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Posterior circumflex humeral artery pathology and digital ischemia in elite volleyball: Symptoms, risk factors & suggestions for clinical management

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ABSTRACT

Objectives: To assess the association between posterior circumflex humeral artery (PCHA) pathology (PCHAP), symptoms and associated risk factors, in elite volleyball players, and to suggest profiles for clinical management and monitoring.
Design: Cross-sectional study.
Methods: A questionnaire assessed symptoms of digital ischemia (DI) in the dominant hand and risk factors among 278 elite indoor and beach volleyball players of whom 6.1% (17/278) was diagnosed with PCHAP using ultrasound. Odds Ratios (OR) including 95% confidence intervals (95%CI) were calculated using binary logistic regression.
Results: All 278 players completed the questionnaire. Three participants with PCHAP were symptomatic (18%). Ninety-three of 96 symptomatic participants had no PCHAP (OR = 0.39; 95% CI 0.13–1.13). Total years playing volleyball (OR 1.14; 95% CI 1.03–1.25) and age (OR 1.17; 95% CI 1.00–1.29) were dose-response related risk factors: a volleyball career of ≥17 years and age of ≥27 years were associated with a 9-fold and 14-fold increased risk of PCHAP, respectively.
Conclusions: The volleyball career duration and age are dose-response related risk factors for PCHAP among elite indoor and beach volleyball players. DI symptoms are prevalent in a minority of athletes with PCHAP (3/17; 18%). To enable worldwide standardized care for these athletes at risk, four profiles for clinical management and monitoring have been suggested based on questionnaire and ultrasound outcomes.

1. Introduction

Elite overhead athletes are at risk of ischemic digits and vascular overuse injuries in the dominant shoulder due to repetitive abduction and external rotation of the arm.[1] Aneurysmal degeneration, thrombosis and distal occlusion of the proximal posterior circumflex humeral artery (PCHA) is a rare sport-related vascular overuse injury mostly found among elite volleyball players and elite baseball pitchers.[2] Thrombosis might lead to distal embolization to the circulation of the forearm, hand, and digits in the ipsilateral limb during the spiking or serving motion in volleyball, when the humeral head acts to compress the aneurysmal PCHA and the intraluminal thrombus like a tube of toothpaste, causing retrograde embolism into the nearby axillary artery.[3] In 1993, Reekers et al. was the first to describe a traumatic aneurysm of the PCHA in a volleyball player, suggesting a causal relationship.[4] Almost twenty-five years later, a dozen case reports have been published worldwide on volleyball players with this injury. Knowledge about this sports-related overuse injury needs to be extended on an international scale considering the potential amputation of a finger as the devastating end result in a population of young, healthy and fit elite volleyball players. A recently published study revealed a 6.1% prevalence of PCHA pathology (PCHAP) in 278 elite volleyball players, ranging from dilatation to aneurysms and occlusion.[5] However, the prevalence of related thromboembolic complications is still unknown.

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Eighty-nine percent of volleyball players with angiographically confirmed digital ischemia (DI) caused by emboli due to pathological changes of the PCHA in the ipsilateral shoulder reported cold and discolored digits.[2] Among surveyed elite indoor and beach volleyball players, these symptoms were present in respectively 31% and 38%, with the duration of the volleyball career, the intensity of performing strength-increasing weight training, and female sex identified as associated risk factors.[2,6,7] These data, although self-reported and cross-sectionally collected, are indicative of underlying PCHAP. Since these volleyball players are considered potentially at risk for developing critical DI, further analysis of the association between PCHAP, self-reported symptoms and associated risk factors is warranted for prevention. Ultimately, establishing profiles of individual athletes based on the results could stimulate worldwide standardized clinical management and monitoring.

For this purpose, the Shoulder PCHA pathology and digital Ischemia in Known Elite volleyball players (SPIKE) study was conducted. The aim of this study was: (1) to determine the association between self-reported symptoms of DI and PCHAP in the dominant shoulder among elite volleyball players; and (2) to assess personal- and sports-related risk factors, including a dose-response relationship, in order to describe profiles of individual athletes and to formulate suggestions for clinical management and monitoring.

