitriol functions via intracellular autocrine pathways to facilitate tissue specific genomic responses to extracellular stimuli. Autocrine functions include facilitation of gene expression, protein and hormone synthesis, cell growth, apoptosis, and the inflammatory response (Heaney, 2008; Norman, 2008; Issa et al., 1998).

The gold standard for assessing vitamin D status is measurement of serum 25OHD. However, reporting only serum vitamin D level is problematic because defining vitamin D status using objective measurements has been debated in recent years. The Endocrine Society defines vitamin D deficiency as serum 25OHD less than 20 ng/mL, and sufficiency as serum 25OHD greater than 30 ng/mL (Holick et al., 2011). The Institute of Medicine, however, classifies vitamin D sufficiency as serum 25OHD greater than 20 ng/mL, and adds that serum 25OHD greater than 30 ng/mL does not offer additional benefits for protection from chronic diseases such as cardiovascular disease and cancer (Ross et al., 2011). Some studies have suggested measurement of serum 25OHD is not the best marker for assessing vitamin D status in populations and offered measurement of PTH as an alternative(Garg et al., 2013; Valcour et al., 2012). A major consequence of vitamin D deficiency is reduced calcium absorption and ionized serum calcium. The physiologic response is an increase in PTH to mobilize calcium stored in bone to ultimately return serum ionized calcium to homeostatic levels (Garg et al., 2013). The relationship among PTH, vitamin D, calcium, may make consistently elevated PTH levels an early indicator of vitamin D deficiency.

Inflammatory Cytokines

Provvedini et al. (1983) identified immune cells express VDR, and subsequently there has been considerable interest in vitamin D's role in the immune response, particularly its influence on cytokine production. Cytokines are small proteins secreted by cells that have specific effects on intra- and inter-cellular communication and interaction. They are predominately produced by helper T cells and macrophages, all three being essential to the inflammatory response (Provvedini et al., 1983; Zhang & An., 2007).

Following tissue damage, immune cells surround the injured site and secrete cytokines and growth factors to regenerate and heal tissue. Macrophages produce mostly pro-inflammatory cytokines, increasing blood flow to the damaged tissue to aid in repair (Takahashi et al., 2014). While necessary, pro-inflammatory cytokines such as interleukin-1 beta (IL-1β), interleukin-6 (IL-6), interferon-gamma (IFN-ϒ), and tumor necrosis factor-alpha (TNF-α) have been shown to affect the development and persistence of pain (Zhang & An,, 2007). Current evidence suggests these pro-inflammatory cytokines have the ability to dysregulate the inflammatory response and may directly modulate spontaneous activity of pain-sensing neurons. In vivo studies of nociceptive neurons in the peripheral nervous system demonstrate an abnormal increase in spontaneous activity after application of TNF-α, lending to the etiology of prolonged and chronic pain (Zhang & An, 2007). In high concentrations, TNF-α has the ability to promote damage, impair recovery in bone and muscle tissue, and increase risk for illness (Barker et al., 2013; Main et al., 2010; Willis et al., 2012). Chronically high levels of TNF-α have shown to be a powerful muscle-wasting cytokine (Bhatnagar et al., 2010). Anti-inflammatory cytokines can prevent these negative effects. They are immunoregulatory molecules that inhibit excessive pro-inflammatory cytokine production. Potent anti-inflammatory cytokines include several interleukins (IL): IL-1 receptor antagonist, IL-4, IL-10 and IL-13 (Barker et al., 2015; Main et al., 2010; Zhang & An., 2007). Animal and in-vitro studies have found vitamin D enhances production of the anti-inflammatory cytokine IL-4 and reduces production of pro-inflammatory cytokines IL-6, IFN-ϒ, and TNF-α in different disease models (Marcotorchino et al., 2012; Tang et al., 2015; Wöbke et al., 2014; Zhu et al., 2005). In vivo studies, however, fail to demonstrate similar effects and the link between vitamin D status and cytokine profile is less conclusive (Ghashut et al., 2014; Mangin et al., 2014; Waterhouse et al., 2015) .

Few studies have investigated the relationship between vitamin D status and cytokine concentrations in athletes, and results of these studies are inconsistent. Willis et al. (2012) found 25OHD levels significantly inversely correlated with the circulating concentration of TNF-α in female endurance runners. There was no correlation between vitamin D status and IFN-ϒ, IL-4, or IL-10. In contrast, a study investigating the relationship between vitamin D status and upper respiratory tract infection incidence in athletes found pro-inflammatory cytokine production was significantly lower, and infection risk/severity significantly higher in the group with low serum vitamin D. This study also found no correlation between production of anti-inflammatory cytokines, IL-4 and IL-10, and vitamin D status. To explain the associations, researchers proposed vitamin D as the key to activating the innate immunity response (He et al., 2013). Some data suggest a positive correlation between anti-inflammatory cytokines and vitamin D level. Barker et al. (2014) showed increases in IL-10 and IL-13 after intense exercise in vitamin D sufficient individuals. In this study, no changes in pro-inflammatory cytokine concentration were observed. A subsequent study by Barker et al. (2015) showed supplemental vitamin D increased both pro- and anti-inflammatory cytokines after fatiguing exercise. These conflicting results highlight the need for further research to more clearly define the role of vitamin D on pro- and anti-inflammatory cytokines in athletes. A better understanding of vitamin D's role in the inflammatory response could have important implication for muscle recovery and the prevention of injury and illness.

