Curr Hypertens Rep (2016) 18: 77
DOI 10.1007/s11906-016-0685-y

Hypertension in Athletes and Active Populations

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Published online: 13 October 2016

Abstract Hypertension continues to be the most common cardiovascular disorder in the USA and worldwide. While generally considered a disorder of aging individuals, hypertension is more prevalent in athletes and the active population than is generally appreciated. The timely detection, diagnosis, and appropriate treatment of hypertension in athletes must focus on both adequately managing the disorder and ensuring safe participation in sport while not compromising exercise capacity. This publication focuses on appropriately diagnosing hypertension, treating hypertension in the athletic population, and suggesting follow-up and participation guidelines for athletes.

Keywords Hypertension · Athletes and hypertension · Treatment of hypertension

This article is part of the Topical Collection on *Antihypertensive Agents: Mechanisms of Drug Action*

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Introduction

Hypertension continues to be the most common cardiovascular disorder in the USA and worldwide, affecting approximately 33 % of those over 18 years of age in the USA [1] and over 40 % of those 25 years of age and older worldwide [2]. While the incidence of hypertension increases with age, a number of publications have highlighted that the prevalence of hypertension among young athletes is not insignificant [3], and as in the general population, hypertension is the most common cardiovascular disorder diagnosed in athletes [4]. It is estimated that 9.1 % of men and 6.7 % of women aged 20 to 34 years in the USA have hypertension or are taking antihypertensive medications [5•]. It has previously been found that nearly 19 % of collegiate American-style football (ASF) athletes meet criteria for a diagnosis of hypertension [6•]. While it has been hypothesized that the body habitus of ASF players may put them at an increased risk of hypertension and cardiovascular disease [7], a small sample of Norwegian professional football players has also been shown to have a relatively high prevalence of masked hypertension and elevated overnight ambulatory blood pressure (ABP) readings [8•].

The timely detection, diagnosis, and treatment of hypertension in athletes require the same vigilance as the general population. Adolescents involved in athletics often have greater access to medical care than adult athletes, as pre-participation physical examinations (PPEs) are required and elevated BP readings are the most common abnormalities found at these visits [9]. The importance of appropriately following up an elevated blood BP reading must not be underestimated, as 24-h ambulatory BP monitoring (ABPM) and home BP measurements are effective ways to determine which individuals have white coat hypertension (WCH) compared to a true diagnosis of hypertension. While hypertension in the general population is most prevalent in aging adults, rates of cardiovascular mortality in some former athlete populations are strikingly high [10].

This review presents contemporary issues related to the epidemiology, diagnosis, and management of hypertension in athletes. We provide an updated literature review since this topic was last addressed by Leddy and Izzo in 2009 [11] and Asplund in 2010 [12], including the most recent prevalence data on hypertension in the athletic/active population. We will also discuss appropriate treatment options for athletes who are diagnosed with hypertension and where selection of antihypertensive medications must carefully consider their potential effects on athletic performance as well as the regulations of national and international athletics-governing bodies. Finally, we propose a treatment and follow-up algorithm for the management of hypertension in athletes.

Definition, Diagnostics, and Pre-participation Physical Examinations

While BP is the most frequently measured clinical parameter, it is often measured incorrectly, either because of poor equipment, inappropriate technique, or a combination of the two. Small, seemingly insignificant deviations from the proper technique can lead to variances of up to 50 mmHg in SBP readings [13]. It is of particular importance to use a properly sized and fitted cuff when measuring BP in athletes with a large body habitus, like many that play ASF. Further, a single elevated BP in the clinic setting is not sufficient to diagnose hypertension. BP must be elevated on at least two separate occasions at least 1 week apart in adults [14] and on three or more separate occasions in adolescents to diagnose hypertension [15]. Additionally, blood pressure should be measured in both arms at the initial visit and, if elevated, confirmed in the contralateral arm.

