Quantification of the Physical Demands and Perceived Wellness Associated with Practice and Competition in NCAA Division I College Football Players

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A thesis submitted in fulfillment of the requirements of the degree of Doctor of Philosophy

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Declaration of Originality

I declare that the work in this confirmation document has not previously been submitted in whole or in part, for a degree or diploma to any university. To my knowledge, this thesis contains no material previously published or written by another person except where due reference is made within the thesis itself.

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American football is a field-based team sport, characterised by high-intensity collisions, and repeated high-intensity movements, requiring high levels of muscular strength, power, speed and agility (197). Competitive games are intermittent in nature, involving high-intensity bouts of exercise following brief periods of recovery (111). Further, the intensity of impact forces sustained during collisions that frequently occur in American football contribute an additional stress and trauma (216) which can alter athlete performance (105), contributing to post-match fatigue and prolonged recovery reported in similar collision-based team-sports (158). During the in-season phase of competition, players competing in National Collegiate Athletic Association (NCAA) division I college football participate in twelve regular season games on a weekly basis. Throughout the total duration of pre-season preparation and in-season competitive periods, players are required to participate in football specific training that includes repeated exposure to high-intensity exercise and high-impact forces, which have been associated with fatigue in collision sport athletes (157, 158, 237). Managing the volume and intensity of exercise workloads throughout the course of weekly training and competitions is a critical component of physical preparation in NCAA division I football players, in attempts to reduce the risk of acute and residual fatigue, and optimise preparedness for on-field performance.

The development of global positioning system (GPS) technology with integrated tri-axial accelerometers (IA) have allowed the physiological demands of training and match-play in team contact sport to be quantified (9, 242). Movement profiles, which include measurements of total distances, velocities of movement, and the number, distance, and durations of sprint, acceleration and deceleration efforts can be quantified utilising GPS (49, 50, 240). Integrated tri-axial accelerometers, which assess the frequency and magnitude of full-body acceleration (m·s\(^{-2}\)) in three dimensions, namely, anterior-posterior, mediolateral, and vertical (143), offer a valid tool for detecting the frequency and magnitude of collisions associated with training and competition in team contact sport (73).

The impetus for the present body of work arose from several years of observing high pre-season training loads in NCAA division I football teams, particularly in the first week of pre-
season training camp, and the residual fatigue associated with these loads, which often lingered into week one of the competitive season. The lack of information pertaining to the practice and competitive demands of NCAA division I football players is indisputable in any systematic review of the literature. Moreover, no study had quantified the positional movement demands of practice or competition, let alone the individual perceived wellness profiles associated with these demands.

The present body of work was undertaken to establish the physical movement demands associated with pre-season training camp practice, in-season practice sessions, and competitive games, along with the resulting perceptions of wellness associated with these demands. A novel series of studies was designed to provide a framework from which sport coaches and performance staff may utilize the findings as a means to improve practice planning and recovery strategies to optimize competitive performance and mitigate the deleterious effects of fatigue in NCAA division I football players.
Navigation of the Thesis

This thesis comprises five studies presented as five individual chapters. At the time of submission, three of the five studies have been published, while the remaining two have been accepted for publication. All papers are presented in the format accepted for publication and include an introduction, review of the literature, methods, results, and discussion section.

There are eight chapters which make up the present thesis. Chapter 1 provides an introduction of the purpose, significance of the research, presents the hypothesis associated with each study and outlines the research questions. Chapter 2 provides an overview of the literature with specific reference to the physiological and movement demands of contact team sport, including NCAA division I football, Rugby League, and Australian rules football. The reader is introduced to Global Positioning System (GPS) and IA (Integrated Accelerometry) technology for movement analysis in team sport, in addition to the validity and reliable of portable GPS technology. Chapter 2 also contains a review of the utilization of self-report measures, in the form of questionnaires, to evaluate the perceived wellness associated with training and competition in athletes.