Muscle Function

Recent research has found that skeletal muscle cells express VDR, which supports the clinical characterization of vitamin D deficiency, namely muscle weakness and loss of fast twitch muscle fibers (Gunton et al., 2015; Pojednic et al., 2015a). Consistent with that finding are observational studies that have shown serum vitamin D levels are positively correlated with muscular strength and functional performance in various populations (Cannell et al., 2009; Farrell et al., 2011; Scott et al., 2015). Alternatively, insufficient vitamin D levels have been correlated with impaired skeletal muscle function, accumulation of muscle fat, increased circulation of pro-inflammatory cytokines and decreased circulation of anti-inflammatory cytokines (Fitzgerald et al., 2015; Forney et al., 2014; Ghashut et al., 2014). These findings suggest vitamin D levels may have a direct impact on muscle structure and function, and may play a role in regulating skeletal muscle development, strength and recovery (Houston et al., 2012; Pojednic et al., 2015b).

Dietary Intake of Vitamin D

Vitamin D is naturally present in very few foods (e.g., fatty fish, beef liver, egg yolk) but many foods in the American diet are fortified with vitamin D (e.g., milk, yogurt, cereals), and over the counter vitamin D supplements are widely available. Recently, the Institute of Medicine increased vitamin D intake recommendations from 400 IU/day to 600 IU/day for both male and female adults who are 18-65 years of age. It is difficult to meet this recommendation through diet alone, and exposure to sunlight is strongly recommended as a strategy for assuring adequate vitamin D status (Institute of Medicine (US) Committee to Review Dietary Reference Intakes for Vitamin D and Calcium, 2011). In athletic populations, however, studies have called for increased recommended intakes of 1000 IU/day, making sunlight exposure even more important for athletes (Cannell et al., 2009; Todd et al., 2015; Wyon et al., 2014). The best available method to measure adequacy is through serum analysis of 25OHD as this is the primary storage form of vitamin D. Two studies have demonstrated that a sun exposure questionnaire, assessing time spent outdoors and amount of skin exposed in a week, is a good predictor of 25OHD concentrations during the summer months (Exebio et al., 2015; Hanwell et al., 2010). Additionally, food frequency questionnaires and 24-hour diet analysis are useful to identify dietary vitamin D intake (Bescós García et al., 2011).

Ultraviolet Exposure

For most people, UVB radiation is the primary source of vitamin D. Multiple factors have an effect on UVB exposure, such as latitude, altitude, time of year, time of day, amount of skin exposed, and application of sunscreen (Ajabshir et al., 2014; Exebio et al., 2015; Hanwell et al., 2010). Additionally, personal characteristics such as age, body mass index (BMI), and skin color, can affect cutaneous vitamin D production (Park et al., 2013). Research suggests that higher amounts of melanin pigment in the skin significantly effect cutaneous vitamin D synthesis. Increasing amounts of melanin in the skin decrease the amount of vitamin D produced because melanin absorbs UVB radiation. Ajabshir et al. (2014) found that lighter skin tone correlated with higher levels of serum 25OHD and darker skin tone correlated with lower serum 25OHD.

Summary

Vitamin D's role in regulation of the immune system may prevent illness and reduce muscle soreness associated with prolonged and intense training. In regard to muscle tissue and function, vitamin D prevents loss of fast twitch muscle fibers and has a positive effect on muscle performance and function. Consideration of muscle mass, function and recovery for optimal athletic performance is particularly important to athletes who put extreme demands on their skeletal muscle system for long periods of time. Review of the literature suggests maintaining optimal vitamin D status may enhance athletic performance. Optimal vitamin D status cannot be achieved through diet alone. It is important, therefore, to assess dietary intake, supplementation, and degree of sun exposure to achieve a more complete picture of vitamin D status. Assessing vitamin D status, and its effects on many aspects of performance, is a research area that may prove to be important for helping athletes perform up to their conditioned capacities.

Chapter III

Methods

Background

This study investigated the relationship between sun exposure, diet and exercise-related muscle soreness using a cross-sectional design.

Participants

The study participants included 24 out of 60 collegiate football players currently in-season with an age range of 18-23 years. Potential participants were recruited during a scheduled athletic assessment during the month of October 2015. All active members of the team were included as potential participants. Consumption of NSAIDS and other medications (both prescribed and over-the-counter) was considered in the analysis. There were no exclusion criteria.

Data Acquisition

Subjective information was obtained via interview, using the questionnaire formats for diet/activity analysis, sunlight exposure, and muscle soreness (see appendix, p. 28). There were no risks or discomforts associated with the completion of these questionnaire forms. As this study is cross-sectional, it did not require re-analysis or additional questionnaires of participants and no personally identifying information (phone, address, name, etc.) was obtained. Each individual who agreed to participate in the study signed an informed consent prior to data collection. Participants invested approximately 30 to 60 minutes to complete the study.

Player weight and body composition were collected using the Inbody 320 Bioelectical Impedance Analyzer (BIA). This method is a simple, quick and accurate measure of body composition and has been validated in several studies (Faria et al., 2014; Kafri et al., 2014; Ling et al., 2011). The BIA requires that players wipe their hands and feet with a disposable electrolyte cleaning cloth (provided), then stand on the scale and hold the attached handles for approximately 20 seconds. The BIA is non-invasive and did not pose any risk or discomfort to the players.

