A COMPARISON OF THE NATIONAL FOOTBALL LEAGUE COACHES STRENGTH AND CONDITIONING PRACTICES 1997-1998 TO 2018

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A Comparison of the National Football League Coaches Strength and Conditioning Practices
1997-1998 to 2018

By:

Corey F. Fitzgerald

THESIS

Submitted to
Northern Michigan University
In Partial fulfillment of the requirements
For the degree of

MASTER’S OF SCIENCE

School of Health & Human Performance
Office of Graduate Education and Research
SIGNATURE APPROVAL FORM


The thesis by Corey F. Fitzgerald is recommended for approval by the student’s Thesis Committee and Department Head in the Department of Health and Human Performance and by the Assistant Provost of Graduate Education and Research.

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Abstract

This study describes the results of a survey of the strength and conditioning practices of the National Football League’s (NFL) strength and conditioning (S&C) coaches. The primary purpose was to identify the common and unique aspects of the NFL S&C practices during 2018. A secondary purpose was to compare those results to 1997-1998 (‘97-98) to determine differences across years. The survey response rate was 28.1% (9 of 32 NFL teams) agreeing to participate. The survey instrument was a 150 item assessment divided into 10 sections examining the entire training program. Results revealed that subjects test 6.8 ± 3.1 fitness variables using 9.0 ± 3.7 tests; compared to 7.0 fitness variables using 10.0 tests in ‘97-98. Six subjects prescribe plyometric exercises to “all players” 1.8 ± .4 days per week. During the in-season subjects prescribed resistance training 2.3 ± .8 days per week (n=6); similar to 2.8 ± 0.8 days per week in ‘97-98 (p=.220). Subjects prescribed off-season resistance training 3.5 ± 0.8 days per week; compared to 2.0 ± 2.9 days per week in ’97-98 (p=.007). Five subjects prescribed “all players” balance and stability training “year round”; on average 3.3 ± .9 days per week (n=4). This data should be useful for future research as a source for comparison. With this new source of information, researchers are able to continue to empirically investigate various aspects of training programing. Additionally, a variety of other S&C practices were examined. This research was funded by two Excellence in Education Research Grants.
Acknowledgements

The thesis follows the Journal of Strength and Conditioning Research submission format along with the School of Health and Human Performance at Northern Michigan University. We wish to thank all the survey participants whose time and efforts made this research possible. This research was funded by two Northern Michigan University Excellence in Education Research Grants.

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Abbreviations

Body fat percentage ..............................................................................................(BF%)
Body mass .............................................................................................................(BM)
Carbohydrates ......................................................................................................(CHO)
Creatine ................................................................................................................(Cr)
Dual-energy X-ray absorptiometry ..........................................................................(DEXA)
Essential Amino Acid .........................................................................................(EAA)
Fat mass ...............................................................................................................(FM)
Fat-free mass .......................................................................................................(FFM)
National Collegiate Athletic Association .............................................................(NCAA)
National Football league ......................................................................................(NFL)
One-repetition Maximum .....................................................................................(1RM)
Strength and Conditioning ...................................................................................(S&C)
Strength and Conditioning Coach .........................................................................(S&CC)
Chapter 1.1 - Part I: Background Information, Plyometric, and Speed Training

Introduction

The strength and conditioning (S and C) profession is deeply rooted in American football history (124). Intuitively it appears that from the nature of the sport, S and C is important for success (230). An effective and efficient training program can be achieved by manipulating various training variables and interventions (297). Coaches and sport scientists agree that various physical fitness variables (e.g. strength, power, speed, agility) are essential for performance in football (126).

Elite athletes require effective movement capabilities (e.g. acceleration, change-of-direction, sprint performance) in response to a stimulus that occurs in fractions of a second to be successful (278, 287). Speed training is essential to develop high contractile velocity and biomechanical variables (e.g. increase stride length and acceleration capacity) that enhance sprint performance (173). Another method of improving speed and power is the use of plyometric exercises, which include various stretch-shortening cycle movements (e.g. jumping, bounding, and horizontal movements) that are both unilateral and bilateral (73, 266). Additionally, exercise selection depends upon the purpose of the desired training adaptations (75). However, very few researchers have examined how the National Football League’s (NFL) S and C coaches prescribe these training interventions.
Surveys have been shown to be an effective method to identify and examine S and C practices. A variety of previous surveys have analyzed the S and C practices for high school (79, 148), collegiate (2, 113, 192, 241), and professional sports (81, 82, 83, 251). Ebben and Blackard (81) provided the most comprehensive and in-depth examination of NFL S and C practices. However, the S and C practices of the NFL have not been studied for 20 years.

Whereas previous investigations have examined NFL S and C practices there remain gaps in the literature. To comprehensively examine current NFL S and C practices a three-part research study was conducted. The primary purpose of the current article was to identify the background information of NFL S and C coaches and identify details of current NFL speed and plyometric training programs and practices. A secondary purpose was to compare the results obtained by Ebben and Blackard (81) and current practices to determine differences across time.

Methods

Experimental Approach to the problem

This cross-sectional study was designed to investigate the common and unique aspects of current NFL S and C practices compared to publically accessible data from 1997-98 (‘97-98) (81). The independent variables were the time at which the measurements were taken separated by studies. Dependent variables were demographics, coaching responsibilities, formal education, professional certifications, professional opinions, training frequency and position-specific characteristic variables.
Subjects

Nine of 32 (28.1%) subjects participated in the current research study; details on responses are presented in Table 1.1.1. However, two subjects agreed to participate but did not provide any data; thus excluding them from the current research study. All subjects signed an informed consent to ensure understanding of the purpose and procedures along with all risks and benefits of the study. Subjects were free to not answer or disclose any information they wished on any particular question. Upon completion of the survey each subject received monetary compensation for their time and effort. No subjects’ names were associated with any results to retain anonymity. All procedures were approved by the Institutional Review Board.

- For Table 1.1.1 see page 10 -

Survey

A survey instrument was developed, reviewed, and pilot tested. To ensure clarity and validity, an advisory committee of current S and C coaches and academic professors with qualitative research experience reviewed the instrument. The instrument for the current study was adapted from the research instrument previously used by Ebben and Blackard (81); additionally the instrument was modified to reflect the most current S and C research. The instrument was 37 pages in length, included 150 items divided into 10 sections, and is the most comprehensive strength and conditioning survey ever administered. This article covers (i) background information, (ii) speed development, and (iii) plyometric training. Question format included: open ended questions to allow for greater elaboration, five-point Likert Scale questions, and questions allowing multiple selections to analyze precise detail. The survey instrument was transferred to an electronic analysis software (Qualtrics, LLC research core™, Provo, Utah USA).
**Procedures**

An introductory letter that described the research purposes and implications was mailed to all head NFL S and C coaches; several attempts were made to contact non-responding coaches to increase response rate. Upon coaches’ acceptance of understanding all procedures and risks of the study, subjects received the electronic survey instrument via email access. A secondary email was sent to all subjects who did not respond or complete the survey after the initial email.

**Statistical Analysis**

Collected numerical data were entered into a statistical analysis program (SPSS v. 24.0 IBM). Descriptive statistics were performed for demographic variables. Data between the current study and results obtained by Ebben and Blackard (81) were compared via one sample t-tests using the means from the previous study as the population mean. The alpha level was set at \( p < 0.05 \). Comprehensive non-numerical open-ended data were content analyzed according to methods described by Patton (221), and previously used in studies assessing practices of NFL S and C coaches (81).

**Results**

**Background Information**

In comparing the current results to ‘97-98 (81), findings indicate that there were statistically significant difference for years of NFL coaching tenure (6.52: ’97-98; 14.3 ± 4.9: 2018) \( (p=.005) \). Subjects had 25.6 ± 5.6 years of S and C coaching experience and reported 3.9 ± 1.1 S and C staff members per teams (n=7). Subjects’ coaching responsibilities included “all
aspects of strength development, running protocols, and assist in recovery modalities, nutrition”,
“maintain and develop clubs strength and conditioning facility and equipment”, and “provide
recommendations to the Head Football Coach in hiring strength and conditioning staff”. Six
subjects reported having a Bachelor’s degree; majors included “Biology/ Pre-Med”, “Health and
Sport Science”, and “Science in Physical Education”; while, four subjects indicated obtaining a
Master’s degree. Professional certification results are illustrated in Figure 1.1.1.

-For Figure 1.1.1 see page 15 –

Speed Development

Six subjects reported prescribing speed training. During the season, speed training was
prescribed 1.0 ± 0.0 d/wk (n=2); compared to 2.0 ± 0.0 d/wk (n=6) during the off-season. In
response to the question assessing the most common positional group to which speed training
was prescribed, the most common answer was “all players” (n=5); however, one subject
indicated prescribing speed training to all skill positions excluding linemen, kickers, and long
snappers. The most common mesocycles in which subjects implemented speed training were
“year round” and “other” (n=2); however, no other data were provided. Additionally, one subject
indicated they did not prescribe speed training in post-training camp. Subjects reported the
specific speed exercises prescribed (see Table 1.1.2) and the method for integrating speed
training (see Figure 1.1.2). Five subjects reported utilizing global positioning systems; while one
subject indicated not utilizing this technology.

-For Table 1.1.2 see page 11 –

-For Figure 1.1.2 see page 16 –
Plyometric Training

Six subjects prescribed plyometric exercises to “all players” for a frequency of 1.8 ± 0.4 d/wk. Subjects identified when plyometric training was prescribed and the type of exercises prescribed (see Figure 1.1.3 and Table 1.1.3) as well as their methods for integrating plyometric training (see Figure 1.1.4). Subjects provided professional opinions and the purpose of prescribing various speed and plyometrics (see Tables 1.1.4-1.1.5).

- For Figure 1.1.3 see page 17 -
- For Figure 1.1.4 see page 18 -
- For Table 1.1.3 see page 12 –
- For Table 1.1.4 see page 13-
- For Table 1.1.5 see page 14-

Discussion

This is the first comprehensive survey of NFL S and C practices in nearly 20 years. The statistically significant differences found between the current study and that of Ebben and Blackard (81), demonstrate that training practices have been evolving over the last 20 years. Despite numerous attempts to enhance the response, the survey response rate of 28.1% (9 of 32 NFL teams) was substantially lower than the previous response rate of 87% (26 of 30 NFL teams) (81). However, the current response rate did exceed various other S and C survey research, which ranged from 11.4 to 27.7% (113, 148, 241). It is important to note, that six subjects directly expressed a desire not to participate in this research; compared to one coach in the previous study (81). These findings suggest that current NFL S and C coaches may be less
willing to share information regarding programming. This claim is supported by one subject who stated “sorry, this is something that our organization does not allow us to be a part of.”

The current study subjects’ NFL tenure was greater than NFL S and C coaches reported in a study published in 1999, whose NFL tenure was 8.7 years (177). Subject’s S and C experience was similar to that of NFL S and C coaches that reported in a study published in 1999, who had on average 26.6 years. In the current study, no subjects reported having additional positional coaching responsibilities; compared to four (15.3%) coaches in the previous study; who reported coaching special teams, assistant with special teams, and defensive quality control coach (81). This finding suggests that NFL S and C coaches are becoming more specialized and primarily focused on enhancing athletes’ on-field performance; and those teams are allocating more resources to this position.

Formal education and professional certifications were not investigated in the previous study (81). Most strength and conditioning coaches in all divisions of collegiate athletics, are earning Master’s degrees (113). The most common professional certification for the subjects in the current study was Certified Strength and Conditioning Specialist (CSCS) offered by the National Strength and Conditioning Association. The percentage of coaches who had this certification (55.5%) was higher compared to NFL S and C coaches in a study published in 1997 (31.2%) (265). Additionally, the finding of the current study is in agreement with previous literature that found the CSCS to be the most common certification for head S and C coaches (34, 231). The CSCS remains the certification of choice for head S and C coaches. Furthermore, these findings suggest the importance of obtaining a Master’s degree and certification in the S and C field. It should be noted that one subject did not provide any further data following the background section.
Speed training was prescribed by all subjects in both the previous (81) and current study. Subjects reported speed training frequency consistent with recommendations of one to two days per week (162). This prescription can improve acid-base buffering capacity; thus decreasing the occurrence of performance decrements in power and speed during competition (164). Additionally, subjects indicated variations in the specific positions that received speed training. One subject reported that offensive and defensive linemen were excluded from speed training. This finding may be explained in that linemen rely more on strength, power, and acceleration than linear speed (140).

Form running was among the most common speed exercises prescribed during the current and previous study of NFL S and C practices (81). Running technique is essential for sprint performance and directional changes (245). Additionally, resisted running was regularly prescribed by subjects in both studies (81). High resistance running can enhance acceleration; while moderate resistance running can improve speed endurance (58, 74).

Five subjects reported utilizing global positioning systems; this was not previously investigated in the previous study, possibly due to the fact that this technology was not readily available. This microtechnology provides an accurate representation of acute physiological stress experienced and produces quantifiable data related to player movement (75, 85). Additionally, advanced technology has provided quantitative data for monitoring training status, load, and response to physiological stressors (91). These findings validate a finding from a study published in 2005, in which a National Basketball Association S and C coach predicted that technology will enable coaches to make gains towards a higher level of training (251).

All coaches in the current study prescribed plyometric training compared to 73.1% in the previous study (81). Current findings contrasted with previous literature, the percentage of
coaches implementing complex training increased from (26.9%) in the previous study to (83.3%) during the current study (81). This finding could be due to the fact that complex training is superior compared to only utilizing one training intervention (73). Complex training is also an effective organizational strategy that incorporates resistance training and plyometric exercises during the same training session (143). During the current study one subject stated that “all aspects of plyometrics differ, different exercise for different times of the year”. This suggests there may be a substantial amount of training variable manipulation occurring during the training program.

**Practical Application**

This article describes the background information, speed training, and plyometric training programs of NFL S and C coaches. These data are useful for practitioners who seek ideas for the implementation of these training strategies and for future research as a source of comparison. Furthermore, with this updated information regarding NFL S and C training data, researchers are able to continue to empirically investigate various aspects of training programing. Additionally, current S and C coaches at all levels can review these data as a source of new ideas and consequently alter current and traditional methods of training. Future research should examine more detailed aspects of how coaches are manipulating various training variables, specifically for the position groups.
Table 1.1.1 – Response rate for the current study and that of a 1999 study of NFL S and C coaches (81).

<table>
<thead>
<tr>
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<tr>
<td></td>
<td>n</td>
<td>Percentage (%)</td>
<td>n</td>
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<td>Acceptance</td>
<td>26</td>
<td>86.6</td>
<td>9</td>
</tr>
<tr>
<td>Decline</td>
<td>1</td>
<td>3.3</td>
<td>6</td>
</tr>
<tr>
<td>No response</td>
<td>3</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Total response rate</td>
<td>27</td>
<td>90</td>
<td>15</td>
</tr>
</tbody>
</table>
Table 1.1.2 - Speed training exercises subjects prescribed in the current study and that of a 1999 study of NFL S and C coaches (81).

<table>
<thead>
<tr>
<th>Category</th>
<th>97-98 Response</th>
<th>n</th>
<th>2018 Response</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form running</td>
<td>“All aspects stride frequency and stride length”, “form running (only to correct major flaws)”</td>
<td>4</td>
<td>“Resistance running: sled pulls, tethers, weighted vest.”</td>
<td>4</td>
</tr>
<tr>
<td>Resisted running</td>
<td>“Hill resistance”, “sleds with a partner”</td>
<td>17</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Speed endurance</td>
<td>“Longer in [the] off-season, 100 and 200s down to 40s and under”</td>
<td>21</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Plyometrics</td>
<td></td>
<td>17</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Over-speed running</td>
<td>“Assisted over-speed running”</td>
<td>15</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>“1-legged 30 to 40–yd runs” “positional-specific speed workouts” “the best way to develop speed is to do speed work. Running fast, running 40s, 20s, and 10s is the best way to develop speed” “mini-hurdle drills, quick foot ladder drills, and cone drills” “sprint work” “stride length and stride speed drills” and “upper-body mechanics training”</td>
<td>7</td>
<td>“Sprint training”</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 1.1.3- Plyometric exercises subjects prescribed in the current study and that of a 1999 study of NFL S and C coaches (81).

<table>
<thead>
<tr>
<th>Category</th>
<th>‘97-98 Response</th>
<th>n</th>
<th>2018 Response</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bounding activities</td>
<td></td>
<td>17</td>
<td>“Bounding”</td>
<td>3</td>
</tr>
<tr>
<td>Multiple hops and jumps</td>
<td></td>
<td>17</td>
<td>“Cone hops and line hops”</td>
<td>3</td>
</tr>
<tr>
<td>Box drills</td>
<td></td>
<td>15</td>
<td>“Box jumps”</td>
<td>2</td>
</tr>
<tr>
<td>Standing jumps</td>
<td></td>
<td>12</td>
<td>“Vertical jumps”</td>
<td>1</td>
</tr>
<tr>
<td>Upper-body plyometrics</td>
<td></td>
<td>12</td>
<td>“Med ball work and explosive push up variations”</td>
<td>2</td>
</tr>
<tr>
<td>Jumps in place</td>
<td></td>
<td>12</td>
<td>“Jump rope”</td>
<td>1</td>
</tr>
<tr>
<td>Depth jumps</td>
<td></td>
<td>7</td>
<td>“Fewer depth jumps with the larger guys”</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>5</td>
<td>“All aspects of plyometrics differ, different exercise for different times of the year”, “jump landing mechanics”, “band resisted and assisted jumps” and “variety”</td>
<td>4</td>
</tr>
</tbody>
</table>

“1-legged 30 to 40–yd runs”
“mini-hurdles, quick foot ladder”
“plyometric push-ups”
“weighted plyometrics such as log training, bounds, hops, split jumps, etc., with a log on your shoulders”
“cord-resisted jumps to free jumps; this would include dumbbell jumps to free jumps”
Table 1.1.4 – Subjects’ professional opinions on various aspects of S and C.

<table>
<thead>
<tr>
<th>Question</th>
<th>Extremely % (n)</th>
<th>Very % (n)</th>
<th>Moderately % (n)</th>
<th>Slightly % (n)</th>
<th>Not at all % (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed development?</td>
<td>50.0 (3)</td>
<td>16.7 (1)</td>
<td>33.3 (2)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Plyometric training?</td>
<td>33.3 (2)</td>
<td>33.3 (2)</td>
<td>33.3 (2)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### Table 1.1.5 - Subjects primary purpose for prescribing various training interventions.

<table>
<thead>
<tr>
<th>Training intervention</th>
<th>Response (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed training</td>
<td>“injury prevention and resilience” (3) “improve or maintain speed” (2), to “create better mechanics, speed, and better running efficiency which will help players endurance and reduce risk of injury”, and “it’s a game of speed” (1)</td>
</tr>
<tr>
<td>Plyometric training</td>
<td>“develop and maintain explosive power” (4) “injury prevention and resilience”, “link between the weightroom and the football field” and “improve power, help players learn how to absorb force and redirect it and to prepare musculature, ligaments, and tendons for forces that will be felt on the field” (1)</td>
</tr>
</tbody>
</table>

Note – responses are raw data provided by subjects
CSCS – represents National Strength and Conditioning Association, Certified Strength and Conditioning Specialists
SCCC - represents Collegiate Strength and Conditioning Coaches Association, Strength and Conditioning Coach Certified
USAW – represents USA Weightlifting Certification
PN1- represents Precision Nutrition Level 1 Certification
FMS - represents Functional Movement Screen Certification
MSCC - represents Collegiate Strength and Conditioning Coaches Association, Master Strength and Conditioning Coach
ACSM – represents Undisclosed American College of Sports Medicine Certification
PES – represents National Academy of Sport Medicine, Performance Enhancement Specialist
CES – represents National Academy of Sport Medicine, Corrective Exercise Specialist

**Figure 1.1.1** – Professional certifications subjects obtained.
Note – other comments included “2 days a week in the off-season and 1 day a week during in-season until game 12”, “a section during the run days”, and “during off-season training 2 days per week vertical speed and plyometric work and 2 days change-of-direction before strength training and in certain phases integrated into strength and power program”

Figure 1.1.2 - How current subjects integrate speed training.
Note – during the current research study other comments included “leg days”, “in speed and agility session” and “depending on phases of training plyometrics are done prior to strength program (with speed program) or often integrated with strength programs as complexes”; in ’97-98 other comments included “speed days” when athletes had some form of plyometric training, conducting plyometric training while they “perform agility drills” and “performing a combination of separate days, after weight training, and complex training.”

**Figure 1.1.3** - How subjects integrate plyometric training in the current study compared to that of a 1999 study of NFL S and C coaches (81).
Note – one subject reported “other”; however, no other data were provided.

**Figure 1.1.4** – When subjects’ implement plyometric training in the current study and that of a 1999 study of NFL S and C coaches (81).
Chapter 1.2 - Part II: Physical Fitness Testing and Program Design

Introduction

An effective resistance training program specifically for athletes (i.e. American Football) can enhance strength, power, body composition, and physiological processes (5, 253). One way to effectively manipulate acute training variables is via periodization programming. Periodization is a logical methodology to manipulate training variables into sequential mesocycles (17).

Physical fitness testing is commonly implemented as a means to establish a baseline for individuals and evaluate the effectiveness of a training program (66). The selection of physical fitness tests should be to adequately measure and address strength, power, and movement coordination (118). However, very few researchers have examined how the National Football League’s (NFL) S and C coaches prescribe these training interventions and manipulate these variables.

Whereas previous investigations have examined NFL S and C practices there remain gaps in the literature. To comprehensively examine current NFL S and C practices a three-part research study was conducted. The primary purpose of the current article was to identify physical fitness testing and resistance training programs and practices implemented in 2018. A secondary purpose was to compare the results obtained by Ebben and Blackard (81) and current practices to determine differences across time.
Methods

Experimental Approach to the problem

This cross-sectional study was designed to investigate the common and unique aspects of current NFL S and C practices compared to publically accessible data from 1997-98 (‘97-98) (81). The independent variables were the time at which the measurements were taken separated by studies. Dependent variables were fitness variables tested and methodologies utilized to determine training load, repetitions, sets, exercise order, and professional opinions.

Subjects

Nine of 32 (28.1%) subjects participated in the current research study; details on responses are presented in Table 1.2.1. However, two subjects agreed to participate but did not provide any data; thus excluding them from the current research study. All subjects signed an informed consent to ensure understanding of the purpose and procedures along with all risks and benefits of the study. Subjects were free to not answer or disclose any information they wished on any particular question. Upon completion of the survey each subject received monetary compensation for their time and effort. No subjects’ names were associated with any results to retain anonymity. All procedures were approved by the Institutional Review Board.

- For Table 1.2.1 see page 31 -

Survey

A survey instrument was developed, reviewed, and pilot tested. To ensure clarity and validity, an advisory committee of current S and C coaches and academic professors with qualitative research experience reviewed the instrument. The instrument for the current study was adapted from the research instrument previously used by Ebben and Blackard (81);
additionally the instrument was modified to reflect the most current S and C research. The instrument was 37 pages in length, included 150 items divided into 10 sections, and is the most comprehensive strength and conditioning survey ever administered. This article covers (i) physical fitness testing and (ii) resistance training. Question format included: open ended questions to allow for greater elaboration, five-point Likert Scale questions, and questions allowing multiple selections to analyze precise detail. The survey instrument was transferred to an electronic analysis software (Qualtrics, LLC research core TM, Provo, Utah USA).

*Procedures*

An introductory letter that described the research purposes and implications was mailed to all head NFL S and C coaches; several attempts were made to contact non-responding coaches to increase response rate. Upon coaches’ acceptance of understanding all procedures and risks of the study, subjects received the electronic survey instrument via email access. A secondary email was sent to all subjects who did not respond or complete the survey after the initial email.

*Statistical Analysis*

Collected numerical data were entered into a statistical analysis program (SPSS v. 24.0 IBM). Descriptive statistics were performed for physical fitness tests, frequencies, and durations of variables. Data between the current study and results obtained by Ebben and Blackard (81) were compared via one sample t-tests using the means from the previous study as the population mean. The alpha level was set at p < 0.05. Comprehensive non-numerical open-ended data were content analyzed according to methods described by Patton (221), and previously used in studies assessing practices of NFL S and C coaches (81).
Results

Physical Fitness Testing

Six subjects conducted physical fitness testing. In comparing the current results to ‘97-98 (81), findings indicate that there were similar findings for number of fitness variables measured (7.0: ’97-98; 6.8 ± 3.1: 2018) (p=.899) and testing methodologies utilized (10.0:’97-98; 9.0 ± 3.7: 2018) (p=.582). Measured fitness variables and test methodologies used are shown in Table 1.2.2. Six subjects assessed “all players” body composition 5.3 ± 4.6 times per year. In response to the question assessing the most common positional group to which measured muscular strength, the most common answer was “all players” (n=4); however, one subject reported testing all positions, except quarterbacks. Subjects measure muscular strength 4.0 ± 4.4 times per year (n=5); and conducted aerobic capacity tests 1.5 ± 0.7 times per year (n=2); on “all players” (n=1). Agility tests were conducted 2.0 ± 1.4 times per year; on “all players” (n=2). Anaerobic capacity was measured 1.5 ± 0.7 times per year; on “all players” (n=2). Muscular power was measured 6.0 ± 5.3 times per year; on “all players” (n=3). Speed tests were conducted 3.0 ± 1.4 times per year; on “all players” (n=2). Subjects measured flexibility 1.7 ± 0.6 times per year; with “all players” (n=3). One subject reported measuring acceleration 4.0 times per year on “all players”. Subjects measured anthropometrics 8.3 ± 6.4 times per year (n=3); with “all players” (n=2). One subject reported measuring muscular endurance; however, no other data were provided. Two subjects reported testing “other” physical fitness variables. Subjects identified that fitness variables were assessed at different times during the year (see Table 1.2.3). Four subjects reported modifying individual training programs based on physical fitness test results.

- For Table 1.2.2 see page 32 –

- For Table 1.2.3 see page 33 –
Resistance Training

Six subjects prescribed resistance training. In the comparison of the current results to ‘97-98 (81), findings indicate that there significant differences for off-season resistance training frequency d/wk (2.0: ‘97-98; 3.5 ± 0.8: 2018) (p= .007). During the off-season subjects reported training session duration of 70.0 ± 35.1 minutes. In the comparison of the current results to ‘97-98 (81), findings indicate that there were similar findings for in-season resistance training frequency d/wk (2.8: ’97-98; 2.3 ± 0.8: 2018) (p= .220) and in-season training session duration minutes (48.5: ’97-98; 37.5 ± 12.5: 2018) (p= .085).

All subjects indicated using a periodization model; specific models included “undulating”, “other” (n=2), and “linear” (n=1). On average subjects implemented 6.3 ± 3.2 mesocycles during the macrocycle (n=3). One subject described the goal of each mesocycle stating “Mesocycle 1: unload, Mesocycle 2: corrective-stability, Mesocycle 3: hypertrophy and work capacity, Mesocycle 4: strength, Mesocycle 5: elastic equivalent-power”. Furthermore, one other subject described the duration and goals of each mesocycle stating “Mesocycle 1: (9 weeks) work capacity, corrective, mobility, and strength; Mesocycle 2: (6 weeks) corrective, mobility, strength, and power; Mesocycle 3: (20 weeks) strength, power, and maintenance; Mesocycle 4: (17 weeks) regeneration, recovery, corrective, mobility, and strength”. Subjects identified the specific methodologies utilized to determine training load, sets and repetitions, rest intervals, exercise order, and the most important exercises prescribed (see Tables 1.2.4-1.2.9). Four subjects reported prescribing variations in repetition tempo during resistance training; while one did not. No other data were provided related to repetition tempo manipulation. Five subjects designed training programs based on position-specific needs.