2. Methods

A cross-sectional questionnaire (Q) survey study was performed among elite male and female indoor and beach volleyball players active at national and international top level from January through July 2014. Official approval was granted by the Institutional Review Board at our academic hospital and permission was obtained from the Fédération Internationale de Volleyball (FIVB).

Volleyball players were recruited in cooperation with the FIVB and the Dutch Volleyball Association (Nevobo). Those eligible for inclusion were (1) all elite male indoor volleyball players active in the Dutch national top league, second league or Dutch national volleyball team in the 2013–2014 season, and all 112 elite male and female beach volleyball players active at the 2014 The Hague Beach Volleyball Grand Slam Tournament. Exclusion criteria included a positive history for vascular surgery of the dominant shoulder, confirmed Raynaud's phenomenon, use of cardiovascular medication, age below 16 years, and lack of written informed consent.

All volleyball players, coaches, and medical staff were informed about the study via email and via a website (www.spikestudy.com). Indoor volleyball players' teams were visited on-site during a practice session, and beach volleyball players were visited on-site during the main tournament. All participants gave written informed consent and completed the Q survey. Afterwards ultrasound (US) examination of the PCHA in the dominant shoulder was performed. The result of the US examination have been reported in a previous study.[5]

The SPI-Q (Shoulder PCHA pathology and digital Ischemia-Questionnaire) was used; a reliable standardized questionnaire that can be used for detecting elite volleyball players with symptoms of DI, and for grading the severity of these symptoms.[8] The SPI-Q questionnaire was developed using reports of volleyball players with confirmed DI, based on evidence from the medical literature,[2] and comprises three general domains: (A) those regarding specific symptoms of DI, such as cold, blue or pale digits during practice or competition (answer categories: 'never', 'sometimes', 'often', 'always'); (B) those regarding demographics and personal risk factors, such as age and cardiovascular disease in first-degree family members; and (C) those regarding sports-related risk factors, such as the total duration of the volleyball career, and position on the court.

The prevalence of PCHAP, as reported in van de Pol et al.,[5] was assessed by experienced registered vascular technologists using the standardized SPI-US protocol which enabled precise sonographer-independent PCHA and Deep Brachial Artery (DBA) diameter measurements.[9,10] US images of all pathological and doubtful cases were reviewed, discussed and definitively classified as normal or pathological during consensus meetings in which both RVTs and a vascular radiologist participated. PCHAP was detected in 17 of 278 volleyball players (6.1%): three dilatations (1.1%), 13 aneurysms (4.7%), of which three contained intravascular thrombus, and one occlusion (0.4%).[5]

Data were entered in SPSS (version 21.0, 2012, SPSS Inc.) and checked by a second researcher. A p-value ≤ 0.05 was considered statistically significant in all tests. For discrete variables, the mean, standard deviation, minimum, and maximum were reported. Percentages were reported for categorical variables. The prevalence of symptoms was calculated in the following manner: the percentage of all volleyball players who sometimes or more often reported having cold or blue or pale digits in the dominant hand during or directly after practice or competition.

Based on the results of van de Pol et al.,[5] two groups were formed:

1) Volleyball players who showed PCHAP on US examination (US+ group).
2) Volleyball players who did not show PCHAP on US examination (US− group).

The association between detected PCHAP and reported symptoms and risk factors was expressed as an odds ratio (OR) including 95% confidence intervals (95% CI) using a univariate binary logistic regression. This was done for the following: (A) symptoms of DI; (B) personal risk factors; and (C) sports-related risk factors.

Subsequently, the collinearity between the univariate variables with a p-value ≤ 0.05 was calculated. Next, for all non-collinear variables with a p-value <0.05, an OR including 95% CI was calculated using a multivariate binary logistic regression analysis. In addition, to assess a potential dose-response relationship between PCHAP and symptoms and risk factors with a p-value <0.10, three groups of almost equal size were formed, and the association was expressed as an OR including 95% CI, using a univariate binary logistic regression analysis. Finally, four profiles of individual athletes were formed based on the combination of the presence of PCHAP (yes or no) and symptoms of DI (yes or no).

