Tackling Cardiovascular Health Risks in College Football Players

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There is no doubt that the life of a college football player is demanding and rigorous, yet the rewards are many. Teamwork, physical fitness, admiration and prestige, financial scholarships, and perhaps, privilege; all while doing something you love—playing football.

Football players are widely recognized for their physical prowess. Decades of research have demonstrated that physical activity and fitness are associated with lower all-cause mortality and a variety of health benefits in healthy individuals and individuals with chronic diseases. The specific mechanisms responsible for these outcomes appear to be multifactorial and include a reduction in cardiovascular risk factors, and favorable effects on thrombosis, inflammation, endothelial function, and autonomic tone. However, a distinction must be made between competitive sports and recreational exercise, the latter from which the majority of research on the benefits of exercise are derived. The physiological and emotional demands during training and performance of competitive athletics are indeed quite different. Competitive athletes participate in an organized sport that rewards athletic excellence and achievement and requires systematic training and regular competition. Accordingly, these athletes characteristically extend themselves to high levels of effort for long periods of time, often doing so regardless of other considerations.

Although the health benefits of regular exercise and physical activity are unequivocal, and overall cardiovascular risks during exercise and sports activities appear to be low, a small proportion of athletes often with undiagnosed pathological cardiac conditions are at risk of tragic cardiovascular events. Most known hazards described in football players are traumatic, and these include musculoskeletal injury and the newly described, very disturbing potential risk of chronic traumatic encephalopathy. Yet, sudden cardiac death is the leading medical cause of death and cause of death during exercise in National Collegiate Athletic Association student–athletes. A recent series demonstrates this risk to be 1:38,497 football players per year. Are there other, more insidious cardiovascular health risks to college football players perhaps incurred by the lifestyle, diet, and training demands of these players? This question is addressed by the provocative study by Weiner et al in this issue of Circulation.

Blood Pressure and Echocardiographic Changes in College Football Players

Over 6 consecutive seasons, the authors prospectively and systematically collected and analyzed anthropometric data, resting blood pressure, and echocardiographically-derived left ventricular (LV) measurements obtained before and after a single season of competitive football among a total of 113 first-year members of the Harvard University Football Team. All participants were male (age = 19±1 years), of whom 62% were white and 27% were black. There were 64 linemen (100±15 kg) and 49 nonlinemen (93±11 kg). One player had an established diagnosis of hypertension, and 27% had a family history of hypertension. Athletes averaged about 8 hours per week of nearly equal amounts of endurance and strength-based exercise training during the 8 weeks before enrollment, whereas most of the 17 total hours of training per week during the subsequent 90-day season was strength-based. Blood pressure was measured in triplicate in the supine position using an appropriate-sized cuff. Echocardiography was performed in the standard manner. Concentric and eccentric LV hypertrophy was defined using standard definitions.

Preseason versus postseason comparisons showed significant increases in systolic (116±8 mm Hg versus 125±13 mm Hg, P<0.001) and diastolic blood pressure (64±8 mm Hg versus 66±10 mm Hg, P<0.001). At postseason, 47% of all football players demonstrated prehypertension, and 14% demonstrated Stage 1 hypertension. Linemen had significantly higher blood pressures at preseason than nonlinemen; at postseason, 83% of linemen were either prehypertensive (58%) or hypertensive (25%). In contrast, the majority of nonlinemen maintained normal blood pressure and none demonstrated hypertension. Linemen demonstrated significantly greater increases in body mass during the season compared with nonlinemen. Significant increases in LV mass and LV mass index were observed in both linemen and nonlinemen during the season, with a similar magnitude of increase in both groups. However, among linemen, the prevalence of concentric LV hypertrophy rose significantly from 3% to 31%, whereas in nonlinemen concentric LV hypertrophy was present in only 1 player, and eccentric LV hypertrophy was a more common finding in the postseason. Change in LV mass had a modest correlation with intraseason change in systolic blood pressure and echocardiographic LV mass index.

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pressure ($R=0.46$, $P<0.001$). Lineman field position, inseason weight gain, and family history of hypertension were the strongest independent predictors of postseason blood pressure. Notably, in the comparison group of competitive rowers, who performed predominantly endurance type exercise and gained little weight (1 kg) during the season, minimal changes in blood pressure were observed. The authors conclude that American-style football participants may be at risk for the development of hypertension during youth.