Participants were then assessed using the Research Questionnaire developed for this study (see appendix). The participants' age, team position and number of completed seasons on the team was recorded. Participants were asked to complete demographic information, including race. They selected a skin tone that most closely matches the color of their inner forearm (untanned skin) using the Fitzpatrick Scale for the purpose of evaluating the relationship between total time in the sun and muscle soreness by race and skin tone classification. Increased melanin pigment inhibits the cutaneous synthesis of vitamin D. Therefore darker skin tones require more sun exposure to synthesize the adequate vitamin D as a lighter skin tone (Gilchrest, 2007).

Using the sun exposure recall questionnaire, developed by Hanwell et al. (2010), each participant was asked about their daily sun exposure over the previous week. For each of the seven days, participants reported time spent in the sun (0= 0-4 minutes; 1= 5-30 minutes; 2= 30-60 minutes; 3= 60-90 minutes; 4= 90-120 minutes) and amount of skin exposed while in the sun (1= hands and face, no helmet; 0.965= hands and face, helmet; 2= hands, face and arms, no helmet; 1.93= hands, face and arms, helmet; 3= hands, face and legs, no helmet; 2.895= hands, face and legs, helmet; 4= bathing suit). Values associated with wearing a helmet were calculated by subtracting 3.5% from the original value (1-4). Wearing a helmet covers the face and is a 3.5% reduction in the amount of skin exposed in each category (Godar et al., 2012). A daily sun exposure score (SES) was calculated by multiplying the score for amount of time in sun and the score for amount of skin exposed (min=0, max=8). The sum of scores from the same day gave the daily SES. The sum of SES for all seven days equaled the weekly SES. Similarly, the weekly time spent in sun score and weekly skin exposure score was calculated by adding the seven daily scores (time in sun: min= 0, max=112; skin exposure: min= 27.02, max=112). There was no risk or discomfort with completing this questionnaire via interview. Additionally, body composition data was used to assess the same relationship by age and body fat percentage. Data were subcategorized by player position to account for physical soreness related to practice.

The short-form McGill Pain Questionnaire (SF-MPQ), a validated test to measure pain, was used to evaluate the quality and intensity of muscle pain/soreness (Dworkin et al., 2009; Dworkin et al., 2015; Hatton et al., 2015; Hoskins et al., 2009; Melzack, 1987).

Descriptors representing the sensory dimension (throbbing - splitting) and affective dimension (tiring – punishing) of pain sensation were read aloud to participants and they then ranked each descriptor on an intensity scale of 0 = none, 1 = mild, 2 = moderate, 3 = severe. Sensory, affective, and total pain intensity scores were calculated for the SF-MPQ. (Hoskins et al., 2009; Melzack, 1987). Pain rating scores are the sum of the intensity values for the descriptors in each subclass and the total score is the sum of all intensity values. The Present Pain Intensity (PPI) scale is also included on the SF-MPQ to provide an average intensity score over the past week. On the PPI, participants were asked to rate the average intensity of their pain over the past week on the scale 0 = no pain, 1 = mild, 2 = discomforting, 3 = distressing, 4 = horrible, 5 = excruciating (Melzack, 1987). Sensory, affective, and total SF-MPQ pain scores and PPI scores were used for correlation studies. Data on the type of muscle (small, minor use or large major use) and proportion of entire muscle experiencing pain (1 = some 10%, 2 = quarter 25%, 3 = half 50%, 4 = most 75%, 5 = all 100%) were collected. For the purposes of this study, the terms 'pain' and 'soreness' were used interchangeably by the researcher. There was no risk or discomfort with completing this questionnaire via interview.

The data from the dietary recall was analyzed using NutriTiming (NutriTiming® Nutrient and Energy Analysis 2.1, NutriTiming LLC, 2014). Statistical analyses were performed using IBM SPSS version 20.0. Descriptive statistics for weekly total sun exposure, time in sun, skin exposed sensory, affective, and total SF-MPQ scores by age, race, and body fat percentage are presented in the results. The Spearman rank correlation coefficient was used to examine the relationship between weekly sun exposure score and muscle pain scores.

Chapter IV

Results

Participant Characteristics

Twenty-four male collegiate football players participated in this cross-sectional study (Table 1). The mean age of athletes was 20.7 ± 1.3 years. Mean height was 186.4 ± 6.9 cm and is similar to previous reports of NCAA Division IA football players' height (Oliver et al., 2012; Smith et al., 1984). Mean weight was 101.8 ± 19.2 kg and is 3 to 5 kg heavier than a previous report of NCAA Division IA football players' weight (Smith et al., 1984). Mean BMI was 29.0 ± 4.5, which, in the general population, is classified as overweight by the World Health Organization standards. BMI, however, does not distinguish between muscle mass and fat mass and thus is a dubious measure of health in athletic populations. Mean body fat percentage was 17.7 ± 5.9% and mean fat-free mass was 82.8 ± 10.7 kg. Compared to previous reports of NCAA Division IA football players' body composition, participants of the current study had an average of 4.9% more body fat and 2.5 kg less fat-free mass (Smith et al., 1984). The majority of participants identified as African American (71%; Figure 1) and reported having a skin tone of Type

IV or darker (75%; Figure 2). Complete participant characteristics are presented in Table 1.

Figure 1. Participant ethnicity.