Chapter 3 is Study 1, and has been published as:


Chapter 4 is Study 2, and has been published as:


Chapter 5 is Study 3, and has been published as:

Chapter 6 is Study 4, and has been accepted for publication as:


Chapter 7 is Study 5, and has been accepted for publication as:


The Journal of Strength and Conditioning Research was selected as the journal to receive the results of studies 1-5. It was reasoned that if the applied programming of practice and training protocols was to be improved, the results of these studies should be presented in a journal widely read by strength and conditioning coaches and sport performance practitioners. As such, the Journal of Strength and Conditioning was the journal of choice.

In addition to the studies listed in chapters 3-7, the research conducted in completion of the present thesis also contributed to the preparation of the following poster presentation:

Wellman, AW, Coad, SC, Goulet, GC, and McLellan, CP. Quantification of competitive game demands of NCAA division I college football players using global positioning systems. Presented at the 2015 National Strength and Conditioning Association national conference, July 8-11, Orlando, FL.
Chapter 8 contains the overall discussion and conclusions, a summary of the findings of the studies, and recommendations for future research, which may increase our understanding of the physiological movement demands and perceived wellness associated with participation in NCAA division I football. The results of the present body of work will aid coaches and performance staff in the programming of practice loads and recovery protocols, which optimize game-day performance and mitigate the deleterious effects of fatigue that may accompany participation in NCAA division I football.
Acknowledgements

I would like to acknowledge a number of people for their support and encouragement throughout the period of my doctoral candidature. My wife, Shellie, has been a source of unwavering support throughout this period, as well as throughout my entire professional career. I would also like to thank my children, Grant and Grace, for the sacrifices they have made to allow me to pursue my passion. Words do no justice in expressing my love and gratitude to them.

To my supervisor, Chris McLellan, thank you for your consistent approach, your availability, your critical review throughout this entire process, and for helping me bring this dream to fruition.

I would also like to extend a genuine “thank you” to a number of colleagues including Sam Coad, Ty Siam, Patrick Flynn, Grant Goulet, and Mike Climstein.
Abstract

The primary aim of this thesis was to quantify the positional movement demands of pre-season and in-season practice and competition in NCAA division I football players. A secondary aim of this thesis was to examine the subsequent perceived wellness, utilizing a modified questionnaire, associated with pre-season training camp and competition throughout an NCAA division I football season.

Chapter 3 (Study 1 – Paper 1)

The aim of the present study was to examine the competitive physiological movement demands of NCAA division I college football players using portable global positioning system (GPS) technology during games, and to examine positional groups within offensive and defensive teams, to determine if a player’s physiological requirements during games are influenced by playing position. Thirty-three National Collegiate Athletic Association (NCAA) Division I Football Bowl Subdivision football players were monitored using GPS receivers with integrated accelerometers (GPSports, Canberra, Australia) during 12 regular season games throughout the 2014 season. Individual datasets (n = 295) from players were divided into offensive and defensive teams, and subsequent position groups. Movement profile characteristics including total, low-, moderate-, high-intensity and sprint running distances (m), sprint counts, and acceleration and deceleration efforts, were assessed during games. A one-way ANOVA and post-hoc Bonferroni statistical analyses were used to determine differences in movement profiles between position groups within offensive and defensive teams. For both offensive and defensive teams, significant (p<0.05) differences exist between positional groups for game physical performance requirements. The results of the present study identified that wide receivers (WR) and defensive backs (DB) completed significantly (p<0.05) greater total distance, high-intensity running, sprint distance, and high-intensity acceleration and deceleration efforts compared to their respective offensive and defensive positional groups. Data from the present study provide novel quantification of position-specific physical demands of college football games and support the use of position-specific training in the preparation of NCAA Division I college football players for competition.
Chapter 4 (Study 2 – Paper 2)
The aims of the present study were to 1) examine positional impact profiles of NCAA division I college football players using global positioning system (GPS) and integrated accelerometry (IA) technology, and 2) determine if positional differences in impact profiles during competition exist within offensive and defensive teams. Thirty-three NCAA division I Football Bowl Subdivision players were monitored using GPS and IA (GPSports, Canberra, Australia) during 12 regular season games throughout the 2014 season. Individual player datasets (n = 294) were divided into offensive and defensive teams, and positional sub-groups. The intensity, number, and distribution of impact forces experienced by players during competition were recorded. Positional differences were found for the distribution of impacts within offensive and defensive teams. Wide receivers (WR) sustained more very light and light to moderate (5-6.5 G force) impacts than other position groups, while the running backs (RB) were involved in more severe (>10 G force) impacts than all offensive position groups, with the exception of the quarterbacks (QB) (p<0.05). The defensive back (DB) and linebacker (LB) groups were subject to more very light (5.0-6.0 G force) impacts, and the defensive tackle (DT) group sustained more heavy and very heavy (7.1-10 G force) impacts than other defensive positions (p<0.05). Data from the present study provide novel quantification of positional impact profiles related to the physical demands of college football games and highlight the need for position-specific monitoring and training in the preparation for the impact loads experienced during NCAA Division I football competition.