- For Table 1.2.4 see page 34 –
Five subjects implemented a pre-resistance training warm-up; while one subject did not. The average pre-resistance training warm-up duration was 12.0 ± 4.5 minutes. Four subjects implemented a post-resistance training cool-down; while two subjects did not. The average post-resistance training cool-down duration was 10 minutes. Four subjects utilized power output analyzers during resistance training sessions; while one subject indicated not utilizing this technology. Additionally, subjects provided professional opinions regarding various questions (see Table 1.2.10).

Discussion

Surprisingly, one subject reported not conducting physical fitness testing; similar to two coaches in the previous study (81). These findings are in contrast to previous literature that states, conducting regular physical fitness tests are recommended, as it can identify areas of weakness and evaluate the effectiveness of the training program (242). Current subjects indicated testing a similar number of fitness variables and used a comparable number of tests as coaches in the previous study (81). Additionally, these findings validate findings from previous literature, in which National Hockey League S and C coaches measured 7.4 fitness variables using 9.8 tests and National Basketball Association S and C coach measured 7.3 fitness variables using 7.8 tests (82, 251). The results of the current research revealed greater variations in which specific
mesocycle testing occurred and positions tested, regarding specific fitness variables. This suggests that the S and C coaches are utilizing sport-specific and position-specific physical fitness tests.

Current findings contrasted with previous literature, the percentage of coaches measuring muscular strength increased from (50%) in the previous study to (85.7%) during the current study (81). This finding is similar to those of anaerobic capacity (34.6%: ’97-98; 57.1%: 2018), muscular power (34.6%: ’97-98; 57.1%: 2018), flexibility (30.7%: ’97-98; 57.1%: 2018), anthropometric measurements (19.2%: ’97-98; 57.1%: 2018), agility (34.6%: ’97-98; 42.8%: 2018), speed (34.6%: ’97-98; 42.8%: 2018), and acceleration (23.1%: ’97-98; 28.5%: 2018) (81). It is important to note, that one subject did not provide any further data following the physical fitness variables section.

It should be noted that only one subject reported utilizing a Dual-energy X-ray absorptiometry (DEXA); similar to a study published in 2015, when only one NFL team reported using DEXA scans (213). These findings are surprising as DEXA has been established as a superior testing methodology for body composition (213). However, the DEXA methodology is very expensive to utilize (213), which may explain why very few teams are using it.

The results from the current study found that subjects tested muscular strength regularly. This finding could be due to the fact that maximum strength changes rapidly and frequent testing is recommended (14). It is critical to note, that during the current study one subject stated quarterbacks were (or “are”) not tested for muscular strength. However, muscular strength is a vital component for all positions in football (136). For example, quarterbacks need arm and hip strength to have successful on-field performance (161). Thus, suggesting that all players’ muscular strength should be assessed. Nevertheless, Fitzgerald and Jensen (90) found that
quarterbacks routinely do not participate in the NFL 225 lb (102.06 kg) bench press during the NFL Combine. Further research is required to determine if S and C coaches should measure all positions for muscular strength.

Coaches continue to test aerobic capacity despite previous literature establishing that the predominant energy contribution during football is through the phosphagen system (125). The calculated work-to-rest ratio was 1:6.2 during an NFL game, regardless of position (169, 284). While aerobic processes are important for the recovery system, determination of this capacity is likely not necessary.

One subject indicated utilizing a multiple sprint test; however, no other data were provided regarding the specific protocol. During the previous study two coaches used multiple sprint test protocols of “16x 110-yd sprints” and “14x 40-yd sprints within a designated percentage of the best 40-yd dash time” (81). The advantage of a multiple sprint test methodology is the similarity to the specific demands of football (305). In the current study, one subject reported using a 40-yd dash for skill players and a 20-yd dash for lineman; similar to one coach in the previous study (81). These findings suggest that coaches consider position-specific characteristics when implementing physical fitness testing.

Muscular power was regularly assessed during both studies; this may be due to the fact that the ability to produce high power outputs during movement is essential for sport performance (81, 111). The vertical jump test was the most common muscular power test during both studies (81). Previous literature has established that the vertical jump test is a common and effective muscular power test (47).

One subject reported utilizing the Functional Movement Screen (FMS), which was not previously utilized in the previous study (81). This is likely because the FMS was not introduced
to the public until 1997, but has since been established as a qualitative method to decrease the risk of injury and improve movement patterns by identifying areas of deficiency (28).

One subject measured acceleration by testing 10-15 yd starts; similar to coaches in the previous study (e.g. 20-yd dash and time splits for 0 to 10-yd, 10 to 20-yd, 20 to 30-yd, and 30 to 40-yd) (81). These tests are specific to football as the distance is similar to the average play length of 5-20 yds (32). Additionally, nearly every player executes some form of acceleration on almost all plays (58).

Four subjects reported modifying individual training programs based on physical fitness testing results; this was not previously investigated in the previous study (81). This finding suggests that individual variability should be emphasized when designing the training program. Additionally, large differences in physical characteristics exist between and within positional groups (85). Thus, examining position-specific characteristics will likely improve the training program.

The prescribed in-season resistance training frequency decreased over time (81). These findings are consistent with previous recommendations for resistance training frequency of one to two days per week (5). A weekly split routine allows for training volume to be maintained, while performing fewer sets; thus allowing for greater recovery (243). Although in-season training session duration was not statistically different, it was nearly so. A decrease in training session duration during the in-season suggests that current training programs may be more effective and efficient.

In the comparison of the current results to ‘97-98, findings indicate that all subjects reported utilizing periodized model programs while seven (26.9%) coaches that utilized non-periodized model programs in the previous study (81). Previous literature has established that
periodized model programs are superior compared to non-periodized programs (235, 276). More subjects reported utilizing undulating periodization models compared to linear models. Consistent with this, undulating periodization is superior compared to linear periodization and non-periodized model programs (5).

Training load was regularly determined by formula based methods during both studies (81). Prescribing load based on a zone is an effective loading scheme (5). It is important to note that during the current study, one subject reported that the percentage of max load differs per position group. Thus, indicating that determining training load is position-specific. Four subjects reported utilizing power output analyzers during resistance training sessions. Furthermore, one subject expanded upon this, stating that the bar speed, taken from an estimated 1RM, was utilized to determine training load. This advanced technology (e.g. linear position transducer) allows coaches to identify optimum training loads with less inter-subject variability compared to other methods (98).

Specific ranges were the most common method of determining sets and repetitions during both studies (81). However, the specified sets and repetition ranges varied according to the desired training goal. These findings are supported by a study published in 2009, which reported that multi-set programs are superior compared to single-set programs for enhancing strength (5). During the current study one subject did not report manipulating repetition tempo during resistance training. This finding is in contrast with a study published in 2017, which established that manipulating training tempo can elicit positive training adaptations (68).

The pre-resistance training warm-up duration was 12.0 ± 4.5 minutes; this was not investigated in the previous study. Surprisingly, one subject reported not utilizing a pre-resistance training warm-up. This contrasted with a study published in 2006, which
recommended a 4-15 min pre-activity warm-up to prepare the musculature for the training session (267). Similarly, two subjects reported not utilizing a post-resistance training cool-down. However, a post-activity cool-down immediately following the training session is highly recommended (150).

Exercise order and selection are two critical training variables that affect training program effectiveness (255). Prescribing high velocity and ballistic movements at the start of a training session is recommended because the neuromuscular system is in a non-fatigued state (199). One subject indicated starting the training session with corrective exercises. This finding agrees with recommendations that exercise order should be prioritized to allow for deficient movement patterns to be performed before fatigue is present (199).

Compound movements, such as the squat, are essential exercises to develop key movement patterns for successful sport performance (171). Squats and squat variations were the top ranked exercise during both studies (81). This finding is not surprising as previous literature has established that the squat exercise is the most common exercise prescribed during resistance training in athletics (53). The functional nature of the squat movement can overload the muscles in a safe manner and improve various performance parameters (e.g. countermovement jump, acceleration, running speed) (171).

The hips were ranked as the most important body part to develop. This finding can be explained by the fact that hip extensors are critical for horizontal propulsion at maximum speed and hip flexors can enhance maximum running speed by increasing stride frequency (304). Additionally, hip adductor strength is critical for movement and stability (135).
Practical Application

This article describes the training program design and physical fitness testing implemented by NFL S and C coaches. These data are useful for practitioners who seek ideas for the implementation of these training strategies and for future research as a source of comparison. Furthermore, with this updated information regarding NFL S and C training data, researchers are able to continue to empirically investigate various aspects of training programing. Additionally, current S and C coaches at all levels can review these data as a source of new ideas and consequently alter current and traditional methods of training. Future research should examine more detailed aspects of how coaches are manipulating various training variables, specifically for the position groups.
Table 1.2.1 – Response rate for the current study and that of a 1999 study of NFL S and C coaches (81).

<table>
<thead>
<tr>
<th>Survey response</th>
<th>‘97-98 n ( /30)</th>
<th>Percentage (%)</th>
<th>2018 n ( /32)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance</td>
<td>26 / 30</td>
<td>86.6</td>
<td>9 / 32</td>
<td>28.1</td>
</tr>
<tr>
<td>Decline</td>
<td>1 / 30</td>
<td>3.3</td>
<td>6 / 32</td>
<td>18.7</td>
</tr>
<tr>
<td>No response</td>
<td>3 / 30</td>
<td>10</td>
<td>17 / 32</td>
<td>53.1</td>
</tr>
<tr>
<td>Total response rate</td>
<td>27 / 30</td>
<td>90</td>
<td>15 / 32</td>
<td>46.8</td>
</tr>
</tbody>
</table>
Table 1.2.2 - Physical fitness testing utilized in the current study and that of a 1999 study of NFL S and C coaches (81).

<table>
<thead>
<tr>
<th>Fitness Variable</th>
<th>1997-98 Test methodology (n)</th>
<th>2018 Test methodology (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body composition</td>
<td>Skin calipers (9), hydrodensitometry (3), Skyndex (2), 3-site skin folds using Jackson-Pollock equations, bioelectrical impedance, and underwater weighing of 3–5 players a year (1)</td>
<td>Bioelectrical impedance analysis (2), skin calipers, BOD POD, and DEXA (1)</td>
</tr>
<tr>
<td>Muscular strength</td>
<td>Bench press-max test (7), squat-max test (5), incline bench press max test (2), a bench press repetition test, estimated maximum for bench and leg press, and maximal tests (1)</td>
<td>Bench press (4), squat tests (3), Nordbord (2), vertical jump, force plates, groin bar, grip test, eccentric hamstring strength, adductor iso, 2-3 rep squat, and Other a (1)</td>
</tr>
<tr>
<td>Aerobic capacity</td>
<td>12 min run, 1-mile run (2), a 300 to 400m monitored run, a VO2 max, 3 gasser tests of 200-yd (1:30 rest), 16 110-yd dashes, 300-yd shuttle, and an 800-yd run (1)</td>
<td>2 12-min run test (1)</td>
</tr>
<tr>
<td>Agility</td>
<td>20 yd shuttle (4), a 5-10-5 lateral test and cone drills, a short shuttle, a 60-yd shuttle, a 3-cone drill, and a T-test (1)</td>
<td>3 3-cone/ L-drill (2), pro-agility, and 60-yd shuttle (1)</td>
</tr>
<tr>
<td>Anaerobic capacity</td>
<td>300 yd shuttle (2), consecutive 300-200-100m drills, a shuttle, 16 110-yd sprints and a long shuttle of 300 yd, positional-specific metabolic workouts, and 14 40-yd sprints within a % of the best 40-yd dash time (1)</td>
<td>Multiple sprint test and “40-yd dash for Skill [players] and 20-yd dah for lineman [players]” (1)</td>
</tr>
<tr>
<td>Muscular power</td>
<td>Vertical jump test (8), power clean test (2), standing long jump, a “battery of weight-room tests including a 1RM test and a 225-lb rep test, etc.” and core lifts (1)</td>
<td>4 Vertical/ straight-leg vertical jump (2) and force plate (1)</td>
</tr>
<tr>
<td>Speed</td>
<td>20 and 40-yd dash (4), 40-yd dash (3), 10-20-40 yd dash (2), lineman doing 20-yd dashes and the rest of the team doing 40-yd dashes (1)</td>
<td>3 Flying 20 test and measured stride length and frequency (1)</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Sit-and-reach (5), stand-and-reach (2), a hand-shoulder test, and a hip and groin test (1)</td>
<td>4 Sit-and-reach, FMS, and overhead squat/ ankle mobility (1)</td>
</tr>
<tr>
<td>Acceleration</td>
<td>40 yd dash (2), a 10-20-40-yd progression, a 20-yd dash, a 300-yd shuttle, and 0 to 10-, 10 to 20-, 20 to 30-, 30 to 40–yd splits (1)</td>
<td>2 10-15 yd start (1)</td>
</tr>
<tr>
<td>Anthropometrics</td>
<td>Height and weight (2), arm span, trainer’s measure, and circumference measurements (1)</td>
<td>4 Height, body weight (2) and numerous (1)</td>
</tr>
<tr>
<td>Muscular endurance</td>
<td>225 lb bench repetition test (2), and a “battery of weight-room tests including 1RM, 225-lb repetition test, etc.”</td>
<td>1 N/A</td>
</tr>
<tr>
<td>Other</td>
<td>“every lift is monitored and recorded and that every lifting and training session is viewed as a test”</td>
<td>2 Conditioning tests and wellness readiness markers (1)</td>
</tr>
</tbody>
</table>

a - “Personal records obtained usually 3-5 rep for strength exercises (e.g. squat variations, horizontal and vertical pushes and pulls) 1-3 rep for power exercises (e.g. Power Clean variations) and max reps for body weight exercises (e.g. chin ups) for major exercises used per training cycle”
Table 1.2.3 – Time when subjects conducted physical fitness testing.

<table>
<thead>
<tr>
<th>Fitness Variable</th>
<th>Pre-training camp (n)</th>
<th>Post-training camp (n)</th>
<th>Pre-mini camp (n)</th>
<th>Pre-season (n)</th>
<th>In-season (n)</th>
<th>Post-season (n)</th>
<th>Other (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Comp.</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2^a</td>
</tr>
<tr>
<td>Musc. Str.</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3^b</td>
</tr>
<tr>
<td>Aer. Cap.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Agility</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2^c</td>
</tr>
<tr>
<td>Anaer. Cap.</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1^d</td>
</tr>
<tr>
<td>Musc. Pow.</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2^e</td>
</tr>
<tr>
<td>Speed</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2^f</td>
</tr>
<tr>
<td>Flexibility</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2^g</td>
</tr>
<tr>
<td>Accel.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1^h</td>
</tr>
<tr>
<td>Musc. Endur.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anthropom.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2^i</td>
</tr>
</tbody>
</table>

a - represents “beginning and end of off-season” (2) and during “physicals” (1)
b - represents during “pre off-season”, “developmental April-June”, and “testing of personal records are taken as part of workouts as exercises are cycled through workouts” (1)
c - represents during “end of off-season” and “during off-season program” (1)
d - represents during “end of off-season” (1)
e - represents during “end of off-season” and “throughout” the year (1)
f - represents during the “end of off-season” and “during off-season program” (1)
g - represents during the “end of off-season” and “during off-season program” (1)
h - represents “throughout off-season” (1)
i - represents during “start of off-season program” and “height [measured] once annually and body weight [measured] weekly” (1)
Table 1.2.4: How subjects determine training loads in the current study and that of a 1999 study of NFL S and C coaches (81).

<table>
<thead>
<tr>
<th>Methodology</th>
<th>‘97-98 Response</th>
<th>2018 Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
<td>n=11</td>
<td>“3% formula to determine load”, “percentage and bar speed taken from estimated 1RM”, “% of max load ranges per position group”</td>
</tr>
<tr>
<td></td>
<td>3% rule, percentage of repetition maximum</td>
<td>4</td>
</tr>
<tr>
<td>Previous workout</td>
<td>n=1</td>
<td>“Previous workouts players’ rep max PRs per exercise is recorded. On max effort days players are encouraged to set new ones. Dynamic days loads are reduced to a percentage of max effort and speed, under control- good form, is encouraged”</td>
</tr>
<tr>
<td></td>
<td>“We adjust training load from previous workout”</td>
<td>2</td>
</tr>
<tr>
<td>Coaches discretion</td>
<td>n=7</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>“Training load is determined by the coach”</td>
<td>0</td>
</tr>
<tr>
<td>Coach and athlete discretion</td>
<td>n=2</td>
<td>“In some exercises I [the coach] determine and in some they [the athlete] determine”</td>
</tr>
<tr>
<td>Failure</td>
<td>n=5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>High-intensity training, 1 set to failure</td>
<td>1 “2 rep rule”</td>
</tr>
<tr>
<td>Other</td>
<td>n=0</td>
<td></td>
</tr>
</tbody>
</table>
Table 1.2.5— How subjects determine sets and repetition utilized in the current study and that of a 1999 study of NFL S and C coaches (81).

<table>
<thead>
<tr>
<th>Methodology</th>
<th>'97-98</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Response (sets x reps)</td>
<td></td>
</tr>
<tr>
<td>Specified range</td>
<td>12: Major lifts: 3-5 x 8-3;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Auxiliary lifts: 2-3 x 8-5</td>
<td></td>
</tr>
<tr>
<td>High intensity concept</td>
<td>5: 1 set to failure; about</td>
<td></td>
</tr>
<tr>
<td></td>
<td>22 sets; most routines are</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 x 10</td>
<td></td>
</tr>
<tr>
<td>Specified to mesocycle</td>
<td>4: Cycle our routines not</td>
<td></td>
</tr>
<tr>
<td></td>
<td>only weekly by within each</td>
<td></td>
</tr>
<tr>
<td></td>
<td>week; Mon: high volume;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wed-Fri: lower volume with</td>
<td></td>
</tr>
<tr>
<td></td>
<td>higher intensity</td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td>3: 3 basic loads (1RM):</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70% x 10, 80% x 5-6, 90-95%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x 2-3</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2: “Too much to list”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Off-season Response (sets x reps)</td>
<td>11: Major lifts: 5-6 x 10-12;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Auxiliary lifts: 3 x 6-10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 set to failure, reps vary</td>
<td></td>
</tr>
<tr>
<td></td>
<td>somewhat randomly; 8-100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>legs and 8-20 upper-body</td>
<td></td>
</tr>
<tr>
<td>Year round Response (sets x reps)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use too many different</td>
<td></td>
</tr>
<tr>
<td></td>
<td>combinations for different</td>
<td></td>
</tr>
<tr>
<td></td>
<td>exercises and players to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>list; and varies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

a – represents during “Hypertrophy mesocycles: major lifts: 3x8; auxiliary lifts: 3x8-10; pre-rehabilitation exercises: 10-15 rep; and during strength mesocycles: major lifts: 3x6, 3x5, 3-5-7, 2-4-6, 1-3-5; auxiliary lifts: 3x6” and “Ranges based on goals of training during hypertrophy mesocycles: 2-4 x 8-12; during general strength mesocycles: 3-6 x 3-6; during maximal strength power: 3-8 x 1-3”
### Table 1.2.6 – How current subjects determined rest intervals for multi-joint core movements.

<table>
<thead>
<tr>
<th>Category</th>
<th>Subjects</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5 min</td>
<td>2</td>
<td>“3-5 minutes, often with a non-taxing exercise performed during rest (e.g. specific stretching, mobility work, neck training, etc.)” and “3-4 min”</td>
</tr>
<tr>
<td>Circuit</td>
<td>2</td>
<td>“Majority of training is in mini circuits or paired movements”, “a 3-man rotation: 1 working, 1 spotting, and 1 resting”</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>“Depends upon the training phase and intensity”</td>
</tr>
</tbody>
</table>

Note – responses are raw data provided by subjects
**Table 1.2.7 - Exercise order current subjects implement.**

<table>
<thead>
<tr>
<th>Category</th>
<th>Subjects</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power, strength, then auxiliary</td>
<td>2</td>
<td>“explosive movement, strength movement, auxiliary movements”</td>
</tr>
<tr>
<td>Corrective, power, strength, auxiliary, pre-rehabilitation</td>
<td>1</td>
<td>“Corrective, power, strength, auxiliary, pre-hab.”</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>“Varies daily” and “highly technical to low technical, high stress to low stress, avoid placing too much fatigue on stabilizers of the core before highly technical or high force exercises”</td>
</tr>
</tbody>
</table>

Note – responses are raw data provided by subjects
**Table 1.2.8** - The top 5 most important exercises for the current study and that of a 1999 study of NFL S and C coaches (81).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Exercise Modality (n)</th>
<th>‘97-98 (n)</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Squat (8), neck exercises (7), clean (6), box squats, step-ups, core exercises (1)</td>
<td></td>
<td>Squat/squat variations (2), glute-ham raise (1)</td>
</tr>
<tr>
<td>2</td>
<td>Cleans (7), shoulders, leg press, squat (3), bench (2), push press, lower-body explosive exercises, groin exercises, and snatch (1)</td>
<td></td>
<td>Clean variations (2), squat patterns (1)</td>
</tr>
<tr>
<td>3</td>
<td>Bench (8), squat (3), military press, incline press (2), Legs exercises, sled dragging, dumbbell incline, lumbar extension, posterior delt exercises, cleans, low back exercises (1)</td>
<td></td>
<td>Nordic leg-curl, deadlift, power/shrug pull (1)</td>
</tr>
<tr>
<td>4</td>
<td>Bench, shoulder press (2), push pull movements, core, incline, upper-body explosive exercises, close-grip lat, dorsiflexors exercises, snatch, lateral shoulder raise, lunges, push press, dead lift, supplemental work, lat row and pulldown (1)</td>
<td></td>
<td>Russian leans, chain-up variations, upper-body row variations (1)</td>
</tr>
<tr>
<td>5</td>
<td>Medicine-ball exercises, leg press and extension, upright row, neck exercises (2), core exercises, back exercises, dead lift, hamstring curl, jerk, low back exercises, knee exercises, incline bench press, pulling exercises (1)</td>
<td></td>
<td>Pull-up variations, single-leg movement variations, vertical and horizontal upper-body push variations (1)</td>
</tr>
<tr>
<td>Other</td>
<td>“Individual needs” (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rank</td>
<td>Muscle groups (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Hips (2), gluteals, neck (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Core (2), hamstring (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Quadriceps, low back, posterior shoulder, neck (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other “Individual needs” (1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1.2.10 – Current Subjects professional opinions on various aspects of S and C.

<table>
<thead>
<tr>
<th>Question (How important is ...)</th>
<th>Professional opinion (how important)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extremely % (n)</td>
</tr>
<tr>
<td>Physical fitness testing?</td>
<td>28.6 (2)</td>
</tr>
<tr>
<td>Strength and power development?</td>
<td>66.7 (4)</td>
</tr>
</tbody>
</table>
Chapter 1.3 - Part III: Training Interventions

Introduction

A well-designed training program effectively combines various training interventions (e.g. balance and stability, core training, Olympic weightlifting, injury prevention). Proper manipulation of related training variables and optimal dose-response relationships are critical for optimal enhancements of sport performance, as well as reducing the risk of overtraining syndrome (224).

Surveys have been shown to be an effective method to identify and examine S and C practices. Ebben and Blackard (81) provided the most comprehensive and in-depth examination of NFL S and C practices. However, the S and C practices of the NFL have not been studied for 20 years.

To comprehensively examine current NFL S and C practices a three-part research study was conducted. The primary purpose of the current article was to identify the common and unique aspects of NFL flexibility, balance and stability, core training, Olympic-weightlifting, injury prevention, recovery modalities, nutrition, supplementation programs and practices. A secondary purpose was to compare the results obtained by Ebben and Blackard (81) and current practices to determine differences across time.

Methods

Experimental Approach to the problem

This cross-sectional study was designed to investigate the common and unique aspects of current NFL S and C practices compared to publically accessible data from 1997-98 (‘97-98) (81). The independent variables were the time at which the measurements were taken separated
by studies. Dependent variables were training frequency, professional opinions, and position-specific characteristic variables.

**Subjects**

Nine of 32 (28.1%) subjects participated in the current research study; details on responses are presented in Table 1.3.1. However, two subjects agreed to participate but did not provide any data; thus excluding them from the current research study. All subjects signed an informed consent to ensure understanding of the purpose and procedures along with all risks and benefits of the study. Subjects were free to not answer or disclose any information they wished on any particular question. Upon completion of the survey each subject received monetary compensation for their time and effort. No subjects’ names were associated with any results to retain anonymity. All procedures were approved by the Institutional Review Board.

*For Table 1.3.1 see page 51*

**Survey**

A survey instrument was developed, reviewed, and pilot tested. To ensure clarity and validity, an advisory committee of current S and C coaches and academic professors with qualitative research experience reviewed the instrument. The instrument for the current study was adapted from the research instrument previously used by Ebben and Blackard (81); additionally the instrument was modified to reflect the most current S and C research. The instrument was 37 pages in length, included 150 items divided into 10 sections, and is the most comprehensive strength and conditioning survey ever administered. This article covers (i) flexibility development, (ii) balance and stability, (iii) core training, (iv) Olympic weightlifting,
(v) injury prevention, (vi) recovery modalities, and (vii) nutrition and supplementation. Question format included: open ended questions to allow for greater elaboration, five-point Likert Scale questions, and questions allowing multiple selections to analyze precise detail. The survey instrument was transferred to an electronic analysis software (Qualtrics, LLC research core TM, Provo, Utah USA).

**Procedures**

An introductory letter that described the research purposes and implications was mailed to all head NFL S and C coaches; several attempts were made to contact non-responding coaches to increase response rate. Upon coaches’ acceptance of understanding all procedures and risks of the study, subjects received the electronic survey instrument via email access. A secondary email was sent to all subjects who did not respond or complete the survey after the initial email.

**Statistical Analysis**

Collected numerical data were entered into a statistical analysis program (SPSS v. 24.0 IBM). Descriptive statistics were performed for frequencies and durations of variables. Data between the current study and results obtained by Ebben and Blackard (81) were compared via one sample t-tests using the means from the previous study as the population mean. The alpha level was set at p < 0.05. Comprehensive non-numerical open-ended data were content analyzed according to methods described by Patton (221), and previously used in studies assessing practices of NFL S and C coaches (81).
Results

Flexibility Development

Six subjects reported prescribing flexibility exercises to “all players” on a “year round” basis; on average 6.4 ± 1.3 d/wk (n=5). Subjects identified when athletes performed flexibility exercises, the type of exercise prescribed, and the most important body part that flexibility is required for performance (see Figures 1.3.1 and 1.3.2 and Table 1.3.2). In comparing the current results to ‘97-98 (81), findings indicate that there were similar findings for static stretch duration seconds (18.0: ’97-98; 18.3 ± 9.8: 2018) (p=.937).

- For Figure 1.3.1 see page 55-
- For Figure 1.3.2 see page 56 -
- For Table 1.3.2 see page 52 –

Balance and Stability

Five subjects prescribed balance and stability training to “all players” on a “year round” basis; average 3.3 ± 0.9 d/wk (n=4). One subject stated that balance and stability training was “done in warm-up, daily”.

Core Training

Five subjects prescribed “all players” core training “year round”; on average 3.5 ± 0.6 d/wk (n=4). One subject stated that core training was “done in warm-up, daily”.

Olympic Weightlifting

Five subjects prescribed Olympic weightlifting; on average 2 d/wk (n=4). In response to the question assessing the most common positional group to which Olympic weightlifting was
prescribed, the most common answer was “all players” (n=4); however, one subject indicated prescribing Olympic weightlifting to all positions, except kickers and long snappers. In response to the question assessing when Olympic weightlifting was prescribed, the most common answer was “year round” (n=3); however, one subject reported prescribing Olympic weightlifting year round, except during the post-season.

**Injury Prevention**

Five subjects prescribed injury prevention to “all players”; on average 3.8 ± 0.5 d/wk on a “year round” basis (n=4). Subjects reported the specific body parts targeted during injury prevention (see Figure 1.3.3).

- *For Figure 1.3.3 see page 57 –*

**Recovery Modalities**

Five subjects implemented recovery modalities “year round” to “all players”. One subject reported “other” regarding the mesocycle; however, no other data were provided. One subject implemented recovery modalities 7 d/wk. Subjects identified when recovery modalities were implemented and the specific modalities utilized (see Figures 1.3.4 and 1.3.5).