3. Results

From January 2014 through July 2014, a total of 281 elite volleyball players were assessed. Three players were excluded from the study: two due to clinically confirmed Raynaud's phenomenon and one due to a history of PCHA surgery in the dominant shoulder. As a result, 278 elite volleyball players were included: 243 men and 35 women. This group consisted of 217 male elite indoor volleyball players from two countries (78%), and 61 elite beach volleyball players from 19 countries (22%): 35 women (57%) and 26 men (43%). On average (±SD), volleyball players were 25 ± 5 years old (range: 17–41 years), had a body height of 193 ± 8 centimeters (cm) (range: 169–212 cm), and had been playing volleyball for 15 ± 5 years (range 4–31 years) and 12 ± 6 h a week (range 3–30 h). On average, volleyball players in the US+ group were 29 ± 4 years old, and played volleyball for 18 ± 4 years, while volleyball players in the US− group were on average 25 ± 5 years old, and played volleyball for 14 ± 5 years. In the US+ group, 12% (n = 2) reported the

Table 1
Univariate binary logistic regression outcomes (odds ratio and 95% confidence interval) of symptoms of digital ischemia and risk factors for PCHA pathology in elite male and female beach and indoor volleyball players.

	US+ versus US− group
Domain A: symptoms of digital ischemia	
Cold digits during volleyball (sometimes/often/always)	OR 0.55 (95% CI 0.15–1.98)
Cold digits after volleyball (sometimes/often/always)	OR 0.95 (95% CI 0.21–4.37)
Blue digits during volleyball (sometimes/often/always)	OR 1.45 (95% CI 0.31–6.75)
Blue digits after volleyball (sometimes/often/always)	OR 1.19 (95% CI 0.15–9.70)
Pale digits during volleyball (sometimes/often/always)	OR 1.03 (95% CI 0.27–8.26)
Pale digits after volleyball (sometimes/often/always)	OR 0.39 (95% CI 0.05–3.04)
Symptomatic (one of the symptoms cold or blue or pale during or after volleyball)	OR 0.39 (95% CI 0.11–1.38)
Domain B: personal risk factors	
Age	OR 1.17 (95% CI 1.06–1.29)
Height	OR 0.96 (95% CI 0.91–1.02)
Weight	OR 0.98 (95% CI 0.93–1.02)
Sex (male)	OR 1.09 (95% CI 0.24–4.96)
Raynaud's Phenomenon in first-degree family (yes)	OR 0.00 (95% CI 0.00–)[a]
Cardiovascular disease in first-degree family (yes)	OR 1.00 (95% CI 0.22–4.59)
Smoking (yes)	OR 1.37 (95% CI 0.46–4.04)
Domain C: sports-related risk factors	
Type of volleyball (beach volleyball)	OR 1.10 (95% CI 0.35–3.51)
Total years playing volleyball	OR 1.14 (95% CI 1.03–1.25)
Total years playing professional volleyball	OR 1.03 (95% CI 0.91–1.17)
Total practice and competition hours in a week	OR 0.95 (95% CI 0.86–1.05)
Position in the field (indoor attacker i.e. opposites & outside hitters)	OR 0.98 (95% CI 0.32–3.03)
Position in the field (indoor blocker i.e. middle blockers)	OR 1.74 (95% CI 0.54–5.54)
Smashing/spiking frequency (regularly/often)	OR 2.01 (95% CI 0.45–9.04)
Smashing/spiking 'away from the shoulder' (often/always)	OR 1.94 (95% CI 0.70–5.40)
Performing dominant limb weight training in general (yes)	OR 0.57 (95% CI 0.19–1.69)
Frequency of performing weight training to increase dominant limb strength (often/always)	OR 0.69 (95% CI 0.25–1.92)
Number of hours per week performing weight training to increase dominant limb strength	OR 0.76 (95% CI 0.35–1.67)
Frequency of performing weight training to maintain dominant limb strength (often/always)	OR 1.48 (95% CI 0.53–4.13)
Number of hours per week performing weight training to maintain dominant limb strength	OR 1.11 (95% CI 0.59–2.09)