Chapter 5 (Study 3 – Paper 3)
The aims of the present study were to examine the movement demands of pre-season practice in National Collegiate Athletic Association (NCAA) division I college football players using portable global positioning system (GPS) technology and to assess perceived wellness associated with pre-season practice to determine if GPS-derived variables from the preceding day influence perceived wellness the following day. Twenty-nine players were monitored using GPS receivers (Catapult Innovations, Melbourne, Australia) during 20 pre-season practices. Individual observations (n=550) were divided into offensive and defensive position groups. Movement variables including low-, medium-, high-intensity, and sprint distance, player load, and acceleration and deceleration distance were assessed. Perceived
wellness ratings (n=469) were examined using a questionnaire which assessed fatigue, soreness, sleep quality, sleep quantity, stress, and mood. A one-way ANOVA for positional movement demands, and multi-level regressions for wellness measures were used, followed by post-hoc testing to evaluate the relational significance between categorical outcomes of perceived wellness scores and movement variables. Results demonstrated significantly (p<0.05) greater total, high-intensity, and sprint distance, along with greater acceleration and deceleration distances for the DB and WR position groups compared to their respective offensive and defensive counterparts. Significant (p<0.05) differences in movement variables were demonstrated for individuals who responded more or less favorably on each of the six factors of perceived wellness. Data from the present study provide novel quantification of the position-specific physical demands and perceived wellness associated with college football pre-season practice. Results support the use of position-specific training and individual monitoring of college football players.

Chapter 6 (Study 4 – Paper 4)

The aim of the present study was to quantify the individual practice and game loads throughout an NCAA division I football season to determine if significant differences exist between the practice loads associated with pre-season training camp and those undertaken during the in-season period. Thirty-one NCAA division I football players were monitored using GPS and IA (MinimaxX S5; Catapult Innovations, Melbourne, Australia) during 22 pre-season practices, 36 in-season practices, and 12 competitions. The season was divided into four distinct phases for data analysis: pre-season week 1 (pre-season1), pre-season week 2 (pre-season2), pre-season week 3 (pre-season3), and 12 in-season weeks. Individual IA datasets represented players from every offensive and defensive position group (WR: n=5), (OL: n=4), (RB: n=4), (QB: n=2), (TE: n=3), (DL: n=4), (LB: n=4), (DB: n=5). Data were set at the practice level, where an observation for each player’s maximum player load (PLMax) or mean player load (PLMean) from each training camp phase was referenced against each player’s respective PL from each game, Game -4, Game -3, or Game -2 practice session. Notable results included significantly (p<0.05) greater PLMax values attributed to pre-season1 compared to PL resulting from all in-season practices, and significantly (p<0.05) higher cumulative PL reported for pre-season1, 2, and 3 compared to every in-season week.
Data from the present study augment our understanding of the practice demands experienced by NCAA division I college football players, and provide scope for the improvement of pre-season practice design and physical conditioning strategies for coaches seeking to optimize performance.