- *For Figure 1.3.4 see page 58 –*
- *For Figure 1.3.5 see page 59 –*

**Nutrition and Supplementation**

Five subjects prescribed a position-specific dietary program based on dietary needs. Four subjects reported having a Registered Dietitian on staff; while one subject did not. Four subjects
counsel players regarding substance and/or drug abuse. One subject reported administering supplements; while two subjects indicated that supplements were not administered. Four subjects reported advising athletes to consume a nutritionally-dense meal before resistance training. One subject advised athletes to consume this meal 1.5 hours before with 51g of carbohydrates, 30g of protein, and 21g of fat. Five subjects reported advising athletes to consume a nutritionally-dense meal post-resistance training. One subject advised athletes to consume this meal 2.0 hours post-resistance training with 51g of carbohydrates, 30g of protein, and 20g of fat. Additionally, subjects provided professional opinions regarding various questions and identified the purpose of prescribing various training interventions (see Tables 1.3.3 and 1.3.4).

- For Table 1.3.3 see page 53-
- For Table 1.3.4 see page 54-

Discussion

As this article is a three part paper these results are based off of six subjects, as one subject withdrew previously. Therefore, all coaches in the current study prescribed flexibility training compared to 84.6% in the previous study (81). The reported flexibility training frequency is in agreement with recommendations of at least three days per week; ideally five to seven days per week (70). Flexibility exercises were prescribed commonly before and after practice during the current and previous study of NFL S and C practices (81). Additionally, performing stretching exercises prior to activity and during the cool-down may enhance overall flexibility (130).

The reported duration of each static stretch during both studies is in agreement with recommendations of 10-30 seconds (81, 267). Additionally, 15-30 seconds of passive stretching is superior compared to shorter duration stretches (272). Current findings contrasted with
previous literature, the percentage of coaches implementing dynamic stretching increased from (53.8%) in the previous study to all subjects during the current study (81). This increase could be due to the fact that a study published in 2011, showed that dynamic stretches can enhance explosiveness, sprint, and jump performance (300). It is important to note that no subjects prescribed ballistic stretches; compared to 30.6% of coaches in the previous study (81). This finding is consistent with the belief that ballistic stretching increases the risk of injury and decreases maximum knee range of motion if used before exercise (208).

The hips were among the top ranked areas for flexibility requirements; this was not previously investigated in the previous study (81). Hip flexibility is essential for functional movements and to prevent injuries (69, 135). Additionally, subjects reported that the shoulders, thoracic spine, and upper-body flexibility were important. This finding is consistent with the fact that shoulder mobility and stability are critical for functional demands (29). Thoracic spine mobility is essential for force generation during horizontal trunk rotational movements (300). Furthermore, overhead throwing, specifically for quarterbacks, places significant stress on the shoulder (12). Therefore, implementing shoulder stability, range of motion, and thoracic rotation into quarterbacks’ training programs are highly recommended (162). It is important to note, that one subject did not provide any further data following the flexibility section.

Balance and stability and core training were not previously investigated in the previous study (81). One subject expanded upon the findings stating that both are incorporated daily during the warm-up. This protocol has been demonstrated to be effective in preventing knee and ankle injuries (272). Furthermore, core strength and power are essential for sport performance and to generate maximal force during horizontal trunk rotational movements (56).
All coaches in the current study prescribed Olympic weightlifting compared to 53.8% in the previous study (81). Previous literature has established Olympic weightlifting to be a superior methodology compared to traditional resistance training (e.g. power lifting) to improve vertical jump performance (110, 126). One subject expanded upon this finding stating that “we do not use classical [Olympic weightlifting] lifts, but variations”. Prescribing Olympic weightlifting variations allows the athlete ability to overload various fitness parameters (e.g. peak force, rate of force development, and velocity) to enhance performance; while eliminating stress placed on the wrists, shoulders, low-back, hips, and knees (262, 263).

All coaches reported prescribing injury prevention programs. These findings validate a finding from a study published in 2005, in which a Major League Baseball S and C coach predicted that programs will be designed with pre-habilitation in mind (83). Injury prevention programs need to be diverse to address risk factors of participation (171); thus subjects were asked to identify the specific body parts emphasized during their injury prevention program. The shoulders were among the top ranked body parts emphasized during injury prevention. Shoulder injuries are common among football players (88, 162); additionally, NFL players with a medical history of shoulder instability; have drastically shorter expected career lengths (35).

It is essential to implement a scientific, evidence-based recovery protocol, as structural damage of the musculature and connective tissue alter muscle function and movement patterns (188). One subject stated that recovery modalities were utilized “as needed” by athletes; suggesting that a large amount of individual variation occurred during the training program. This finding is consistent with the fact that the amount of muscle damage occurring during the season is greatly intra-individually based; and should be treated accordingly (163).
During the current study four subjects reported having a Registered Dietitian on staff. This finding exceeds that of a previous study published in 2004, in which only one NFL team had a full time Registered Dietitian on staff (228). While, a previous study published in 2018 found that 59% (19 of 32) of NFL teams had a full time Registered Dietitian on staff (220).

Previous literature has established that adequate nutritional intake can directly enhance sport performance (15, 33). Additionally, training adaptations are affected by the quality and quantity of nutrient availability (141); therefore, we asked subjects about the nutrients that players were provided. One subject reported that athletes were advised to consume “51g of carbohydrates, 30g of protein, and 21g of fat” 1.5 hours before resistance training. It is critical to note, that these macronutrient values are low for carbohydrates and proteins if following Kerksick’s (153) recommendation (i.e. 1-2 g/kg carbohydrate and 0.15-0.25 g/kg protein). Additionally, requirements may vary based on training frequency, exercise selection, intensity, and inter-individual variability (86).

During the post-resistance training period, one subject indicated that athletes consume “51g of carbohydrates, 30g of protein, and 20g of fat” 2 hours post-resistance training. However, previous literature has established that nutrition administration 30 min post-training is optimal (153, 229). Furthermore, heavy resistance training can facilitate acute micro-trauma in muscle fibers requiring additional protein intake immediately post-exercise (12).

Ebben and Blackard (81) stated that future surveys should examine the use of supplements; thus, subjects were asked questions regarding supplementation. One subject reported administering supplements; expanding upon this finding, they identified administering “Collagen, vitamin-C, and UCAN mix 30-0 minutes before training” and “Cheribundi, whey
protein, and Gatorade mix within 20 minutes Post-training”. However, two subjects reported that supplements were not administered to players at any time.

This was the first comprehensive survey to analyze position-specific variables at the NFL level. The findings suggest that professional American Football training programs emphasize positional-specific characteristics.

**Practical Application**

This article describes flexibility, balance and stability, core training, Olympic-weightlifting, injury prevention, recovery modalities, nutrition, and supplementation programs and practices of NFL S and C coaches. The data are useful for practitioners who seek ideas for the implementation of these training strategies and for future research as a source of comparison. Furthermore, with this updated information regarding NFL S and C training data, researchers are able to continue to empirically investigate various aspects of training programing. Additionally, current S and C coaches at all levels can review these data as a source of new ideas and consequently alter current and traditional methods of training. Future research should examine more detailed aspects of how coaches are manipulating various training variables, specifically for the position groups.
**Table 1.3.1** – Response rate for the current study and that of a 1999 study of NFL S and C coaches (81).

<table>
<thead>
<tr>
<th>Survey response</th>
<th>‘97-98 n ( /30)</th>
<th>Survey response</th>
<th>‘97-98 Percentage (%)</th>
<th>2018 n ( /32)</th>
<th>2018 Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance</td>
<td>26 ( /30)</td>
<td>86.6</td>
<td>9 ( /32)</td>
<td>28.1</td>
<td></td>
</tr>
<tr>
<td>Decline</td>
<td>1 ( /30)</td>
<td>3.3</td>
<td>6 ( /32)</td>
<td>18.7</td>
<td></td>
</tr>
<tr>
<td>No response</td>
<td>3 ( /30)</td>
<td>10</td>
<td>17 ( /32)</td>
<td>53.1</td>
<td></td>
</tr>
<tr>
<td>Total response rate</td>
<td>27 ( /30)</td>
<td>90</td>
<td>15 ( /32)</td>
<td>46.8</td>
<td></td>
</tr>
</tbody>
</table>
Table 1.3.2 – Current subjects reported top 3 most important body parts where flexibility is required.

<table>
<thead>
<tr>
<th>Order of importance</th>
<th>Body part (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hips (3), lower-body (1)</td>
</tr>
<tr>
<td>2</td>
<td>Hamstring (2), posterior chain, middle-body (1)</td>
</tr>
<tr>
<td>3</td>
<td>Shoulders, thoracic spine, groin, upper-body (1)</td>
</tr>
<tr>
<td>Other</td>
<td>“Individual needs” (1)</td>
</tr>
<tr>
<td>Question (How important is ...)</td>
<td>Professional opinion (how important)</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Extremely % (n)</td>
</tr>
<tr>
<td>Flexibility development?</td>
<td>33.3 (2)</td>
</tr>
<tr>
<td>Balance and stability training?</td>
<td>20.0 (1)</td>
</tr>
<tr>
<td>Core training?</td>
<td>80.0 (4)</td>
</tr>
<tr>
<td>Olympic weightlifting?</td>
<td>20.0 (1)</td>
</tr>
<tr>
<td>An injury prevention program?</td>
<td>40.0 (2)</td>
</tr>
<tr>
<td>Recovery modalities?</td>
<td>40.0 (2)</td>
</tr>
<tr>
<td>Nutritionally-dense food?</td>
<td>100.0 (5)</td>
</tr>
<tr>
<td>Supplementation?</td>
<td>0</td>
</tr>
<tr>
<td>Training intervention</td>
<td>Response (n)</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Flexibility training</td>
<td>“improve and maintain joint mobility” (3) “reduce risk of injury and injury prevention”, “improve quality of range of motion” (2), to “find and correct asymmetry” and “improve performance” (1)</td>
</tr>
<tr>
<td>Balance and Stability training</td>
<td>“kinematic awareness” (2) to “improve proprioception and strength stabilizers”, and for “injury prevention” (1)</td>
</tr>
<tr>
<td>Core Training</td>
<td>“develop strong core to transfer power, reduce injury, and improve performance”, “to tie the upper and lower body together build stability”, and “efficiency of movement” (1)</td>
</tr>
<tr>
<td>Olympic weightlifting</td>
<td>“improve and develop power production” (4) “injury prevention” and “to develop functional strength” (1)</td>
</tr>
<tr>
<td>Injury prevention</td>
<td>player “availability” (3)</td>
</tr>
<tr>
<td>Recovery modalities</td>
<td>“lifestyle development and professional habits”, “help avoid overtraining and injury”, and “help them recover from workouts and practice so they can go hard again the next day” (1)</td>
</tr>
</tbody>
</table>

Note – responses are raw data provided by subjects
Other – Five coaches in ‘97-98 reported other; comments including “athletes were encouraged to perform flexibility exercises before practice but after the warm-up”

**Figure 1.3.1** - When subjects prescribed flexibility exercises in the current study and that of a 1999 study of NFL S and C coaches (81).
PNF - represents proprioceptive neuromuscular facilitation

**Figure 1.3.2** - Flexibility exercises subjects prescribed in the current study and that of a 1999 study of NFL S and C coaches (81).
Figure 1.3.3 – Specific body parts identified by the current subjects in emphasizing an injury prevention program.
Other – represents one subject comment that athletes performed recovery modalities “as needed”

**Figure 1.3.4** - When current subjects implemented recovery modalities.
Figure 1.3.5 - Specific recovery modalities utilized by the current subjects
Chapter II: Literature Review

Introduction

The literature review will provide an extensive compilation of existing literature related to the scientific findings of the physiological effects of football and aspects of the training programs. Powers (231) states that S&CC hold an indispensable coaching role within athletics that directly affect on-field performance. The main objective for S&CC is to prescribe an effective and efficient training program with a clear and precise goal of overall player development, accomplished by manipulating various training variables (297). This chapter will be divided into ten sections including: (i) physiological demands of football, (ii) general role of resistance training in football, (iii) general role of plyometric training in football, (iv) general role of speed training in football, (v) general role of flexibility training in football, (vi) unique aspects of S&C programs, (vii) general role of recovery in football, (viii) general role of nutrition and supplementation in football, (ix) general role of physical fitness testing in football, and (x) surveys of S&C practices.

The Physiological Demands of Football

This section is intended to provide an understanding of the physiological demands and to provide a framework for designing a training program. Football places significant loads on the musculoskeletal system that may result in maladaptation (e.g. biomechanical pattern alterations, decreased joint range of motion, force production) (67). Understanding the physiological response is necessary to optimally develop and prescribe a sport-specific training program that effectively enhances performance (227). Considering position-specific physiological demands can allow for a more precise training program for greater transfer to on field performance (124,
125, 227). For a more thorough understanding it is essential to analyze the acute physiological demands during both competitive games and practice.

**The Physiological Demands of a Competitive Game**

Competitive games are primarily composed of short duration intermittent bouts executed at maximum intensity (75, 125, 261). This claim is supported by Brechue et.al (32), who reported that an average play’s length is 5-20yds. Furthermore, there were approximately 6.3-6.6 plays per series, with 11-14 series per game, during a competitive game (58, 125). Hoffman (124) analyzed NFL gameplay, finding that each play lasts approximately 5.0s, with average rest intervals of 26.9–36.4s in-between plays. Similarly, Lindon (169) found that an average NFL play lasts 6.04s; ranging from 2-13s. The calculated work-to-rest ratio was 1:6.2 during a NFL game, regardless of position (169, 284); illustrated in Table 2.1.

**Table 2.1** – Average play duration and rest intervals (77)

<table>
<thead>
<tr>
<th>Style of Play</th>
<th>Average play duration (s)</th>
<th>Rest intervals between plays (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run focused</td>
<td>4.84</td>
<td>16.59–46.93</td>
</tr>
<tr>
<td>Pass focused</td>
<td>5.41</td>
<td>16.59–45.92</td>
</tr>
<tr>
<td>Balanced</td>
<td>5.44</td>
<td>16.59–45.44</td>
</tr>
<tr>
<td>Average</td>
<td>5.23</td>
<td>16.59–46.9</td>
</tr>
</tbody>
</table>

Table 2.1 is replicated from Table 2 (77)

To adequately calculate the physiological stressors experienced, one must analyze the movement profiles, work-to-rest ratios, and the magnitude and frequency of collisions. By nature, the game of football alters multiple metabolic processes (124, 227). The primary energy system utilized during a competitive game is directly dependent upon the game intensity (261). Game intensities differ at times due to coaching strategies and player level. Regardless, the predominant energy contribution is through the phosphagen system; with 90% of the energy
production (124, 125, 169, 227). The remaining energy contribution is through the anaerobic glycolytic system (124 125, 169). Thus, athletes who are able to resynthesize adenosine triphosphate and phosphocreatine substrates between plays will have greater capacity to generate force and power on subsequent plays (77).

Previous literature has established hormonal and blood biochemical profiles during a competitive game that assesses the acute physiological response (124, 125, 127). These assessments revealed a correlation between a competitive game and muscle damage (124, 125, 127). Previous literature has established that a competitive game results in a significant increase in plasma myoglobin, creatine kinase, and lactate dehydrogenase concentrations; that correlate to acute muscle damage and stress (124, 125).

Repeated high intensity intermittent bouts (i.e. plays) result in performance decrements. Hoffman (124) found that baseline peak force and peak power decreased steadily until reaching a plateau prior to half time. It is critical to note, these values returned to baseline by the end of the game via effective coach monitoring and strategy (124). Ward et al. (285) found that during a National Collegiate Athletic Association (NCAA) Division I football game wide receiver and defensive backs covered greater total distance and number of sprints compared to other positional groups.

Players experience numerous collisions and impacts directly resulting in microtrauma of the muscle tissue at the molecular level (127). Wellman et al. (289) found differences of impact loads experienced among positon groups during a 12-game season. Impacts sustained are commonly classified into six categories; represented in Table 2.2. Hoffman et al. (127) reported that throughout the season players acquire some degree of musculature sensitization in response
to the repeated trauma. The contact adaptation theory is a possible mechanism through which, players are able to withstand and adapt to these stresses (125).

**Table 2.2 – Classification of Impact values (289)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Gravitational force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>&lt;5-6</td>
</tr>
<tr>
<td>Light-to-moderate</td>
<td>6.1-6.5</td>
</tr>
<tr>
<td>Moderate-to-heavy</td>
<td>6.6-7</td>
</tr>
<tr>
<td>Heavy</td>
<td>7.1-8</td>
</tr>
<tr>
<td>Very heavy</td>
<td>8.1-10</td>
</tr>
<tr>
<td>Severe</td>
<td>&gt;10</td>
</tr>
</tbody>
</table>

Wellman et al. (289) found that wide receivers’ endured more “very light” and “light-to-moderate” impacts compared to other positional groups; while running backs endured more “severe” impacts compared to other offensive positional groups. Defensive linemen endure more “heavy” and “very heavy” impacts compared to other defensive positions (289). Additionally, defensive backs and linebackers endured more “very light” impacts compared to other positional groups (289). These findings support the need for position-specific training programs. A full description of impacts sustained by each position is available in Table 2.3.
Table 2.3- Number of impacts sustained by positional groups during a 12-game NCAA division I football season (289)

<table>
<thead>
<tr>
<th>Position</th>
<th>Very light</th>
<th>Light-to-moderate</th>
<th>Moderate-to-heavy</th>
<th>Heavy</th>
<th>Very heavy</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>QB</td>
<td>2,060.7 ± 241.8</td>
<td>333.3 ± 109.9</td>
<td>44.3 ± 11.3</td>
<td>15.5 ± 5.3</td>
<td>9.3 ± 5.7</td>
<td>13.6 ± 5.9</td>
</tr>
<tr>
<td>RB</td>
<td>1,929.9 ± 469.2</td>
<td>582.7 ± 184.8</td>
<td>78.4 ± 31.4</td>
<td>21.4 ± 10.4</td>
<td>9.5 ± 4.9</td>
<td>16.6 ± 7.9</td>
</tr>
<tr>
<td>WR</td>
<td>4,093.0 ± 791.6</td>
<td>1,155.9 ± 401.7</td>
<td>172.7 ± 56.7</td>
<td>38.4 ± 14.7</td>
<td>11.1 ± 5.5</td>
<td>12.3 ± 5.0</td>
</tr>
<tr>
<td>TE</td>
<td>2,615.3 ± 725.7</td>
<td>869.5 ± 255.6</td>
<td>175.2 ± 58.4</td>
<td>31.6 ± 14.5</td>
<td>9.1 ± 4.4</td>
<td>5.9 ± 2.3</td>
</tr>
<tr>
<td>OL</td>
<td>2,732.8 ± 415.4</td>
<td>851.6 ± 222.9</td>
<td>162.1 ± 103.9</td>
<td>35.9 ± 18.7</td>
<td>12.9 ± 6.8</td>
<td>11.5 ± 5.9</td>
</tr>
<tr>
<td>DL</td>
<td>1,847.4 ± 431.1</td>
<td>699.2 ± 215.6</td>
<td>198.4 ± 102.4</td>
<td>49.6 ± 20.9</td>
<td>18 ± 10.2</td>
<td>10.6 ± 4.6</td>
</tr>
<tr>
<td>LB</td>
<td>2,638.9 ± 566.4</td>
<td>545.8 ± 287.3</td>
<td>100.1 ± 47.5</td>
<td>23.6 ± 13.3</td>
<td>9.3 ± 6.0</td>
<td>12.7 ± 7.4</td>
</tr>
<tr>
<td>DB</td>
<td>2,938.9 ± 569.1</td>
<td>581.5 ± 186.6</td>
<td>100.9 ± 42.5</td>
<td>19.3 ± 9.5</td>
<td>7.4 ± 4.1</td>
<td>9.6 ± 4.9</td>
</tr>
</tbody>
</table>

QB - represents quarterback  
RB - represents running back  
OL - represents offensive lineman  
TE - represents tight end  
WR - represents wide receiver  
DL - represents defensive lineman  
LB - represents linebacker  
DB - represents defensive back  
K - represents kicker  
LS - represents long snapper

The Physiological Demands of Practice

Practice intensities determine the severity of physiological stress and energy system utilization (125). Hoffman (125) classified practice intensities in four distinct categories; illustrated in Table 2.4. Non-starting players spent more time standing (i.e. 0 km/h) compared to starting players (125). All players spent more time at “low intensity” (i.e. jogging) compared to “moderate intensity” (i.e. running) and “high intensity” (i.e. sprinting) during practice (125). Ward et al. (285) found differences between running and non-running activities for positional groups during practice. Lineman groups engaged in more non-running activities during three training sessions (285).
Table 2.4 – Practice intensity classifications (290)

<table>
<thead>
<tr>
<th>Category</th>
<th>Intensity (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0-10</td>
</tr>
<tr>
<td>Moderate</td>
<td>10.1-16</td>
</tr>
<tr>
<td>High</td>
<td>16.1-23</td>
</tr>
<tr>
<td>Maximal effort</td>
<td>&gt;23</td>
</tr>
</tbody>
</table>

Pre-season training camp commonly involves high intensity exercise in stressful conditions (e.g. hyperthermia, dehydration) producing considerable physiological strain (75). Hoffman (125) analyzed the physical demands, movement profile, and cardiovascular responses of a NCAA Division I football pre-season training camp. Creatine kinase levels were elevated at the completion of pre-season training camp (124). Each practice session duration was on average 144 ± 13min (125).

Pincivero and Bompa (227) identified position-specific physiological demands and various biomechanical loads experienced. This claim is supported by Hoffman (125), who reported that non-lineman players (i.e. skill position) covered significantly greater distances compared to linemen during practice. A full description of cardiovascular responses during pre-season training camp is available in Table 2.5.

Table 2.5- Position specific cardiovascular response during an NCAA Division I pre-season training camp (125)

<table>
<thead>
<tr>
<th>Position</th>
<th>Average HR (bpm)</th>
<th>Maximum HR (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lineman</td>
<td>136 ± 7</td>
<td>197 ± 9</td>
</tr>
<tr>
<td>Non-lineman</td>
<td>135 ± 11</td>
<td>203 ± 8</td>
</tr>
</tbody>
</table>
The General Role of Resistance Training in Football

This section is intended to provide an understanding of various aspects of resistance training and training variable manipulation. Previous literature has established that resistance training is an effective training intervention associated with positive health benefits (89). Specifically for athletics (i.e. football players), resistance training can enhance strength, power, body composition, and physiological processes (253). An emphasis should be placed on the development of strength and power characteristics when designing the training program; as previous literature has identified both to be critical for sport performance (65,111, 253, 264).

An effective resistance training program can enhance the absolute and relative muscular strength (264). Maximal strength is the maximum amount of muscular force produced in a single repetition during a voluntary contraction against an external resistance (296). The development of muscular strength is beneficial for sport-specific movement patterns (89, 264), sprint performance (264, 304), and force-time characteristics (48, 264). Additionally, muscular strength has been reported to decrease the risk of injury via enhanced structural characteristics of ligaments, tendons, joint cartilage, and soft tissue (264). Schoenfeld (243) reported a strong correlation between the cross-sectional area of a muscle and muscular strength. Athletes with superior strength are able to significantly generate force faster and express higher power outputs compared to weaker athletes (111). Furthermore, muscular strength is considered a fundamental element required to develop muscular power (111).

Muscular power is the rate at which an individual is capable of accomplishing work (i.e. energy conversion) per unit of time (87). Suchomel et al. (264) stated that an athlete’s power capability is one of the most important factors related to sport performance. This claim is supported by Haff and Nimphius (111), who stated that the ability to express high power outputs
during movement is essential for sport performance. Batolomei et al. (17) stated there are numerous neuromuscular factors (e.g. motor unit recruitment, rate coding, and synchronization) directly influence power output and production. To develop a complete training program, a multitude of factors must be considered, this requires the manipulation of acute training variables (253).

Lloyd et al. (171) stated that resistance training should be individualized based on age, injury history, and movement capabilities. Prescribing position-specific training programs can allow for greater transfer to on-field performance (162, 280). This claim is supported by Pincivero and Bompa (227), who identified that implementing position-specific characteristics will improve the training program. Kovacs and Katzfey (162) provided programming recommendations for training quarterbacks, which specifically focuses on strengthening the rotator cuff muscles and scapula stabilizers for throwing mechanisms. McHenry (195) provided programing recommendations for training lineman, that specifically focuses on footwork, hand speed, and core training to enhance performance. Jacobson et al. (140) stated that the offensive lineman require strength and power for takeoff speed to block an opposing player.

Training variables that are commonly manipulated include: training intensity, volume, duration, frequency, specificity, progression, and rest intervals (63, 288, 296). The National Strength and Conditioning Association states that an effective training program includes: needs analysis, training load, repetitions, exercise selection, and order (9, 297). Proper manipulation of these training variables and prescribing the optimal dose-response relationship is critical for optimal enhancement of sport performance, as well as reducing the risk of overtraining syndrome (224).
One way to effectively manipulate acute training variables is via periodization programming. Periodization is a logical methodology to enhance training adaptions by manipulating training variables into sequential mesocycles (e.g. training cycles, periods, phases) to distribute workload across the macrocycle (i.e. annual plan) (17, 235,296). A periodized program has been reported to be a superior methodology compared to non-periodized programming for facilitating peak performance characteristics (276). This claim is supported by Rhea and Alderman (235), who found that periodization programs are more effective compared to non-periodization programs for facilitating strength gains. This is due the ability for athletes to train at a higher volume and training intensity while avoiding overtraining (235). A periodization program is commonly classified as linear or nonlinear (253).

Linear periodization (i.e. traditional model) is a step-like alteration with an inverse relationship in training intensity and volume; observed within a mesocycle (17, 129). Typically, each mesocycle emphasizes one specific training adaption (e.g. hypertrophy, strength development, power development) (129, 253). Typically, mesocycle progress from general to specific adaption (276).

Non-linear periodization (i.e. undulating) involves manipulation of training intensity and volume more frequently (e.g. daily, weekly) for greater variations and progression of workload (92, 129, 164). Daily non-linear periodization programs are more common; additionally it elicits greater strength gains (92). Non-linear periodization provides the ability to facilitate a training goal (i.e. strength gain) without neglecting multiple other training adaptions (e.g. hypertrophy, power) during the same mesocycle (253). Previous literature has established the effectiveness of non-linear periodization in eliciting significant strength gains compared to non-periodized programs (129).
Training volume is the overall accumulation of work completed during a specific period of time, dependent upon the training frequency, number of sets, repetitions, and movement velocity (68, 89, 100, 108, 243). Lorenz et al. (175) stated that manipulating training volume can be accomplished by altering the number of repetitions performed per set, number of sets per exercise, and number of exercises per session. Williams et al. (295) found a correlation between increased training volume and strength adaptions. To increase muscular strength, Mangine et al. (181) recommends a low training volume with high training intensity, utilizing long duration rest intervals. To maximize hypertrophy, Schoenfeld (243) recommends the training volume to progressively increase with brief periods of overreaching. To increase muscle hypertrophy, Mangine et al. (181) recommends a high training volume with moderate-to-high training intensity; utilizing short duration rest intervals.

Training frequency represents the total number of training sessions completed during a specific period of time (e.g. day, week, month) (296). Williams et al. (296) found a positive correlation between training frequency and maximal strength adaptions. Implementing a weekly split routine maintains training volume, while performing fewer sets during the training session and allowing for greater recovery (243). Lorenz et al. (175) recommends power training to be conducted 2-3 days per week for novice athletes and 4-5 days per week for advanced athletes.

Multiple-set programs have been found to be superior compared to single-set programs (243). This claim is supported by Krieger (167), who stated that 2-3 sets per exercises are superior compared to 1 set. Fisher et al. (89) found the greatest strength gains occurred when prescribing 8 sets for each muscle group.

