An Updated Review of the Applied Physiology of American Collegiate Football: The Physical Demands, Strength/Conditioning, Nutritional Considerations and Injury Characteristics of A...

Article *in* International Journal of Sports Physiology and Performance · March 2017
DOI: 10.1123/ijspp.2016-0783

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Note. This article will be published in a forthcoming issue of the *International Journal of Sports Physiology and Performance*. The article appears here in its accepted, peer-reviewed form, as it was provided by the submitting author. It has not been copyedited, proofread, or formatted by the publisher.

Section: Brief Report

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Journal: *International Journal of Sports Physiology and Performance*

Acceptance Date: March 7, 2017

DOI: https://doi.org/10.1123/ijspp.2016-0783

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Submission Type: Brief Review

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Running head: An updated review on the applied physiology of American Football

Abstract word count: 250

Text only word count: 5127

Number of Tables: 0

Number of Figures: 0

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ABSTRACT

Whilst there are various avenues for performance improvement within collegiate American football (AF), there is no comprehensive evaluation of the collective array of resources around performance, physical conditioning and injury and training/game characteristics to guide future research and inform practitioners. Accordingly, the aim of the present review was to provide a current examination of these areas within collegiate AF. Recent studies show that there is a wide range of body compositions and strength characteristics between players, which appear to be influenced by playing position, level of play, training history/programming and time of season. Collectively, game demands may require a combination of upper and lower body strength and power production, rapid acceleration (positive and negative), change of direction, high-running speed, high intensity and repetitive collisions and muscular strength endurance. These may be affected by the timing of, and between, plays and/or coaching style. AF players appear to possess limited nutrition and hydration practices, which may be disadvantageous to performance. AF injuries appear due to a multitude of factors: strength, movement quality, and previous injury whilst there is also potential for extrinsic factors such as playing surface type, travel, time of season, playing position and training load. Future proof of concept studies are required to determine the quantification of game demands with regards to game style, type of opposition and key performance indicators. Moreover, more research is required to understand the efficacy of recovery and nutrition interventions. Finally, the assessment of the relationship between external/internal load constructs and injury risk is warranted.

1 Conceptual introduction

American Football (AF) is one of the most popular and wealthiest sports in the world[1]. Extensive resources are dedicated to the sport at the collegiate level (National Collegiate Athletics Association; NCAA) where the sport is considered a mainstay of American culture[1,2]. In addition, collegiate AF is now broadcast and played in other countries, expanding its global brand and giving it a wider exposure than in previous years. Scientific studies on collegiate AF have grown exponentially since the first paper in 1969, leading to various avenues of scientific development in key areas from this time to the present day. These include injury prevention[3,4], concussion[5], return to play injury characteristics[6,7], analysis of strength and conditioning[8-11], overall health[12] and wellbeing and most recently the objective quantification of training and games[13-15].

Despite the popularity, social impact and economic investment in collegiate AF, there are few collective peer-reviewed resources which assess the wide scope of AF and guide scientific support for staff, coaches and practitioners within the sport. Indeed, whilst previous reviews have explained the basic rules and physiological demands of the sport[16,17], there remains no comprehensive evaluation of the collective array of performance, physical conditioning, injury and training/game characteristics. This is surprising given the high injury rates (36 per 1000 athlete exposures[18]) in collegiate AF and the negatively associated monetary cost, performance outcomes and overall student-athlete health and welfare[1].

Given both the economic and scientific growth of AF since previous reviews, there is a clear need for a comprehensive updated evaluation of the applied physiology of collegiate AF to guide future research and inform practice. Therefore, the aims of this critical review were focused on evaluating the demands of training and games, the differing components of physical conditioning, an analysis of nutritional considerations and requirements, and injury characteristics of collegiate AF.