Chapter 7 (Study 5 – Paper 5)
The present study assessed the influence of movement demands resulting from weekly practice sessions and games, on perceived wellness measurements taken post-game (Game +1) and 48 hours pre-game (Game -2) throughout the in-season period in National Collegiate Athletic Association (NCAA) division I football players. Thirty players were monitored using GPS receivers (Catapult Innovations OptimEye S5, Melbourne, Australia) during 12 games and 24 in-season practices. Movement variables included low-intensity distance, medium-intensity distance, high-intensity distance, sprint distance, total distance, player load, and acceleration and deceleration distance. Perceived wellness, including fatigue, soreness, sleep quality and quantity, stress, and mood, was examined using a questionnaire on a 1-5 Likert scale. Multi-level mixed linear regressions determined the differential effects of movement metrics on perceived wellness. Post-hoc tests were conducted to evaluate the pair-wise differentials of movement and significance for wellness ratings. Notable findings included significantly (p<0.05) less player load, low-intensity distance, medium-intensity distance, high-intensity distance, total distance, and acceleration and deceleration distance at all intensities, in those reporting more favorable (4-5) ratings of perceived fatigue and soreness on Game +1. Conversely, individuals reporting more favorable Game +1 perceived stress ratings demonstrated significantly (p<0.05) higher player load, low-intensity and medium-intensity distance, total distance, low-intensity and medium-intensity deceleration distance, and acceleration distance at all intensities than individuals reporting less favorable (1-2) perceived stress ratings. Data from the present study provide a novel investigation of perceived wellness associated with college football practice and competition. Results support the use of wellness questionnaires for monitoring perceived wellness in NCAA division I college football players.
List of Publications


List of Conference Proceedings

List of Tables

Table 1. Means ± standard deviations for height, mass, and body fat percentage of NCAA division I football players. 42

Table 2. 2014 NFL Scouting Combine averages by position. 44

Table 3. Positional anthropometric data from study 1. 90

Table 4. Movement classification system used in study 1. 92

Table 5. Results of offensive positional movement profiles from study 1. 95

Table 6. Results of defensive positional movement profiles from study 1. 97

Table 7. Positional anthropometric data from study 2. 108

Table 8. Impact Classification System used in study 2. 110

Table 9. Results of offensive positional impacts profiles from study 2. 112

Table 10. Results of defensive positional impacts profiles from study 2. 113

Table 11. Positional anthropometric data from study 3. 126

Table 12. Movement classification system used in study 3. 128

Table 13. Results of defensive positional movement profiles from study 3. 132

Table 14. Results of offensive positional movement profiles from study 3. 134

Table 15. Ratings of perceived fatigue from study 3. 136

Table 16. Ratings of perceived soreness from study 3. 138

Table 17. Ratings of perceived sleep quantity from study 3. 140

Table 18. Ratings of perceived sleep quality from study 3. 141

Table 19. Ratings of perceived stress from study 3. 143
Table 20. Ratings of perceived mood from study 3. 144

Table 21. Player load max predicted means resulting from pre-season and in-season practice sessions from study 4. 160

Table 22. Player load mean and cumulative player load predicted means resulting from pre-season and in-season practice sessions from study 4. 161

Table 23. Average and maximum session duration for pre-season1, pre-season2, pre-season3, Game -4, Game -3, and Game -2 practice sessions, in addition to average and maximum game durations from study 4. 162

Table 24. Game +1 ratings of perceived fatigue and soreness from study 5. 179

Table 25. Game +1 ratings of perceived stress and sleep quality from study 5. 180

Table 26. Game -2 ratings of perceived fatigue from study 5. 182

Table 27. Game -2 ratings of Perceived Soreness from study 5. 184

Table 28. Game -2 ratings of Perceived Stress from study 5. 186

Table 29. Game -2 ratings of Perceived Sleep Quality from study 5. 187

List of Figures

Figure 1. Wellness questionnaire used in studies 3 and 5. 129
List of Symbols and Abbreviations

Symbols

Dot (·) above any symbol indicates a time derivative
< less than
> greater than
± plus or minus
% percent
p statistical significance
° degree