Key: US+, volleyball players with PCHA pathology on ultrasound examination; US−, volleyball players without PCHA pathology on ultrasound examination.
[a] No odds ratio (OR) could be calculated as none of the US+ group reported being exposed to this risk factor.

presence of cardiovascular disease in first-degree family and 30% (n = 5) reported that they smoked or had smoked in the past, while in the US− group these numbers were respectively 12% (n = 30) and 23% (n = 60). For a complete overview of the characteristics of the participants we refer to Appendix A.

In total, 96 volleyball players (35%) reported symptoms of cold or blue or pale digits in the dominant hand during or directly after practice or competition sometimes or more often in the questionnaire (Q+ group), whereas 182 volleyball players did not (Q− group) (65%). Three of 17 US+ volleyball players (two aneurysms and one occlusion) reported symptoms of DI, a prevalence of 18% in the US+ group (3/17), and a prevalence of 2% in the Q+ group (3/96).

No significant association between PCHAP and symptoms of DI between the two groups was revealed (OR = 0.39; 95% CI 0.11–1.38) (Table 1).

The univariate binary logistic regression revealed a significant association for the personal risk factor age (OR = 1.17; 95% CI 1.06–1.29) and for the sports-related risk factor total years playing volleyball (OR = 1.14; 95% CI 1.03–1.25). The univariate binary logistic regression revealed no other significant associations with PCHAP (Table 1).

Although no collinearity between age and total years playing volleyball was found (VIF = 2.396, tolerance = 0.417), no multivariate regression analysis was performed due to a strong correlation between both (0.74). For both risk factors, a dose-response relationship was present. For age, the OR increased by 3.07 (23–26 years) to 13.61 (27–41 years) compared with the reference group of 17–22 years. For total years volleyball, the OR increased from 5.65 (12–16 years) to 9.21 (17–31 years) compared with the reference group of 4–11 years (Table 2).

Volleyball players were categorized into four suggested profiles for clinical management and monitoring based on the combination of the presence or abscence of PCHAP (US+ or US−) and symptoms of DI (Q+ or Q−). The distribution across the four profiles was: (I) 1.1% US+Q+ (n = 3); (II) 5.0% US+Q− (n = 14); (III) 33.5% US−Q+ (n = 93); and (IV) 60.4% US−Q− (n = 168).

Table 2
Categorical univariate binary logistic regression outcomes (odds ratio and 95% confidence interval) of age and total years playing volleyball.

	US+ versus US− group
Age	OR 1.17 (95% CI 1.06–1.29)
- 17–22 years (n = 90)	Reference
- 23–26 years (n = 90)	OR 3.07 (95% CI 0.31–30.08)
- 27–41 years (n = 98)	OR 13.61 (95% CI 1.74–106.32)
Total years playing volleyball	OR 1.14 (95% CI 1.03–1.25)
- 4–11 years (n = 82)	Reference
- 12–16 years (n = 92)	OR 5.65 (95% CI 0.67–47.97)
- 17–31 years (n = 98)	OR 9.21 (95% CI 1.15–73.51)

Key: US+, volleyball players with PCHA pathology on ultrasound examination; US−, volleyball players without PCHA pathology on ultrasound examination.

4. Discussion

Among 278 elite indoor and beach volleyball players, PCHAP was detected in a minority of athletes with symptoms of DI (3/96; 2%) and symptoms of DI were reported by a minority of athletes with PCHAP (3/17; 18%). A total volleyball career duration of 17 years or more and an age of 27 years or more were associated with a 9-fold and a 14-fold increased risk of PCHAP, respectively.