The pre-participation physical examination in athletes affords an opportunity to screen for overt cardiovascular disease and, perhaps more importantly in this population, to screen for cardiovascular disease risk factors, since many athletes would not ordinarily be seen for routine health maintenance. As mentioned previously, ensuring proper follow-up after a positive screen for hypertension during the pre-participation physical examination is even more important than the initial screening. Historically, 24-h ABPM has been the gold standard to evaluate for WCH or the artificial elevation of blood pressure due to anxiety of being in a medical environment. However, 24-h ABPM is not universally available, expensive, and often not reimbursed by third-party payers. Home BP monitoring, when carried out one to two times per day, at different times throughout the day, with an appropriately fitting cuff and proper technique, has been shown to be an adequate initial step to rule out WCH [16–21].

Epidemiology

The prevalence of hypertension (HTN) and all-cause cardiovascular disease in athletes has been addressed in the medical literature. Most find that hypertension is the most common chronic cardiovascular disorder in athletes, particularly athletes of more advanced age [3]. Many of these publications focus on hypertension in elite athletes. However, Stiefel et al. recently reported on the increasing incidence of obesity and elevated BP in adolescent student athletes in Mississippi [22•]. Approximately 7700 student athletes 14 to 18 years of age were grouped into three categories: normal weight (BMI ≤85th percentile), overweight (BMI >85th and <95th percentiles), and obese (≥95th percentile). The students were classified as having elevated BP if their BP exceeded the 95th percentile for their age. The overall prevalence of obesity was 23.5 %, and an additional 20.3 % of students were overweight; 21.4 % had an elevated BP at the pre-participation physical examination, a finding consistent with previous studies [23]. Importantly, obese students were 2.40 times more likely to have an elevated BP at the pre-participation physical examination compared to their non-obese counterparts. While these findings may not be generalizable to all populations of adolescent athletes, they highlight the important link between obesity and hypertension and the increasing prevalence of both in the adolescent population in general.

Cardiovascular Disease and HTN in Athletes

Increased body weight and elevated BP may increase the overall risk of cardiovascular disease in ASF players [6•, 24]. In one study comparing 323 ASF athletes with 313 non-football athlete controls, 19.2 % of ASF players were hypertensive compared to only 7.0 % of the non-football controls. The majority of the ASF athletes (69.0 %) in this study were *non-linemen*, which indicates that collegiate football athletes were more likely to have hypertension compared to non-football controls regardless of position or potential body composition [6•]. Another small study compared cardiometabolic risk factors and non-invasive measures of vascular structure between 23 ASF athletes and 19 non-athlete controls. The ASF players had thicker carotid artery intima-media thickness measured by ultrasound, higher 24-h SBP, a higher percent body fat, and lower VO_2 levels on exercise testing compared to the controls. Of note, there was no statistically significant difference in total cholesterol or blood glucose levels between the ASF athletes and the control group. However, the control group did have significantly higher high-density lipoprotein (HDL) and higher low-density lipoprotein (LDL) levels. The authors concluded that ASF players, while largely underreported in the literature, may have a higher cardiovascular risk compared to the general physically active population [25•].

A study by Allen et al. [7] tested whether body size and body composition played an equally important role in the pathogenesis of cardiovascular disease compared to other cardiovascular risk factors, such as hypertension in 504 active professional ASF players. Interior linemen were compared to players in other positions, and both groups were compared to patients enrolled in the Coronary Artery Risk Development in Young Adults (CARDIA) group. All players, regardless of position, had a greater BMI than the general population, and interior linemen had a substantially greater BMI than players in other positions. However, the percent body fat in proportion to BMI was much smaller in both groups of football players compared to the general population, indicating that while these players were all significantly bigger than the general population, they did not necessarily have a significantly increased proportion of adiposity. Consistent with previous studies, the mean BP in both ASF groups was in the pre-hypertensive range and significantly higher in interior linemen compared to players in other positions, while other factors like mean LDL, HDL, total cholesterol, triglycerides, and glucose were similar to those in the CARDIA group. This finding suggests that an increased body habitus may contribute to a higher incidence of hypertension which may be one of the more significant risk factors for cardiovascular disease in ASF players. In addition to increased body habitus, sleep-disordered breathing may be a confounding factor for overall cardiovascular risk in ASF players. However, a small study showed that while sleep-disordered breathing in active National Football League (NFL) players was present to a modest degree, it was generally mild in severity and could not account for increased cardiovascular risk in ASF players [26].