Units of Measurement

ANOVA analysis of variance
AU arbitrary units
b·min⁻¹ beats per minute
CI confidence interval
cm centimeter
CV coefficient of variance
d Cohen’s effect size statistic
g gram
G gravitational force
Hz hertz
kg kilogram
km·h⁻¹ kilometers per hour
m meters
m·s⁻¹ meters per second
m·s⁻² meters per second squared
mm  millimeter
n²  eta-square
OLS  ordinary least squares
pNN50  time domain measure of heart rate variability
r  Pearson's product moment correlation coefficient
sec  seconds

Variables and Abbreviated Terms

ABQ  athlete burnout questionnaire
AFL  Australian football league
ANS  autonomic nervous system
ARF  Australian rules football
ASRM  athlete self-report measure
ATPase  enzyme catalyzing hydrolysis of adenosine triphosphate
BAM  brief assessment of mood
Ca²⁺  calcium ion
CK  creatine kinase
CMJ  countermovement jump
CNS  central nervous system
DALDA  daily analysis of life demands for athletes
DB  defensive back
DE  defensive end
DJ  depth jump
DT  defensive tackle
ECG  electrocardiogram
FBS  football bowl subdivision
GPS  global positioning systems
HF  high frequency
HFF  high frequency fatigue
HFnu  high frequency power expressed in normal units
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>heart rate</td>
</tr>
<tr>
<td>HRmax</td>
<td>maximum heart rate</td>
</tr>
<tr>
<td>HRV</td>
<td>heart rate variability</td>
</tr>
<tr>
<td>IA</td>
<td>integrated accelerometer</td>
</tr>
<tr>
<td>K+</td>
<td>potassium ion</td>
</tr>
<tr>
<td>KE</td>
<td>knee extension</td>
</tr>
<tr>
<td>KF</td>
<td>knee flexion</td>
</tr>
<tr>
<td>LB</td>
<td>linebacker</td>
</tr>
<tr>
<td>LF</td>
<td>low frequency</td>
</tr>
<tr>
<td>LFF</td>
<td>low frequency fatigue</td>
</tr>
<tr>
<td>LFnu</td>
<td>low frequency power expressed in normal units</td>
</tr>
<tr>
<td>MVC</td>
<td>maximum voluntary contraction</td>
</tr>
<tr>
<td>n</td>
<td>number of subjects</td>
</tr>
<tr>
<td>Na+</td>
<td>sodium ion</td>
</tr>
<tr>
<td>NCAA</td>
<td>National Collegiate Athletic Association</td>
</tr>
<tr>
<td>NMF</td>
<td>neuromuscular fatigue</td>
</tr>
<tr>
<td>N-N</td>
<td>normal-to-normal intervals on an electrocardiogram</td>
</tr>
<tr>
<td>NRL</td>
<td>national rugby league</td>
</tr>
<tr>
<td>OL</td>
<td>offensive linemen</td>
</tr>
<tr>
<td>PF</td>
<td>peak force</td>
</tr>
<tr>
<td>PL</td>
<td>player load</td>
</tr>
<tr>
<td>PLmax</td>
<td>maximum player load</td>
</tr>
<tr>
<td>PLmean</td>
<td>mean player load</td>
</tr>
<tr>
<td>PNS</td>
<td>parasympathetic nervous system</td>
</tr>
<tr>
<td>POMS</td>
<td>profile of mood states</td>
</tr>
<tr>
<td>POMS-A</td>
<td>profile of mood states for adolescents</td>
</tr>
<tr>
<td>PP</td>
<td>peak power</td>
</tr>
<tr>
<td>Pre-season1</td>
<td>week one of pre-season camp</td>
</tr>
<tr>
<td>Pre-season2</td>
<td>week two of pre-season camp</td>
</tr>
<tr>
<td>Pre-season3</td>
<td>week three of pre-season camp</td>
</tr>
<tr>
<td>PRFD</td>
<td>peak rate of force development</td>
</tr>
<tr>
<td>QB</td>
<td>quarterback</td>
</tr>
</tbody>
</table>
QRS  graphical deflections seen on an electrocardiogram
RB   running back
REST-Q Sport recovery-stress questionnaire for athletes
RFD  rate of force development
RMSSD root mean square of the successive differences
R-R  interval between successive R’s on an electrocardiogram
SD   standard deviation
SDNN standard deviations of normal-to-normal intervals
SJ   squat jump
SNS  sympathetic nervous system
SPSS statistical package for the social sciences
SSC  stretch shortening cycle
TE   tight end
TRIMP training impulse
VJ   vertical jump
VO₂max maximum oxygen uptake
WR   wide receiver
### List of Appendices

