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Risk factors associated with self-reported symptoms of digital ischemia in elite male volleyball players in the Netherlands

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One in every four elite male volleyball players in the Netherlands reported blue or pale digits in the dominant hand. Little is known about risk factors. To assess whether personal-, sports-, and work-related risk factors are associated with these symptoms in these volleyball players, a survey was performed among elite male volleyball players in the Dutch national top league and in the Dutch beach volleyball team. The questionnaire assessed the presence of symptoms and risk factors. Binary logistic regression was performed to calculate odds ratios (ORs). A total of 99 of the 107 athletes participated – a response rate of 93%. Two sports-related risk factors were associated with symptoms of blue or pale digits: 18–30 years playing volleyball [OR = 6.70; 95% confidence interval (CI) 1.12–29.54] and often/always performing weight training to increase dominant limb strength (OR = 2.70; 95% CI 1.05–6.92). No significant other sports-, personal-, or work-related risk factors were found. Playing volleyball for more than 17 years and often/always performing weight training to increase dominant limb strength were independently associated with an increased risk on ischemia-related complaints of the dominant hand in elite male volleyball players.

Symptoms of cold, blue, and pale digits in the dominant hand during or immediately after practice or competition are associated with digital ischemia. A striking percentage of 31% of elite male volleyball players with a mean age of 24 years reported at least one of these symptoms in the dominant hand (van de Pol et al., 2012). This high prevalence of potential vascular pathology, detected using a literature-based questionnaire, has led to some concerned publicity in the international media (Grens, 2012). High rates of complaints, strongly related to digital ischemia, are not expected in these young, healthy elite athletes.

The presence of unilateral ischemia-related symptoms in the *upper extremity* in elite male volleyball players can be explained by a wide variety of vascular pathologies, including arterial thoracic outlet syndrome (Reeser, 2007), aneurysms of the axillary artery or its branches (Jackson, 2003; Atema et al., 2012; van de Pol et al., 2012), quadrilateral space syndrome (Reeser, 2007), forearm vessel aneurysms like the antebrachial–palmar hammer syndrome (Kostianen & Orava, 1983), hypothenar hammer syndrome (Massada et al., 2011), digital arterial pathology (Buckhout & Warner, 1980; Ho et al., 1981; Sugawara et al., 1986; Itoh et al., 1987), and vasomotor disorders such as Raynaud's phenomenon (Block & Sequeira, 2001; Wigley, 2002) and Raynaud-like vasospasm of the digital arteries (McCarthy et al., 1989).

Given the high prevalence raising the suspicion of digital ischemia in these elite male volleyball players, risk factors should be identified as a first step in prevention. Potential risk factors include both personal-, sports-, and work-related risk factors. No epidemiological studies on this subject have been found in the medical literature.

Therefore, the aim of the present study was to assess which risk factors are associated with self-reported symptoms of digital ischemia among elite male volleyball players in the Dutch national top league and in the Dutch beach volleyball team.

Methods

Study design

A cross-sectional questionnaire survey was performed among elite volleyball players in the Dutch national top league and the Dutch beach volleyball team to assess risk factors associated with self-reported symptoms of digital ischemia. The results of the prevalence of self-reported symptoms of digital ischemia in elite male volleyball players in the Netherlands have previously been reported (van de Pol et al., 2012).

The Medical Ethics Review Committee of our academic hospital has informed us that the Medical Research Involving Human

Subjects Act did not apply to this questionnaire survey and that no official approval of this study was required.

Participants

In cooperation with the Dutch Volleyball Association, all team managers of the Dutch national top league teams and the Dutch beach volleyball team were invited to participate in the study. After permission had been granted by the coaches, a researcher (D. v. d. P.) visited the team, explained the aim of the study and the pathology that they were potentially at risk of, and requested that the questionnaire be filled in immediately after a practice session during the competitive season. Participation was voluntary and anonymous. Questionnaires and return envelopes were left behind to be picked up and completed by players absent at the time of the visit. This survey was administered once during the 2010–2011 season. After 1 and 3 weeks, respectively, a polite reminder was sent by e-mail, requesting that the questionnaire be returned within 1 month of the initial group session.

Questionnaire content

A literature-based questionnaire was developed to detect ischemic symptoms using reports of volleyball players with confirmed digital ischemia (van de Pol et al., 2012). In this study, symptoms of cold, blue, and pale digits in the dominant hand during or immediately after practice or competition were considered to be associated with digital ischemia based on the following arguments (van de Pol et al., 2012):

1. These symptoms were the only symptoms that were reported as present, in at least 50% of the medical files of volleyball players with confirmed digital ischemia at our hospital.
2. Pain was excluded because it is hard to distinguish between ischemic pain and pain resulting from trauma.
3. Jackson (2003) stated that the signs of ischemia that typically distinguish arterial injury from musculo-skeletal injury are those of changes in temperature and color.