Focusing on elite athletes of disciplines other than ASF, Berge et al. performed an extensive systematic review of the literature published prior to 2014 related to BP and hypertension in athletes [27•]. The review compared the prevalence of hypertension and related left ventricular hypertrophy (LVH) between elite athletes of different disciplines compared to the general population. Results of the review were largely mixed as to the prevalence of hypertension in athletes compared to controls, as some studies demonstrated a higher prevalence of hypertension in elite athletes compared to the general population. However, the true prevalence of hypertension was difficult to ascertain due to non-standardized definitions of hypertension and poor standardization of BP monitoring in the studies cited. The authors did find a higher incidence of hypertension in male athletes compared to female athletes. Additionally, athletes focusing specifically on strength training had a higher prevalence of hypertension compared to primarily endurance-trained athletes.

Berge and colleagues have examined the prevalence of hypertension documented by ABPM and surrogate cardiovascular disease outcomes in elite athletes, specifically focusing on European football players, a sport which, unlike ASF, is predominantly aerobic in nature, and less focused on body size/impact. Initially, an association was found between elevated BP and surrogate cardiovascular disease outcomes, including reduced arterial compliance, increased left ventricular mass, and increased left atrial volume [8•]. Subsequent research found that while office BP readings are often normal in athletes, up to one third of athletes had masked hypertension during the daytime. Masked hypertension was defined as an office BP <140/90 mmHg but an ABP average ≥135/85 mmHg. Additionally, more than half of the athletes had high BP readings at night, which could potentially be attributed to increased sympathetic activity [28]. These findings highlight the importance of utilizing the data obtained at a PPE and the need for a standardized protocol to ensure athletes have appropriate follow-up to assess their BP status and overall cardiovascular risk as the overall risk of disease cannot be dismissed due to the thought that routine physical activity may be cardioprotective.

Pathophysiology of HTN in Athletes

When evaluating elevated BP in athletes, white coat hypertension must be considered because it can be present in up to 42–88 % of athletes at a PPE [9, 27•]. When an elevated BP is detected in an athlete, it is important to obtain a family history focusing on the presence of hypertension, premature cardiovascular disease, and stroke. In addition, there are a number of lifestyle factors that must be addressed if the BP is elevated at the time of the PPE. Table 1 [14, 29–35] lists a number of lifestyle behaviors that can increase SBP and the magnitude of the BP increases that typically occur. While the individual lifestyle factors result in modest elevations in SBP, combinations of factors can lead to SBP increases large enough to move SBP into the hypertensive range. Additionally, many of the medications that are often used in this population (i.e., steroids, oral contraceptives, and stimulants) have been shown

Table 1 Lifestyle effects on systolic blood pressure

Lifestyle	Systolic BP increase (mmHg)
High sodium intake (fast food)	2–14
Recent alcohol consumption	2–4
Energy drinks/caffeine	2–8
Stimulant medications	3–6
Cocaine	~8
Anabolic steroids	~9
Oral contraceptives	8–15
Nonsteroidal anti-inflammatory drugs (NSAIDs)	2–4
Recent tobacco (any form)	10–12

to have dose-dependent pressor effects. Importantly, the BP-elevating effects of these medications are generally readily reversible when the medications are discontinued [30, 32, 33]. Chronic non-steroidal anti-inflammatory drug (NSAID) use, on the other hand, is known to be a risk factor for the development of chronic kidney disease and hypertension. NSAIDs have been reported to be the most commonly used medication among Canadian athletes at both the Atlanta and Sydney Olympic Games [36]. The use of NSAIDs is clearly not limited to elite athletes, as one out of seven high school athletes has reported using NSAIDs daily [37]. Additionally, the pre-participation use of NSAIDs in a recreational sport has been reported to range from 5 to 29 % [37, 38].

Physiologic changes in the cardiovascular system of athletes that contribute to BP elevation have been described. "Athlete's heart" is defined as the hypertrophic cardiomyopathy that results from a persistently elevated SBP due to elevated stroke volume and cardiac output in the setting of low peripheral vascular resistance and heart rate [39, 40]. Additionally, studies have demonstrated that, similar to a positive Osler's maneuver in elderly patients [40], brachial BPs may be elevated compared to true central BPs in athletes due to exaggerated pulse pressure amplification in the arm [41–43].