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix A</td>
<td>Participant Explanatory Statement: Study 1-2</td>
<td>210</td>
</tr>
<tr>
<td>Appendix B</td>
<td>Participant Informed Consent: Study 1-2</td>
<td>215</td>
</tr>
<tr>
<td>Appendix C</td>
<td>Participant Explanatory Statement: Study 3-5</td>
<td>220</td>
</tr>
<tr>
<td>Appendix D</td>
<td>Participant Informed Consent: Study 3-5</td>
<td>222</td>
</tr>
<tr>
<td>Appendix E</td>
<td>Perceived Wellness Questionnaire</td>
<td>224</td>
</tr>
</tbody>
</table>
# Table of Contents

Preface

Navigation of the Thesis

Acknowledgements

Abstract

<table>
<thead>
<tr>
<th>Chapter 3 (Study 1 – Paper 1)</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 4 (Study 2 – Paper 2)</td>
<td>11</td>
</tr>
<tr>
<td>Chapter 5 (Study 3 – Paper 3)</td>
<td>11</td>
</tr>
<tr>
<td>Chapter 6 (Study 4 – Paper 4)</td>
<td>12</td>
</tr>
<tr>
<td>Chapter 7 (Study 5 – Paper 5)</td>
<td>13</td>
</tr>
</tbody>
</table>

List of Publications | 15

List of Conference Proceedings | 15

List of Tables | 16

List of Figures | 17

List of Symbols and Abbreviations | 18

List of Appendices | 22

Chapter 1

<table>
<thead>
<tr>
<th>1.1 Introduction</th>
<th>29</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 Purpose of the Research</td>
<td>33</td>
</tr>
<tr>
<td>1.3 Significance of the Research</td>
<td>33</td>
</tr>
<tr>
<td>1.4 Research Questions</td>
<td>34</td>
</tr>
<tr>
<td>1.5 Research Progress Linking the Experimental Studies</td>
<td>35</td>
</tr>
</tbody>
</table>

Chapter 2

Overview of the Literature | 38

<table>
<thead>
<tr>
<th>2.1 NCAA Division I College Football</th>
<th>38</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1.1 Physical Demands Associated with NCAA Division I College Football</td>
<td>38</td>
</tr>
<tr>
<td>2.1.2 Anthropometric and Physiological Characteristics of NCAA Football Players</td>
<td>41</td>
</tr>
</tbody>
</table>

| 2.2 Global Positioning Systems | 45 |
2.2.1 Performance Analysis Using GPS  45
2.2.2 Validity and Reliability of GPS Analysis  48
2.2.3 GPS Analysis in Contact Team Sports  50
2.2.4 GPS Analysis in College Football  54

2.3 Athlete Monitoring Strategies  56
  2.3.1. Monitoring the Training Response  56
    2.3.1.1 Heart Rate Variability  57
    2.3.1.2 Biochemical Measures  61
    2.3.1.3 Neuromuscular Measures  63
    2.3.1.4 Athlete Self Report Measures  70
  2.3.2 Self-Report Measures of Perceived Wellness  76
    2.3.2.1 Profile of Mood States (POMS)  76
    2.3.2.2 Recovery-Stress Questionnaire for Athletes (RESTQ-Sport)  77
    2.3.2.3 Daily Analysis of Life Demands for Athletes (DALDA)  79
    2.3.2.4 Custom Questionnaires  80
  2.3.3 Considerations for Athlete Monitoring  82

2.4 Summary  85

Chapter 3  87
Quantification of Competitive Game Demands of NCAA Division I College Football Players Using Global Positioning Systems