Unilateral ischemia-related symptoms in elite volleyball players might be caused by repeated microtrauma of the hand by vigorous ball contact, as occurs during volleyball, or a wide variety of vascular pathologies including arterial thoracic outlet syndrome, aneurysms of the axillary, forearm or palmar arteries, such as

Table 3
Suggestions for clinical management and monitoring of elite volleyball players based on the combination of the presence of US-detected PCHAP (US+ or US−) and reporting of symptoms of DI (Q+ or Q−).

	Prevalence	Suggestions for clinical management and monitoring
US+Q+	1% (3/278)	* At risk for irreversible tissue damage from prolonged DI. →Consider a referral to vascular surgeon for additional imaging and therapy.
US+Q−	5% (14/278)	* At risk for aneurysm expansion, thrombosis and distal embolization from the aneurysmal PCHA. →SPI-US monitoring at regular intervals (e.g. annually) to identify progress of PCHAP. Consider consulting a vascular surgeon in case of thrombus formation. →SPI-Q monitoring at regular intervals (e.g. twice a year) to detect onset of DI and to increase awareness. Consider consulting a vascular surgeon when symptoms arise acutely or are associated with pulse deficits, pallor or differences in temperature between digits in the spiking hand.[22]
US−Q+	34% (93/278)	* Consider other causes of DI such as arterial thoracic outlet syndrome, axillary artery aneurysm, quadrilateral space syndrome, forearm vessel aneurysms, Raynaud's phenomenon, and hand vessel aneurysms or traumatic vasospasm.[7] ** Remain vigilant for PCHAP given the increased risk as the career progresses. →SPI-Q monitoring at regular intervals to grade severity of DI and to increase awareness (e.g. every four and two years for a career duration of 0-12 and ≥17 years, respectively). Consider consulting a vascular surgeon when symptoms aggravate acutely or are associated with pulse deficits, pallor or differences in temperature between digits in the spiking hand.[22]
US−Q−	60% (168/278)	* At risk for PCHAP when symptoms of DI arise and as the career progresses. →SPI-Q monitoring at regular intervals to detect the onset of DI and to increase awareness. (e.g. every four and two years for a career duration of 0-12 and ≥17 years, respectively). Consider consulting a vascular surgeon when symptoms arise acutely or are associated with pulse deficits, pallor or differences in temperature between digits in the spiking hand.[22]

hypothenar hammer syndrome, and vasomotor disorders such as Raynaud's phenomenon (Table 3). This might explain why PCHAP was detected in a minority of athletes with symptoms of DI. Additionally, in an early stage of disease a PCHA aneurysm stays occult as long as the player is free of symptoms. The aneurysm is prone to expansion and thrombosis, especially when traumatic PCHA compression and stretching continues. Eventually, intravascular thrombus is formed which leads to distal embolization and transient symptoms of DI. This might explain why symptoms of DI were reported by a minority of athletes with PCHAP.

The 6,1% rate[5] of this sports-related vascular overuse injury among healthy elite athletes in the prime of their career is alarming since it implies that worldwide one in every 16 elite volleyball players has PCHAP in the dominant shoulder, a known source of digital embolization, which is equivalent to two players in every three indoor volleyball teams. In contrast, several studies in the past detected no PCHAP in some 350 examined PCHAs of healthy subjects.[11–13] Volleyball players with confirmed DI caused by emboli due to pathological changes of PCHA in the ipsilateral shoulder are known to present themselves at a later stage of the condition.[10] Therefore, active surveillance to detect and monitor PCHAP at an early stage seems warranted as this might prevent thromboembolic complications, irreversible tissue damage, and surgical ligation of the PCHA.[2]