**Are Football Players at Greater Risk of Hypertension?**

These data demonstrate that there is an increased incidence of prehypertension and hypertension among college football players, particularly linemen, even after 1 season. However, many questions remain before concluding that football participation may have adverse cardiovascular health consequences in a subset of athletes: does college football cause hypertension, particularly among those who might be predisposed? Or, does college football provide a snapshot into the lifestyle of a susceptible college student that might lead to hypertension? On the other hand, does a college football program provide a venue to tackle (ie, mitigate) cardiovascular health risks, such as weight gain and hypertension, and to promote cardiovascular health?

Linemen in the present study gained an average of 3 kg during the season, but it is not clear what type of weight was gained: fat, muscle, body size (height/shoulder width/bone growth) in late adolescence? This weight gain was most likely attributable to all of these factors, but no measures of body composition are provided. Weight gain is well known to occur among college students. A recent detailed prospective study done to evaluate changes in body weight and composition in a group of male and female students over the 4-year college period demonstrated significant gains in weight, body mass index, waist circumference, body fat, and absolute fat mass in both males and females. The changes in males were greater than females, and at the end of 4 years the percentage of participants classified as overweight-obese increased from 18% to 31%. Hence, the comparison group of competitive rowers selected for this study who are heavily engaged in high-intensity, calorie-burning exercise may not allow distinction between football participation and weight gain as the primary reason for increases in blood pressure. A different comparison group to consider would be age-, gender-, race-ethnicity-matched college students, not engaged in athletics, and followed prospectively over a similar time period as the football season.

**What Affects Blood Pressure Measurements in College Football Players?**

Accurate blood pressure measurements in large, heavy-set athletes are notoriously difficult and potentially influenced by other factors in football players. Day to day variation in blood pressure may be exaggerated by fatigue, poor sleep, and recent travel for away games. Pain from musculoskeletal injuries, use of nonsteroidal anti-inflammatory medications, which are common pre- and postgame, and recent alcohol consumption may also affect blood pressure readings. Additional studies would benefit from addressing these potential confounders, some of which are less likely in a comparison group of rowers. Furthermore, serial blood pressure measurement on multiple days remains the standard for a diagnosis of hypertension. Because postseason measurements were made on a single day, additional monitoring is critical to clarify whether these changes represent lasting blood pressure elevations. Co-existing obstructive sleep apnea, especially in those with recent weight gain, also should be explored in linemen identified with elevated blood pressure.

**Does the Type of Exercise Affect Cardiovascular Risk–Benefit?**

Arterial hypertension is the most common cardiovascular condition observed in competitive athletes. It has long been recognized that individuals with systemic hypertension benefit from regular endurance-type physical activity because it reduces blood pressure, protects against stroke, and protects against obesity-induced hypertension. The weight of evidence to date also demonstrates that resistance (strength) training has a beneficial effect on cardiovascular risk factors. A recent meta-analysis reports that resistance training does not increase resting blood pressure, and in fact, may reduce resting systolic blood pressure. However, the study concludes that more evidence is needed before recommending resistance training as a specific blood pressure–lowering therapy. Furthermore, resistance training appears to enhance insulin sensitivity and improve glucose tolerance in a wide range of study groups. There is also substantial evidence that regular resistance training can favorably alter body composition in both men and women. It has been shown to increase total fat-free mass and decrease total fat mass with the preferential mobilization of both subcutaneous and visceral fat in the abdominal region. Because lean skeletal muscle is known to have an average daily resting energy expenditure of $≈17.6$ kcal/kg, it has been suggested that resistance training can be used as a means to increase or at least maintain resting metabolic rate and fat free mass, thereby helping to slow, stop, or reverse gains in adipose tissue in an aging and sedentary population.

It has long been observed that systematic endurance or strength training in sports yields physiological adaptations and cardiac remodeling, including increased left ventricular wall thickness, enlarged ventricular and atrial cavity dimensions, and calculated cardiac mass, in the presence of normal systolic function (ie, athlete’s heart). In a large series of $>1400$ athletes, the amount of physiological hypertrophy varied according to the particular type of sports training. Endurance-trained athletes and strength-trained athletes differed significantly with respect to mean relative wall thickness (0.39 versus 0.44, $P<0.006$), and there were no significant differences between athletes and control subjects in left ventricular ejection fraction, fractional shortening, and E/A ratio, although the latter is an inadequate measure of diastolic function relative to current standards. Similar findings of concentric hypertrophy were reported in a series of elite professional football players, in whom the mean relative wall thickness was 0.424. These findings were again found in the present
study, where college football lineman demonstrated significantly greater relative wall thickness (concentric hypertrophy) compared with nonlinemen.