  3.1 Introduction  87
  3.2 Methods  89
    3.2.1 Experimental Approach to the Problem  89
    3.2.2 Subjects  89
    3.2.3 Procedures  91
    3.2.4 Global Positioning System Units  91
    3.2.5 Movement Classification System  92
    3.2.6 Statistical Analyses  93
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3 Results</td>
<td>93</td>
</tr>
<tr>
<td>3.3.1 Offense</td>
<td>93</td>
</tr>
<tr>
<td>3.3.2 Defense</td>
<td>96</td>
</tr>
<tr>
<td>3.4 Discussion</td>
<td>98</td>
</tr>
<tr>
<td>3.5 Practical Applications</td>
<td>102</td>
</tr>
<tr>
<td><strong>Chapter 4</strong></td>
<td>104</td>
</tr>
<tr>
<td>Quantification of Accelerometer Derived Impacts Associated with Competitive Games in NCAA Division I Football Players</td>
<td>104</td>
</tr>
<tr>
<td>4.1 Introduction</td>
<td>104</td>
</tr>
<tr>
<td>4.2 Methods</td>
<td>106</td>
</tr>
<tr>
<td>4.2.1 Experimental Approach to the Problem</td>
<td>106</td>
</tr>
<tr>
<td>4.2.2. Subjects</td>
<td>107</td>
</tr>
<tr>
<td>4.2.3 Procedures</td>
<td>108</td>
</tr>
<tr>
<td>4.2.4 Global Positioning System Units</td>
<td>108</td>
</tr>
<tr>
<td>4.2.5 Impact Classification System</td>
<td>110</td>
</tr>
<tr>
<td>4.2.6 Statistical Analyses</td>
<td>111</td>
</tr>
<tr>
<td>4.3 Results</td>
<td>111</td>
</tr>
<tr>
<td>4.3.1 Offense</td>
<td>111</td>
</tr>
<tr>
<td>4.3.2 Defense</td>
<td>112</td>
</tr>
<tr>
<td>4.4 Discussion</td>
<td>113</td>
</tr>
<tr>
<td>4.5 Practical Applications</td>
<td>119</td>
</tr>
<tr>
<td><strong>Chapter 5</strong></td>
<td>121</td>
</tr>
<tr>
<td>Movement Demands and Perceived Wellness Associated with Pre-season Training Camp in NCAA Division I College Football Players</td>
<td>122</td>
</tr>
<tr>
<td>5.1 Introduction</td>
<td>121</td>
</tr>
<tr>
<td>5.2 Methods</td>
<td>124</td>
</tr>
<tr>
<td>5.2.1 Experimental Approach to the Problem</td>
<td>124</td>
</tr>
<tr>
<td>5.2.2. Subjects</td>
<td>125</td>
</tr>
<tr>
<td>5.2.3 Procedures</td>
<td>126</td>
</tr>
<tr>
<td>5.2.4 Global Positioning System Units</td>
<td>126</td>
</tr>
</tbody>
</table>
Chapter 7

Perceived Wellness Associated with Practice and Competition in NCAA Division I Football Players

7.1 Introduction

7.2 Methods

7.2.1 Experimental Approach to the Problem

7.2.2 Subjects

7.2.3 Procedures

7.2.4 Global Positioning System Units

7.2.5 Movement Classification System

7.2.6 Perceived Wellness

7.2.7 Statistical Analyses

7.2.7.1 Game +1 Model

7.2.7.2 Game -2 Model

7.3 Results

7.3.1 Game +1 Perceived Wellness

7.3.2 Game -2 Perceived Wellness

7.4 Discussion

7.5 Practical Applications

Chapter 8

General Discussion, Conclusions, and Recommendations for Future Research

8.1 Quantification of Competitive Game Demands of NCAA Division I College Football Players Using Global Positioning Systems

8.2 Quantification of Accelerometer Derived Impacts Associated with Competitive Games in NCAA Division I Football Players

8.3 Movement Demands and Perceived Wellness Associated with Pre-season Training Camp in NCAA Division I College Football Players

8.4 A Comparison of Pre-season and In-season Practice and Game Loads in NCAA Division I Football Players

8.5 Perceived Wellness Associated with Practice and Competition in NCAA Division I Football Players