2. Description of American collegiate football

There are three divisions in NCAA football, with Division I also having two divisions (the upper FBS; football bowl and the lower FCS; football championship). During a typical regular season, players in the highest NCAA level (Division I; DI) participate in 12 games on a consecutive weekly basis. The biggest differences between the collegiate and professional games are that collegiate athletes are not paid a large salary (rather scholarship and stipend allowances), they are involved in full-time education and are subject to NCAA compliance laws. Collegiate AF is also unique from the professional version of the game in that players cannot be bought and sold with a limit on the number of scholarships per university (85 at FBS level, 63 at FCS level). Student-athletes are recruited from high school based on their athletic ability, strength testing, high school highlights, cognitive ability and personality. It is well established that getting the best talent is paramount for success[19]. Indeed, a 5-star or 'blue-chip' recruit may mean $150K in Championship income to his chosen school[19] as they can bring 0.44 more wins than a 4-star recruit. This effect may last for five years upon initial recruitment[20] (i.e. the maximum duration of their time at the university).

Since the most recent review on AF[16], the basic principles of the game have not changed. The game is still played over four 15 minute quarters by 11 players on the field for each team. These players come from a squad of 70-120 depending on if the game is at home or away, and interchange freely. Players specialize in positions and as such their specific responsibilities shape the demands and training styles of the sport. These are examined more closely in section 3.2 but comprise of defensive (defensive backs, DB; linebackers, LB;

defensive line, DL), offensive (quarterbacks, QB; offensive line, OL; wide receivers, WR; tight ends, TE; running backs, RB) and special teams (ST; kickers, punters and long snappers).

3. Physiology overview of D1 American Football

3.1 Mass, stature, body composition and muscle function of players

Stature and body size is considered a major contributor to performance in AF[21]. The trend has been for mass to increase longitudinally over time with associated improvements in strength, power and speed[22]. In DI players body fat measures typically range from 9-24% across positions with a mass in the range of 88 – 137 kg when they enter training camp at the beginning of preseason[23,24]. OL and DL have been shown to possess ~9% greater fat mass than the skilled positions, possibly increasing susceptibility to health risks due to their size[25]. While this may be a health concern after their football careers it can also be a problem during. These positions typically exhibit a number of at risk criteria for obesity[25] which in turn contributes to the ability to dissipate heat which is compromised by their relatively static training regime[26,27].

Body fat levels vary significantly across positions, with DB's, RB's and WR's being the leanest and the OL and DL having the most[17,24,25]. The methods to assess though have also differed across studies with no definitive measure prevailing. It would seem pertinent to follow the skinfold measurement guidelines recommended by the International Society for the Advancement of Kinanthropometry (ISAK) or use direct measurement via Dual-energy X-ray absorptiometry (DXA) to ensure accuracy and reliability of these measures.

Across a season it has been shown at a team level that there are reductions in lean mass and increases in percentage body fat as measured by DXA[28]. There is typically no significant relationship between body composition and playing year[29] or physical performance[30]. The body composition related to differing football positions may place individuals at an increased risk for cardiovascular disease with higher fasting glucose, lower HDL, increased blood pressure and thicker arteries[12]. Another study has shown that 80% of football athletes have at least 1 abnormal resting ECG finding with the majority being left ventricular hypertrophy[31] – these findings tended not to be replicated during maximal exercise stress tests but raise questions about the strain of maintaining a football physique for certain positions (i.e. those that typically have a high body fat %). However, although high body fat may be present in some positions, there is evidence to show that linemen do become leaner after their first year of collegiate football[22].

3.2 The physiological demands of AF

AF can be characterized as an acyclic sport with many functions being continuously performed. For example, a DB may backpedal, cut, accelerate and tackle an opponent in one given play. Thus, players need to have a combination of physical qualities to be able to cope with the intense collisions and high-intensity bouts of exercise that are short in duration but frequent in number over a 60 min game of regular playing time (3-4 h in real time). These repeated short (~5s per play[32]) but high intensity actions over the course of a prolonged period suggest a combination of energy contributions from the phosphocreatine (PCr) energy system and anaerobic glycolytic pathway[17]. Although variable (46.9 ± 34 seconds[32]), the different styles of offenses/plays and injury-, tactical- and advertising-derived time-outs, result in typical recovery time between plays being ~25-40 s. However, specific repeated plays with short periods of rest (i.e. 'up-tempo' football) may also place an additional demand on the aerobic system. This may be concerning given the cardiovascular endurance of football players is historically not well developed[33]. Unfortunately, there is no research to the authors' knowledge which has investigated the physiological response (e.g. cardiovascular changes) of players during an actual football game (though limited simulations have occurred[34]) – making it difficult to infer the exact physiological requirements required to perform AF.