**Left Ventricular Hypertrophy: Physiological or Pathological Response?**
The authors suggest that concentric hypertrophy may be a pathological response to hypertension rather than an adaptive response to high volumes of strength training. This hypothesis assumes that the physical conditioning and balance between strength and endurance training is similar between linemen and nonlinemen throughout the season. However, the physical demands, practice drills, and nature and technique of repetitive position-specific skills are quite dissimilar for linemen versus nonlinemen. On nearly every play, linemen engage at the line of scrimmage with an intense burst of isometric force and push-off, often combined with breath holding and Valsalva. In contrast, most nonlinemen perform short sprints and rapid movements without contact on each play. Strength training in linemen also places a greater emphasis on heavy, power lifting during weightlifting. It is possible that these differences in both on-field and off-field athletic activities over a 3-month season contribute to the differences found in concentric versus eccentric LV remodeling. Although there was, at most, a modest correlation of LV mass with the presence of hypertension in this study, no analysis was done relative to the presence of concentric hypertrophy, likely because of the small number of cases in this report. Assessment of diastolic function in this study would have been helpful, because no echocardiographic study of athletes to date has demonstrated abnormal diastolic function, as might be seen in hypertensive subjects.

**Long-Term Cardiovascular Risks and Football**
A 1994 study reported the long-term cardiovascular risks of 3439 retired players from the National Football League (NFL). The overall death rate and risk of dying of heart disease was lower in the retired NFL players than in an age-equivalent general population database. However, a higher body mass index (>30) carried twice the risk of death from heart disease, and defensive linemen were found to have a 42% higher risk of death from heart disease compared with men in the general population. In more recent studies, a 2006 report on the prevalence of cardiovascular disease risk factors in active NFL players demonstrated that hypertension (13.8%) and prehypertension (64.5%) were significantly more common than in the general US population, and that large size measured by body mass index was associated with increased blood pressure. A follow-up report in 2010 confirmed that the mean systolic blood pressure and prevalence of prehypertension among linemen was higher than in other football position groups or the general population.

**Tackling the Risks**
Based on these past reports and the current study by Weiner et al, it appears that football linemen are at greater risk of prehypertension and hypertension and may have an increased risk of dying from cardiovascular disease. Thus, we strongly recommend that physicians and athletic trainers responsible for the healthcare of football players implement more rigorous blood pressure monitoring, especially in linemen. Blood pressure should be assessed before the season, at multiple time points during the season, and in the offseason. Weight gain often is stressed for football linemen to enhance performance, but athletes should be monitored closely for the development of central obesity, and healthy dietary habits and strength training regimens to increase muscle mass emphasized. The volume of nonsteroidal anti-inflammatory medication and its impact on blood pressure should be closely examined. All football linemen should undergo, at minimum, a questionnaire assessing for the signs and symptoms of obstructive sleep apnea and a low threshold maintained for further evaluation by sleep study. Restriction of alcohol should be fostered, as well as regular endurance type training, particularly in the offseason, because these have been shown to favorably affect blood pressure. Finally, these athletes should be encouraged to maintain a healthy, active lifestyle in the postcollege years, because seminal lessons learned from their predecessors in the Harvard Alumni Study demonstrate lower mortality among those who remain physically active throughout their lifetime, compared with those who become sedentary. Athlete education and the need for continued monitoring should be emphasized in players with prehypertension, and antihypertensive medication should be considered in athletes falling consistently in a hypertensive range.

**Future Studies**
What accounts for the differences in the prevalence of hypertension between linemen and nonlinemen? Additional studies are needed to better understand the relationship of position specific requirements in football, body mass index and body composition, diet and alcohol intake, elevated blood pressure, and long-term cardiovascular risk. The existing paradox of emphasizing weight gain for performance with the potential for deleterious health consequences needs to be explored. Although the current evidence on resistance training demonstrates otherwise, could the greater emphasis on resistance training and daily power requirements of football linemen during the season be the cause of their prehypertension or hypertension? Does their blood pressure remain elevated in the offseason when the day-to-day pressure load of their sport is markedly reduced? Is there a difference in diastolic function indices in those athletes with concentric versus eccentric hypertrophy, and does hypertrophy regress in the offseason? What are the influences of nonsteroidal anti-inflammatory medications or coexistent obstructive sleep-disordered breathing? The answers are not clear, but the data presented suggest that inherent characteristics may have predisposed certain players to be at greater risk. Hence, this study has important implications in the care of collegiate football players and identifies athletes at higher risk of elevated blood pressure (linemen, those with family history of hypertension, weight gain) where more rigorous blood pressure surveillance during and after the season seems prudent. Long-term surveillance of retired college and professional football players is needed to more clearly elucidate cardiovascular risk factors and optimize their long-term cardiovascular health.
None.

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