Repetition ranges are commonly classified into three categories; represented in Table 2.6. Schoenfeld (243) states that “moderate” (i.e. 6-12 reps) repetition ranges are optimal for eliciting
hypertrophic responses. It is important to note that “low” repetition ranges (i.e. 1-5 reps) rely exclusively on the phosphocreatine system for specificity training (243).

**Table 2.6**– Repetition range classifications (243)

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Repetitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1-5</td>
</tr>
<tr>
<td>Moderate</td>
<td>6-12</td>
</tr>
<tr>
<td>High</td>
<td>15+</td>
</tr>
</tbody>
</table>

Movement velocity is defined as the unit of time to execute both the concentric and eccentric muscle contractions during a movement (68, 89). Movement velocity can be commonly classified into three categories; represented in Table 2.7. Schoenfeld (243) recommends performing “moderate” (i.e. 1-2 s) concentric contractions with slightly “slower” (i.e. >2 s) eccentric contractions to elicit increased hypertrophy. Performing exercise with a “fast” movement velocity (i.e. <1:1 s) at a moderate load can elicit superior muscular strength adaptations compared to a moderate-slow velocity movement at the same load (68). This claim is supported by Fisher et al. (89), who stated that fast velocities are more effective for enhancing muscular performance.

**Table 2.7**– Movement velocity classifications (68)

<table>
<thead>
<tr>
<th>Category</th>
<th>Velocity (Concentric: Eccentric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow</td>
<td>&gt;2:2 s</td>
</tr>
<tr>
<td>Moderate</td>
<td>1-2:1-2 s</td>
</tr>
<tr>
<td>Fast</td>
<td>&lt;1:1 s</td>
</tr>
</tbody>
</table>

Prescribing optimal rest intervals allow for specific training adaptations to occur, that are strictly dependent upon the energy system utilized (219). Rest intervals can be commonly classified into three categories; represented in Table 2.8. A “short” rest interval (i.e. >30 s) is
effective in generating metabolic stress, but does not allow sufficient time to regain muscular strength deficits (243). Schoenfeld (243) stated that “moderate” rest intervals (i.e. 60-90 s) are superior for eliciting maximal hypertrophy. Furthermore, prescribing “long” rest intervals (i.e. <3 min) allows for ample recovery of strength deficits (199, 243). This claim is supported by Lorenz et al. (175), who stated that during power training rest intervals need to be long enough to allow for maximum effort to be achieved on subsequent sets. Additionally, consideration of work-to-rest ratios should be emphasized to emulate specific game characteristics (77).

**Table 2.8** – Rest Interval classifications (243)

<table>
<thead>
<tr>
<th>Category</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td>&gt;30 s</td>
</tr>
<tr>
<td>Moderate</td>
<td>60-90 s</td>
</tr>
<tr>
<td>Long</td>
<td>&lt;3 min</td>
</tr>
</tbody>
</table>

It is critical to prescribe a training stimulus (i.e. load) that will provide efficient external mechanical resistance to elicit positive training adaptions. Lorenz et al. (175) stated load is the most crucial training variable. Previous literature has established various effective loading schemes including: increasing load based on 1RM, increasing absolute load based on repetitions number, and increasing load within a repetition’s zone (175). External mechanical load are commonly classified into three categories; represented in Table 2.9. Lorenz et al. (175) stated there is an inverse relationship between the prescribed load and number of repetitions (i.e. Holten curve).

**Table 2.9** – Training load classifications (254, 296)

<table>
<thead>
<tr>
<th>Category</th>
<th>Load (1RM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>&lt;30%</td>
</tr>
<tr>
<td>Moderate</td>
<td>30-70%</td>
</tr>
<tr>
<td>Heavy</td>
<td>&gt;80%</td>
</tr>
</tbody>
</table>
Prescribing a “light” training load (i.e. <30% 1RM) produces the highest mean and peak power output (254). Prescribing a “moderate” training load (i.e. 30-70% 1RM) is the optimal to enhance power output (254). A “heavy” training load (i.e. >80% 1RM) is beneficial for developing maximal strength, due to a greater stimulation of high threshold motor units (296). These claims are supported by Fry (96), who found that the prescription of an external load of 80-95% 1RM can elicit maximum hypertrophy. Due to biomechanical differences of various movements it has been speculated that an exercise-specific load range exists; due to the fact that training load affects various kinetic variables (e.g. mean and peak power) (254).

Kraemer et al. (164) stated that exercise selection during each training session should correlate with the goal of the training session, movement patterns of competition, and capabilities of each athlete. Specific exercise parameters (e.g. angle of pull, position of extremity, number of joints required) result in various activation patterns within the musculature (243). Prescribing a single-joint exercises provide specific attention individual muscles; provides the ability to target underdeveloped muscles and asymmetries (243). Whereas, multi-joint exercises activate muscle stabilizers that are not utilized during single-joint exercises (243). Lloyd et al. (171) stated that compound movements (e.g. squat, deadlift, lunging, single-leg exercises) are essential exercises to develop key movement patterns for successful sport performance. McHenry (195) recommends prescribing two posterior upper-body exercises for every one anterior exercise, when training lineman specifically. McHenry (195) recommended prescribing two posterior lower-body exercises for every one anterior lower-body exercise, when training lineman specifically.

Exercise order is an important training variable to manipulate. Simao et al. (250) recommend avoiding determining exercise order based on the magnitude of muscle mass
involved, but rather based on individual training goals, movement patterns, or specific adaptions desired. This claim is supported by Miranda et al. (199), who stated that exercise order should be prioritized to allow for weaker muscles and deficit movement patterns to be performed before fatigue is present. Additionally, Spineti et al. (255) state that if an exercise is essential for the specific training adaptations desired, regardless if a large or small muscle group is activated, it should be performed at the beginning of the training session. Miranda et al. (199) recommends prescribing high velocity and ballistic movements at the start of the training session to enhance power outputs. This is due to the fact that when the neuromuscular system is in a non-fatigued state the athlete has a greater capacity for maximal voluntary contractile velocity and rate of force production (199).

Previous literature has established evidence-based systemic pre-activity warm-ups and post-activity cool-down that facilitate improved sport performance and decrease the risk of musculoskeletal injuries (150, 215). To ensure the athlete is ready for physical activity a pre-activity warm-up is recommended (150, 206). A pre-activity warm-up is the execution of various exercises prior to a training session or competitive competition to prime the muscular system (215). Swanson (267) stated that a well-designed pre-activity warm-up mentally and physically prepare the athlete for movements associated with training or competition. The pre-activity warm-up should be systematic and progressive to stimulate the musculature that will be utilized (150). Swanson (267) stated that the warm-up should last approximately 4-15 min.

An active warm-up will reduce the incidence of sustaining musculoskeletal injuries; due to increased muscle temperature and compliance (150). Additionally, a proper pre-activity warm-up can increased core body temperature, working capacity of cardiovascular and respiratory system, nerve impulse, metabolic metabolism, joint range of motion, the speed and force of
muscular contractions, and decrease blood lactate accumulation (215, 267). Utilizing a dynamic warm-up has been shown to increase power output immediately following (130). A dynamic warm-up is classified by movements that are similar to those that will be performed during the training session (130). Judge et al. (150) recommend incorporating some form of a general warm-up followed by a pre-activity stretch before participating in physical activity. However, there is contradicting research that found pre-activity stretching inhibits optimal performance (50, 196, 300). Acute bouts of pre-activity stretching will temporarily inhibit the ability to generate the maximal muscular force (196). Wong et al. (300) stated that if static stretching of >90 s will impair sprint performance. Furthermore, Chaouachi et al. (50) reported that pre-activity stretching impairs various performance characteristics (i.e. decreased force development, jump height, sprint performance, muscular electromyography activity, and increased reaction time).

Immediately following a training session or competitive game prescribing a post-activity cool-down and stretching protocol is recommended (150). Active recovery is another common modality utilized to properly recover from stress experienced. Typically, active recovery incorporates some form of whole-body exercise to facilitate therapeutic benefits and enhance recovery (207). Park (219) states that active recovery is superior compared to passive recovery for reducing blood lactate concentration levels in trained individuals following an intense training session.

The General Role of Plyometric Training in Football

This section is intended to provide a precise understanding of training recommendations for implementing plyometric exercises. Plyometric exercises are classified as a whole body training intervention; which involves various stretch-shortening cycle movements (e.g. jumping,
bounding, and horizontal movements), both unilateral and bilateral (73, 266, 304). Stretch-shortening cycle exercises are defined as a rapid stretch of a muscle fiber (i.e. eccentric contraction) immediately followed by a shortening action (i.e. concentric contraction) (73, 244). Whole-body plyometric training emphasizes the need for optimal movement patterns and high contraction velocities for sport performance (304). Previous literature states that scientific evidence-based plyometric training facilitate multiple training adaptations including; enhanced neuromuscular performances (73, 244, 266), reaction time (244), strength (72, 73), power output (72, 178), muscular coordination (72), sprint performance (172, 236), acceleration (172), agility (198), and athletic performance (72). Prescribing plyometric training involves the manipulation of various training variables (e.g. load, intensity, frequency) (73, 71, 104, 185, 244).

De Villarreal et al. (73) states that when prescribing plyometrics training to follow the principle of overload for training intensity, volume, and exercise selection (73). Gleason et al. (104) recommends the greatest volume to be prescribed during the preparatory phase (e.g. summer training, spring football). Furthermore, De Villarreal et al. (73) stated that plyometric training cycle of <10 weeks (i.e. 6-10 weeks ideally) with 3 sessions per week is superior compared to than longer durations. This claim is supported by De Villarreal et al. (71), who stated that short-term training cycles (i.e. 7 weeks) is optimal for enhancing jump performance. Additionally, Markovic and Mikulic (185) stated that a short-term plyometric training cycle (i.e. 6-15 weeks with 2-3 sessions per week) can elicit various training adaptations (e.g. lower-extremity strength, power, and stretch-shortening cycle function).

Training intensity for plyometric exercises can be classified as low intensity (i.e. double leg hops) or high intensity (i.e. unilateral drills) (73). Shankar et al. (244) found that prescribing high intensity plyometrics are superior compared to low intensity plyometrics for eliciting
various training adaptions. This claim is supported by De Villarreal et al. (73), who stated that high intensity plyometrics facilitate greater enhancement in strength adaptions compared to low intensity. De Villarreal et al. (71) found that prescribing a moderate number of repetitions (i.e. 840 jumps) elicits similar adaptions compared to high number of repetitions (i.e. 1680 jumps); thus allowing for a higher training efficiency and decreases the risk of overtraining. Clark (58) recommends that during speed development mesocycles plyometric training volume should be low (i.e. 50 repetitions per session).

Exercise selection is dependent upon the purpose of the training program, with respect to the desired training adaptations (73). De Villarreal et al. (73) recommends starting with low intensity, single joint, less complex exercises and progressing to a high intensity, multi-joint, complex exercises. Clark (58) stated that prescribing both vertical and horizontal based plyometric exercises (e.g. broad jumps, power skips for distance, sprint bounding) can enhance acceleration capacity. Additionally, Clark (58) recommends prescribing exercises that emphasize short ground contact times and landing mechanics (e.g. impulse pogo jumps, single/double leg mini hurdle jumps, single-leg hops). The prescription of various plyometric exercises in conjunction with resistance training exercise (i.e. complex training) is superior compared to only utilizing one training intervention (73).

The General Role of Sprint-specific Training in Football

This section is intended to provide an understanding of training recommendations for implementing various aspects of sprint training. Elite athletes require effective movement capability (e.g. accelerate, decelerate, change-of-direction, sprint performance) in response to a stimulus that occur in fractions of a second to be successful (278, 287). The purpose of sprint
training is to enhance the neuromuscular system, increase whole-body force production, motor unit recruitment, and synchronization (87).

Sprint training it is essential to develop high contractile velocity and various biomechanical variables (e.g. increase stride length and acceleration capacity) that enhance sprint performance (173). Clark (58) stated that individuals capable of greater maximal velocity are able to generate more vertical force, with shorter ground contact times, compared to slower individuals. During maximal speed, force application is more dependent upon the leg swing mechanics and stiffness during ground contact (58). This claim is supported by Young et al. (304), who stated that maximum speed can be enhanced by increasing either stride length and/or stride frequency. Markovic et al. (187) states that sprint training can facilitate similar, if not greater, training adaptations compared to plyometric exercises.

Clark (58) stated that the development of the posterior chain musculature is critical for maximal speed running. This claim is supported by Young et al. (304), who recommended developing the hip extensors (e.g. gluteals and hamstrings) to improving maximum sprint speed. The development of plantar flexor muscles is essential for sprint performance (304). While, the development of the hip flexors is essential for maximal speed, as it allows for decreased stride time; resulting in increased stride frequency (304).

Markovic et al. (187) found that 10 weeks of sprint training significantly increased leg extensor strength, power production, and enhanced stretch-shortening cycle function. Behara and Jacobson (19) found a 5-10% increase in type I and II muscle fiber cross sectional area following sprint programs ranging from 8 weeks to 8 months. Furthermore, Ross and Leveritt (240) found that prescribing brief maximal intensity sprints over various distances, interspaced with either
long or short duration recovery periods, can elicit enhance peak power and mean power in 3 weeks.

When selecting the exercises for sprint training, Clark (58) recommends incorporating eccentric muscle actions that mimic absorption forces of the ground contact phase. Proper free-sprinting exercises, without utilizing any external resistance or inclines, can increase running velocity, vertical and horizontal power, and isometric force production (173). Furthermore, Gleason et al. (104) recommend prescribing sport-specific drills that mimic position-specific movements and intensities of a competitive game. Bolger et al. (27) recommend utilizing both fixed plane resistance training exercises (e.g. back squat, squat jumps, leg extension) and locomotor resistance training exercises (e.g. sled pulls) to enhance sprint performance. Resisted-sprinting exercises utilize external resistance; resulting in increased lower limb muscular force output, step length, strength, power, and acceleration (173); illustrated in Table 2.10.

**Table 2.10- Specific exercise selection for sprint training (304)**

<table>
<thead>
<tr>
<th>Specificity</th>
<th>Exercise</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Parallel squat, deadlifts, hip extension/flexion exercises, core stability exercises</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Quarter squat, Romanian deadlift, single-leg squats/lunges, Olympic lifts from blocks, drop jumps, bounding exercises for distance</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Sled sprints with a jogging start at a low load, incline sprints with a jogging start at a low incline, speed bounding, weighted vest sprinting</td>
<td></td>
</tr>
</tbody>
</table>

Football relies primarily on the ability to accelerate and change directions, compared to linear speed (32). This claim is supported by Brechue (32), who states that football players’ ability to rapidly change direction and accelerate is more beneficial compared to maximum linear speed. Lockie et al. (174) states that shorter foot contact-time is directly linked to improved
acceleration. Additionally, Clark (58) states that individuals with greater acceleration capacity are able to generate more horizontal force. Lockie et al. (173) stated that athletes need a high force generation capacity; to overcome the body’s inertia when accelerating out of a stationary or moving stance.

When selecting the exercises for acceleration development Clark (58) recommends incorporating close-kinetic chain and multi-joint movements. To improving short sprint performance, Young et al. (304) recommend developing the quadriceps. Lockie et al. (172) found that prescribing maximal intensity runs over various distances, with a primary focus on acceleration; featuring shorter sprints, can facilitate improved 10-15m sprint performance. Furthermore, Clark (58) stated that implementing resisted sprinting exercises (e.g. sled pulls, incline treadmill sprints, uphill sprints) are superior to level free-sprinting exercises for improving acceleration. A full description of exercise selection for acceleration is available in Table 2.11.

**Table 2.11- Specific exercise selections for acceleration training (304)**

<table>
<thead>
<tr>
<th>Specificity</th>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Parallel squat, deadlifts, hip extension/flexion exercises, core stability exercises</td>
</tr>
<tr>
<td>Medium</td>
<td>Half squats, single-leg squats/lunges, Olympic lifts from floor</td>
</tr>
<tr>
<td>High</td>
<td>Sled sprints with a standing start at a medium load, incline sprints with a standing start at a medium incline</td>
</tr>
</tbody>
</table>

Agility is a skill-related movement defined by a rapid body movement while efficiently changing direction and/or velocity, with speed and accuracy, in response to a stimulus (37, 49, 104). An athlete’s lower-body relative strength is a key factor for agility performance (104). Agility is primarily composed of two fundamental components: physical (i.e. speed of body
movement) and cognitive (i.e. perceptual decision-making process) (37, 104). Brughelli et al. (37) states, that the ability to change direction while sprinting, is a key factor in sport performance.

Gleason et al. (104) provided recommendations for agility and change-of-direction programs training volume. Agility training volume should progressively increase during the spring mesocycle and further increase during summer mesocycle (104). During summer mesocycles training frequency should range between 3-4 d/wk with a shift to position-specific movements (104). Volume should progressively decrease during the pre-competitive mesocycle (i.e. pre-season training camp) until plateauing during the competitive mesocycle (i.e. in-season) (104). Agility training should continue to be prescribed throughout the competitive mesocycle, to maintain improvements that were obtained during previous mesocycles (104). Additionally, rest intervals during agility training should be decreased to prepare for competition (104). Young et al. (304) provided a model speed program; available in Table 2.12.

Table 2.12- Periodized speed training program (304)

<table>
<thead>
<tr>
<th>Mesocycle</th>
<th>Objective of mesocycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>General preparation</td>
<td>Increase neuromuscular capacity and injury prevention</td>
</tr>
<tr>
<td>Specific preparation</td>
<td>Increase neuromuscular capacity and develop maximum strength</td>
</tr>
<tr>
<td>Precompetition</td>
<td>Develop power</td>
</tr>
<tr>
<td>Competition</td>
<td>Maintain power and refine running mechanics</td>
</tr>
<tr>
<td>Transition</td>
<td>Recovery and rehabilitation</td>
</tr>
</tbody>
</table>

The General Role of Flexibility Training in Football

This section is intended to provide an understanding of training recommendations for implementing flexibility exercises. Flexibility is an intrinsic property of the musculature, ligaments, and connective tissues that is dependent upon viscoelasticity; which defines the range of motion of a joint (272). Limited flexibility predisposes an athlete to various musculoskeletal
overuse injuries (205). The ability of athletes to move fluidly and efficiently is dependent upon flexibility and mobility of their joints (87, 212). This claim is supported by McHenry (195), who stated that lineman with adequate lower body flexibility can successfully get into the proper stance and quickly achieve triple extension. Various flexibility exercises have been established to improved joint range of motion, joint function, and enhanced muscular performance (70). When implementing flexibility exercises scientific, evidence-based approaches (e.g. static stretching, dynamic stretching, proprioceptive neuromuscular facilitation) are recommended to ensure optimal training adaptations occur (272).

Shurley and Newman (248) recommends prescribing static stretching protocol of, 3 sets of 30s isometric holds for each exercise, post-exercise. Previous literature has established that static stretching during the cool-down period can enhance flexibility (130, 150). It is critical to note, that an acute bout of pre-activity stretching will inhibit the ability to generate maximal force, maximal power output, and impair sprint performance (130, 150, 196, 300). Contradictory research indicates that performing a dynamic stretching protocol following static stretching, will reduce and/or remove the induced performance decrements (300).

Dynamic stretching is defined as a movement of a limb through full range of motion; achieved by contracting the agonist muscle while simultaneously relaxing and elongating the antagonist muscles (131). Judge et al. (150) recommends performing dynamic stretching prior to activity. Proper dynamic stretching has been shown to increase leg extension power production and enhance explosive, sprint, and jump performances (131, 300).

Proprioceptive neuromuscular facilitation is a commonly prescribed stretching technique (123). There are two common protocols of proprioceptive neuromuscular facilitation, the contact-relax method and the contract-relax-antagonist-contact method (123, 205). Hindel et al.
(123) found that contractions held during proprioceptive neuromuscular facilitation for 3-10s (i.e. 6 s is preferred) were able to produce better effects. Hindel et al. (123) recommend prescribing proprioceptive neuromuscular facilitation ≥2 times per week, to maintain range of motion enhancements and muscular performance gained. Previous literature has established that both protocols can improve active range of motion, passive range of motion, muscle elasticity, and neuromuscular efficiency (123). To improve flexibility, Swanson (267) recommends stretching 3 muscles, 1-2 times each, with a 6-10s contractions. It is critical to note, if proprioceptive neuromuscular facilitation is performed prior to activity it will significantly decrease muscular performance, vertical jump, power, ground reaction time, muscular strength, and muscle electromyography activity (123).

De Baranda et al. (70) recommend the minimal flexibility frequency to be at least 3 d/wk (i.e. 5-7 d/wk is ideal). De Baranda et al. (70) recommends 3-5 repetitions of each stretch, while holding each position for 10-30s, with a daily dose ranging from 30-150s. This claim is supported by Swanson (267), who stated that each static stretch should be held for 10-30s to maximize potential improvements.

**Unique Aspects of Strength and Conditioning Programs**

This section is intended to provide a precise understanding of various unique aspects of the training program. A well-designed training program efficiently combines various training intervention, to yield greater training adaptations (87). This section is divided into 4 training interventions including: (i) balance and stability, (ii) core training, (iii) injury prevention, and (iv) Olympic weightlifting.
The General Role of Balance and Stability in Football

This section is intended to provide a precise understanding of training recommendations for implementing balance and stability exercises. Balance is the dynamic reaction of involuntary sensations and coordinated neuromuscular contractions that maintains the center of gravity over the base of support (137, 301). Balance is achieved through passive and active restraints of the musculoskeletal system and functional awareness of deviations in the center of gravity over the base of support (6, 301). This process is directly dependent upon continues feedback received via the visual, vestibular, and somatosensory mechanisms (137).

Hammami et al. (115) recommends utilizing a variety of exercises and progressions to improve balance. Athletes with poor dynamic balance are at increased risk of noncontact lower extremity injury (43). Enhanced balance can be achieved through implementing various protocols (e.g. balance training, neuromuscular training, instability resistance training) throughout the training program (20, 137, 201, 216, 269, 301, 306). Balance training specifically targets the enhancement of postural control through perturbation of the musculoskeletal system to facilitate greater neuromuscular capacity, readiness, and reaction (201, 301). Previous literature has established that proper balance training can improve postural control (269, 306), functional balance during dynamic movements (306), sprint performance (306), regeneration of neuromuscular structures (e.g. neuromuscular capacity) (137, 201, 269, 306), rate of force development (201, 269) and reduce the incidence of injury (i.e. noncontact lower limb) (43, 306).

To optimize neuromuscular adaptions, Muehlbauer et al. (201) recommend variations in training intensity (e.g. increased duration, number of sets) to adequately challenge the sensorimotor system. Previous literature has established that 5-10 weeks of balance training,
without added resistance, can facilitate adaptions (62, 151, 154, 257, 282, 301). The American College of Sport Medicine (54) recommends reducing the base of support (i.e. from two leg stance to one leg stance) and manipulating the sensory input (i.e. eyes open vs. closed) to facilitate adaptions.

Another effective training intervention is neuromuscular training (121, 306). The prescription of neuromuscular training incorporates balance and stability exercises that enhance sport performance, while also preventing injuries by facilitate rehabilitation (306). This is accomplished by enhancing proprioception mechanisms in the musculature and neuromuscular control throughout the body (306). Furthermore, neuromuscular training can enhance neural recruitment pattern, increase nervous system activation, motor unit synchronization, and decrease neural inhibiting reflex (121).

Another training intervention that specifically targets the enhancement of neural adaptions is instability training (154). Instability training mimic movements experienced during competitions, providing a more effective transfer of training adaptions (154). Previous literature has established that instability can challenge the neuromuscular system facilitating improved neuromuscular coordination and vertical jump height (20, 154). Furthermore, Kibele and Behm (154) found that instability training 2 times per week, for 7 weeks, can enhance strength, balance, and functional movement. It is critical to note, that during instability training significantly impaired leg extension and plantar flexor force outputs (20, 154); however, muscle electromyography was not altered (7, 20). Due to these findings, Kibele and Behm (154) recommend prescribing higher repetitions at a lower load and to prescribe instability resistance training in conjunction with traditional resistance training.
The General Role of Core Training in Football

This section is intended to provide an understanding of training recommendations for implementing core exercises. The core (e.g. trunk, lumbopelvic-region) encompasses all skeletal musculature between the shoulders and pelvis (3, 247, 294, 298). The core incorporates both passive and active structures (e.g. bones, skeletal musculature, and ligaments of the lumbar spine) to provide local strength and balance to enhance sport performance (155, 234). Gibson et al. (102) stated that core training is an essential component of the training program. Core musculature development is critical for optimal sport performance, as it stabilizes the trunk and pelvis, enhances force transferability, and is recruited during specific movements (i.e. rotation) (56). There are two basic elements of core training; core stability and strength.

Core stability is the ability of both active and passive components of the lumbopelvic-region to stabilize and maintain equilibrium of the spinal column; while modulating optimal force production, transfer, and control through dynamic movements (3, 121, 138, 155, 234, 298). Core stability focuses on maintaining spinal alignment and the transfer of loads through the kinetic chain (138, 293). The core is pivotal for efficient biomechanical synergy to maximize energy generation capacity and maximum force transferability to distal terminal extremities (121, 155). Previous literature suggests athletes require core stability to enhance distal mobility (3, 64).

Core strength is the ability to generate force and control the lumbar spine, while maintaining functional capacity and stability throughout dynamic movements (121, 234). Willardson (294) stated that core strength and power are essential for sport performance movements (e.g. jumping, speed, agility). Lloyd et al. (171) stated that core strength is critical to prevent unnecessary multi-planar movements.
Core endurance, can prevent injuries, which is accomplished through various neuromuscular mechanisms (121, 294). Hibbs et al. (121) recommends implementing low load motor control training, as it has been established as an essential component to both core strength and stability enhancements. Low load motor control training specifically improves the ability of the central nervous system to control muscle coordination, resulting in enhanced movement efficiency (121).

Akuthota et al. (3) recommend prescribing core training in stages with gradual progression. This claim is supported by Willardson (294), who stated that during pre-season and in-season mesocycles; the primary goal should be to facilitate core strength and power development. During the post-season mesocycle, the primary goal should be to facilitate increased core endurance (294). Additionally, McHenry (195) stated that core exercises that require the torso to be controlled (i.e. planks) are superior compared to exercises on stable surfaces where the glutes and/or back are supported (i.e. sit-ups). Progressive core training can elicit increased muscular protection of the spinal column (298), muscular coordination via the central nervous system (121), and decrease workload placed on extremities (116, 138).

**The General Role of Olympic Weightlifting in Football**

This section is intended to provide an understanding of training recommendations for implementing Olympic weightlifting. Olympic weightlifting consists of exercises executed with high muscular force while maintaining a high movement velocity through the completion of the movement (126, 133). Olympic weightlifting pulling derivations remove the catch phase while emphasizing the second pull (i.e. triple extension); examples of which are the clean pull, snatch pull, hang-high pull, jump shrug, and mid-thigh pull (263). The biomechanical synergy of the
triple extension (e.g. hip, knee, and ankle joints) requires lower-body power and intramuscular coordination (233, 271). Teo et al. (271) states that the development of the triple extension is essential for athletes, as this movement is sport-specific due to the high degree of biomechanical similarity. This claim is supported by Suchomel et al. (263), who reported a strong relationship between Olympic weightlifting and sprinting, vertical jump, and change-of-direction movements.

Previous literature has found that Olympic weightlifting programs are superior compared to traditional resistance training (110), power lifting (126), plyometrics (110), and vertical jump (274) exercises for eliciting specific training adaptations. Hackett et al. (110) reported a greater increase in vertical jump height following Olympic weightlifting compared to traditional resistance training. Furthermore, Hackett et al. (110) reported a greater increase in vertical jump height following Olympic weightlifting program compared to plyometrics. Hoffman et al. (126) has reported statistically significant increases in vertical jump after Olympic weightlifting programs, compared to power lifting programs (e.g. bench, squat, deadlift). Due to the fact that it is performed at high movement velocities with heavy loads increasing power output (126). Prescribing Olympic weightlifting 3 times per week, for 8 weeks, can improve jumping and sprinting performance (274).