Regardless of the etiology of the elevated BP in athletes, it is essential that the information from the PPE is followed appropriately to determine the presence or absence of clinical hypertension. If hypertension is diagnosed, adequate treatment is necessary to preserve exercise capacity as well as to prevent long-term cardiovascular complications. Elite male athletes with elevated BP have been shown to have significantly lower maximal oxygen consumption (VO_2max), ventilatory anaerobic threshold (VAT), and heart rate reserve (HRR) [44]. Of particular importance, these reduced performance measures were present in the absence of structural or functional heart damage, giving substantive evidence that elevated BP per se can lead to decreased athletic performance.

Hypertension Treatment

When a diagnosis of hypertension has been appropriately made in an athlete, there are a number of factors to consider outside the standard hypertension treatment guidelines in adults [45•]. First, clinicians must focus on obtaining adequate BP control while producing minimal negative effects on hemodynamic changes related to exercise (i.e., heart rate and VO_2max). Second, particularly for participants in outdoor sports, medications which can affect the heat illness threshold should be avoided. Finally, clinicians must be aware of which antihypertensive medications are banned by the regulatory oversight committees for the sport in which the athlete participates.

For the general population, the Joint National Committee (JNC 8) recommends thiazide-type diuretics, angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs), or calcium channel blockers (CCBs) as first-line antihypertensive medications [45•]. Therefore, we will focus on these four classes of agents and the literature supporting their use. Of note, α-blockers and β-blockers are not considered first-line antihypertensive medications and should particularly be avoided in athletes because of their unfavorable hemodynamic effects on exercise performance [12]. Figure 1 is an algorithm that can help guide the diagnosis and treatment of hypertension in the athletic population.

ACE inhibitors have been shown to have little to no effect on exercise capacity [46, 47] and therefore may be an attractive first-line option for some athletes. However, there has been concern that ACE inhibitors may not be as effective as other classes of antihypertensive agents for controlling BP in the black population. A recent meta-analysis challenged that assessment by demonstrating that renin-angiotensin system (RAS) inhibitors are not inferior to other classes of antihypertensive agents with regard to prevention of all-cause mortality, myocardial infarction, heart failure, or cardiovascular mortality in blacks [48]. RAS inhibitors were not as effective in preventing stroke compared to CCBs in the black population, however. Since an adequate control of hypertension is integral in stroke prevention, RAS inhibitors may not be the best choice for hypertension control in black athletes. Further, ACE inhibitors have serious adverse effects that limit their use in some hypertensive patients. They are absolutely contraindicated in women of childbearing potential and in pregnancy because they are associated with fetal abnormalities. Importantly, many female athletes are of childbearing age. ACE inhibitors are also associated with a comparatively high incidence of angioedema. Of particular concern, the risk of angioedema is up to fivefold higher in blacks [49] and also somewhat increased in Latinos/Latinas compared to whites [50].

ARBs are generally considered a reasonable alternative to ACE inhibitors for the treatment of hypertension because when comparing ACE inhibitors to ARBs, no difference in morbidity or mortality has been noted [51]. However, since ACE inhibitors were developed first and ARBs were not available until the early 1990s, much of the literature supporting RAS inhibition, including much of the sports medicine literature, was centered on ACE inhibitors. Like ACE inhibitors, ARBs do not generally affect exercise capacity [52] and are contraindicated in women of childbearing potential. Unlike ACE inhibitors, ARBs are not likely to cause angioedema. However, if one has developed angioedema with an ACE inhibitor, there is still approximately a 10 % chance of cross-reactivity and resultant angioedema with an ARB [53]. One of the perceived benefits of ARBs compared to ACE inhibitors is the low incidence or absence of the dry cough that is associated with ACE inhibitor use. However, it has been reported that up to 29 % of patients who experience a cough with an ACE inhibitor may have a cough with an ARB [54]. Another caveat of