3.2.1 Quantification and effect of game-related AF activity

Although the use of global positioning systems (GPS) and built in inertial measurement units (IMU) to quantify external training and match load is becoming commonplace in AF (personal communication), there are presently limited studies which have quantified the physical demands of AF game-play. Wellman and colleagues[14] monitored 33 DI players during 12 regular season games. The authors found significant differences between offensive and defensive positional groups, with WR's and DB's completing significantly greater total distance, high-intensity running, sprint distance, and high-intensity acceleration (positive and negative) efforts than other positions. These total distances reached ranges of 3013-5530 m (655 m of high intensity running), with the high intensity portion (5-20%) made up of ~10 sprints and ~100 accelerations (both positive and negative) depending on position[14]. The differences in high intensity work are consistent with pre-season periods where non-linemen cover more high intensity distance than linemen[35]. Wellman and colleagues[13] also separately analysed the intensity, number and distribution of impact forces experienced by players during competition using integrated accelerometry. Within the offensive groups, WR's sustained more 5-6.5 G force impacts (moderate to light) than other position groups, whereas RB's were found to endure the most severe (>10 G force) impacts bar the QB's. DB's and LB's absorbed more very light (5.0-6.0 G force) impacts, and defensive tackles (interior DL) reported significantly more heavy and very heavy (7.1-10 G force) impacts than other defensive positions[13]. These studies further our understanding of the demands imposed on players, which may form the basis for the design of position-specific monitoring and training in the preparation for the external load and impact forces performed in games. For instance, since RB's endure the most severe impacts in games within skill positions, practitioners must balance the need for ensuring these players are sufficiently recovered from each game whilst also ensuring they are adequately prepared to cope with these in-game impacts. In this example, RB's may benefit from off-season conditioning which focuses on the development of physical attributes (e.g. upper body muscular adaptation) which enhance their resilience to absorb these impact forces.

In addition to GPS and IMU, some studies have also attempted to evaluate the average duration of play, rest intervals and series within games to guide practitioners in developing appropriate conditioning programs for their teams. Iosia and Bishop[32] reported that the average duration of a play was 5.23 ± 1.7 s, with significant differences apparent between run plays (4.86 ± 1.4 s) and pass plays (5.60 ± 1.7 s). The average duration of rest between plays without extended rest (time outs and injury attention) was 36.1 ± 6.7 s with the average rest time between series was 11:39 ± 4:19 min. These results should be treated with caution though, as they were analysed on only two teams over ten years ago[32]. Given the difference in game styles across teams, divisions and professional levels, along with the development of various offenses in the last decade, especially at the collegiate level (e.g. 'spread', 'up-tempo', 'air raid'), practitioners are encouraged to conduct 'in-house research' to determine the average duration and rest intervals of their playbook to develop appropriate training and conditioning programs. Indeed, this preparation is critical since it can determine adequate player preparation with regard to both performance and injury resilience[11]. Although the evidence is limited, it is generally assumed that in-game demands incur greater impact collisions and pose greater injury risk than training[15]. For example, Wilkerson and colleagues[15] retrospectively analysed inertial measurement and injury training and game data for 45 DI players, with both the coefficient of variation for average inertial load and increased exposure to game conditions found to be strongly associated with injury occurrence ($\chi = 9.048$; $p = 0.004$; odds ratio = 8.04; 90% CI: 2.39, 27.03). It has also been shown that line players experience significantly higher cumulative linear acceleration forces (a combination of impacts of player on player and player on ground) when compared to skill positions in both practices and games[36].

Despite this recent growth in the quantification of training and game-related activity in AF, there remains several gaps in the current literature. The objective quantification of game and training demands with regards to game style, time of the season (acute vs chronic), type of opposition and performance success (e.g. winning/losing, key performance indicators) remains unknown. Furthermore, our understanding of the relationship between the various external load constructs (e.g. total distance, high intensity running, speed, accelerations, impacts) and other markers of load (e.g. s-RPE-TL, markers of wellness) within AF is limited. Perhaps most pertinently, despite the growth in literature in other football codes which assess the complex relationship between training/game loads and injury risk, there is a dearth of such evaluations in AF.