An effective Olympic weightlifting program follows the principle of specificity, based on position-specific needs (233). Throughout the training program the exercise selection varies with different mesocycles based on the desired training adaptations. Implementing Olympic weightlifting pulling derivations are beneficial for three reasons: (i) majority of the transferability of training adaptations are directly related to the pull, compared to the catch; (ii) place less stress on the wrists, shoulders, and low back; (iii) produce greater magnitudes of
various muscular characteristics (i.e. peak force, rate of force development, velocity, power development) (263).

Suchomel et al. (263) recommend prescribing Olympic weightlifting pull deviations throughout the entirety of the training program. During the preparation mesocycle a high training volume of Olympic weightlifting is recommended (263). During the transmutation mesocycle, decrease the repetitions to enhance power characteristics (263). Training loads can exceed 100% 1RM clean and snatch for the clean pull, snatch pull, mid-thigh pull due to eliminating the catch phase (263). Suchomel et al. (263) recommend prescribing mid-thigh pulls at 120% 1RM of clean during strength mesocycles. Furthermore, they recommend loads ranging between 60-110% 1RM for 3x10 during a strength-endurance mesocycles; and reducing volume to 3x5 or 3x3 while increasing training load during strength and strength-power mesocycles. Additionally, Suchomel et al. (263) recommend further reducing volume to 3x3, 3x2, or 2x2 while decreasing training loads during speed and maintenance mesocycles.

Previous literature has established that proper Olympic weightlifting training can improve strength (126), power production (126, 133, 271), skeletal and soft tissue characteristics (263), intramuscular coordination (271), sprint performance (126, 271), and vertical jump performance (110, 126, 271). Furthermore, Hoffman et al. (126) found an 18% increase in squat 1RM and a significant decrease in 40-yd dash times following an Olympic weightlifting program. Specifically for football, it is essential to prescribe Olympic weightlifting to enhance the ability to accelerate a load and rapidly accept an external load (e.g. lineman blocking) (263).
The General Role of Injury Prevention in Football

This section is intended to provide a precise understanding of training recommendations for implementing an effective injury prevention program. The basic principle of injury prevention (e.g. pre-rehabilitation) is to decrease the risk of injury and enhance sport performance (253). Lloyd et al. (171) stated that the injury prevention program needs to be diverse to address risk factors of participation. Football involves an inherent risk of sustaining an injury due to high-velocity movements and frequent collisions, either player-to-player and/or player-to-ground, increasing internal load values sustained (85, 134, 291). Players are at risk of muscular and skeletal contact injuries that directly result in acute and chronic inflammation (302). Due to higher injury risk, it is critical to prescribe injury prevention exercises (43). Howe et al. (134) recommends implementing a 5-step injury prevention model, which involves; (i) establishing the risk of injury associated with participation, (ii) identifying the injury mechanisms and individual risk factors, (iii) design and implement a screening protocol, (iv) design and prescribe the injury prevention program, (v) repeat screening protocol to assess effectiveness.

The first step of the 5-step injury prevention model is to examine the injury epidemiology of the particular sport (i.e. football) accomplished by assessing the injury incidence throughout the year, each position, and the specific injury sustained (134). Football has been reported to have the highest injury rate associated with participation (43, 291); illustrated in Table 2.13.
Table 2.13- Injury rates of football sustained throughout the year

<table>
<thead>
<tr>
<th>Description</th>
<th>Injury Rate (Athletic Exposures)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFL training camp</td>
<td>13.36/1000</td>
<td>85</td>
</tr>
<tr>
<td>NFL pre-season</td>
<td>64.7/1000</td>
<td>88</td>
</tr>
<tr>
<td>NFL practice</td>
<td>12.7/1000</td>
<td>88</td>
</tr>
<tr>
<td>Overall</td>
<td>17.3/1000</td>
<td>88</td>
</tr>
<tr>
<td>Football</td>
<td>40/1000</td>
<td>197</td>
</tr>
</tbody>
</table>

It is critical to discuss, the specific positions that commonly sustain injuries to prioritize injury prevention programming for them. Feeley et al. (88) reported that on defense, defensive backs and linebackers are the most common positions to sustain an injury. Additionally, Feeley et al. (88) reported that on offense, wide receivers and tight ends are the most common positions to sustain an injury; illustrated in Table 2.14.

Table 2.14- Injury rates of each football position (88)

<table>
<thead>
<tr>
<th>Position</th>
<th>Injury Rate (Athletic Exposures)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarterback</td>
<td>1.2/1000</td>
</tr>
<tr>
<td>Running back</td>
<td>1.9/1000</td>
</tr>
<tr>
<td>Wide receiver</td>
<td>2.3/1000</td>
</tr>
<tr>
<td>Tight end</td>
<td>2.7/1000</td>
</tr>
<tr>
<td>Offensive line</td>
<td>1.6/1000</td>
</tr>
<tr>
<td>Defensive line</td>
<td>1.7/1000</td>
</tr>
<tr>
<td>Linebacker</td>
<td>2.3/1000</td>
</tr>
<tr>
<td>Defensive backs</td>
<td>2.6/1000</td>
</tr>
<tr>
<td>Kicker</td>
<td>0.7/1000</td>
</tr>
</tbody>
</table>

Table 2.14 is replicated from Table 5 (88, p1601)

Once the incidence of injury is established, examine the specific injury sustained and assess the injury severity. Feeley et al. (88) reported that the most frequent injuries sustained by NFL players during a competitive game regardless of position, were knee and ankle sprains. Feeley et al. (88) reported that the most frequent injuries sustained during practices were knee
and lumbar strains; illustrated in Table 2.15. Howe et al. (134) stated that injuries with greater severity and commonly occur should be the major focus of the injury prevention program.

**Table 2.15- Injury rates for specific injuries NFL players sustain (88)**

<table>
<thead>
<tr>
<th>Injury</th>
<th>Practice (Athletic Exposures)</th>
<th>Competitive game (Athletic Exposures)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee sprain</td>
<td>2.12/1000</td>
<td>10.84/1000</td>
</tr>
<tr>
<td>Hamstring strain</td>
<td>1.79/1000</td>
<td>4.07/1000</td>
</tr>
<tr>
<td>Contusion</td>
<td>0.92/1000</td>
<td>12.47/1000</td>
</tr>
<tr>
<td>Ankle sprain</td>
<td>1.10/1000</td>
<td>6.78/1000</td>
</tr>
<tr>
<td>Lumbar sprain</td>
<td>1.17/1000</td>
<td>2.44/1000</td>
</tr>
<tr>
<td>Shoulder sprain</td>
<td>0.80/1000</td>
<td>5.42/1000</td>
</tr>
<tr>
<td>Fracture or dislocation</td>
<td>0.67/1000</td>
<td>6.23/1000</td>
</tr>
<tr>
<td>Groin strain</td>
<td>0.70/1000</td>
<td>1.63/1000</td>
</tr>
<tr>
<td>Foot sprain</td>
<td>0.52/1000</td>
<td>3.52/1000</td>
</tr>
<tr>
<td>Cervical sprain</td>
<td>0.60/1000</td>
<td>1.36/1000</td>
</tr>
<tr>
<td>Hip flexor strain</td>
<td>0.65/1000</td>
<td>1.08/1000</td>
</tr>
<tr>
<td>Quadriceps strain</td>
<td>0.60/1000</td>
<td>1.08/1000</td>
</tr>
<tr>
<td>Achilles strain</td>
<td>0.55/1000</td>
<td>1.36/1000</td>
</tr>
<tr>
<td>Concussion</td>
<td>0.17/1000</td>
<td>3.25/1000</td>
</tr>
<tr>
<td>Abdominal strain</td>
<td>0.17/1000</td>
<td>0.81/1000</td>
</tr>
<tr>
<td>Elbow sprain</td>
<td>0.10/1000</td>
<td>1.63/1000</td>
</tr>
<tr>
<td>Gluteal strain</td>
<td>0.12/1000</td>
<td>0.00/1000</td>
</tr>
</tbody>
</table>

Table 2.15 is replicated from Table 3 (88, p1600)

The second step of the 5-step injury prevention model is to identify and examine the injury mechanisms and risk factors (134). Whiting (291) established several force-related factors that can influence the severity of the injury including; magnitude, location, direction, duration, frequency, variability, and rate of force applied. Additionally, to demonstrate various movement patterns to observe any dysfunctions Howe et al. (134) recommends utilizing biomechanical screening tools. Ford (95) stated the importance of utilizing a multi-factorial approach to assess associated risk factors. Understanding the various injury risk factors, both intrinsic (e.g. age, sex, health status, injury history, training background) and extrinsic (e.g. equipment, playing surface,
weather), risk factors experienced on a daily basis will influence the appropriate intervention prescribed (95, 134). Risk factors can be classified as modifiable or non-modifiable (134). Previous literature has identified various modifiable risk factors including: body mass (BM) index, strength, and flexibility (43). Identifying modifiable risk factors is essential to accurately assess the risk of sustaining an injury (134). This claim is supported by Wilkerson et al. (293), who found that NCAA Division I football players with ≥2 modifiable risk factors, associated with the core function, were 2 times more likely to sustain an injury. One way to fully assess risk factors is by following a comprehensive model for injury causation (134); represented in Table 2.16.

Table 2.16- A comprehensive model for injury causation in an athlete (134)

<table>
<thead>
<tr>
<th>Internal risk factors</th>
<th>External risk factors</th>
<th>Mechanism for injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>P r e A</td>
<td>Sport factors</td>
</tr>
<tr>
<td>Sex</td>
<td>d t i h s l p e o t s e</td>
<td>Protective equipment</td>
</tr>
<tr>
<td>Body composition</td>
<td></td>
<td>Sports</td>
</tr>
<tr>
<td>Health</td>
<td></td>
<td>equipment</td>
</tr>
<tr>
<td>Physical fitness</td>
<td></td>
<td>Environment</td>
</tr>
<tr>
<td>Anatomy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skill level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiological factors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.16 is adapted from Figure 3 of (134)

The third step of the 5-step injury prevention model is to design and implement screening protocol, to establish a complete athlete profile (134). Conducting screening tests are essential for identifying poor dynamic movement patterns, muscular imbalances, and asymmetries (156). Lloyd et al. (171) has identified an increased risk of injury associated with quadriceps dominant athletes and/or athletes with any asymmetries present. Panteleimon et al. (217) has recommended
incorporating various joint mobility tests. Previous literature has established that the functional movement screen and star excursion balance test are valid and reliable.

The functional movement screen assesses several movement patterns; (i) deep squat, (ii) hurdle step, (iii) in-line lunge, (iv) shoulder mobility, (v) active straight leg raise, (vi) trunk stability push up, (vii) rotary stability test (28, 157, 291). Each individual movement pattern is scored on a 3 point ordinal scale; represented in Table 2.17. Scores lower than 14 point total, predispose individuals to be more susceptible to injury (156, 1575); additionally any asymmetries experienced, regardless of total score, is 2.3 times more susceptible to sustain an injury (157).

Table 2.17 – Functional Movement Screening movement pattern ordinal score representation (157)

<table>
<thead>
<tr>
<th>Ordinal Score</th>
<th>Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>The participant experienced any pain during the completion of the movement</td>
</tr>
<tr>
<td>1</td>
<td>The participant could not complete the movement as instructed</td>
</tr>
<tr>
<td>2</td>
<td>The participant completed the movement pain free but experienced some level of compensation</td>
</tr>
<tr>
<td>3</td>
<td>The participant completed the movement as instructed and is/ was pain free and without any compensation</td>
</tr>
</tbody>
</table>

The star excursion balance tests assess of lower-body dynamic balance and reach deficits, associated with lower extremity injury and function (43, 160, 214). The star excursion balance test protocol involves balancing on a single leg with the contralateral leg reaching in an 8 point circle (214). Butler et al. (43) reported that football players with a score of >89.6% were 3.5 times more susceptible to sustain an injury. Additionally, Kivlan and Martin (160) reported a ≥4cm anterior reach difference is 2.5 times more susceptible to sustain an injury.
The fourth step of the 5-step injury prevention model is to design and prescribe the injury prevention program (134). One critical component of an effective injury prevention program is focusing on the development of the cervical spine (i.e. neck). An athlete’s ability to maintain the biomechanical alignment and isometric strength of the cervical spine will experience less concussive forces (25). It is well established by previous literature and medical findings that concussions can result in neurocognitive effects (e.g. impaired memory, cognitive, functional ability) and long-term health problems (25, 170). Lisman et al. (170) stated that football has a higher incidence of sustaining a concussion compared to other sports. This claim is supported by McIntosh and McCrory (197), who found that sports (i.e. football) that involve body contact and high speeds are associated with increased risk of head and neck injury. Additionally, once an athlete sustains a concussion they are 3 times more susceptible to sustain a second (25). However, with proper training intervention an athlete can decrease the instance and severity of concussions (25, 39, 60, 84, 170, 279).

Collins et al. (60) stated that one risk factor for sustaining a concussion is poor cervical spine strength. This claim is supported by Black (25) who stated that insufficient cervical spine strength cannot produce sufficient internal muscular force compared to external force experienced, resulting in head acceleration. Athletes with greater isometric cervical spine strength were able to reduce the risk of injury by decreasing the peak head acceleration, velocity, and displacement experienced (84, 170, 279).

As stated previously, limited flexibility predispose an athlete to various musculoskeletal overuse injuries (205). McHugh and Cosgrave (196) provided three recommended pre-participation stretching protocols to follow: (i) target muscle groups known to be at risk for the particular sport (ii) perform 4-5 repetitions for 60 s to pain tolerance, bilaterally for the target
muscle groups (iii) perform a dynamic drill before performance to avoid any stretch-induced adaptions.

The fifth step of the 5-step injury prevention model is to repeat the screening protocol to assess effectiveness of the injury prevention program (134). After a designated period of time reassessment is required to reflect any training adaptions and/or new risk factors. Prescribing this systematic approach to injury prevention programming can be an effective strategy of reducing the risk of injury (134).

The General Role of Recovery in Football

This section is intended to provide an understanding of training recommendations for implementing effective recovery modalities. Participating in high intensity exercise induces fatigue in multiple physiological processes (e.g. musculoskeletal, nervous, metabolic system) disrupting cellular homeostasis (222, 256, 270). Furthermore, when participating in exercise above anaerobic threshold, recovery is essential due to accumulation of muscle acidosis, inhibiting optimal performance (207). The ability to adapt to physiological stress by repairing and reestablishing homeostasis levels is one of the most basic biological principles, referred to as the general adaptation syndrome (87). The degree of fatigue and muscle damage experienced is directly dependent upon training intensity, frequency, duration, and exercise selection (114, 122, 222).

It is critical to implement a scientific evidence-based recovery program, as structural damage of the musculature and connective tissue alters muscle function and movement patterns (222). This claim is supported by Barnett (16), who states that it is essential to balance physiological stress and recovery; to optimize sport performance. Furthermore, the rate and overall quality of the recovery is essential to prepare for the next training session or competitive
game (114). Additionally, consideration of the amount of time until the next training session will influence which type of recovery modalities to prescribe (114). Previous literature has provided various recovery modalities that are effective and including hydrotherapy, massage therapy, compression garments, and cryotherapy (15, 16, 19, 55, 114, 204, 219, 270, 292).

Hydrotherapy (i.e. water immersion) is a common recovery modality utilized to promote recovery and enhance acute performance (114, 292). There are three common forms of hydrotherapy: cold water immersion, hot water immersion, and contrast water therapy (i.e. alterations between hot and cold) (114). Murray et al. (204) found that cold water immersion was the most commonly utilized recovery modality of collegiate athletes. Furthermore, cold water immersion was also classified as one of the most effective recovery modalities (204). Wilcock et al. (292) states that contrast water therapy has become popular in recent years. The duration of exposure is critical during cold water immersion, as it impacts the magnitude of recovery (270). Wilcock et al. (292) recommend water immersion durations ranging between 6-20 min. This claim is supported by Tavares et al. (270), who recommended repeated exposures of cold water immersion for 5 min 2 times with 10 min in-between bouts. With respect to water temperature for cold water immersions, the ideal range is between 10-15\(^\circ\)C (55, 114, 270); illustrated in Table 2.18. Hydrotherapy acute therapeutic benefits include: decreasing inflammation, muscle damage, perception of fatigue (114, 292); alterations in peripheral blood flow, skin, muscle, and core temperature (114), and reduce the decrease in maximal force induced by intense exercise (55).
Table 2.18- Various hydrotherapy protocol recommendations and respective recovery periods (114)

<table>
<thead>
<tr>
<th>Hydrotherapy</th>
<th>Temperature (°c)</th>
<th>Protocol (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold water immersion</td>
<td>10-15</td>
<td>2x5</td>
</tr>
<tr>
<td>Hot water immersion</td>
<td>38-40</td>
<td>2x5</td>
</tr>
<tr>
<td>Contrast water therapy</td>
<td>Cold-10-15</td>
<td>3x2</td>
</tr>
<tr>
<td></td>
<td>Hot-38-40</td>
<td>3x2</td>
</tr>
</tbody>
</table>

Massage therapy (i.e. myofascial release) is a common intervention technique for treating fibrous adhesions of the muscle fascia layers and connective tissues (15, 19, 114, 222). Myofascial tissue disturbances are induced by musculoskeletal injury, imbalances, reoccurring microtrauma, and/or over recruitment patterns resulting in inhibitory mechanisms (e.g. decrease in joint range of motion, muscle length and coordination, maximum strength, and power output production) (19). Massage therapy is commonly utilized to prevent and decrease the pain associated with delayed onset muscle soreness and enhance recovery (16, 222). Furthermore, Barnett (16) stated that the increase of muscular blood flow during post-exercise period may facilitate enhanced rate of blood lactate removal. Further research is needed to provide sufficient evidence that massage therapy has therapeutic benefits during recovery periods (16).

Foam rolling (i.e. self-myofascial release), is a common technique utilized for treating and preventing soft tissue structural damage (19, 114, 222). Pearcey et al. (222) recommends prescribing a 20 min bout of foam rolling, utilizing a high-density roller immediately post-exercise and repeated every 24 hours following, to enhance the recovery mechanisms for delayed onset muscle soreness. Furthermore, previous literature established that foam rolling protocols can increased blood flow (19, 114), sprint performance (222), power (222), lymphatic system
function (19, 114); decreased fatigue (19, 114), and resynthesis of muscle tendon, ligament, and soft tissue excitability (19, 114).

Another recovery modality commonly utilized is compression garments (122). Compression garments can treat and prevent deep vein thrombosis and reduce swelling (16). These claims are supported by Behara and Jacobson (19), who stated that external pressure applied by the compression garment decreases inflammation via decreased intramuscular space. Additionally, compression garment application can enhance acute venous return (114). Chatard et al. (52) found that utilizing compression garments during an 80 min post-exercise recovery period with the legs elevated can decrease blood lactate concentration and enhanced performance post-recovery. Additionally, Gill et al. (103) found that utilizing compression garments for a 12 hrs. post-competition in rugby players enhanced muscle damage recovery.

Cryotherapy is an effective recovery modality for treating musculoskeletal injury during both acute post-exercise recovery periods and rehabilitation periods (78, 120). Tavares et al. (270) recommends prescribing cryotherapy for short exposures of extreme temperatures ranging between -110 to -140°C. Previous literature established that cryotherapy can facilitate the following therapeutic benefits; decrease tissue temperatures (120, 256), pain (78, 120, 256), inflammation (78, 120), and tissue metabolism (120, 256).

The General Role of Nutrition and Supplementation in Football

This section is intended to provide an understanding of nutrition and supplementation recommendations. A careful strategically planned dietary protocol can enhance sport performance (273). The acute and chronic training adaptations initiated from the training program, may be amplified or diminished by nutrition habits. It is critical to note, that a large inter-
individual variability can be demonstrated; emphasizing the need for an individualized, periodized, dietary protocol that are position-specific (220). Performing resistance training facilitates a significant glycogenolytic effect resulting in performance decrements (112). An extensive understanding of both nutritional and supplementation recommendations are require to prescribe an optimal dietary protocol.

**Nutritional Recommendations for Football Players**

An unhealthy dietary practice can elicit negative performance indicators and overall health problems (146). Jeukendrup (145) stated that training adaptations are affected by the quality and quantity of nutrient availability. Previous literature has established that adequate nutritional intake can directly enhance sport performance (15, 33, 147, 229, 230, 273). It is critical to establish nutritional goals and implement dietary protocols on an individual basis with precise timing, quantity, nutrient quality, and fluid intake to optimize performance capabilities (132, 230). Long term goals should be constantly taken into consideration when prescribing dietary protocols (145). Jeukendrup (145) recommends nutritional periodization, which correlates nutrition protocols simultaneously with the current mesocycle. This claim is supported by Jagim et al. (141), who found a significant increase in physical demands during pre-season training camp that increases the total daily energy expenditure, requiring a greater energy requirement and macronutrient values. Additionally, Patel (220) stated that before designing the nutrition program the yearly and daily schedule should be considered.

The foundation of an effective dietary protocol is sufficient energy intake. On a molecular level, calories are essential for anabolic processes, muscle resynthesizing, and neuromuscular processes (i.e. nerve impulse) (99). Nutrients modulate cell signaling pathways
throughout the body to facilitate skeletal muscle adaptations (59). It is essential to consume sufficient energy to maintain an energy balance during periods of high energy expenditure (229). Potgieter (229) recommends consuming 4-6 meals/d, focusing on nutrient dense foods to meet metabolic energy demands. A well-balanced dietary protocol will include a wide variety of foods from all major food groups (229, 295). Jagim et al. (141) states that athletes require a greater energy intake requirement than the Recommended Dietary Allowance recommends; providing a need for precise and individualized dietary protocol prescriptions. If an athlete is consuming insufficient energy compared to metabolic demands, the physiological response is detrimental to sport performance (141). Various guidelines for energy intake in athletes are available in Table 2.19.

Table 2.19 - Daily energy intake guidelines for athletes (229)

<table>
<thead>
<tr>
<th>Type of athlete</th>
<th>Recommendation (kcal/kg/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High volume of intense training</td>
<td>50-80</td>
</tr>
<tr>
<td>Elite athletes</td>
<td>150-200</td>
</tr>
<tr>
<td>Large athletes</td>
<td>60-80</td>
</tr>
<tr>
<td>High volume - 3-6h/d for 1-2 sessions/d training 5-6 d/wk</td>
<td></td>
</tr>
</tbody>
</table>

Total daily caloric intake is the total amount of energy consumption consumed during a 24h period of time (99). Total daily energy expenditure is unique and involves inter-individual variability (42). The total daily caloric intake should reflect the total daily energy expenditure. There are two distinct classifications of nutrients; macronutrients and micronutrients.

Macronutrients require a larger daily quantity and include: carbohydrates (CHO), proteins, and fats (44). Adequate macronutrient consumption is capable of modulating acute physiological regulatory responses to training stressors (86). Escobar et al. (86) state those
macronutrient intakes are essential modulators for acute and chronic training adaptations, fuel utilization, acute cell signaling, and protein gene expression.

Individual CHO availability is essential for muscular and central nervous system function that influences exercise performance (40). Daily CHO consumption guidelines for athletes are provided in Table 2.20. Escobar et al. (86) recommended consuming a moderate CHO intake (i.e. 3-7 g/kg/d) to prevent glycogen depletion and enhance performance characteristics. Additionally, requirements vary based on training frequency, exercise selection, intensity, and inter-individual variability (86). Furthermore, inadequate endogenous CHO availability impairs optimal sport performance (119).

**Table 2.20- Daily CHO consumption guidelines for athletes**

<table>
<thead>
<tr>
<th>Quantity (g/kg/d)</th>
<th>Description</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-10</td>
<td>Athletes</td>
<td>110</td>
</tr>
<tr>
<td>8-10</td>
<td>High volume exercise</td>
<td>110</td>
</tr>
<tr>
<td>4-7</td>
<td>Strength trained athletes</td>
<td>110</td>
</tr>
<tr>
<td>9-10</td>
<td>Intense exercise on consecutive days</td>
<td>77</td>
</tr>
<tr>
<td>6-10</td>
<td>Training at moderate-high intensities ≤3h/d</td>
<td>80</td>
</tr>
</tbody>
</table>

Note- High volume exercise represents 3-6 h training sessions with 1-2 sessions/d for 5-6 d/wk

Athletes require daily protein to balance the physiological stressors of training (i.e. increased catabolic processes) (226). High intensity training decreases essential amino acid (EAA) availability resulting in the slowed rate of tissue repair and growth (152). It is essential to adequately supply skeletal musculature with sufficient substrates for fuel utilization (41). Phillips and Van Loon (226), state that resistance training athletes (i.e. football players) require larger quantities of daily protein, above the Recommended Dietary Allowance guidelines, to resynthesize muscle protein. Skeletal muscle mass and molecular make up are regulated by the
protein balance (i.e. balance between muscle protein synthesis and breakdown) (98). Daily protein consumptions guidelines for athletes are provided in Table 2.21.

Table 2.21 - Daily Protein consumption guidelines for athletes

<table>
<thead>
<tr>
<th>Quantity (g/kg/d)</th>
<th>Description</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5-2</td>
<td>High volume of intense training</td>
<td>229</td>
</tr>
<tr>
<td>1.2-1.7</td>
<td>Strength and Endurance athletes</td>
<td>229</td>
</tr>
<tr>
<td>1.3-1.8</td>
<td>Athletes</td>
<td>229</td>
</tr>
<tr>
<td>1.6-1.7</td>
<td>Strength trained athletes</td>
<td>229</td>
</tr>
<tr>
<td>1.2-1.7</td>
<td>Resistance training athletes</td>
<td>225</td>
</tr>
</tbody>
</table>

Athlete’s dietary fat guidelines are comparable or slightly higher compared to the general population’s Recommended Dietary Allowance (229). It is essential to consume adequate quantities of fat through the diet to ensure optimal health, fat-soluble vitamin transportation ability, and replenish intramuscular triglyceride stores (229). Bird (23) recommends consuming a majority of the dietary fat intake as mono unsaturated and polyunsaturated fats (i.e. 10-15% daily caloric intake) and small quantities of saturated fats (i.e. <10% daily caloric intake). Daily fat consumptions guidelines for athletes are provided in Table 2.22.

Table 2.22 - Daily Fat consumption guidelines for athletes

<table>
<thead>
<tr>
<th>Quantity (Daily caloric intake)</th>
<th>Description</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30%</td>
<td>Strength athletes</td>
<td>23</td>
</tr>
<tr>
<td>20-35%</td>
<td>Moderate-high training intensity ≤ 3h/d</td>
<td>159</td>
</tr>
</tbody>
</table>

Micronutrients (e.g. vitamins and minerals) are required at minuscule daily quantities (e.g. mg, μg) (179). Adequate micronutrients consumption is essential for metabolic processes (281), energy metabolism (189), and overall health benefits (229). Micronutrient deficiencies can
result in higher rates of illness and overall health problems (24). Deficiencies of iron, magnesium, and vitamin-D have been reported to negatively affect sport performance (230). Additionally, blood sodium levels decrease as result of training conditions during preseason training camp predisposing athletes to dehydration and decreased performance (105).

National Football League players with adequate Vitamin-D blood serum levels have demonstrated significantly longer careers due to healthy and optimal musculoskeletal systems, compared to NFL players with insufficient or deficient levels (200, 230). Vitamin-D blood serum levels are classified in three categories; illustrated in Table 2.23. During the NFL pre-season training camp, released players had significantly lower vitamin-D levels, compared to players who made the roster (230). Vitamin-D deficiencies increase the risk of bone fractures; players who sustained at least one bone fracture had significantly lower vitamin-D blood serum levels (200).