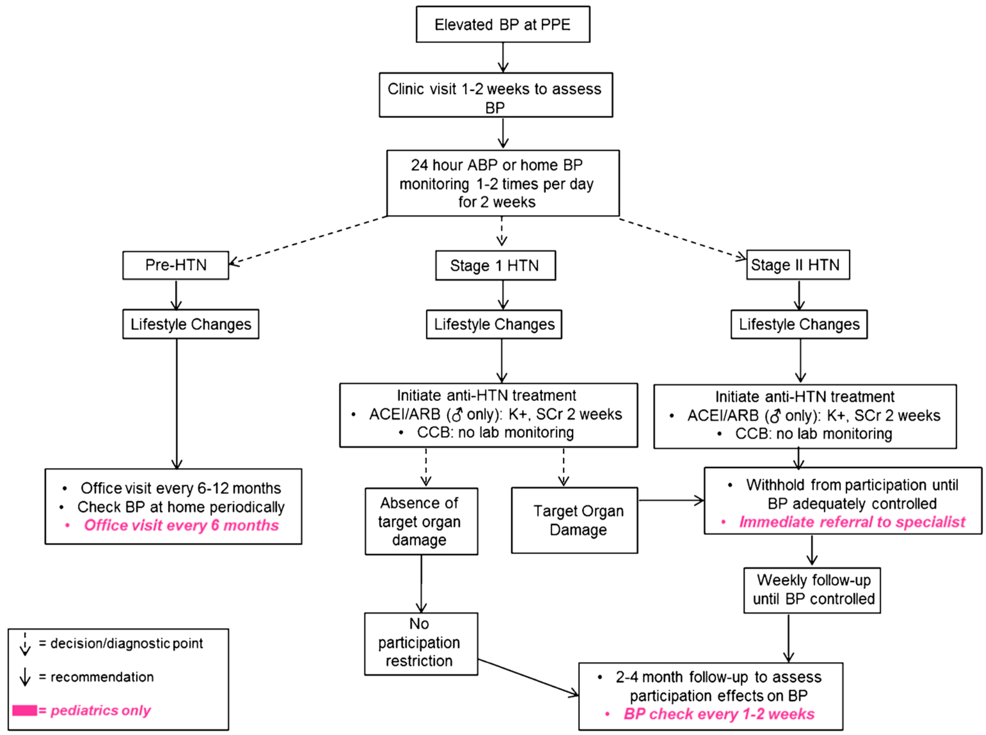

Fig. 1 Adult and pediatric HTN treatment algorithm

RAS inhibitor use is that serum potassium and creatinine levels should be monitored after initiation and dose escalation.

CCBs, particularly dihydropyridine CCBs, are a reasonable first-line option for hypertension control in athletes. CCBs may be especially useful in black athletes [55, 56] because they decrease peripheral vascular resistance, which is a key contributor to the pathogenesis of hypertension in blacks [57]. Like the RAS inhibitors, CCBs have not been shown to significantly affect exercise parameters such as HR and/or VO_2max. However, non-dihydropyridine CCBs like diltiazem [58] and verapamil have negative effects on maximum heart rate, while the dihydropyridine CCBs have a small negative effect on VO_2max [59]. Dihydropyridine CCBs are generally well tolerated, with dose-dependent peripheral edema being the most common adverse effect, occurring in up to 10 % of patients. The greatest increase in incidence of peripheral edema occurs on increasing the dose of amlodipine from 5 to 10 mg daily. It has been suggested that CCBs could increase the risk of developing severe heat-related illness [52]; however, the magnitude of effect and the exact mechanism are not fully understood. Agents that can increase the risk of hypotension, particularly via peripheral vasodilation, have been theorized to increase the severity of heat-related illness by limiting the body's ability to thermoregulate [60]. Despite this potential concern, CCBs remain an important antihypertensive class in athletes as they are generally well tolerated, do not have adverse biochemical/metabolic side effects, and do not require routine laboratory monitoring.

Thiazide-type diuretics are the least desirable class of first-line agents for athletes for a number of reasons. First, diuretics can act as a masking agent for banned substances such as anabolic steroids and are therefore prohibited by most sports oversight committees, including the World Anti-Doping Agency (WADA) [61•]. Additionally, diuretics by virtue of their mechanism of action increase the risk of dehydration and thus have significant potential to decrease the heat illness threshold [52] and may precipitate muscle cramps during and after participation in sport. Because of the aforementioned concerns, diuretics should be avoided as first-line agents in athletes.