3.2.2 Recovery and fatigue markers in response to games

The effect of the aforementioned loading demands during games can cause short term reductions in power and peak force, muscle damage (creatine kinase; CK) and an increase in cortisol[37]. A longitudinal examination of biochemical markers in DIII players showed that the most stressful time in the season is typically (pre-season) training camp as this was associated with the largest increase in markers of muscle damage[38]. The suggestion is that this intense period of training creates a buffer for adaptation for the repeated trauma of the season. Indeed, once games are played in the competitive season, players are reported to incur "contact adaptation", indicating that players may build up a response to the repeated contacts and muscular trauma induced throughout the season[39]. For instance, Kraemer and colleagues[40] showed that changes in CK and adrenal cortical stress over a typical DI season are minimal, although large individual variations can be observed[40]. Practitioners should also be aware that players can possess above normal resting soft tissue damage levels going into games, indicating that recovery should be carefully monitored throughout the training week[39]. Indeed, it has recently been shown that perceptions of wellness (soreness, sleep, energy) can take longer than 4 days to return to pre-game levels in DI players[41] and thus should be considered when prescribing training and/or recovery during an in-season week.

Consideration should also be given to the travel induced in a typical season. For instance, cross-country (westward) air travel across the United States (~6 h; three time zones) followed by simulated sporting competition and a return flight home has been shown to worsen measures of jet lag, sleep quality, hormonal responses (epinephrine, testosterone, and cortisol), muscle tissue damage markers (CK), and physical performance (countermovement jump, pro-agility drill and 40-yd sprint)[42]. Interestingly, within this study, a control group whom wore compression garments were shown to result in no reductions in any parameters of physical performance[42]. Although outside the scope of this review, there are various recovery methods which may benefit the return of exercise or psychological performance following training or games (e.g. sleep, nutrition, cold-water immersion, compression, active recovery). However, it should be noted that there is a scarcity of research of the effectiveness of these methods (individual or combined) for AF players. At present it would appear most beneficial to target recovery practises at specific individuals based on the demands or load response of their position and/or the individual's preference.

4. Components of AF training

The majority of research within AF is directed towards the importance of optimising physical training and performance outcomes. Specifically, there is a widely acknowledged importance for the development of strength, power, speed and conditioning for AF players to be both successful and resilient to injury throughout the course of a season and their careers[11].

Indeed, since the physical demands of the sport place a wide variety of stressors on players' bodies[16], it is pertinent that various physical attributes are developed in order to enhance performance and be resilient to injury. This importance has led to an increased significance bestowed upon strength and conditioning coaches, whose primary role is to improve the physical performance of their players. Indeed, such focused significance may explain the improvement in various physical parameters in more recent players compared to those in previous decades (e.g. RBs in 2000 had higher scores in bench press, power, and vertical jump by 11, 9, and 7.7%, respectively than those in 1987[43]). Furthermore, programs display improved strength and power performance (e.g. significant increases in strength [~30% improvement in the 1RM bench press and ~35% increase in squat strength][10]) during the course of an athlete's career. With this in mind, the following section briefly examines the various components of AF training and programming.

4.1. Strength and conditioning training programs

Strength and conditioning within AF is historically classified as developing and improving the individual player for specific physical characteristics or testable goals of the program (rather than wins vs losses[11]). This physical development is directed by the day-to-day exercise prescription of choice and order of exercises, number of sets, level of intensity and length of rest periods[11]. Typically, a balanced strength and conditioning program entails a variety of strength/power training, aerobic and anaerobic conditioning, speed (linear and multidirectional) development and muscular strength endurance both within the weight room and on the training field. The development of physical performance characteristics in AF primarily take place in the off-season period, where the majority of gains in upper and lower body exercises occur. However, there is no clear indication to which is the most efficacious periodization strategy within this period (e.g. non-periodised versus traditional linear periodisation or non-linear periodised training[44]). It has been suggested that the efficacy of the offseason training program is dependent on the length of both the program itself and the period of rest/recovery prior[44]. Comparatively, physical performance enhancement in the in-season period is likely limited by accumulated fatigue from playing time thus a focus is directed towards strength and power maintenance during this period[16]. However, there are studies which report 1RM squat improvements in DIII players during the regular season[9], with improvements suggested to most likely occur under with a linear design in-season weight training program[45]. In-season improvements for higher division and professional players would appear more difficult to attain, as these players are physically more advanced in terms of strength, power, speed and agility[46]. Indeed, this re-emphasises the importance of physical performance development prior to the season (and over subsequent off-seasons) since these characteristics (power, speed and agility) have been shown to favour players whom are both drafted as professionals over those who are not[47] and order of draft status[48].