Table 2.23– Vitamin-D blood serum level classifications (230)

<table>
<thead>
<tr>
<th>Category</th>
<th>Level (ng/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deficient</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Insufficient</td>
<td>20-32</td>
</tr>
<tr>
<td>Adequate</td>
<td>&gt;32</td>
</tr>
</tbody>
</table>

In recent years, research has identified the increased emphasis of the timing of specific nutrient ingestion administration (46). The timing of nutritional administration is critical to optimize training adaptions (153). This claim is supported by Bird (23), who stated the type and timing of protein and amino acid ingestion had significant effects on exercise performance. Furthermore, prior and post-exercise nutrient ingestion are essential to prevent compromising performance (23). Nutritional administration can be categorized in three distinct phases; prior, intra, and post-exercise.
Prior to initiating exercise it is critical to maximize endogenous glycogen stores to effectively enhance performance, decrease exercise-induced muscle damage, and delay fatigue (153). Kerksick et al. (153) recommends 1-2 g CHO/kg consumed 3-4 h prior to exercise with an emphasis on high glycemic index food sources. Bird (23) reported that liquid pre-exercise CHO ingestion can reduce the muscle and liver glycogen depletion; especially with multiple training sessions per day. Kerksick et al. (153) recommends consuming 0.15-0.25 g protein/kg, 3-4 h prior to exercise; with an additional 6 g of EAA. The co-ingestion of EAA, protein, and creatine (Cr) prior to exercise can enhance exercise performance (153). Macronutrients prior to exercise administration recommendations are available in Table 2.24.

Table 2.24- Macronutrient and nutritional guidelines 3-4 h prior to exercise

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Recommendation</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHO+ protein</td>
<td>1-2 g CHO/kg+0.15-0.25 g protein/kg or 35 g CHO+6 g EAA</td>
<td>153</td>
</tr>
<tr>
<td>Meal</td>
<td>200-300 g meal low in fat and daily fiber, high in CHO and moderate protein</td>
<td>229</td>
</tr>
<tr>
<td>CHO</td>
<td>1-2 g CHO/kg</td>
<td>229</td>
</tr>
</tbody>
</table>

During moderate-to-high (i.e. 65-85% VO2 max) intensity exercise endogenous glycogen stores will last an estimated 90-180 min; relative to inter-individual variability (153). Nutrient administration intra-exercise can increase anabolic physiological responses (153). This claim is supported by Bird (23), who stated that liquid CHO ingestion intra-exercise can induce hormonal response towards an anabolic state. Specifically, consuming a 6-8% CHO solution both prior and intra-exercise enhanced anabolic potential (23). The ingestion of CHO can delay hypoglycemia, maintain a high rate of CHO oxidation, and increase exercise capacity during a training session (144). Slater and Phillips (252) reported that ingesting CHO both prior and intra-exercise (i.e. 1 g/kg; 0.5 g/kg respectively) can increase overall work capacity. Furthermore, the ingestion of CHO and EAA (i.e. 6:6% respectively) solution during resistance training can increase the cross
sectional area of type I, IIa, and IIb muscle fibers, and decreased urinary 3-methylhistidine levels (153). Macronutrient intra-exercise administration recommendations are available in Tables 2.25.

**Table 2.25- Macronutrient and nutritional guidelines during intra-exercise**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small amounts of CHO</td>
<td>Short duration 30-60 min, high intensity exercise</td>
<td>144</td>
</tr>
<tr>
<td>Small amounts of CHO</td>
<td>High intensity 45-75 min duration</td>
<td>229</td>
</tr>
<tr>
<td>30-60 g CHO/h</td>
<td>Intermittent exercise for 1-2.5h duration</td>
<td>229</td>
</tr>
<tr>
<td>30-60 g CHO/h</td>
<td>2h+ duration exercise</td>
<td>144</td>
</tr>
<tr>
<td>6 CHO:6 EAA% solution</td>
<td>Single bout of resistance training</td>
<td>153</td>
</tr>
</tbody>
</table>

Note- Small amounts of CHO represents CHO mouth rinse

The main nutritional objective immediately post-exercise is to promote the acute recovery processes (145). Slater and Phillips (252) reported that a single resistance training session can reduce muscle glycogen stores by 24-40%; dependent upon the training duration, intensity, volume, and exercise selection. Additionally, the extent of macronutrients and micronutrients required post-exercise is directly dependent upon the training season (145). Heavy resistance training can facilitate acute microtrauma in muscle fibers requiring additional protein intake immediately post-exercise (128). Bird (23) states that protein and amino acid during the recovery period is essential for hypertrophy. An absence in protein consumption post-training can result in a low net muscle protein synthesis, and in extreme cases, a negative protein balance (145). Additionally, post-exercise CHO ingestion improved the net muscle protein balance (23). Bird (23) found that subjects who consumed leucine enriched CHO and EAA post-exercise increased the mechanistic target of rapamycin signaling by 145%. Macronutrient post-exercise administration recommendations are available in Table 2.26.
Table 2.26- Macronutrient and nutritional guidelines during post-exercise

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 min post-exercise</td>
<td>1.5 g CHO/kg</td>
<td>153</td>
</tr>
<tr>
<td>Post-exercise glycogen depletion</td>
<td>0.6-1 g CHO/kg *</td>
<td>153</td>
</tr>
<tr>
<td>30 min post-exercise</td>
<td>1.2-1.5 g simple CHO/kg 0.3-0.5 g protein/kg</td>
<td>153</td>
</tr>
<tr>
<td>Post-exercise</td>
<td>≈ 20 g protein</td>
<td>8</td>
</tr>
<tr>
<td>30 min post-exercise and every 2h for 4-6h</td>
<td>1-1.5 g CHO/kg</td>
<td>229</td>
</tr>
<tr>
<td>Speedy recovery next training session is &lt;8h</td>
<td>1-1.2 g CHO/kg/h for 4h</td>
<td>229</td>
</tr>
</tbody>
</table>

*- Consume during first 30 min and again every 2h for 4-6h

It is critical to note that nutritional requirements vary based on intra-individual variability, level of competition, position, and training goals (146). This claim is supported by Jagim et al. (141), who observed that linemen have a higher BM, fat-free mass (FFM), and fat mass (FM) compared to other athletes; which correlates to a higher resting energy expenditure.

Supplementation Recommendations for Football Players

Nutritional supplements can enhance various metabolic processes (e.g. increased muscle protein synthesis, mitochondrial biogenesis, fat oxidation, and performance capacity) (145). Before prescribing supplements it is critical to evaluate the theoretical rationale of prescription and scientific evidence of the proposed effects on exercise performance and metabolism (166). Jeukendrup (145) found that specific supplements (e.g. caffeine, sodium bicarbonate, nitrate) can enhance exercise performance. The most commonly consumed nutritional supplements among athletes include: Cr monohydrate (109), caffeine, sport beverages (132), and protein powder (1).

Creatine is a non-essential endogenously produced via the liver, pancreas, and kidney and stored within skeletal muscle (119). Previous literature has established that Cr monohydrate is the most effective nutritional supplement (38, 45). Additionally, proper Cr supplementation can
increase sprint capacity during repeated intervals, strength measures, work capacity, BM, and FFM (109, 145, 166). Heaton et al. (119) reported a 20% increase in muscle Cr levels after a 5 day supplementation period with 20g/d; subsequently enhanced exercise performance that relies heavily on phosphocreatine and adenosine triphosphate. These findings are similar to Kreider (166); who stated that supplementing 20g/d for 5-7 day increased the muscle Cr levels by 10-30% and phosphocreatine stores by 10-40%. Kerksick et al. (153) recommends consuming 0.1g Cr/kg/d co-ingested with CHO and protein to facilitate greater training adaptations.

Caffeine (e.g. tri-methyl xanthine) is a common ergogenic aid which is a central nervous system stimulant commonly consumed through oral ingestion (59, 132, 193). McCormack and Hoffman (193) stated that caffeine supplementation during high intensity exercise can enhance power production. Additionally, McCormack and Hoffman (193) stated that caffeine can enhance the neuromuscular transmission and muscular activation. Close et al. (59) recommends supplementing 3 mg/kg of caffeine both prior to and intra-exercise to enhance performance; with practical consideration of inter-individual variability to potency and usage experience.

Protein supplementation can facilitate upregulation of anabolic processes in skeletal muscle by increasing the rate of muscle protein synthesis (258). Morton et al. (200) reported that 20 g (i.e. 0.25 g/kg) of protein is an ample quantity for optimal adaptations. Furthermore, 20 g of protein ingestion every 3 h, during a 12 h period, is the most effective methodology to stimulate muscle protein synthesis (200). Supplementing 3-6 g of Leucine has been shown to increase muscle protein synthesis and myofibrillar protein cross sectional area resulting in increased strength and muscle mass (86, 145).

It is critical to note, that after the Dietary Supplement Health and Education Act of 1994, dietary supplements are regulated as food, rather than drugs (211). Due to the non-regulation of
the supplement industry, inadvertent doping of banned substance has increased (18). Before consuming any nutritional supplement athletes are advised to consume products that have been evidence-based tested for quality and safety through a third party (119). This claim is supported by Potgieter (229) who recommends counseling athletes regarding appropriate ergogenic aid utilization after a precise evaluation of safety, efficiency, potency, and legality.

The General Role of Physical Fitness Testing in Football

This section is intended to provide a precise understanding of physical fitness testing recommendations. Physical fitness testing (i.e. performance testing) is commonly implemented as a means to evaluate the effectiveness of the training program and allows for a controlled environment to simulate performance (66, 260). When selecting which physical fitness test to administer the test validity, reliability, and sensitivity must be considered (10, 66, 209). The selection of physical fitness testing should measure and address strength, power, and movement coordination (118).

It is critical to discuss the NFL Combine, as it offers a unique opportunity for NFL scouts, coaching staff, and upper management to evaluate prospect players (90). Participants perform a series of physical fitness tests including: the 40-yp dash, pro-agility shuttle, 3-cone drill, NFL 225 lb bench press repetition test, vertical jump, broad jump, and anthropometric measurements (90). Fitzgerald and Jensen (90) found that when comparing performance from 1999-2000 to 2015-2016 players performance has significantly improved with players becoming bigger, faster, and stronger.

Previous literature has established a variety of acceptable muscular strength test that can be implemented to gather qualitative and quantitative information (142). Hrysomallis (136) found a positive correlation of upper-body strength and power to successful on-field
performance. Upper-body strength was a major determinant of merit for coaching evaluations of player’s classification (242). One-way that maximum muscular force can be measured is by utilizing a dynamometer (142). Additionally, functional tests (i.e. bench press repetition test) are commonly prescribed among athletics to measure muscular strength (142). Furthermore, Mann et al. (183) stated that the NFL 225lb bench press repetition test is one of the most commonly utilized tests among NCAA Division I football. The NFL 225lb bench press repetitions test assesses upper-body strength and endurance (90, 168, 237, 238, 249). Additionally, Krause (165) found a positive correlation between repetitions and NFL Pro-Bowl appearances.

Previous literature has established various effective muscular power tests for both lower-body (e.g. vertical jump, Margaria-Kalamen power test, broad jump) and upper-body (e.g. medicine ball throw) (90, 184, 242, 249, 260, 278). The vertical jump test assesses lower-body muscular power and jump capability (90, 249). VanHoy (278) stated that vertical jump results are a key indicator of sport performance. Similarly, the broad jump test assesses horizontal lower-body power and muscular strength (90, 249). VanHoy (278) found a positive correlation between broad jump and sport performance. Furthermore, the Margaria-Kalamen power test results indicate a significant difference between groups based on potential player success (184, 242).

Previous literature has established the medicine ball throw test as a valid and reliable fitness test (260). Participants completing the medicine ball throw test generate explosive power from the lower extremities, trunk, and upper extremities (260). The medicine ball throw test was designed to simulate the same musculature and movement sequence commonly utilized in sports (260).
Previous literature has established a variety of fitness tests to assess movement patterns. The nature of football requires athletes to accelerate, decelerate, and change direction multiple times in a single play (246). Assessing these variables can help identify target areas to improve to enhance on-field performances.

The 40-yd dash test assesses linear acceleration, velocity, maximal running speed, and lower-body explosiveness (32, 90, 109, 164, 237, 249). VanHoy (278) reports that the 40-yd dash is the most commonly utilized test at the collegiate level for football. Previous literature has established results to indicate future success (21, 26, 90, 101, 158, 218, 232, 239, 278, 299). Furthermore, Krause (165) found a positive correlation between wide receiver’s NFL Combine 40-yd dash time and future NFL success.

The repeated shuttle sprint ability test evaluates the ability to sprint and recover from intense anaerobic exercise (13, 139). The test protocol consists of six 40 m (i.e. 20 m sprint with 180° turn and 20 m sprint) with a 20 s passive recovery (139). Similarly, the running anaerobic sprint test is a valid and reliable test to evaluate various anaerobic power variables (e.g. peak power, mean power, fatigue index) (305). The test protocol consists of six 35 m sprints with 10 s passive recovery (305). The advantage of both these protocols is the similarity to the specific physical demands of football (305).

Previous literature has established that analyzing the first 10-yds and 20-yds of a sprint can measure acceleration capacity (182). These short distance measurements are critical, as it closely mimics to the nature of a competitive game (32). The pro-agility assesses linear speed, acceleration, change-of-direction ability, and muscular coordination (90, 168, 249). Pro-agility results are a key indicator for position-specific performances. This claim is supported by Krause (165), who found a positive coefficient between RB pro-agility time and NFL success.
The 3-cone drill assesses agility, change-of-direction ability, acceleration, speed, muscular coordination, and skill performance (e.g. cutting ability) (90, 165, 238, 249). Previous literature found an inverse relationship between 3-cone drill time and future success (165, 218, 249). VanHoy (278) stated that the pro-agility and the 3-cone drill are the most commonly utilized agility tests.

Athlete monitoring is a strategic methodology to determine how individuals are coping with physiological stress and adapting to the training program (31, 85, 203, 228). Monitoring training load is critical to analyze fatigue and recovery mechanisms to minimize nonfunctional overreaching, injury, and illness (31). The training load is either internal (e.g. heart rates, blood lactate, oxygen consumption) or external (e.g. power output, speed, acceleration) (31). Technological advancements allow for precise understanding of training load, position-specific movement profiles, and decreased inter-individual variability (85, 91, 104, 169, 176). Technology has provided quantitative data for monitoring training status, load, and physiological response from physiological stressors (91).

Microtechnology is capable of registering and quantifying collision and impact data (85). Tri-axial accelerometers are microsensors capable of quantifying external workload and measuring movement profiles in precise detail (85, 91). This microtechnology provides an accurate representation of the acute physiological stress experienced (85). Global positioning systems are commonly utilized to gather quantifiable data related to player movement (75, 85). Additionally, this technology is capable of recording real-time objective data (75). Global positioning systems are capable of recording various external load metrics including; distance covered, effort exerted, speed, and acceleration threshold (31).
Bourdon et al. (31) recommends monitoring training load during the beginning of the pre-season. Additionally, Murray (203) recommends monitoring training load globally by assessing physiological, biochemical, and psychological to create a comprehensive profile. Conducting a series of exams and reexaminations, on a regular basis, can identify and evaluate the effectiveness and efficiency of the prescribed training program (22, 242). Mann et al. (183) recommends administering physical fitness tests at the end of each mesocycle to track the degree of training adaptations facilitated.

Conducting regular dietary assessments and implement strategies that promote optimal nutritional habits can enhance training adaptations. Furthermore, Abbey et al. (1) conducted a dietary assessment on lineman finding; lineman consumed higher quantities of total fat, saturated fat, and dietary cholesterol, with insufficient CHO, fiber, and essential fats compared to non-lineman (1).

Conducting body composition assessments are essential for monitoring players throughout the training program (213). Tumagol (275) stated that body composition is associated with sport performance variability. Bosch (30) found that the greatest variance between positional group’s FM distribution was within the torso. Previous literature established various body composition assessments as a valid and reliable including: anthropometric measurements, bioelectric impedance analysis, air-displacement plethysmography, hydrostatic analysis, and DEXA (19, 76, 213, 275).

Bioelectric impedance analysis utilizes an electrical current through the body to estimate FM (30). Air-displacement plethysmography (i.e. BOD POD) utilizes a two-compartment model, FM (i.e. body fat) and FFM (i.e. lean body mass) (107, 213). The DEXA is a non-invasive method that utilizes a three-compartment model consisting of: FM, FFM, and bone mineral
The DEXA method is considered the “gold-standard” of body composition measurements (76). Furthermore, Oliver (213) stated that the DEXA has superior precision and accuracy compared to hydrostatic analysis (i.e. hydrodensitometry), skinfold caliper, and bioelectric impedance analysis; illustrated in Table 2.27.

**Table 2.27- Review of Body Composition tests**

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Test accuracy (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioelectric impedance analysis</td>
<td>4-10</td>
<td>30</td>
</tr>
<tr>
<td>Air-displacement plethysmography</td>
<td>4-10</td>
<td>30</td>
</tr>
<tr>
<td>Hydrostatic analysis</td>
<td>2-4</td>
<td>4</td>
</tr>
<tr>
<td>Skinfold caliper</td>
<td>3-5</td>
<td>210</td>
</tr>
<tr>
<td>DEXA</td>
<td>1-3</td>
<td>30</td>
</tr>
</tbody>
</table>

Multiple body composition variables including (e.g. body fat percentage (BF%), BM, FM, FFM) are key indicators for sport performance. This claim is supported by Pryor et al. (232), who found that the 2011 NFL Super Bowl Champions had statistically significant differences in height, BM, and BF% when compared to normative NFL data. Oliver (213) stated that an increase in either BM and/or height is associated with increased playing time. Additionally, weight management is critical, as underweight athletes increase their risk of injury (165); contrarily, over weight athletes exhibit a decrease in performance (90). Furthermore, weight management is critical as football players can lose 3.5-5kg body weight on average during preseason training camp (106).

Oliver (213) found a direct relationship between increases in FFM, enhanced strength, speed, and explosiveness. Additionally, Oliver (213) found a negative association between FM and both physiological fatigue and the development of various metabolic syndromes (e.g. impaired glucose tolerance, dyslipidemia, and hypertension). Additionally, excessive BF will
inhibit optimal sport performance via various metabolic conditions (e.g. obstructive sleep apnea, vitamin-D deficiencies, cardiovascular disease) (213). Aharon (2) recommends lineman BF% to range between 10-16% for peak performance; while >20% will decrease performance. An increase in BF% is associated with various negative performance indicators (e.g. decreases in speed, power production, muscular endurance, overall movement efficiency, and increased reaction time) (232).

**Survey Analyses of Strength and Conditioning Practices**

Previous literature has provided comprehensive survey data for: high school S&C practices (79), supplementation prevalence among high school athletes (268), collegiate S&C practices (2, 192), collegiate S&CC demographics (21), and collegiate weight room injuries (307). Furthermore, previous literature analyzed the common and unique aspects of S&C practices for the NFL (81), National Basketball Association (251), National Hockey League (82), and Major League Baseball (83).

Survey research has previously been conducted at the professional level with response rates ranging from 63-87% (81, 82, 83, 251, 265). Sutherland and Wiley (265) surveyed five professional sport leagues (e.g. NFL, Major League Baseball, Canadian Football League, National Hockey League, National Basketball League) response rate of 63% (i.e. 74/118). Ebben and Blackard’s (81) survey response rate was 87% (i.e. 26/30 NFL S&CC). Additionally, survey research has previously been conducted at the collegiate level with response rates ranging from 11.4-42.7% (80, 149, 241, 283). Haggerty (113) reported a response rate was 11.4% (i.e. 66/578) for NCAA Division II and III S&CC. Furthermore, survey research at the high school level response rates ranging from 27.7-29.6% (79, 148); illustrated in Table 2.28.
Table 2.28- Response rates of previous literature related to S&CC survey research

<table>
<thead>
<tr>
<th>Subjects level</th>
<th>Number of Subjects</th>
<th>Response rate</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFL</td>
<td>26/30</td>
<td>87%</td>
<td>81</td>
</tr>
<tr>
<td>NHL</td>
<td>23/30</td>
<td>76.6%</td>
<td>82</td>
</tr>
<tr>
<td>MLB</td>
<td>21/30</td>
<td>70%</td>
<td>83</td>
</tr>
<tr>
<td>NBA</td>
<td>20/29</td>
<td>68.9%</td>
<td>251</td>
</tr>
<tr>
<td>Professional sports</td>
<td>74/118</td>
<td>63%</td>
<td>265</td>
</tr>
<tr>
<td>NCAA Division I</td>
<td>137/321</td>
<td>42.7%</td>
<td>80</td>
</tr>
<tr>
<td>NCAA Division I</td>
<td>110/285</td>
<td>38.6%</td>
<td>149</td>
</tr>
<tr>
<td>NCAA Division I</td>
<td>125/1,000</td>
<td>12.5%</td>
<td>241</td>
</tr>
<tr>
<td>NCAA Division I</td>
<td>57/195</td>
<td>29.2%</td>
<td>283</td>
</tr>
<tr>
<td>NCAA Division II/III</td>
<td>66/578</td>
<td>11.4%</td>
<td>113</td>
</tr>
<tr>
<td>High school</td>
<td>38/128</td>
<td>29.6%</td>
<td>79</td>
</tr>
<tr>
<td>High School</td>
<td>108/390</td>
<td>27.7%</td>
<td>148</td>
</tr>
</tbody>
</table>

Professional sports- NFL, Major League Baseball, Canadian Football League, National Hockey League, National Basketball League
NHL - National Hockey League
MLB - Major League Baseball
NBA - National Basketball Association

Ebben and Blackard’s (81) research is important to discuss as it is the most comprehensive representation of NFL S&C practices. However, Ebben and Blackard (81) did not address various training intervention, frequency, program variable manipulation, specific position-specific characteristics, and professional opinions; providing a gap in literature. Ebben and Blackard (81) originally examined eight sections of training practice including: (i) Background information, (ii) Physical testing, (iii) Flexibility development, (iv) Speed development, (v) Plyometrics, (vi) Strength and power development, (vii) Unique aspects of the program, and (viii) Comments.

Their background section discussed demographics, coaching responsibilities, and administration questions (81). With respect to coaching responsibilities four NFL S&CC reported other coaching responsibilities (e.g. positional coach, assistant coach, assistant special
team coach, and defensive control coach) (81). The mean NFL coaching experience was 6.52±6.25 years (81). These findings are similar to Lougas (177), who found that NFL S&CC had an average 8.7 years of NFL coaching experience; ranging from 2-27 years. Furthermore, Lougas (177) found that NFL S&CC had an average 26.6 years of coaching experience, regardless of level.

Hartshorn et al. (117) stated that both collegiate and professional level S&CC reported holding a Bachelor’s degree. The most common degree majors include physical education and exercise science (117). This claim was supported by Powers (112), who reported that exercise science was the most common major for NCAA Division I S&CC. Furthermore, Durell and Barnes (80) stated that 69% of NCAA Division I S&CC held a Master’s degree, whereas 52% of NCAA Division II S&CC had a Master’s degree. These findings are similar to Haggerty (56), who found 56.5% of 23 NCAA Division II S&CC and 47.1% of 34 NCAA Division III S&CC had a Master’s degree. Magnusen (180) found that of 22 NBA S&CC, all obtained a Bachelor’s degree with 59.1% receiving a Master’s degree. Sutherland and Wiley (265) found that 7 of 16 NFL S&CC (i.e. 43.7%) had a Master’s degree.

The most common certification was the “National Strength and Conditioning Association’s Certified Strength and Conditioning Specialists” (117). This claim was supported by Powers (231), who found 77.8% of 119 NCAA Division I S&CC held this certification. Furthermore, Sutherland and Wiley (265) found that 5 of 16 NFL S&CC (i.e. 31.2%) obtained the “National Strength and Conditioning Association’s Certified Strength and Conditioning Specialists” certification. Additionally, Powers (231) reported that about 50% of 119 NCAA Division I S&CC held the “Collegiate Strength and Conditioning Coaches Association’s
Strength and Conditioning Coaches Certified” certification and the “USA Weightlifting” certification.

Their physical testing section discussed the conduction of physical assessments and the frequencies (81). On average NFL S&CC tested 7.2 fitness variables utilizing 10.0 specific tests (81). Additionally, they found that subjects who followed a periodized model training program assessed 9.8 fitness variables 3.55 times per year. Whereas, subjects that followed a non-periodized model training program on average assessed 2.12 variables 2 times per year (81).

Ebben and Blackard (81) found that two subjects reported that “physical fitness was never tested”. In later literature, all subjects from the National Basketball Association (251), National Hockey League (82), and Major League Baseball (83) conducted physical fitness testing. The specific physical variables and test methodology utilized by NFL S&CC is available in Table 2.29.
Table 2.29-NFL S&CC (n=26) specific fitness variables assessed with physical fitness testing (81)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Subjects</th>
<th>Specific test methodology (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body composition</td>
<td>20</td>
<td>Skin calipers (9), Hydrodensitometry (3), other a</td>
</tr>
<tr>
<td>Muscular strength</td>
<td>13</td>
<td>Bench press-max test (7), squat-max test (5), incline bench press max test (2) other b</td>
</tr>
<tr>
<td>Cardiovascular endurance</td>
<td>11</td>
<td>12 min run (2), other c</td>
</tr>
<tr>
<td>Agility</td>
<td>9</td>
<td>20 yd shuttle (4), other d</td>
</tr>
<tr>
<td>Anaerobic capacity</td>
<td>9</td>
<td>300 yd shuttle (2), other e</td>
</tr>
<tr>
<td>Muscular power</td>
<td>9</td>
<td>Vertical jump test (8), Power clean test (2), other f</td>
</tr>
<tr>
<td>Speed</td>
<td>9</td>
<td>20-40 yd dash (4), 40 yd dash (3), 10-20-40 yd dash (2), other g</td>
</tr>
<tr>
<td>Flexibility</td>
<td>8</td>
<td>Sit-and-reach (5), Stand-and-reach (2), other h</td>
</tr>
<tr>
<td>Acceleration</td>
<td>6</td>
<td>40 yd dash (2), other i</td>
</tr>
<tr>
<td>Anthropometrics</td>
<td>5</td>
<td>Height and weight (2), other j</td>
</tr>
<tr>
<td>Muscle endurance</td>
<td>5</td>
<td>225 lb bench repetition test (2), and a “battery of weight-room tests including 1RM, 225-lb repetition test, etc.” and dips (1)</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
<td>“every lift is monitored and recorded and that every lifting and training session is viewed as a test”</td>
</tr>
</tbody>
</table>

a– Other tests utilized includes skynex (2), 3-site skin folds using Jackson-Pollock equations, electrical impedance, and underwater weighing of 3–5 players a year (1)
b– Other tests utilized includes ), a bench press repetition test, estimated maximum for bench and leg press, and maximal tests (1)
c– Other tests utilized includes a 300 to 400m monitored run, a VO2 max, 3 gasser tests of 200-yd (1:30 rest), 16 110-yd dashes, 300-yd shuttle, and an 800-yd run (1)
d– Other tests utilized includes a 5-10-5 lateral test and cone drills, a short shuttle, a 60-yd shuttle, a 3-cone drill, and a T-test (1)
e– Other tests utilized includes consecutive 300-200-100m drills, a shuttle, 16 110-yd sprints and a long shuttle of 300 yd, positional-specific metabolic workouts, and 14 40-yd sprints within a % of the best 40-yd dash time (1)
f– Other tests utilized includes standing long jump, a “battery of weight-room tests including a 1RM test and a 225-lb rep test, etc.” and core lifts (1)
g– Other tests utilized includes lineman doing 20-yd dashes and the rest [of the team] doing 40-yd dashes (1)
h– Other tests utilized includes a hand-shoulder test, and a hip and groin test (1)
i– Other tests utilized includes a 10-20-40-yd progression, a 20-yd dash, a 300-yd shuttle, and 0 to 10-, 10 to 20-, 20 to 30-, 30 to 40–yd splits (1)
j– Other tests utilized includes arm span, trainer’s measure, and circumference measurements (1)
Their flexibility development section discussed specific flexibility protocols prescribed, frequency, and duration of static isometric stretch (81). The most commonly prescribed flexibility protocol was static stretching; illustrated in Table 2.30. Additionally, NFL S&CC encouraged/required static stretch to be held for 18.0 ± 5.1 s. This finding was similar to Ebben et al. (82), who found that National Hockey League S&CC encouraged/required each static stretch to be held for 17.35 ± 4.1 s.