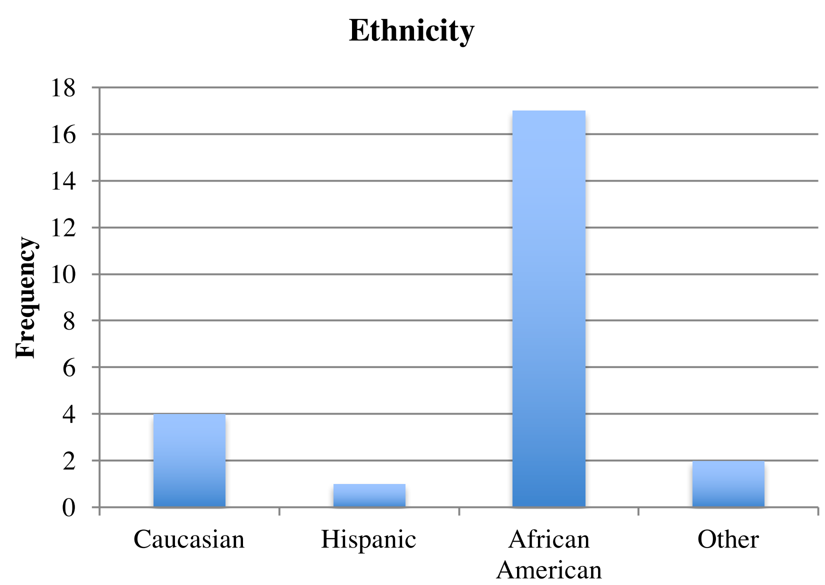


Figure 2. Skin tone using Fitzpatrick Scale.

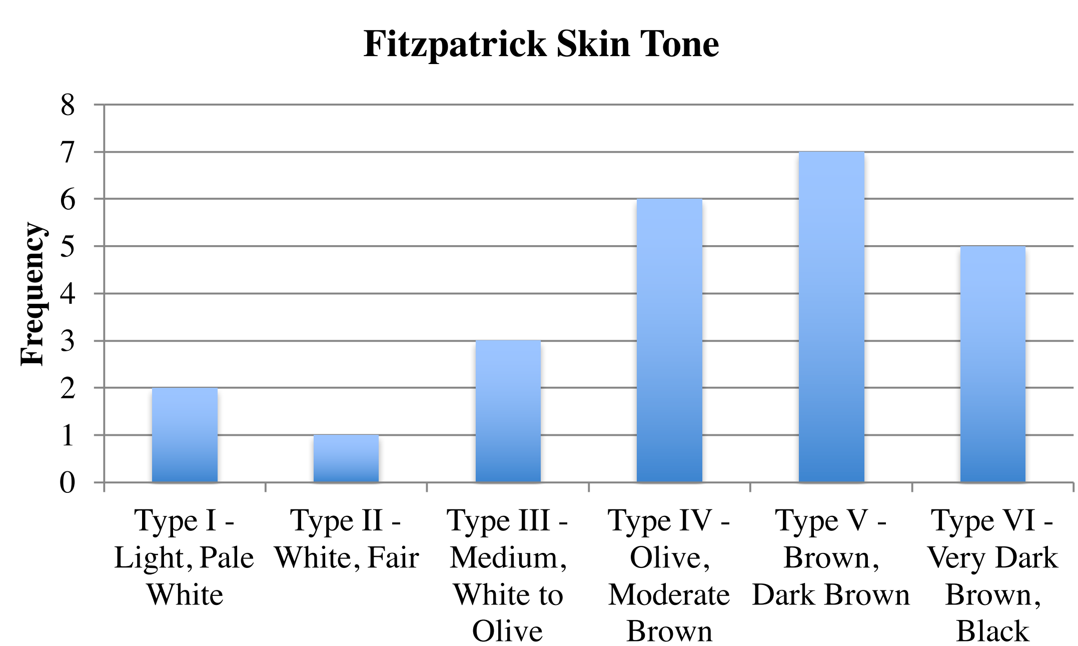


Table 1. Participant Characteristics (N = 24)		
	Mean ± SD	**Minimum – Maximum**
Age (y)	20.7 ± 1.3	18 – 23
Height (cm)	186.4 ± 6.9	174.0 – 196.9
Weight (kg)	101.8 ± 19.2	69.7 – 133.6
BMI (kg/m^2)	29.0 ± 4.5	22.7 – 39.9
Fat mass (kg)	18.9 ± 8.5	9.3 – 35.6
Fat mass (%)	17.7 ± 5.9	6.6 – 28.3
Fat-free mass (kg)	82.8 ± 10.7	60.4 – 98.0
Fat-free mass (%)	82.3 ± 5.9	72.0 – 93.0

Dietary Intake

All participants completed a 24-hour dietary recall. Players consumed an average of 3901 ± 1636 kcal per day. Additionally, energy consumption per day ranged from 1265 to 8445 kcal. The average amount of carbohydrate, protein and fat consumed per day was 497 ± 204 g, 168 ± 93 g and 139 ± 67 g, respectively. While the mean vitamin D intake approached the RDA for vitamin D (15 mcg), only seven participants (29.2%) met or exceeded the RDA. Complete analysis of the dietary recall data is presented in Table 2. T-test results indicated there was no difference in SF-MPQ scores, PPI scores and portion of muscle soreness between participants that consumed the vitamin D RDA and those that consumed less than the RDA.