Stodden and Galitski[49] investigated the longitudinal effects of a strength and conditioning program over four years of consecutive training in 84 DI players. These authors found that certain performance data (% body fat, vertical jump) saw the greatest significant improvements in the first year of eligibility, whilst others also made further improvements into the second year (agility, lean body mass, power index from the vertical jump). Of the performance data only bench press significantly improved throughout the 4 y of training across all subjects, showing that the greatest number of improvements for the majority of parameters may only occur in the initial years of the training program. In contrast, Hoffman and colleagues[10] found significant improvement in the 1RM bench press, vertical jump and squat strength but not speed or agility over DIII player's careers. These findings would suggest that whilst strength and power improvements are attainable over a player's career, speed and agility may be more difficult. It also has been suggested that to elicit further strength gains in previously trained football players there needs to be an increase in work volume[11].

When viewed collectively, it should be noted that strength, power and speed training can typically vary dependant on the offensive/defensive scheme and coaching style. For instance, even when performing sets to failure (e.g. 10-RM), multiple sets are possible if sufficient rest is allowed[11]. This may help build force production with less rest, a characteristic which can contribute to success in a no-huddle (i.e. up-tempo) offensive scheme. Furthermore, an up-tempo coaching scheme may require faster, more agile players and thus speed (linear and multidirectional) development may be a focus for that team's training program[50]. Indeed, speed has been shown to distinguish between players' draft status and playing ability[47,48]. Comparatively, a slower 'pro style' offense, where rest in between plays is maximised, may inherently produce stronger and larger players designed for more 'run-block' plays. From a defensive standpoint, if the defense has to remain on the field for sustained periods due to the types of offenses faced, then they may benefit from multiple circuit style programs which develop local muscular endurance[11]. It is also important to note that improvements in training programs are dependent on the intensity of training and the amount of resistance training players do prior to entering the collegiate setting (i.e. the athlete's training age). Some authors suggest that during traditional strength training the greatest strength improvements are attained when training intensity exceeds 80% of players' 1RM[9,16]. Comparatively, other authors favour Olympic lifting (where loads can range from 65-90%) over traditional power lifting[51,52] , where significantly greater improvements have been reported in 1RM squat, 40-yd sprint time and vertical jump performance[8]. Overall, it would appear a balanced approach using a range of loads depending on how strength and power is demonstrated during football training and games would be the most beneficial.

The training program can also vary dependant on the physical needs of each playing position. For instance, an offensive linemen's primary role is defending the line of scrimmage to either protect the quarterback trying to complete a throw or aid a running back as they run the ball, which involves contesting defensive lineman who weigh up to 150 kg[43]. Thus, a focus for this position may include a greater reliance on upper body isometric strength and lower body power (higher squat and bench press scores[43]; higher body fat %[24]). In contrast, wide receivers must possess the ability to cover large distances at maximal speed, whilst also performing blocking sequences. Thus, these personnel are expected to produce repeated high levels of lower limb power, endurance and acceleration whilst also possessing strong relative isometric strength (lower 40-yd dash times and higher squat/% of body weight than lineman[43]). Following on from this speed requirement, a perhaps commonly overlooked aspect of AF training is the development of linear and multidirectional speed. Indeed, this is considered an important aspect of any football training program[50]. Eight weeks of in-season training has been shown to improve speed in D1 red-shirt (defined as training and practicing with the team but not playing in games) AF players[53] with similar findings reported in long-term training studies in other sports (e.g. rugby union; 2 years[54]). However, whilst speed development appears a critical part of playing AF (especially considering the demands of the game; see section 3), the peer-reviewed research reporting the details and effects of such approaches is limited in AF.