**Table 2.30-** Flexibility protocols that NFL S&CC (n=26) prescribed during the training program (81)

<table>
<thead>
<tr>
<th>Flexibility categories</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static flexibility exercises</td>
<td>22</td>
</tr>
<tr>
<td>Proprioceptive neuromuscular facilitation exercises</td>
<td>18</td>
</tr>
<tr>
<td>Dynamic exercise</td>
<td>14</td>
</tr>
<tr>
<td>Ballistic exercise</td>
<td>8</td>
</tr>
</tbody>
</table>

The most common time-of-day NFL S&CC prescribed flexibility exercises was before practice (81); illustrated in Table 2.31. The most common time-of-day professional level S&CC prescribed flexibility exercises were before practice (82, 83, 251). Ebben and Blackard (81) reported that the average pre-practice flexibility session was 12.4 ± 3.2 min.

**Table 2.31-** Specific time-of-day that NFL S&CC (n=26) prescribed flexibility during the training program (81)

<table>
<thead>
<tr>
<th>Time-of-day</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before practice</td>
<td>24</td>
</tr>
<tr>
<td>During practice</td>
<td>4</td>
</tr>
<tr>
<td>After practice</td>
<td>15</td>
</tr>
<tr>
<td>On their own time</td>
<td>11</td>
</tr>
<tr>
<td>Before resistance training</td>
<td>16</td>
</tr>
<tr>
<td>During resistance training</td>
<td>2</td>
</tr>
<tr>
<td>After resistance training</td>
<td>14</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2.31 is replicated from Figure 3 (81, p51)
The speed development section discussed specific speed protocols prescribed (81). Ebben and Blackard (81) found that all 26 NFL S&CC reported prescribing some form of speed training. These findings are similar to other professional S&CC survey research, with responses ranging from 95.6-100% coaches prescribe some form of speed training (82, 83, 251). Speed endurance was the most commonly prescribed training protocol prescribed with respect to speed development (81); illustrated in Table 2.32.

**Table 2.32**-Speed protocols NFL S&CC (n=26) prescribed during the training program (81)

<table>
<thead>
<tr>
<th>Speed training protocol</th>
<th>Subjects</th>
<th>Specific modalities (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed endurance</td>
<td>21</td>
<td>“Longer in the off-season and 100-200yds down to 40yds and below sprints”</td>
</tr>
<tr>
<td>Form running</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Resistance running</td>
<td>17</td>
<td>Hill sprints (1), Sled pushes with a partner (1)</td>
</tr>
<tr>
<td>Plyometrics</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Over-speed running</td>
<td>15</td>
<td>Over-speed running and assisted over-speed running 1-legged 30-40yd runs, running 40yd-20yd-10yd sprints, Other a</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

a – Other responses included: “power is a force application over time, and we develop force, strength potentials in the weight room. Our coaches develop force application on the field”, positional-specific speed workouts, mini-hurdle drills, ladder drills, cone drills, and upper body mechanics training

The specific modalities responses are raw comprehensive data from the subjects who were surveyed (81, p51)

The plyometric section discussed specific purpose of prescribing plyometrics; when specifically plyometrics were utilized (i.e. mesocycle); the integration of plyometrics with resistance training; and specific plyometric exercises prescribed (81). Ebben and Blackard (81) found that seventeen (56.6%) NFL S&CC implemented plyometric exercises into the training program. Previous literature found that at the professional level the percentage of S&CC that implemented plyometric exercises into the training program ranged between 91.3-100% (82, 83,
The most common method of integrating plyometrics exercises with resistance training was prior to resistance training during the same day (81); illustrated in Table 2.33. Additionally, they found that seven NFL S&CC prescribed plyometric exercises during the pre-season mesocycles (81); illustrated in Table 2.34.

**Table 2.33** – The primary method identified by NFL S&SC for integrating plyometric exercise with resistance training (81)

<table>
<thead>
<tr>
<th>Method</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to resistance training (Same day)</td>
<td>9</td>
</tr>
<tr>
<td>Post-resistance training (Same day)</td>
<td>6</td>
</tr>
<tr>
<td>Complex training</td>
<td>7</td>
</tr>
<tr>
<td>Separate day</td>
<td>4</td>
</tr>
<tr>
<td>Other a</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2.33 is replicated from Figure 9 (81, p52)

a- Other methods included: speed days, plyometrics with agility drills, and combinations of methods

**Table 2.34** – The specific mesocycles that NFL S&CC (n=19) prescribed plyometrics throughout the training program (81)

<table>
<thead>
<tr>
<th>Mesocycle</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-season</td>
<td>7</td>
</tr>
<tr>
<td>Post-season</td>
<td>5</td>
</tr>
<tr>
<td>In-season</td>
<td>3</td>
</tr>
<tr>
<td>Pre training camp</td>
<td>5</td>
</tr>
<tr>
<td>Training camp</td>
<td>1</td>
</tr>
<tr>
<td>Year round</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2.34 is replicated from Figure 8 (81, p52)

The primary purpose NFL S&CC prescribed plyometric exercises to athletes was for speed development (81); illustrated in Table 2.35. Furthermore, Ebben and Blackard (81) identified the most commonly prescribed exercises as bounding activities, multiple hops and jumps, and box drills; illustrated in Table 2.36.
Table 2.35 – Purpose that NFL S&CC (n=19) prescribed plyometrics during the training program (81)

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed development</td>
<td>16</td>
</tr>
<tr>
<td>Lower-body power</td>
<td>13</td>
</tr>
<tr>
<td>Whole-body power</td>
<td>12</td>
</tr>
<tr>
<td>Upper-body power</td>
<td>11</td>
</tr>
<tr>
<td>Other a</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2.35 is replicated from Figure 7 (81, p52)
a- utilize plyometric training for shoulder stabilization

Table 2.36- Type of Plyometric exercises NFL S&CC (n=19) prescribed during the training program (81)

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bounding activities</td>
<td>17</td>
</tr>
<tr>
<td>Multiple hops and jumps</td>
<td>17</td>
</tr>
<tr>
<td>Box drills</td>
<td>15</td>
</tr>
<tr>
<td>Standing jumps</td>
<td>12</td>
</tr>
<tr>
<td>Upper-body Plyometrics</td>
<td>12</td>
</tr>
<tr>
<td>Jumps in place</td>
<td>12</td>
</tr>
<tr>
<td>Depth jumps</td>
<td>7</td>
</tr>
<tr>
<td>Other a</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2.36 is replicated from Figure 10 (81, p52)
a- Other exercises utilized include: 1-legged 30-40yd runs, mini-hurdles, ladder drills, plyometric push-ups, log training, split jumps, band resistance jumps, and weighted dumbbell jumps

The strength and power development section discussed frequencies, duration of resistance training sessions, conceptualized resistance training, the top five most important resistance training exercise prescribed, periodization programming, and the methodology for determining training loads, sets, and repetitions (81). Ebben and Blackard (81) reported that NFL S&CC prescribed resistance training during the in-season 2.8 ± 0.8 days per week; with each training session lasting 48.5 ± 13.2 min. During the off-season NFL S&CC prescribed resistance
training 2.0 ± 2.9 days per week. Previous literature reported that at the professional level, S&CC prescribed training frequency on average 2 days per week during in-season and 4 days per week during off-season mesocycles (82, 83, 251).

Ebben and Blackard (81) found that seven NFL S&CC reported utilizing a non-periodized model program; illustrated in Table 2.37. In later literature, at the professional level fewer (i.e. 2-3) S&CC followed a non-periodized model (82, 83, 251). Additionally, the most common conceptualization of resistance training exercises by NFL S&CC was through multi-joint movements (81); illustrated in Table 2.38.

**Table 2.37**- NFL S&CC (n=26) utilization of types of periodization programming (81)

<table>
<thead>
<tr>
<th>Responses</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodization model</td>
<td>18</td>
</tr>
<tr>
<td>Non-periodization model</td>
<td>7</td>
</tr>
<tr>
<td>Did not respond</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 2.38**- NFL S&CC (n=26) conceptualization of resistance training (81)

<table>
<thead>
<tr>
<th>Conceptualization of resistance training</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-joint</td>
<td>20</td>
</tr>
<tr>
<td>Core lifts</td>
<td>15</td>
</tr>
<tr>
<td>Supplemental exercises</td>
<td>14</td>
</tr>
<tr>
<td>Auxiliary exercises</td>
<td>13</td>
</tr>
<tr>
<td>Total-body</td>
<td>11</td>
</tr>
<tr>
<td>Other a</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2.38 is replicated from Figure 12 (81, p53)
a- Other responses included: free-weights only, special by position, and rehabilitation phase needs
Ebben and Blackard (81) investigated how NFL S&CC manipulated specific training variables (e.g. training load, sets, repetitions, and exercise selection) during the training program. They noted the most common methodology utilized to determine training load was via formula based methods (e.g. 3% rule, 1RM%) (81); illustrated in Table 2.39. During both in-season and off-season mesocycles the most common methodology utilized to determine sets and repetitions was by specific ranges for various movements (81); illustrated in Table 2.40 and 2.41.

**Table 2.39** - Specific methodology that NFL S&CC (n=26) utilized for determining training load (81).

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Subjects</th>
<th>Specific methodology principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
<td>11</td>
<td>- 3% rule</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- percentage of repetition maximum</td>
</tr>
<tr>
<td>Coaches discretion</td>
<td>7</td>
<td>Determined by the coach</td>
</tr>
<tr>
<td>Failure</td>
<td>5</td>
<td>High-intensity training and 1 set to failure</td>
</tr>
<tr>
<td>Coach and athlete discretion</td>
<td>2</td>
<td>some exercises coaches discretion while other exercises are athletes discretion</td>
</tr>
<tr>
<td>Determined by previous training session</td>
<td>1</td>
<td>Adjustments based on previous training sessions</td>
</tr>
</tbody>
</table>

Table 2.39 is replicated from Table 4 (81, p55)

**Table 2.40** - Specific methodology that NFL S&CC (n=26) utilized for determining sets and repetitions during the in-season mesocycle (81).

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Subjects</th>
<th>Specific Methodology Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specified range of sets and repetitions</td>
<td>12</td>
<td>Major lifts: 3-5 sets x 8-3 reps; Auxiliary lifts: 2-3 sets x 8-5 reps</td>
</tr>
<tr>
<td>High-intensity concepts</td>
<td>5</td>
<td>We employ high-intensity concepts; most routines are 1 set x 10 reps; 1 set to failure, ≈22 sets</td>
</tr>
<tr>
<td>Specified to training Mesocycle</td>
<td>4</td>
<td>In-season we cycle our routines not only weekly but within each week: Mon: higher volumes; Wed-Fri: lower volumes with higher intensity.</td>
</tr>
<tr>
<td>%1RM and Sets</td>
<td>3</td>
<td>IRM%, 3 basic loads: 70% x 10 sets, 80% x 5-6 sets, 90-95% x 2-3 sets</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2</td>
<td>“too much to list”</td>
</tr>
</tbody>
</table>

Table 2.40 is replicated from Table 6 (81, p56)
Table 2.41 - Specific methodologies that NFL S&CC (n=26) utilized for determining sets and repetitions during the off-season (81)

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Subjects</th>
<th>Specific Methodology Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specified range of sets and repetitions</td>
<td>11</td>
<td>1-3 sets x 5-50 repetitions; 4-7 sets x 1-8 repetitions; Core movements: 5-6 sets x 10-12 reps; Strength lifts: range from 10-3 reps; Olympic lifts: range from 5-2 reps; Supplemental lifts: 3 sets x 10-6 reps</td>
</tr>
<tr>
<td>High-intensity concept</td>
<td>5</td>
<td>1 set to failure repetitions vary somewhat randomly</td>
</tr>
<tr>
<td>Specified to training Mesocycle</td>
<td>4</td>
<td>Progressive cycling and periodization: wk 1-3: 3-4 sets x 12-10-8 reps wk 4-6: 4-5 sets x 8-6-4 reps wk 7-12: 4-5 sets x 4-3-2-1 reps</td>
</tr>
<tr>
<td>Variable</td>
<td>3</td>
<td>Use too many different combinations for different exercises and players to list (e.g. varies)</td>
</tr>
<tr>
<td>Confidential</td>
<td>2</td>
<td>“No, I am not going to give that away”</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1</td>
<td>“Regardless of which system is prescribed it is not important. What is most important is the athlete’s effort and the level of training intensity”</td>
</tr>
</tbody>
</table>

Table 2.41 is replicated from Table 5 (81, p55)

Ebben and Blackard (81) investigated the self-selected, top 5 most important exercises that NFL S&CC prescribed during the training program; illustrated in Table 2.42. With regards to the number 1 ranked exercise prescribed 8 subjects selected squats, 7 subjects selected neck exercises, 6 subjects selected cleans, and 1 subject selected box-squats, step-ups, and core exercises respectively (81).
Table 2.42- The top 5 most important resistance training exercises that NFL S&CC (n=26) prescribed (81).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Exercise Modality (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Squat (8), neck exercises (7), clean (6), box squats, step-ups, core exercises (1)</td>
</tr>
<tr>
<td>2</td>
<td>Cleans (7), shoulders, leg press, squat (3), bench (2), push press, lower-body explosive exercises, groin exercises, snatch (1)</td>
</tr>
<tr>
<td>3</td>
<td>Bench (8), squat (3), military press, incline press (2), Legs exercises, sled dragging, dumbbell incline, lumbar extension, posterior delt exercises, cleans, low back exercises (1)</td>
</tr>
<tr>
<td>4</td>
<td>Bench, shoulder press (2), push pull movements, core, incline, upper-body explosive exercises, close-grip lat, dorisflexors exercises, snatch, lateral shoulder raise, lunges, push press, dead lift, supplemental work, lat row and pulldown (1)</td>
</tr>
<tr>
<td>5</td>
<td>Medicine-ball exercises, leg press and extension, upright row, neck exercises (2), core exercises, back exercises, dead lift, hamstring curl, jerk, low back exercises, knee exercises, incline bench press, pulling exercises (1)</td>
</tr>
</tbody>
</table>

Table 2.42 is replicated from Table 2 (81, p54)

The unique aspects section discussed various high order themes of different training interventions, and aspects that subjects would consider reassessing and/or altering within their S&C department of operations (81). Ebben and Blackard (81) reported 14 of 26 (i.e. 53.8%) NFL S&CC reported implementing Olympic weightlifting, which is less than both the National Basketball Association S&CC who reported 20 (i.e. 95%) and 23 (i.e. 91.3%) National Hockey League S&CC who reported implementing Olympic weightlifting (82, 251). Surprisingly, Ebben et al. (83) found only 3 Major League Baseball S&CC reported implementing Olympic weightlifting. Hartshorn et al. (117) found that 85% of NCAA Division I S&CC reported implementing Olympic weightlifting. A full description of unique aspects is available in Tables 2.43 and 2.44.
Table 2.43- Various unique aspects that NFL S&CC (n=26) incorporated throughout the training program (81)

<table>
<thead>
<tr>
<th>Unique aspects</th>
<th>Subjects</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific training strategies</td>
<td>18</td>
<td>Single-leg training, grip strength, combination of Olympic weightlifting and high-intensity training, and runs based off of Vo2max</td>
</tr>
<tr>
<td>Unaware of other programs</td>
<td>7</td>
<td>“I am unaware of what other coaches are doing”</td>
</tr>
<tr>
<td>External support</td>
<td>3</td>
<td>“We have tremendous support for our program from upper management and the head coach”</td>
</tr>
<tr>
<td>Conditioning environment</td>
<td>3</td>
<td>Make it fun and one-on-one attention</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>“There are no secrets”</td>
</tr>
</tbody>
</table>

Table 2.43 is replicated from Table 7 (81, p56)

Table 2.44- Various aspects that NFL S&CC (n=26) considered reassessing and/or altering (81)

<table>
<thead>
<tr>
<th>Various aspects</th>
<th>Subjects</th>
<th>Specific alterations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific training changes</td>
<td>5</td>
<td>More medicine-ball activities and speed development</td>
</tr>
<tr>
<td>Facility and staff improvements</td>
<td>4</td>
<td>Hire 2 assistants and 4 graduate students, bigger weight room</td>
</tr>
<tr>
<td>Personal development</td>
<td>3</td>
<td>Continue to improve, learn, and adapt when necessary</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>“Too early in my tenure to know”</td>
</tr>
<tr>
<td>No changes</td>
<td>3</td>
<td>“I would not do anything different”</td>
</tr>
</tbody>
</table>

Table 2.44 is replicated from Table 8 (81, p56)

Ebben and Blackard (81) did not address various aspects of nutrition and supplementation. One subject commented “I wish you would have included a section on supplementation” during the closing comments section (81, p57). Patel (220) found that in 2004 only 1 NFL team had a full time sport Registered Dietitian on staff; while the Collegiate and Professional Sport Dietitian Association reported 11 NFL teams had a full time Sport Dietitians on staff in 2015 (230). Patel (220) found that in 2018, 59% (i.e. 19/32) of the NFL teams reported having a full time sport Registered Dietitian on staff.
With regards to supplementation, Jonnalagadda et al. (146) found that 42% of the freshman on a NCAA football team consumed a nutritional supplement. These findings are similar to Abbey et al. (1), who found that 33% of 88 NCAA Division III football players reported consuming protein power supplements. Furthermore, Brown et al. (36) found that 22 of 100 NCAA Division I football players consumed pre-workout supplements. Finally, Abbey et al. (1) found that <50% of 88 NCAA Division III football players consumed fruits and vegetables daily.

Summary

This literature review demonstrated that there is a substantial variance among previous literature recommendations and training program variability. Additionally, this literature review attempts to provide readers a resource for proper training program design according to the specific evidence-based research. As stated previously, Ebben and Blackard (81) is the most comprehensive and in-depth examination of the NFL S&CC practices to date. However, a comparison of Ebben and Blackard’s study to current day NFL S&C practices has not been conducted. Additionally, Ebben and Blackard provided limitations stating “future surveys should examine specific aspects of S&C (e.g. speed development) and the use of nutritional supplementation in greater depth” (81, p57). Therefore, the primary purpose of the current study is to identify the common and unique aspects of the NFL S&C practices in 2018. A secondary purpose was to compare the common and unique aspects of the NFL S&C practices from ’97-98 to 2018 to determine differences across years.
Chapter III: Conclusion and Recommendations

Prior to the current research study there was very limited research related specifically to NFL S&C programs. The current research study was the first comprehensive survey to investigate various variables at the NFL level to identify the common and unique aspects of the training program. Additionally, the results of this current research study demonstrated significant differences compared to Ebben and Blackard (81). These findings are in agreement with Rhea and Alderman (235), who stated that the S&C profession has developed and advanced dramatically in recent years to include highly advanced and specialized training.

The current study may be valuable to the field of S&C in that it allows practitioners to see what the top level of American Football S&CC are doing. However, the current research study had limitations due to the lack participants, which makes the findings difficult to make generalizations. Future research should continue examine how S&CC are designing and implementing training programs. This research should be expanded upon to include how coaches manipulate position-specific training variables as well as more in-depth analysis of each training intervention. Furthermore, future research should examine a larger sample size to increase validations.
REFERENCES


APPENDIX A: The NFL Strength and Conditioning Practice Survey

Start
Welcome to the National Football League's Strength and Conditioning Coaches Survey.

Please answer this survey as it pertains to the current training program for the NFL team you are coaching at.

Please answer the questions to the best of your knowledge, you are not required to disclose any information that you wish.

To start the survey please click the "Start"

Section 1, Background Information

The following questions are related to specific aspects of your coaching background.

Please describe your coaching responsibilities

Please select all degrees you have earned and indicate the title.

- □ Bachelor’s Degree
- □ Master’s Degree
- □ Doctoral Degree
- □ Other

Please indicate all certifications you have acquired.

How many strength and conditioning staff members are on staff?
How many years have you been working in the strength and conditioning field?

How many years have you been a strength and conditioning coach at the NFL level?
Section 2, A

The following questions are related to specific aspects of physical fitness testing.

Do you conduct physical fitness testing?

○ Yes          ○ No

How important is physical fitness testing?

<table>
<thead>
<tr>
<th>Extremely Important</th>
<th>Very Important</th>
<th>Moderately Important</th>
<th>Slightly Important</th>
<th>Not at all Important</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please select one  ○                ○                ○                ○                ○                ○
Section 2, B

Please select all physical variable(s) that you assess.

- □ Body composition
- □ Muscular strength
- □ Aerobic capacity
- □ Agility
- □ Anaerobic capacity
- □ Muscular power
- □ Speed
- □ Flexibility
- □ Acceleration
- □ Muscular endurance
- □ Anthropometric measurements
- □ Other
Section 2, Physical Fitness Testing

Please identify the body composition assessments that you use (e.g. skin caliper, DEXA, circumference measurements etc.)?

Please identify the specific position(s) for whom you conduct body composition assessments.

- □ All players
- □ Defensive Lineman (DL)
- □ Quarterbacks (QB)
- □ Linebackers (LB)
- □ Running Backs (RB)
- □ Defensive Backs (DB)
- □ Offensive Lineman (OL)
- □ Kickers (K)
- □ Tight Ends (TE)
- □ Long snappers
- □ Wide Receivers (WR)

How frequently is body composition assessed annually?

- □ Pre-training camp
- □ In-season
- □ Post training camp
- □ Post-season
- □ Pre-mini camp
- □ Other
- □ Pre-season

Please identify when you conduct body composition assessments.

Please identify the muscular strength tests that you use (e.g. 1RM bench press, hand dynamometer grip test, isokinetic tests etc.)?
Please identify the specific position(s) to whom you test muscular strength.

- □ All players
- □ Quarterbacks (QB)
- □ Running Backs (RB)
- □ Offensive Lineman (OL)
- □ Tight Ends (TE)
- □ Wide Receivers (WR)
- □ Defensive Lineman (DL)
- □ Linebackers (LB)
- □ Defensive Backs (DB)
- □ Kickers (K)
- □ Long snappers

How frequently is muscular strength assessed annually?

Please identify when you conduct muscular strength tests.

- □ Pre training camp
- □ In-season
- □ Post training camp
- □ Post-season
- □ Pre-mini camp
- □ Pre-season
- □ Other

Please identify the aerobic capacity tests that you use (e.g. VO2 max testing, 12 min run test, 1 mile run test etc.)?

Please identify the specific position(s) to whom you test aerobic capacity.

- □ All players
- □ Quarterbacks (QB)
- □ Running Backs (RB)
- □ Offensive Lineman (OL)
- □ Tight Ends (TE)
- □ Wide Receivers (WR)
- □ Defensive Lineman (DL)
- □ Linebackers (LB)
- □ Defensive Backs (DB)
- □ Kickers (K)
- □ Long snappers

How frequently is aerobic capacity assessed annually?

Number of assessments
Please identify when you conduct aerobic capacity tests.

- Pre training camp
- Post training camp
- Pre-mini camp
- Pre-season
- In-season
- Post-season
- Other

Please identify the agility tests that you use (e.g. pro-agility shuttle, 3-cone drill, T-test etc.)?

Please identify the specific position(s) to whom you test agility.

- All players
- Defensive Lineman (DL)
- Quarterbacks (QB)
- Linebackers (LB)
- Running Backs (RB)
- Defensive Backs (DB)
- Offensive Lineman (OL)
- Kickers (K)
- Tight Ends (TE)
- Long snappers
- Wide Receivers (WR)

How frequently is agility assessed annually?

Please identify when you conduct agility tests.

- Pre training camp
- Post training camp
- Pre-mini camp
- Pre-season
- In-season
- Post-season
- Other

Please identify the anaerobic capacity tests that you use (e.g. Wingate Anaerobic Test, 40-yard dash etc.)?
Please identify the specific position(s) to whom you test anaerobic capacity.

- □ All players
- □ Quarterbacks (QB)
- □ Running Backs (RB)
- □ Offensive Lineman (OL)
- □ Tight Ends (TE)
- □ Wide Receivers (WR)

- □ Defensive Lineman (DL)
- □ Linebackers (LB)
- □ Defensive Backs (DB)
- □ Kickers (K)
- □ Long snappers

How frequently is anaerobic capacity assessed annually?

![Number of assessments graph]

Please identify when you conduct anaerobic capacity tests.

- □ Pre training camp
- □ Post training camp
- □ Pre-mini camp
- □ Pre-season

- □ In-season
- □ Post-season

- □ Other

Please identify the muscular power tests that you use (e.g. vertical jump test, broad jump test, etc.).

How frequently is muscular power assessed annually?

![Number of assessments graph]
Please identify when you conduct muscular power tests.

☐ Pre training camp
☐ Post training camp
☐ Pre-mini camp
☐ Pre-season
☐ In-season
☐ Post-season

Please identify the speed tests that you use (e.g. sprint tests, gait analysis systems etc.)?

Please identify the specific position(s) to whom you test speed.

☐ All players
☐ Quarterbacks (QB)
☐ Running Backs (RB)
☐ Offensive Lineman (OL)
☐ Tight Ends (TE)
☐ Wide Receivers (WR)
☐ Defensive Lineman (DL)
☐ Linebackers (LB)
☐ Defensive Backs (DB)
☐ Kickers (K)
☐ Long snappers

How frequently is speed assessed annually?

Please identify when you conduct speed tests.

☐ Pre training camp
☐ Post training camp
☐ Pre-mini camp
☐ Pre-season
☐ In-season
☐ Post-season
☐ Other

Please identify the flexibility tests that you use (e.g. functional movement screening, sit-and-reach test, trunk rotation, etc.)?
Please identify the specific position(s) to whom you test flexibility.

- □ All players
- □ Quarterbacks (QB)
- □ Running Backs (RB)
- □ Offensive Lineman (OL)
- □ Tight Ends (TE)
- □ Wide Receivers (WR)
- □ Defensive Lineman (DL)
- □ Linebackers (LB)
- □ Defensive Backs (DB)
- □ Kickers (K)
- □ Long snappers

How frequently is flexibility assessed annually?

Please identify when you conduct flexibility tests.

- □ Pre training camp
- □ Post training camp
- □ Pre-mini camp
- □ Pre-season
- □ In-season
- □ Post-season
- □ Other

Please identify the acceleration tests that you use (e.g. sprint tests, pro agility shuttle etc.)?

Please identify the specific position(s) to whom you test acceleration.

- □ All players
- □ Quarterbacks (QB)
- □ Running Backs (RB)
- □ Offensive Lineman (OL)
- □ Tight Ends (TE)
- □ Wide Receivers (WR)
- □ Defensive Lineman (DL)
- □ Linebackers (LB)
- □ Defensive Backs (DB)
- □ Kickers (K)
- □ Long snappers

How frequently is acceleration assessed annually?
Please identify when you conduct acceleration tests.

- [ ] Pre training camp
- [ ] In-season
- [ ] Post training camp
- [ ] Post-season
- [ ] Pre-mini camp
- [ ] Other
- [ ] Pre-season

Please identify the muscular endurance tests that you use (e.g. 225lb. bench press test, push up test, pull up test etc.)?

Please identify the specific position(s) to whom you test muscular endurance.

- [ ] All players
- [ ] Defensive Lineman (DL)
- [ ] Quarterbacks (QB)
- [ ] Linebackers (LB)
- [ ] Running Backs (RB)
- [ ] Defensive Backs (DB)
- [ ] Offensive Lineman (OL)
- [ ] Kickers (K)
- [ ] Tight Ends (TE)
- [ ] Long snappers
- [ ] Wide Receivers (WR)

How frequently is muscular endurance assessed annually?

Please identify when you conduct muscular endurance tests.