Serious consideration should be given to ensure that athletes are not being prescribed substances that are banned by regulating committees governing their particular sport. While there are a number of oversight committees, the WADA [61•] is updated annually and easily understandable. Diuretics are prohibited for all sports due to their potential to mask performance-enhancing substances such as anabolic steroids. β-Blockers, in addition to being no longer considered a first-line therapy for hypertension in either the general population or athletes, are prohibited in a number of sports requiring fine motor movements, including archery, billiards, darts, golf, and shooting. The WADA also prohibits the use of β-blockers in automobile, skiing/snowboarding, and underwater sports. Table 2 summarizes important factors to consider for each of the main classes of antihypertensive medications while treating athletes.

Hypertension and Athletic Participation

Eligibility for adults with a diagnosis of hypertension to participate in sport has been well described previously

Table 2 Practical issues related to antihypertensive medications in athletes

Medication class	Considerations
ACE inhibitors	• Little to no effect on exercise capacity • Minimal effect on heat illness threshold • May not control HTN as well in black athletes • Contraindicated in women of childbearing potential • Relatively high incidence of angioedema (higher in blacks and Latinos/Latinas) • Check SCr and K^+ 1–2 weeks after initiation/dose change
ARBs	• Little to no effect on exercise capacity • Minimal effect on heat illness threshold • May not control HTN as well in black athletes • Contraindicated in women of childbearing potential • Check SCr and K^+ 1–2 weeks after initiation/dose change
β-Blockers	• Poorly tolerated with regard to exercise capacity/adverse effects • Banned by the WADA for sports requiring fine motor movements
DHP-CCBs	• Do not significantly affect HR • Small negative effect on VO_2max • Will decrease heat illness threshold • Particularly useful in black athletes • Dose-dependent edema reported most frequently at 10 mg/day • No routine laboratory monitoring
Diuretics	• Banned by most sports oversight committees, including the WADA • Increase risk of dehydration; decrease heat illness threshold • Precipitate participation and post-participation muscle cramps

SCr serum creatinine, K^+ potassium, *DHP* dihydropyridine, *WADA* World Anti-Doping Agency, *HR* heart rate, VO_2max maximal oxygen capacity

[4] and depends on the level of BP elevation and the presence or absence of target organ damage. Athletes with pre-hypertension are not restricted from participation. Those with stage 1 hypertension (140–159/90–99 mmHg), in the absence of target organ damage, including LVH or established heart disease, have no limitation on participation but should have the BP checked at least every 2 to 4 months to evaluate how participation is affecting BP control. If the athlete has stage 1 hypertension and target organ damage, participation should be suspended until the BP is treated to an appropriate target (<140/90 mmHg). If the athlete has stage 2 hypertension (>160/100 mmHg) [14], he/she should be withheld from participation until the BP is adequately controlled. This is particularly true in sports with both highly static and highly dynamic components, including boxing, canoeing/kayaking, cycling, decathlon, rowing, speed skating, and triathlon [62].

Sports participation guidelines for children with hypertension are similar to those for adults. Children with pre-hypertension are allowed to participate but should continue to have regular BP checks every 6 months. Like adults, children with stage 1 hypertension can still participate in the absence of organ damage, but BP should be checked at 1- to 2-week intervals. If organ damage is present, the athlete should be withheld from sport and referral should be made to a hypertension specialist. Finally, child athletes with stage 2 hypertension should be withheld from sport until the BP is controlled, and should immediately be referred to a hypertension specialist [15].

Conclusion

Cardiovascular disease, and specifically hypertension, continues to be the most significant non-injury-related chronic condition affecting athletes of all ages. While many of the same principles of managing hypertension in the general population can be utilized for treating athletes, there are some important differences in both treatment and follow-up strategies for safely and effectively treating athletes and the active population. Figure 1 can be utilized as a guide for treating an athlete with hypertension from the PPE to follow-up once antihypertensive medications have been prescribed. The ultimate goal is to adequately treat hypertension to minimize long-term cardiovascular complications while having minimal effects on athletic performance. It is essential to be aware of medication options that are banned and be cognizant of monitoring parameters for the medication prescribed.

Compliance with Ethical Standards

Conflict of Interest Drs. Schleich, Smoot, and Ernst declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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