Taken collectively, future research is required to determine the effect of the variety of training programs available, psychological factors and other factors (e.g. environmental, genetics) on physical development in AF. More research which investigates the relationship between physical performance and on-field assessments (e.g. the positive association between 1-RM squat and power clean in linemen with on-field velocity in a particular skill[55]) are also required. Furthermore, whilst appreciating the difficulty of isolating causal effects in field-based athletic performance investigations, the analysis of the relationships between these characteristics and measure of success and/or AF-specific key performance indicators is warranted. Indeed, such analysis would presumably aid recruiting and assist in optimising the physical development and training of individual players.

5. Nutrition requirements and considerations for AF

Sports nutrition is a critical component of any training program; however, is often overlooked by student-athletes. For instance, it has been shown that DI athletes have inadequate sports nutrition knowledge[56]. Football players specifically also need education on sport nutrition[57]. Players have been reported to eat out on average 23% of the time and of those meals eat 'fast food' more than 50% of the time[57]. On entry to college, athletes are challenged by a number of factors including practice schedules and class time[58] which can result in inadequate energy intake when matched for activity level (i.e. training[59]). The energy requirements across positions are estimated to be from 5200-6500 kilocalories daily depending on size and stature[60]

Convenience and cost of food have been shown to be the major determinants of what athletes will eat[61] and some athletes are aware that they don't have adequate consumption of the major food groups[62]. Research should establish the actual metabolic requirements of practice and games to allow tailored nutritional interventions at an individual level. Nutrition staff must also comply with strict NCAA standards, with caffeine and creatine two examples which are banned for distribution (but can be consumed). Furthermore, given the impact of concussion there has been interest in supplements that can mitigate its affects. Omega-3 fatty acids, curcumin and resveratrol have been shown to have protective effects[5] and supplementation of DHA may offset the number of concussions experienced[63] and control the inflammation from acute football exercise[64].

Hydration is also critical to both health and performance – especially when practices can occur in padded equipment in extreme environments. Similar to nutrition, players appear to lack basic knowledge about hydration. Judge and colleagues[65] found that only a quarter of a sample from two schools reported drinking enough fluids before, during and after a practice. Godeck and colleagues[66] showed in a DII programme where fluid was only available during water breaks, that the sweat rate was the same as professional players on average (1.8 L/h) but there was a higher sweat rate in linemen than backs (2.3 v 1.6 L/h). This deficit in linemen can be exacerbated by starting the sessions hypo-hydrated especially given the static nature of their training which can reduce the avenue for heat loss via convection[27] while their increased mass means a higher sweat rate[26]. Furthermore, there is a worrying trend of hyperhydrating intravenously to prevent dehydration, heat illness and cramps[67]. While they may target the high-risk individuals on the team this seems a preventable practice with better education of football student-athletes and more regimented following of their hydration practices.

6. Injury patterns, risk factors and return to play within AF

Due to the inherently aggressive and intense physical demands of AF, injuries are a well-acknowledged aspect of the sport. The consequences of player injury are multifaceted and range in nature from financial and emotional to long-term health related. From collegiate players' perspective, injuries can ultimately have a negative impact on future earning potential if they eventually progress to the NFL[68] due in part to prior serious injury reducing the likelihood of a player being drafted into the NFL[69].

6.1 Epidemiology

Of concern is the high injury rate within college football (e.g. 36 per 1000 athlete exposures[18]). Indeed, a summary of 15 NCAA supported sports over a 16-year observation period revealed that AF displayed the highest injury rates of all the sports included (9.6 and

35.9 injuries per 1000 athlete exposures for training and games respectively)[70]. Perhaps the most concerning aspect related to injury epidemiology within collegiate AF is that there appears to be a trend of increasing lower extremity injury rates[71].