Table 2. Dietary Intake (N = 24)		
	Mean ± SD	**Minimum – Maximum**
Energy (kcal/day)	3901 ± 1636	1265 – 8445
Energy (kcal/kg/day)	40.0 ± 18.8	12.1 – 82.9
Carbohydrate (g/day)	497 ± 204	140 – 967
Protein (g/day)	168 ± 93	54 – 446
Fat (g/day)	139 ± 67	38 – 309
Vitamin D (mcg/day)	10.8 ± 9.5	0.3 – 34

Sun Exposure

The sun exposure questionnaire was administered during October 2015 in Atlanta, Georgia. Participants reported their daily sun exposure for one week in October and weekly scores were calculated as previously described. The average weekly sun exposure score was 48.0 ± 9.6. The mean weekly time outdoors score and skin exposure score were 26.8 ± 4.9 and 19.3 ± 3.1. Complete sun exposure data are presented in Table 3. Analysis of participants' sun exposure indicated there was no difference in sun exposure scores across skin tone groups.

Table 3. Weekly Sun Exposure Characteristics (N = 24)

	Mean ± SD	**Minimum – Maximum**
Sun Exposure Score	48.0 ± 9.6	24.0 – 65.9
Time Outdoors Score	26.8 ± 4.9	10.0 – 36.0
Skin Exposure Score	19.3 ± 3.1	10.9 – 26.7

Muscle Soreness

All participants reported varying degrees of muscle soreness at the time of the interview, and no participant indicated that he was not sore. A higher proportion of participants reported soreness in a large, major use muscle (75%; N= 18) and fewer participants reported soreness in a small, minor use muscle (25%; N= 6). Data on the portion of the entire muscle experiencing pain is shown in Figure 3. To determine if player position was associated with physical soreness, positions were categorized into lineman (N = 11) and non-lineman (N = 13). Muscle soreness was not significantly different across player positions. Participants employed various treatments to alleviate muscle pain. Massage was used by seven participants, 13 used ice packs, nine used heat pads, six used over the counter NSAIDs, 12 sought treatment with the athletic trainer and seven of those 12 were treated with electrical stimulation therapy. No treatment or therapy to alleviate pain was reported by six of the participants. SF-MPQ and PPI scores are presented in Table 4.

Figure 3. Portion of muscle experiencing soreness.

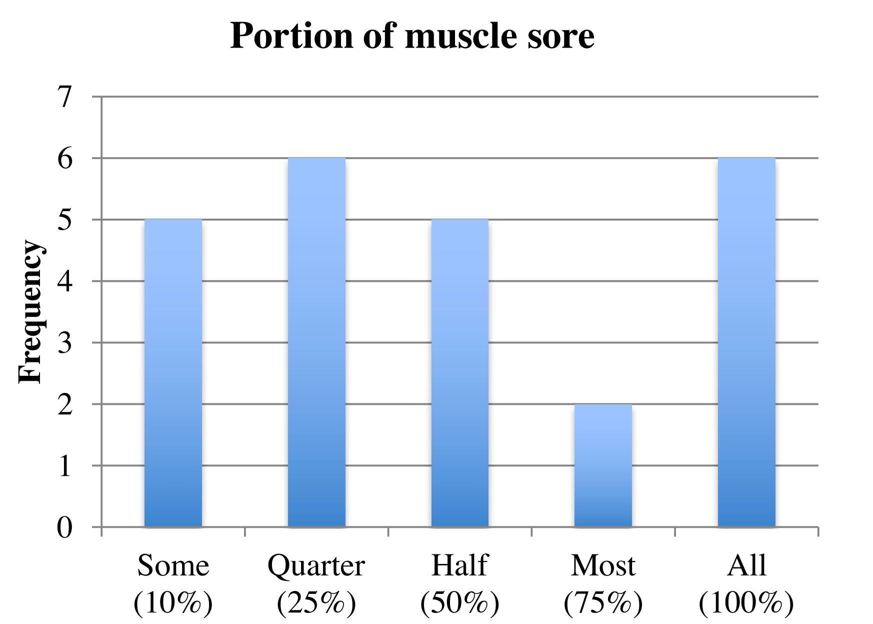


Table 4. Pain Scores (N = 24)

	Mean ± SD	**Minimum – Maximum**
SF-MPQ		
Total Score	5.8 ± 4.9	1 – 22
Sensory Score	4.8 ± 4.1	1 – 18
Affective Score	1.0 ± 1.2	0 – 4
PPI Score	1.7 ± 0.8	0 – 3

<u>Relationship Between Sun Exposure, Diet and Muscle Soreness</u>

Spearman's rho was computed to assess the relationship between the following variables: weekly sun exposure score, weekly time outdoors score, weekly skin exposure score, dietary vitamin D intake, SF-MPQ sensory, affective and total pain scores, PPI score and portion of muscle sore. Dietary vitamin D intake was negatively associated with portion of muscle sore (r_s = -0.393, p = 0.029). SF-MPQ total and affective scores were each negatively associated with weekly time outdoors (r_s = -0.362, p = 0.041; r_s = -0.449, p = 0.014, respectively). PPI score and percent of muscle sore were each positively associated with weekly skin exposure score (r_s = 0.37, p = 0.037; r_s = 0.338, p = 0.030, respectively).