- [ ] Pre training camp
- [ ] In-season
- [ ] Post training camp
- [ ] Post-season
- [ ] Pre-mini camp
- [ ] Other
- [ ] Pre-season

Please identify the anthropometric measurements that you use (e.g. height, weight, arm wingspan, etc.)?
Please identify the specific position(s) to whom you measure anthropometrics.

- □ All players
- □ Quarterbacks (QB)
- □ Running Backs (RB)
- □ Offensive Lineman (OL)
- □ Tight Ends (TE)
- □ Wide Receivers (WR)
- □ Defensive Lineman (DL)
- □ Linebackers (LB)
- □ Defensive Backs (DB)
- □ Kickers (K)
- □ Long snappers

How frequently are anthropometric measurements conducted annually?

<table>
<thead>
<tr>
<th>Number of assessments</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
</table>

Please identify when you measure anthropometrics.

- □ Pre training camp
- □ Post training camp
- □ Pre-mini camp
- □ Pre-season
- □ In-season
- □ Post-season
- □ Other
Section 3, A

The following questions are related to specific aspects of flexibility development.

Do you prescribe flexibility exercises?

○ Yes

○ No

How important is flexibility development?

<table>
<thead>
<tr>
<th>Extremely Important</th>
<th>Very Important</th>
<th>Moderately Important</th>
<th>Slightly Important</th>
<th>Not at all Important</th>
</tr>
</thead>
</table>

Please select one    ○    ○    ○    ○    ○
Section 3, Flexibility Development

Please identify the specific position(s) to whom you prescribe flexibility training.

- [ ] All players
- [ ] Quarterbacks (QB)
- [ ] Running Backs (RB)
- [ ] Offensive Lineman (OL)
- [ ] Tight Ends (TE)
- [ ] Wide Receivers (WR)
- [ ] Defensive Lineman (DL)
- [ ] Linebackers (LB)
- [ ] Defensive Backs (DB)
- [ ] Kickers (K)
- [ ] Long snappers

Please describe the purpose for prescribing flexibility training?


How frequently is flexibility training performed?


Please identify the specific time-of-day you recommend performing flexibility training.

- [ ] Upon awakening
- [ ] Before going to sleep
- [ ] Before practice
- [ ] During practice
- [ ] After practice
- [ ] Other times

Please identify when do you prescribe flexibility training.

- [ ] Year round
- [ ] Pre training camp
- [ ] Post training camp
- [ ] Pre-mini camp
- [ ] Pre-season
- [ ] In-season
- [ ] Post-season
- [ ] Other

Do you prescribe static stretches?

- [ ] Yes
- [ ] No
Do you prescribe proprioceptive neuromuscular facilitation (PNF)?

○Yes ○No

Do you prescribe dynamic stretches?

○Yes ○No

Do you prescribe ballistic stretches?

○Yes ○No

Do you prescribe a pre-resistance training warm-up protocol?

○Yes ○No

Do you prescribe a post-resistance training cool-down?

○Yes ○No

Please rank, in order of importance, the top 3 areas where flexibility is required.

(Example- 1. Shoulder, 2. Hips, 3. Hamstrings)
Section 3, B

How long are static stretch held?

Please indicate the duration of a typical pre-resistance training warm-up protocol?

Please indicate the duration of a typical post-resistance training cool-down?
Section 4, A

The following questions are related to specific aspects of speed development.

Do you prescribe speed training exercises?

○ Yes ○ No

How important is speed development?

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<thead>
<tr>
<th>Extremely Important</th>
<th>Very important</th>
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</table>

Please select one ○ ○ ○ ○ ○ ○
Section 4, Speed Development

Please identify the specific position(s) to whom you prescribe speed training.

- □ All players
- □ Quarterbacks (QB)
- □ Running Backs (RB)
- □ Offensive Lineman (OL)
- □ Tight Ends (TE)
- □ Wide Receivers (WR)
- □ Defensive Lineman (DL)
- □ Linebackers (LB)
- □ Defensive Backs (DB)
- □ Kickers (K)
- □ Long snappers

Please describe the purpose for prescribing speed training?

Please identify the specific speed training strategies you use (e.g. form running, resistance running, over speed running etc.)?

Do you use GPS tracking systems (e.g. Catapult, Titan, etc.) to analyze and monitor players?

- ○ Yes
- ○ No

Please identify when you prescribe speed training.

- □ Year round
- □ Pre training camp
- □ Post training camp
- □ Pre-mini camp
- □ Pre-season
- □ In-season
- □ Post-season
- □ Other

How do you integrate speed training in the training program (e.g. separate days, before resistance training, complex training etc.)?

166
How frequently do you prescribe speed training during the SEASON?

How frequently do you prescribe speed training during the OFF-SEASON?
Section 5, A

The following questions are related to specific aspects of plyometric training.

Do you prescribe plyometric training?

○ Yes  ○ No

How important is plyometric training?

<table>
<thead>
<tr>
<th>Extremely Important</th>
<th>Very Important</th>
<th>Moderately Important</th>
<th>Slightly Important</th>
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Please select one ○ ○ ○ ○ ○ ○
Section 5, Plyometric Training

Please identify the specific position(s) to whom you prescribe plyometric training.

- All players
- Quarterbacks (QB)
- Running Backs (RB)
- Offensive Lineman (OL)
- Tight Ends (TE)
- Wide Receivers (WR)
- Defensive Lineman (DL)
- Linebackers (LB)
- Defensive Backs (DB)
- Kickers (K)
- Long snappers

How frequently is plyometric training prescribed?

- 0 days per week
- 1 day per week
- 2 days per week
- 3 days per week
- 4 days per week
- 5 days per week
- 6 days per week
- 7 days per week

Please describe the purpose for prescribing plyometric training?

Please identify when plyometric training is prescribed.

- Year round
- Pre training camp
- Post training camp
- Pre-mini camp
- Pre-season
- In-season
- Post-season
- Other

How do you integrate plyometric exercises in the training program (e.g. separate days, before resistance training, complex training etc.)?

Please identify the specific plyometrics exercises prescribed (e.g. bounding exercises, box drill, depth jumps, etc.)?
Section 6, A

The following questions are related to specific aspects of resistance training.

Do you prescribe resistance training?

○ Yes  ○ No

How important is incorporating strength and power development?

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<thead>
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<th>Extremely Important</th>
<th>Very Important</th>
<th>Moderately Important</th>
<th>Slightly Important</th>
<th>Not at all Important</th>
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<td>Please select one</td>
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</tbody>
</table>
Section 6, Resistance training

How frequently do you prescribe resistance training during the SEASON?

How frequently do you prescribe resistance training during the OFF-SEASON?

What is the duration of a typical resistance training session during the SEASON?

What is the duration of a typical resistance training session during the OFF-SEASON?

Please identify, in order of importance, the top 5 resistance training modalities.

Please identify the top 3 muscle groups that need to be developed.

(Example- 1. Low back, 2. Neck, 3. Core)

When designing the training program do you use a periodization model?

○ Yes ○ No

Please describe the methodology you use for determining training load (e.g. formula, athlete's discretion, previous workouts, nonspecific etc.).

Please describe the methodology you use for determining the sets and repetitions (e.g. range of sets and reps per specific exercise, ranges according to specific training phase, etc.).

Do you prescribe variations in repetition tempo during resistance training?

○ Yes ○ No

Please describe the rest intervals prescribed for multi-joint core movements (e.g. Olympic weightlifting, squats, etc.).

Please describe the exercise order for each resistance training session (e.g. power then strength then auxiliary exercises etc.).
Do you utilize any power output analyzers during resistance training sessions (e.g. Linear position transducers, TENDO power units etc.)?

○ Yes  ○ No
Section 6, B

Which type of periodization model do you follow?

○ Undulating
○ Linear
○ Other

How many MESOCYCLES make up your MACROCYCLE?

Please describe the mesocycles prescribed (e.g. duration, goals, etc.).
Section 7, A

The following questions are related to specific unique aspects of the training program.

Do you prescribe training programs based on specific position?

○ Yes  ○ No

Do you modify players’ training programs based on their findings from physical fitness tests?

○ Yes  ○ No

Please select any form(s) of training you prescribed during the training program

□ Balance and stability training  □ Olympic-weightlifting (e.g. clean and jerk snatch)
□ Core training  □ Injury prevention

How important do you think it is to prescribed the following forms of training into the training protocol?

<table>
<thead>
<tr>
<th></th>
<th>Extremely Important</th>
<th>Very Important</th>
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<tbody>
<tr>
<td>Balance and stability training</td>
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<td>○</td>
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<tr>
<td>Core training</td>
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</tr>
<tr>
<td>Injury prevention</td>
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<td>○</td>
<td>○</td>
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<tr>
<td>Olympic-weightlifting</td>
<td>○</td>
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</tr>
</tbody>
</table>
Section 7, Unique Aspects of the Program

Please identify the specific position(s) to whom you prescribe balance and stability training.

☐ All players ☐ Defensive Lineman (DL)
☐ Quarterbacks (QB) ☐ Linebackers (LB)
☐ Running Backs (RB) ☐ Defensive Backs (DB)
☐ Offensive Lineman (OL) ☐ Kickers (K)
☐ Tight Ends (TE) ☐ Long snappers
☐ Wide Receivers (WR)

How frequently do you prescribe balance and stability training?

[Blank chart with days of the week]

Please identify when balance and stability training is prescribed.

☐ Year round ☐ Pre-season
☐ Pre training camp ☐ In-season
☐ Post training camp ☐ Post-season
☐ Pre-mini camp ☐ Other

Please describe the purpose for prescribing balance and stability training.

[Blank text box]

Please identify the specific position(s) to whom you prescribe core training?

☐ All players ☐ Defensive Lineman (DL)
☐ Quarterbacks (QB) ☐ Linebackers (LB)
☐ Running Backs (RB) ☐ Defensive Backs (DB)
☐ Offensive Lineman (OL) ☐ Kickers (K)
☐ Tight Ends (TE) ☐ Long snappers
☐ Wide Receivers (WR)

How frequently do you prescribe core training?

[Blank chart with days of the week]
Please identify when core training is prescribed.

- □ Year round
- □ Pre-training camp
- □ Post training camp
- □ Pre-mini camp

Please describe the purpose for prescribing core training.

Please identify the specific position(s) to whom you prescribe injury prevention.

- □ All players
- □ Quarterbacks (QB)
- □ Running Backs (RB)
- □ Offensive Lineman (OL)
- □ Tight Ends (TE)
- □ Running Backs (RB)
- □ Defensive Lineman (DL)
- □ Linebackers (LB)
- □ Defensive Backs (DB)
- □ Kickers (K)
- □ Long snappers
- □ Offensive Lineman (OL)
- □ Kickers (K)
- □ Tight Ends (TE)
- □ Long snappers

How frequently do you prescribe injury prevention?

Please identify when injury prevention is prescribed.

- □ Year round
- □ Pre-training camp
- □ Post training camp
- □ Pre-mini camp

Please identify all body parts targeted with injury prevention.

- □ Neck
- □ Shoulder
- □ Elbow
- □ Wrist/Hands
- □ Abdominal
- □ Upper back
- □ Lower back
- □ Hip
- □ Knee
- □ Ankle/foot
Please describe the purpose for prescribing injury prevention.

Please identify the specific position(s) to whom you prescribe Olympic-weightlifting:

- All players
- Quarterbacks (QB)
- Running Backs (RB)
- Offensive Lineman (OL)
- Tight Ends (TE)
- Wide Receivers (WR)
- Defensive Lineman (DL)
- Linebackers (LB)
- Defensive Backs (DB)
- Kickers (K)
- Long snappers

How frequently do you prescribe Olympic-weightlifting?

Please identify when Olympic-weightlifting is prescribed.

- Year round
- Pre training camp
- Post training camp
- Pre-mini camp
- Pre-season
- In-season
- Post-season
- Other

Please describe the purpose for prescribing Olympic-weightlifting?
Section 8, A

The following questions are related to specific aspects of recovery modalities.

Do you prescribe recovery modalities (e.g. foam rolling, yoga, etc.)?

○ Yes ○ No

How important are recovery modalities?

<table>
<thead>
<tr>
<th>Extremely Important</th>
<th>Very important</th>
<th>Moderately important</th>
<th>Slightly important</th>
<th>Not at all important</th>
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</tbody>
</table>

Please select one ○ ○ ○ ○ ○ ○ ○
Section 8, Recovery Modalities

Please identify all recovery modalities utilized.

- Cold water immersion
- Hot water immersion
- Contrast water therapy
- Active recovery
- Yoga
- Other

Please identify the specific position(s) to whom you recommend performing recovery modalities.

- All players
- Defensive Lineman (DL)
- Quarterbacks (QB)
- Linebackers (LB)
- Running Backs (RB)
- Defensive Backs (DB)
- Offensive Lineman (OL)
- Kickers (K)
- Tight Ends (TE)
- Long snappers
- Wide Receivers (WR)

How frequently do you recommend performing recovery modalities?

- Days per week

Please identify the specific time-of-day you recommend performing recovery modalities.

- Upon awakening
- On their own
- Before going to sleep
- Before workouts
- Before practice
- During workouts
- During practice
- Post workouts
- After practice
- Other times

Please identify when you recommend recovery modalities.

- Year round
- Pre-season
- Pre training camp
- In-season
- Post training camp
- Post-season
- Pre-mini camp
- Other
Please describe the purpose for prescribing recovery modalities?
Section 9, Nutrition and Supplementation

The following questions are related to specific aspects of nutrition and supplementation.

How important is consuming nutritionally-dense food?

<table>
<thead>
<tr>
<th>Extremely Important</th>
<th>Very Important</th>
<th>Moderately Important</th>
<th>Slightly Important</th>
<th>Not at all Important</th>
</tr>
</thead>
</table>

Please select one ○ ○ ○ ○ ○ ○

How important is supplementation?

<table>
<thead>
<tr>
<th>Extremely Important</th>
<th>Very Important</th>
<th>Moderately Important</th>
<th>Slightly Important</th>
<th>Not at all Important</th>
</tr>
</thead>
</table>

Please select one ○ ○ ○ ○ ○ ○

Are players prescribed dietary protocols based on specific dietary needs?

○ Yes ○ No

Does your team have a Registered Dietitian on staff?

○ Yes ○ No

Are players counseled regarding substance and/or drug abuse (e.g. steroids)?

○ Yes ○ No

Are players advised to consume a nutritionally-dense meal at some point before resistance training?

○ Yes ○ No

Are players advised to consume a nutritionally-dense meal post-resistance training?

○ Yes ○ No

Are players provided supplements at any given time?

○ Yes ○ No
Section 9, B

How much time prior to resistance training are players advised to consume a nutritionally-dense meal?

<table>
<thead>
<tr>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>0</td>
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<tr>
<td>0.5</td>
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<tr>
<td>1</td>
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<td>1.5</td>
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<tr>
<td>2</td>
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<td>3.5</td>
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<td>4</td>
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</tbody>
</table>

What macronutrients values are players advised to consume prior to resistance training?

<table>
<thead>
<tr>
<th>Carbohydrates (g/kg)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
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<tbody>
<tr>
<td>Proteins (g/kg)</td>
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<td></td>
</tr>
<tr>
<td>Fats (g/kg)</td>
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</tbody>
</table>

How much time post-resistance training are players advised to consume a nutritionally-dense meal?

<table>
<thead>
<tr>
<th>Hours</th>
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<tbody>
<tr>
<td>0</td>
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<td>3</td>
</tr>
<tr>
<td>3.5</td>
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<tr>
<td>4</td>
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</tbody>
</table>

What macronutrients values are players advised to consume post-resistance training?

<table>
<thead>
<tr>
<th>Carbohydrates (g/kg)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
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<th>50</th>
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<tbody>
<tr>
<td>Proteins (g/kg)</td>
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<tr>
<td>Fats (g/kg)</td>
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</tbody>
</table>

Please describe the supplements provided (e.g. type of supplement, serving quality, purpose of consumption, time of consumption etc.).
Section 10, Comments

Please provide any comments or additional data you feel necessary.

Finish
Compensation

Thank you for the completion of this survey. We know your time and effort is valuable so please provide us with an address so we can send you a gift card for compensation. This data is completely separate from the previous survey and the information provided is not linked together, this ensures that your data is completely anonymous.

Thank you again,

Corey F. Fitzgerald
Graduate Student
Northern Michigan University
School of Health & Human Performance
APPENDIX B: Institutional Review Board Human Subject Research Approval

Memorandum

TO: Corey Fitzgerald
School of Health and Human Performance

CC: Dr. Randall Jensen
School of Health and Human Performance

FROM: Dr. Robert Winn
Interim Dean of Arts and Sciences/IRB Administrator

DATE: February 2, 2018

SUBJECT: IRB Proposal HS18-919
“The Strength and Conditioning Practices of the National Football League's Strength and Conditioning Coaches 2018”

IRB Approval Dates: 2/2/2018 – 2/1/2019
Proposed Project Dates: 2/2/2018 - 5/1/2019

Your proposal “The Strength and Conditioning Practices of the National Football League's Strength and Conditioning Coaches 2018” has been approved under the administrative review process. Please include your proposal number (HS18-919) on all research materials and on any correspondence regarding this project.

Any changes or revisions to your approved research plan must be approved by the Institutional Review Board (IRB) prior to implementation.

If you do not complete your project within 12 months from the date of your approval notification, you must submit a Project Renewal Form for Research Involving Human Subjects. You may apply for a one-year project renewal up to four times.

All forms can be found at the NMU Grants and Research website:
http://www.nmu.edu/grantsandresearch/node/102
MEMORANDUM

TO:            Corey Fitzgerald
                School of Health and Human Performance

CC:            Dr. Randall Jensen
                School of Health and Human Performance

FROM:          Dr. Robert Winn
                Interim Dean of Arts and Sciences/IRB Administrator

DATE:          June 5, 2018

RE:            Modification to HS18-919
                Original IRB Approval Date: 2/2/18
                Modification Approval Date: 6/5/18
                “The Strength and Conditioning Practices of the National Football League's Strength and Conditioning Coaches 2018”

Your modification for the project “The Strength and Conditioning Practices of the National Football League's Strength and Conditioning Coaches 2018” has been approved under the administrative review process. Please include your proposal number (HS18-919) on all research materials and on any correspondence regarding this project.

Any additional changes or revisions to your approved research plan must be approved by the IRB prior to implementation. Unless specified otherwise, all previous requirements included in your original approval notice remain in effect.

If you complete your project within 12 months from the date of your approval notification, you must submit a Project Completion Form for Research Involving Human Subjects. If you do not complete your project within 12 months from the date of your approval notification, you must submit a Project Renewal Form for Research Involving Human Subjects. You may apply for a one-year project renewal up to four times.

NOTE: Failure to submit a Project Completion Form or Project Renewal Form within 12 months from the date of your approval notification will result in a suspension of Human Subjects Research privileges for all investigators listed on the application until the form is submitted and approved.

If you have any questions, please contact the IRB at hsrr@nmu.edu
APPENDIX C: Introduction Letter and Informed Consent

School of Health & Human Performance
1401 Presque Isle Avenue
Marquette, MI 49855-5350
906 227-2130
Fax: 906 227-2181
Web site: http://www.nmu.edu/hhp/

Coaches Name,
Team Name

We are writing to invite you to participate in a thesis research study. The purpose of the study is to gather quantified data related to the strength and conditioning practices of the National Football League. This research study is expansion upon Ebben and Blackard’s original publication titled “Strength and Conditioning Practices of National Football League Strength and Conditioning Coaches” you can review this paper at the Journal of Strength & Conditioning Research by following link


We are inviting you to be in this study because you are the head Strength and Conditioning Coach listed on your particular NFL Team official website. Approximately 32 coaches will take part in this study at Northern Michigan University.

If you agree to participate, we would like you to complete an electronic survey instrument that was developed, reviewed, pilot tested with an informal advisory group of strength and conditioning coaches and academic professors with qualitative research experience, and revised to properly ensure clarity and validity. The survey instrument is divided into 10 sections including: (1) background information, (2) physical fitness testing, (3) flexibility development, (4) speed development, (5) plyometric training, (6) strength and power development, (7) unique aspects of the program, (8) recovery modalities, (9) nutrition and supplementation, and (10) comments. The estimated time of competition is 20-30 minutes. You are free to not answer or disclose any information you wish on any particular question throughout the survey.

The Qualtrics survey software has imbedded programming to ensure anonymous completion of the survey, thus your competition is totally anonymous. Scientific reports will be based on group data and will not identify you or any individual as being in this project.
There are no known risks from being in this study, and upon completion we will provide you with an amazon gift card with a minimum value of $50.00. We hope that others may benefit in the future from what we learn as a result of this study.

Taking part in this research study is completely voluntary. If you decide not to be in this study, or if you stop participating at any time, you won’t’ be penalized or lose any benefits for which you otherwise qualify.

If you have any further questions regarding your rights as a participant in a research project you may contact Dr. Robert Winn of the Human Subjects Research Review Committee of Northern Michigan University (906-227-2300) rwinn@nmu.edu. Any questions you have regarding the nature of this research project will be answered by the Coordinator - Exercise Science, Graduate Studies Faculty who can be contacted as follows: Dr. Randall L. Jensen (906-227-1184) Rajensen@nmu.edu.

Signature: _______________________________ Date: _________________

Name (print): _______________________________

Email Address: _______________________________

(Email address is for distribution of the electronic survey instrument)

I have read the above “Informed Consent Statement.” The nature, risks, demands, and benefits of the project have been explained to me. I understand that I may ask questions and that I am free to withdraw from the project at any time without incurring ill will or negative consequences. I also understand that this informed consent document will be kept separate from the data collected in this project to maintain anonymity (confidentiality). Access to this document is restricted to the principle investigators.

If you decide to NOT participate in this research study please check the box below and no further contact will be made.

☐ I do NOT want to participate in this research study
Thank you very much for your consideration.

Sincerely,

Corey F. Fitzgerald, BS
Graduate Student
School of Health & Human Performance
Northern Michigan University
Marquette, MI 49855

Randall Jensen, PhD, FACSM, FISBS, CSCS
Professor of Sport and Exercise Science
School of Health & Human Performance
Northern Michigan University
Marquette, MI 49855

William P. Ebben, PhD, MSSW, FNSCA, CSCS*D, USAW
Associate Professor of Exercise Science
Lakeland University
Plymouth, WI 53073

Sarah Clarke, PhD, BSc, CSCS
Assistant Professor, Exercise Science
School of Health & Human Performance
Northern Michigan University
Marquette, MI 49855
Thank you for volunteering to participate in this research study. We have provided a hyperlink to the electronic survey instrument below. The instructions are provided at the top of the page before each section. If you have any question regarding the survey you may contact me at (330-232-5526) corfitzg@nmu.edu.

The Survey is Password protected to ensure privacy.

The Password is: Canton1920

**Click Here to Access NFL Strength and Conditioning Coaches Survey**

Thank you very much.

Sincerely,

Corey F. Fitzgerald, BS
Graduate Student
School of Health & Human Performance
Northern Michigan University
Marquette, MI 49855

Randall Jensen, PhD, FACSM, FISBS, CSCS
Professor of Sport and Exercise Science
School of Health & Human Performance
Northern Michigan University
Marquette, MI 49855

William P. Ebben, PhD, MSSW, FNSCA, CSCS*D, USAW
Associate Professor of Exercise Science
Lakeland University
Plymouth, WI 53073

Sarah Clarke, PhD, BSc, CSCS
Assistant Professor, Exercise Science
School of Health & Human Performance
Northern Michigan University
Marquette, MI 49855
APPENDIX E: Northern Michigan University Excellence in Education Grant

March 22, 2018

Corey Fitzgerald
00344339
HHP

Dear Corey:

I am pleased to inform you that you have been selected to receive a $1,500 Excellence in Education Award for the summer of 2018 for your proposed project.

Please carefully read the following requirements for this award. NOTE: If your proposal is for a conference presentation, your funding is contingent on acceptance of your work.

To obtain your award, you must enroll (before May 31, 2018) and complete at least one course related to your area of research during one of the two summer sessions. It is recommended that you enroll for this course as soon as possible. If you do not meet this requirement, no funding will be provided. Once you have enrolled for the required course, you will receive an award for one credit of your summer tuition plus $1,500 in your NMU student account. This will be reflected in the account after your course start date (May 21 for the first session, July 5 for the second session). The $1,500 award and the one credit stipend are distributed by the Financial Aid Office.

Please note your Excellence in Education funds cannot be used for payment for services rendered by a second party. If equipment or supplies for your research must be purchased by NMU, your department will bill your student account for the amount of the purchase. Sales tax (as applicable) will be added to the amount before being deducted from your account. Your adviser and department head are copied on this message so that they are aware of this procedure. Please consult with your adviser about proper disposition of equipment or supplies at the end of your project. For questions regarding the departmental billing process, contact Pam Johnson in Financial Services at 906-227-1448. Excess funds remaining on your account will be dispersed as an average.

**If the work in your project is covered by either Human Subjects Institutional Review Board (IRB) or Institutional Animal Care and Use (IACUC) policies, applications to the appropriate review board must be fully approved before beginning the project.

A final project report must be submitted to your department and to graduate@nmu.edu by October 15, 2018. Requirements for this report can be found on the NMU Grants and Contracts website at http://www.nmu.edu/grantsandresearch/node/85. Failure to complete this report and/or summer course will make you ineligible for a future Excellence in Education Award (students are limited to 2 awards) and may also cause the awarded funds to be rescinded.

If you have any questions or are not able to accept this award, contact the Office of Graduate Education and Research at 906-227-2300. I wish you the very best in your summer research endeavors.

Sincerely,

Lisa S. Eckert, Ph.D.
Interim Director of Graduate Education

cc:      Randy Jensen, rajensen@nmu.edu
         Elizabeth Wurinen, ewurinen@nmu.edu
APPENDIX F: Northern Michigan University Excellence in Education Grant

March 20, 2019

Corey Fitzgerald
60344339
HHP

Dear Corey:

I am pleased to inform you that you have been selected to receive a $1,500 Excellence in Education Award for the summer of 2019 for your proposed project.

Please carefully read the following requirements for this award. NOTE: If your proposal is for a conference presentation, your funding is contingent on acceptance of your work.

To obtain your award, you must enroll (before May 31, 2019) and complete at least one course related to your area of research during one of the two summer sessions. It is recommended that you enroll for this course as soon as possible. If you do not meet this requirement, no funding will be provided. Once you have enrolled for the required course, you will receive an award for one credit of your summer tuition plus $1,500 to your NMU student account. This will be reflected in the account after your course start date (May 20 for the first session, July 1 for the second session). The $1,500 award and the one credit stipend are distributed by the Financial Aid Office.

Please note your Excellence in Education funds cannot be used for payment for services rendered by a second party. If equipment or supplies for your research must be purchased by NMU, your department will bill your student account for the amount of the purchase. Sales tax (as applicable) will be added to the amount before being deducted from your account. Your adviser and department head are copied on this message so that they are aware of this procedure. Please consult with your adviser about proper disposition of equipment or supplies at the end of your project. For questions regarding the departmental billing process, contact Pam Johnson in Financial Services at 906-227-1448. Excess funds remaining on your account will be dispersed as an overage.

**If the work in your project is covered by either Human Subjects Institutional Review Board (IRB) or Institutional Animal care and Use (IACUC) policies, applications to the appropriate review board must be fully approved before beginning the project.

A final project report must be submitted to your department and to graduate@nm.edu by October 15, 2019. Requirements for this report can be found on the NMU Grants and Contracts website at http://www.nmu.edu/grantsandresearch/node/85. Failure to complete this report and/or summer course will make you ineligible for a future Excellence in Education Award (students are limited to 2 awards) and may also cause the awarded funds to be rescinded.

If you have any questions or are not able to accept this award, contact the Office of Graduate Education and Research at 906-227-2300. I wish you the very best in your summer research endeavors.

Sincerely,

Lisa S. Eckert, Ph.D.
Interim Dean of Graduate Education and Research

cc: Randy Jensen, rajensen@nm.edu
    Elizabeth Wuorinen, ewuorine@nm.edu