6.1.1 Anterior cruciate ligament injuries (ACL)

ACL injury represents a season-ending injury within collegiate AF since the majority of NCAA and NFL physicians recommend waiting at least six to nine months before returning to play[7]. The incidence rate of ACL injuries during collegiate gameplay has been reported to range between 8 and 10 per 10,000 athlete exposures and this represents a substantially higher rate when compared with training (0.80 per 10,000 athlete exposures)[3,72]. Furthermore, AF demonstrated the highest incidence rate of ACL injuries when compared to 14 other NCAA supported sports and the average number of such injuries has displayed an increasing trend since 2004[73]. This alarming trend coupled with the already high incidence rate highlights that ACL injury should be viewed as a priority when considering injury prevention measures within collegiate AF. Neuromuscular and proprioceptive training should underpin ACL injury prevention strategies since they have previously demonstrated efficacy in numerous studies[4].

6.1.2 Head/concussion

As mentioned previously, AF-related concussion has received significant attention within scientific research[74]. Indeed, this would appear justified considering the increase in concussion incidence between 2010-2014 compared to 2006-2009[74]. This increase in incidence is likely due to a multitude of factors, including improved recognition and reporting of such events[74]. A recent study within NCAA Division I football programs reported a concussion incidence rate of 4.46 per 1000 athlete exposures during games[74]. Furthermore, over a quarter of all players observed during the nine-year study period suffered at least one concussion[74]. It should be noted that the consequences of suffering a concussion are not exclusive to the head/trunk region; the odds of sustaining a lower extremity musculoskeletal injury after return to play from a concussion are elevated[75]. As a contact sport, AF will likely always be associated with a degree of risk for concussion; however, coaching tackling techniques that limit the chances of sustaining direct blows to the head perhaps represent a strategy that may help reduce incidence.

6.2 Factors affecting injury occurrence

Scientific research identifying risk factors for AF related injury is limited, especially among collegiate players; however, some initial evidence exists. Proposed intrinsic injury risk factors (relating to factors the player can influence) associated with AF include isokinetic strength deficits and ratios[76], movement quality[77], previous injury and body mass index[78]. Numerous extrinsic risk factors (external factors considered beyond the player's control) have also been investigated, including: environmental considerations such as ambient temperature and altitude, playing surface type, travel time, time-zone change, stage of the season, playing position and measures of training load[15,79,80]. Another contributor to injury risk unique to student-athletes is academic stress. Mann et al.[81] reported an almost two-fold greater likelihood of injury among Division I collegiate football players during periods of high versus low academic stress. The factors investigated so far almost certainly do not represent an exhaustive list. Aerobic fitness, absolute strength, match load and playing experience (to name but a few) constitute potential additional contributors to injury likelihood. Clearly, much further scope exists to investigate potential injury risk factors within AF at the collegiate level.

6.3 Rehabilitation and return to play

Since financial investment into university athletic departments cannot be received directly by players it is often funnelled toward support services in the form of training facilities, medical support staff and equipment. However, safe return-to-play protocols pose an inherent challenge to collegiate medical staff. Players and coaches have such a short competitive window (i.e. 12 weeks of regular season games) to perform, it is inevitable that they may be eager to return after injury before it is advisable to do so. In addition to restoring physical qualities eroded by injury it is important that medical staff consider players' psychological readiness to return to play. This is particularly important in the case of players who may be so determined to return to play prematurely that they put their long-term health in jeopardy[6].

7 Conclusion

Collectively AF-physical demands may require a combination of upper and lower body strength and power production, rapid acceleration (positive and negative), change of direction, high running speed, high intensity and repetitive collisions and muscular strength endurance which can be affected by numerous game factors. Given the breadth of variation in physical demands, adequate training programs which allow players to cope with, and recover from, these demands are paramount, especially given the high injury rates within AF cohorts. These high incidences may be due to a multitude of factors such as strength, movement quality, and previous injury whilst there is also potential for external considerations such as playing surface type, travel time, stage of the season, playing position and training load. In addition, AF players appear to possess limited nutrition and hydration practices, which may be disadvantageous to performance. Indeed, more research is required to understand the efficacy of recovery and nutrition interventions. Future proof of concept studies are required to determine the quantification of game/training demands with regards to game style, type of opposition and performance success (e.g. key performance indicators). The assessment of the relationship between external and internal load constructs and injury risk would also appear warranted.

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