To further investigate the association between SF-MPQ total and affective scores and weekly time outdoors score, players were divided into two groups based on the mean weekly time outdoors score. Group 1 players had a time outdoors score less than the mean and group 2 players had a time outdoors score greater than the mean. Results from a t-test showed the mean SF-MPQ affective pain score was significantly lower for players with a time outdoors score above the mean (p = 0.04). The Mann-Whitney U results indicated the median SF-MPQ affective score was also significantly different between the two groups of players (p = 0.04). There was no difference in SF-MPQ total score between groups.

Table 5. Spearman's rho Correlation table					
		Vit D (mcg)	Weekly Sun Exposure Score	Weekly Time Outdoors Score	Weekly Skin Exposure Score
SF-MPQ Total Score	R_s	–0.230	–0.113	**–0.362**	0.118
	P	0.14	0.300	**0.041**	0.292
Sensory Score	R_s	–0.315	–0.007	–0.277	0.094
	P	0.067	0.487	0.095	0.332
Affective Score	R_s	0.029	–0.262	**–0.449**	0.134
	P	0.447	0.108	**0.014**	0.267
PPI Score	R_s	–0.258	0.146	–0.331	**0.371**
	P	0.112	0.249	0.057	**0.037**
Portion of muscle sore	R_s	**–0.393**	0.321	0.093	**0.388**
	P	**0.029**	0.063	0.333	**0.030**

Summary of Findings

The results of this study suggest that higher dietary vitamin D intake is associated with a lower proportion of muscular soreness. Additionally, these results demonstrate a relationship between longer time spent outdoors and lower scores for the affective dimension of pain on the SF-MPQ. These results support the hypothesis that higher total vitamin D, from the combination of greater total weekly sun exposure and dietary intake of vitamin D, is correlated with decreased muscle soreness.

Chapter V

Discussion and Conclusions

In this study, the dietary intake and sun exposure of collegiate football players were examined to determine the relationship, if any, of vitamin D risk on muscle soreness. The main findings were that: (1) the majority of participants did not consume the recommended amount of vitamin D in the diet; (2) higher dietary vitamin D intake was associated with a lower proportion of muscle soreness; and (3) increased time spent outdoors was associated with lower affective pain scores. There were no differences in soreness found between player positions (linemen vs. non-linemen) or among skin tone groups.

Muscle Soreness

Regardless of how the subject population was subdivided (skin tone, body composition, linemen, non-linemen), there was no difference in reported muscle soreness. The absence of differences between groups based on skin tone, body composition and player position, suggest that these factors were not significantly associated with muscle soreness.

Sun Exposure and Muscle Soreness

As previously described, the weekly SES reflects the combined weekly time outdoors and skin exposure scores. The Sun Exposure Questionnaire developed by Hanwell et al. (2010), offers a good prediction of 25(OH)D. Previous studies using the same Sun Exposure Questionnaire have demonstrated a strong correlation between total sun exposure score and serum 25OHD in the summer months at latitudes below 35 degrees North. Additionally, it was shown to correlate with serum 25(OH)D levels in a multi-ethnic population living in south Florida (27.5 degrees N) during the fall months (Ajabshir et al., 2014). However, at latitudes greater than 40 degrees North, the correlation is absent. Sham et al. (2015), found fall sun exposure scores were not correlated with serum 25OHD in an adult population living in Canada (43 degrees North). While not validated for the present population, it was deemed appropriate for this population living in Atlanta, GA (33.8 degrees North) during the month of October.

No statistically significant relationship was found between the weekly SES and muscle soreness. However, significant relationships were observed between components of the SES, time outdoors and skin exposure, and muscle soreness. In this study, more time spent outdoors was associated with a lower total pain score, and a lower affective pain score. This finding suggests players spending more time outside may benefit from an improved affect, or emotional state, which has the potential to influence the ability to cope with muscle soreness in a demanding physical environment. This finding is consistent with previous research demonstrating exposure to bright light reduces the intensity of depressive symptoms and improves mood in healthy adults (Leppämäki et al., 2002; Partonen et al., 2000).

Diet and Muscle Soreness

Compared to a previous report of dietary composition of collegiate football players, these players consumed more total calories and grams of carbohydrate, the same grams of protein and less grams of fat (Kirwan et al., 2012). While energy and macronutrients were sufficient, the majority of athletes in this study did not consume the RDA for vitamin D in the diet. As vitamin D intake positively correlates serum vitamin D, athletes consuming less than the RDA are at a greater risk for vitamin D insufficiency or deficiency as measured in the blood serum (Ajabshir et al., 2014; Villacis et al., 2014). This finding is consistent with the wealth of literature on the prevalence of low vitamin D levels in athletes. Notably, Villacis et al. (2014) found more than one third of NCAA division I athletes had abnormal (low) vitamin D levels. Additionally, male athletes and athletes with dark skin were more likely to be vitamin D deficient. The population of the present study was all male and had mostly (75%) brown to dark skin tones, highlighting the elevated risk for abnormal vitamin D levels in athletes consuming less than the RDA. Between those that consumed the RDA for vitamin D ($n = 7$) and those that consumed less than the RDA ($n = 17$), there was no statistically significant difference in reported pain or muscle soreness. However, the difference in sensory pain score approached significance ($p = .065$) between these groups, suggesting players consuming dietary vitamin D greater than or equal to the RDA may experience less intense muscle soreness or less overall muscle soreness.