The current study is the first to identify dose-response related risk factors in the population at risk: a large cohort of 278 elite indoor and beach volleyball players active at national and international top level. In 1993, Reekers et al. was the first to report three cases of elite volleyball players with ischemic digits due to arterial emboli originating from a thrombosed aneurysm in the PCHA in the dominant shoulder, suggesting a causal relationship.[4] Since then, the majority of cases of PCHAP with distal emboli have been reported in elite volleyball players.[2] Also, multiple cases have been reported in elite baseball pitchers,[2] tennis players,[14–16] swimmers,[17] kayakers,[18] yoga practitioners,[19] trapeze flying artists,[20] and American football players.[16] The assumption is that the common denominator in these sports – repetitive vigorous overhead movements such as spiking and serving in volleyball – causes chronic vessel wall injury as a result of positional traction and compression of the proximal PCHA.[3,4,21] This cumulative trauma can lead to a continuum of PCHAP ranging from intimal lesions to vessel dilatation of <150% (found in three cases), aneurysmal degeneration with vessel dilatation >150% (found in 13 cases), intra-aneurysmal thrombus formation (found in three cases), and occlusion (found in one case).[4,22,23]

Cumulative PCHA trauma is illustrated by the two identified dose-response related risk factors from this study; age and total volleyball career duration. Age is known to be a risk factor for overuse injuries of the shoulder in male and female volleyball players.[24] Interestingly, total volleyball career duration was also associated with self-reported symptoms of DI in the dominant hand in two separate studies among elite indoor and beach volleyball players.[6,7] The fact that this risk factor is a common denominator in these two studies and the current study indicates a causal relation between DI and PCHA aneurysms, although the current study results do not support this.

Based on the combination of the presence of US-detected PCHAP (US+ or US−) and reporting of symptoms of DI (Q+ or Q−), four profiles of individual athletes can be described: (I) symptomatic PCHAP (US+Q+); (II) asymptomatic PCHAP (US+Q−); (III) symptomatic without PCHAP (US−Q+); and (IV) asymptomatic without PCHAP (US−Q−). This continuum of profiles likely progresses from IV, through III or II, to I, with the total duration of the volleyball career as the main sports-related risk factor. To stimulate worldwide standardized care for these athletes at risk for potentially limb-threatening pathology, suggestions for clinical management and monitoring have been formulated for each profile (Table 3). Future research should assess its efficacy and feasibility in practice.

A strength of the current study is that the association between symptoms, risk factors and PCHAP was determined in a large group of elite volleyball players, the population at risk, with the use of reliable and standardized diagnostic modalities. A possible weakness of the current study is that only the PCHA in the dominant shoulder has been assessed for pathology, while unilateral ischemia-related symptoms in the upper extremity can be explained by a wide variety of vascular pathologies, which was not assessed for.

Although symptoms do not seem to be related to PCHAP in this cross-sectional study, future studies should prospectively assess the reporting of symptoms of DI at regular intervals[25] to reveal a possible association with PCHAP. Moreover, since no cause was found for the ischemia-related symptoms in the majority of volleyball players in this study, future studies should assess other possible (vascular) pathologies, as well as elaborate on clinical management.

5. Conclusion

In conclusion, a volleyball career of ≥17 years and age of ≥27 years are dose-response related risk factors with a 9-fold and 14-fold increased risk for PCHAP, respectively. Symptoms of DI are prevalent in a minority of athletes with PCHAP (3/17; 18%). To enable worldwide standardized care for these athletes at risk for potentially limb-threatening pathology, four profiles of individual athletes have been described based on the combination of the presence of US-detected PCHA pathology and reporting of symptoms of DI, and for each profile suggestions for clinical management and monitoring (4P4M) have been formulated. Future research should assess its efficacy and feasibility in practice.

Practical implications

- Athletes at risk for PCHAP do not have a corresponding increased risk of self-reported symptoms of DI assessed using the SPI-Q questionnaire.
- A volleyball career of >17 years is a dose-response related risk factor with a 9-fold increased risk of PCHA pathology.
- An age of >27 years is a dose-response related risk factor with a 14-fold increased risk of PCHA pathology.
- Symptoms of digital ischemia are prevalent in a minority of athletes with PCHA pathology (3/17; 18%).
- To stimulate worldwide standardized care for these athletes at risk for potentially limb-threatening pathology, four profiles of individual athletes have been described based on the combination of the presence of US-detected PCHA pathology and reporting of symptoms of DI.
- For each profile suggestions for clinical management and monitoring (4P4M) have been formulated.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jsams.2018.03.010.

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