Limitations

There are several limitations to the present study. Importantly, this study did not assess serum vitamin D levels. The data collected describes risk factors and outcomes related to serum vitamin D levels. A future study may include serum vitamin D measurements to assess if a correlation exists with muscle soreness. This study took place during the month of October, a transition period where there are fewer hours of daylight and reduced UV index. It may be beneficial to repeat the study, but during the months of June to August, when hours of daylight and UV index are the highest. This analysis was based on a small sample of primarily African American college football players and can only be considered as preliminary evidence upon which to base further research.

Conclusions

An unexpected finding of this study is the positive relationship observed between weekly skin exposure and muscle soreness. Weekly skin exposure positively correlated with both the pain intensity score and the proportion of muscle soreness. Although the correlations were weak, they were significant ($r_s = 0.371$, $p = 0.037$ and $r_s = 0.388$, $p = 0.030$). This finding does not support the proposed hypothesis. It is possible that the skin exposure score is a weaker variable then the time outdoors score. In the findings published by Hanwell et al. (2010), the correlation between the weekly SES and 25(OH)D levels was almost entirely driven by time outdoors, not the amount of skin exposed; the skin exposure score did not correlate significantly with 25(OH)D concentrations. Thus, in a population of student athletes, the amount of time spent outside may be more important than the type of clothing worn when assessing vitamin D risk. However, it may still be beneficial to recommend football players wear minimal clothing under the protective equipment and uniform to increase skin exposure. The researchers do not, however, recommend removing the helmet to achieve greater skin exposure as the risk of concussion and acute brain injury poses a much greater threat to athletic performance in football players.

To the best of our knowledge, this is the first study to report an association between higher dietary intake of vitamin D and reduced muscle soreness in collegiate football players. While not statistically significant, the total sun exposure score was inversely related to SF-MPQ pain scores. This finding suggests, but not conclusively so, that increased cutaneous vitamin D synthesis, resulting from longer periods of time outside, with moderate skin exposure (face and arms, or more), may be related to reduced muscle soreness in collegiate football players.

Major Significant Findings

There is a high prevalence of insufficient dietary vitamin D intake (70.8%) identified in a collegiate football team. Our findings suggest that higher dietary vitamin D intake and more time spent outdoors are associated with a lower proportion of muscular soreness and decreased perceived pain. Thus, achieving a satisfactory vitamin D status, through a combination of diet and sun exposure, may reduce vitamin D deficiency associated risks, including lowering muscle soreness, thereby serving to enhance athletic performance. These data suggest that athletes, their coaches, and affiliated team dietitians should strategize how best to assure optimal vitamin D status to lower muscle soreness risk.

Appendix

Research Questionnaire
Vitamin D and Sunlight Exposure
Department of Nutrition, Georgia State University

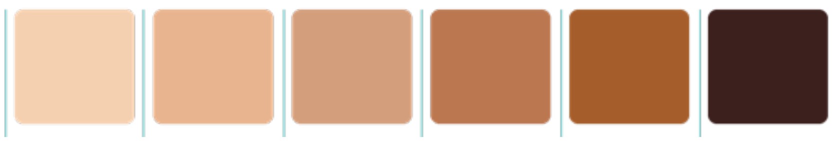
I. Player Information
Age: ______________ Position: ____________________

Number of seasons completed at collegiate level: ______________

Ethnicity (check one):
[ ] Non-Hispanic Caucasian [ ] Non-Hispanic Black [ ] Hispanic

[ ] Asian [ ] Pacific Islander [ ] Other: ______________

Please circle the skin color that most closely matches the color of your inner forearm



Type I	**Type II**	**Type III**	**Type IV**	**Type V**	**Type VI**
Light, pale white	White, fair	Medium, white to olive	Olive, moderate brown	Brown, dark brown	Very dark brown, black
Always burns, never tans	Usually burns, tans with difficulty	Sometimes mild burn, gradually tans to olive	Rarely burns, tans with ease to moderate brown	Very rarely burns, tans very easily	Never burns, tans very easily, deeply pigmented

Adapted from: Gilchrest, BA. (2014) Sun protection and Vitamin D: Three dimensions of obfuscation. The Journal of Steroid Biochemistry and Molecular Biology,103(3–5), 655-663.

II. Vitamin D

Time Outdoors (minutes)						Amount of skin exposed							Daily SES
	0-4	5-30	30-60	60-90	90-120	Hands and face, no helmet	Hands and face, helmet	Hands, face and arms, no helmet	Hands, face and arms, helmet	Hands, face and legs, no helmet	Hands, face, and legs, helmet	Bathing suit	
Monday	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
Tuesday	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
Wednesday	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
Thursday	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
Friday	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
Saturday	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
Sunday	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	
	0	1	2	3	4	1	.965	2	1.93	3	2.895	4	

Adapted from: Hanwell et al. (2010). Sun exposure questionnaire predicts circulating 25-hydroxyvitamin D concentrations in Caucasian hospital workers in southern Italy. *J Ster Biochem Molec Bio.* 121, 334-337.

For Research Purposes:
Weekly SES:_____________ Weekly time in sun: _____________ Weekly skin exposure: _____________

III. Muscle Soreness

SF-MPQ

	None	*Mild*	*Moderate*	*Severe*
Throbbing	0	1	2	3
Shooting	0	1	2	3
Stabbing	0	1	2	3
Sharp	0	1	2	3
Cramping	0	1	2	3
Gnawing	0	1	2	3
Hot-burning	0	1	2	3
Aching	0	1	2	3
Heavy	0	1	2	3
Tender	0	1	2	3
Splitting	0	1	2	3
Tiring-exhausting	0	1	2	3
Sickening	0	1	2	3
Fearful	0	1	2	3
Punishing-cruel	0	1	2	3

Melzack, R. (1987). The short-form McGill Pain Questionnaire. *Pain*, *30*(2), 191–197.

For Research Purposes:
Sensory pain score: _____________ Affective pain score: _____________ Total pain score: _____________

PPI
Please select one descriptor that best describes your overall pain intensity over the past week.

0	**No pain**	______
1	**Mild**	______
2	**Discomforting**	______
3	**Distressing**	______
4	**Horrible**	______
5	**Excruciating**	______

Is the sore muscle a **small minor-use muscle**, or a **large major-use muscle**? (Circle one)

On a scale of 1 to 5, what portion of the entire muscle is sore?

1	**2**	**3**	**4**	**5**
Some (10%)	Quarter (25%)	Half (50%)	Most (75%)	All (100%)

Please select all strategies you used to reduce muscle soreness from exercise this week:

[ ] (1) Massage	[ ] (3) Heating pads	[ ] (5) Athletic trainer	[ ] (7) None
[ ] (2) Ice packs	[ ] (4) Ibuprofen or aspirin	[ ] (6) Physician	

Dietary and Activity Analysis Data Entry Form

Subject Code:______________________

Time of Last Meal Before Day of Analysis:______________

Instructions: Completing this form will help us understand whether the amount of energy (calories) you consume comes close to matching the energy (calories) you expend. This form provides a way of entering your energy expended by using an 'Activity Factor', and your energy consumed by using a description of the foods and drinks you ate. The information is entered by hourly units, so you don't have to remember precisely the time you had an activity or ate some food. Rather, you are asked to enter when you had an activity, its intensity by using the activity factor scale, and how long you did it (example: I had a slow jog between 10 and 11 in the morning that lasted for 30 minutes). Use the Activity Factor Scale Descriptions to help you figure out the best factor to enter when describing an activity. When entering food, describe the food and the way it was prepared fully (example: chicken breast with no skin that was baked; or fried, battered chicken breast, etc), and the amount you consumed (example: 1 apple; 1 ½ cups; 15 red grapes; 1 large banana, etc.). A factor of 1.5 is considered normal daytime activity, and we will assume a factor of 1.5 unless you indicate otherwise. A factor of 1 is equal to sleep, and a factor greater than 1.5 suggests you are doing something more vigorous than normal daytime activity. Please enter a full 24 hours of all your activities and all the foods/drinks you consume. Use the example below to help you understand how to enter the information.

Activity Factor Scale

Factor	Description
1	**Resting, Reclining:** Sleeping, reclining, relaxing
1.5	**Rest +:** Normal, average sitting, standing daytime activity
2.0	**Very Light:** More movement, mainly with upper body. Equivalent to tying shoes, typing, brushing teeth
2.5	**Very Light +:** Working harder than 2.0
3.0	**Light:** Movement with upper and lower body. Equivalent to household chores
3.5	**Light +:** Working harder than 3.0; Heart rate faster, but can do this all day without difficulty
4.0	**Moderate:** Walking briskly, etc. Heart rate faster, sweating lightly, etc but comfortable
4.5	**Moderate +:** Working harder than 4.0. Heart rate noticeably faster, breathing faster
5.0	**Vigorous:** Breathing clearly faster and deeper, heart rate faster, must take occasional deep breath during sentence to carry on conversation
5.5	**Vigorous +:** Working harder than 5.0. Breathing noticeably faster and deeper, and must breath deeply more often to carry on conversation
6.0	**Heavy:** You can still talk, but breathing is so hard and deep you would prefer not to. Sweating profusely. Heart rate very high
6.5	**Heavy +:** Working harder than 6.0. You can barely talk but would prefer not to. This is about as hard as you can go, but not for long
7.0	**Exhaustive:** Can't continue this intensity long, as you are on the verge of collapse and are gasping for air. Heart rate is pounding

Begin Hour	End Hour	Activity Factor	Activity Description	Food/Drink Description	Food/Drink Amount
				****Begin Example****	
12am	7am	1.0	Sleep		
7am	8am	1.5	Nothing Special	Whole Wheat Waffles (Frozen-Kellogg)	3
				Maple Syrup	2 Tablespoons
				1 % Milk	1 Cup
				Orange Juice (from concentrate)	1.5 Cups
				Coffee	2 Cups
				1 % Milk for Coffee	2 Tablespoons
10am	11am	5.0	Jog 30 minutes	Gatorade	16 Ounces
12noon	1pm	1.5	Nothing Special	Medium size beef sandwich with white	1 Sandwich
				bread, mayonnaise, lettuce, and tomato.	
				Coffee	2 Cups
				Artificial Coffee Creamer	2 Packets
				Apple Pie	1 Slice (small)
5pm	6pm	4.0	Walk 1 hour	Water	16 ounces
7pm	8pm	1.5	Nothing Special	Lasagna with ground beef and cheese	Large Plate
				Lettuce Salad with Tomatoes and Cucumbers	Medium Size Salad
				Blue Cheese Salad Dressing	1 Tablespoon
				Red Wine	1 Medium Glass
10pm	11pm	1.5	Nothing Special	Popcorn (air popped; no butter)	100 Calorie Pack
				End Example	

Page _____

Begin Hour	End Hour	Activity Factor	Activity Description	Food/Drink Description	Food/Drink Amount

Page ______

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