In the questionnaire survey, additional questions were formulated to detect and assess potential risk factors possibly associated with digital ischemia. The questionnaire comprised four general domains: those regarding demographics, like age; those regarding personal risk factors, like smoking; those regarding sports-related risk factors, like years spent playing volleyball; and those regarding work-related risk factors, like working with vibrating tools (Appendix).

Data analyses

Data from the returned questionnaires were entered in the Statistical Package for the Social Sciences (version 16.0, 2007, SPSS Inc, Chicago, Illinois, USA). The questionnaires were randomly checked for correct data entry by a second researcher (P. P. F. M. K.).

Participants

Two groups were formed, with one group consisting of volleyball players with symptoms of blue or pale digits in the dominant hand during or immediately after practice or competition, and the other group consisting of players without these symptoms. Additionally, volleyball players who reported only cold digits in the dominant hand during or immediately after competition without reporting blue or pale digits ($n = 5$) were excluded from the analysis because this symptom was considered less specific for digital ischemia.

Mean, standard deviation, minimum and maximum of age, body height, body weight, and number of working hours per week were reported for both groups. Also, the percentage of volleyball players who reported shoulder injury history, the use of medicine, and paid or unpaid work were reported for both groups.

Risk factors

First, to assess differences between the symptomatic and asymptomatic group, personal-, sports-, and work-related risk factors were tested using an independent *t*-test or a chi-square test. Where a frequency in a cell of the 2×2 table was smaller than 5, a Fisher's exact test was used instead of a chi-square test to calculate the *P*-value. In all tests, a *P*-value ≤ 0.10 was considered significant given the relatively small group size and to overcome missing potential clinically relevant differences.

Next, the odds ratio (OR) and 95% confidence interval (95% CI) were calculated for all personal-, sports-, and work-related risk factors using a univariate binary logistic regression. The personal-, sports-, and work-related risk factors are listed in the Appendix. Finally, for the risk factors with a *P*-value ≤ 0.10, an OR and 95% CI were calculated using a multivariate binary logistic regression.

Results

Ten of the 11 included volleyball teams participated in our study. Ninety-nine of the 107 included volleyball players completed and returned the questionnaire – a response rate of 93%.

Participants

Two groups were formed based on the case definition:

1. Players who reported "blue or pale digits in the dominant hand during or directly after practice or competition sometimes or more often" ($n = 26$; symptomatic group).
2. Players who did *not* report "cold or blue or pale digits in the dominant hand during or directly after practice or competition sometimes or more often" ($n = 68$; reference group).

Volleyball players in the symptomatic group were on average 25 years old and in the reference group 24 years old, weighed 86.0 and 87.4 kg, and had a body height of 196.8 and 196.0 cm, respectively (Table 1). The participants in both groups did not differ significantly (Table 1).

Risk factors

Personal-related risk factors

The chi-square test revealed no significant differences between both groups for personal risk factors like smoking and family on cardiovascular disease (Appendix). An overview of all personal risk factors is shown in the Appendix. Also, no significant associations were found in the results of the univariate binary *logistic regression analyses* (Table 2).

Table 1. Characteristics of the participants

	Symptomatic group ($n = 26$)	Reference group ($n = 68$)	Significance
Age (years)	Mean: 25.0 SD: 5.3 Range: 16–38	Mean: 24.0 SD: 4.3 Range: 18–36	$t = 0.98$ $P = 0.33$
Body height (centimeters)	Mean: 196.8 SD: 6.6 Range: 185–210	Mean: 196.0 SD: 7.6 Range: 168–211	$t = 0.49$ $P = 0.62$
Body weight (kilograms)	Mean: 86.0 SD: 7.1 Range: 70–101	Mean: 87.4 SD: 7.4 Range: 70–110	$t = -0.85$ $P = 0.40$
Shoulder injury history (yes: +, no: –)	+: 13/26 (50%) –: 13/26 (50%)	+: 23/67 (34%) –: 44/67 (66%)	$\chi^2 = 1.94$ $P = 0.16$
Use of medicine (yes: +, no: –)	+: 2/26 (8%) –: 24/26 (92%)	+: 1/67 (2%) –: 66/67 (98%)	$\chi^2 = 2.31$ $P = 0.19$
Paid or unpaid work (yes: +, no: –)	+: 14/26 (54%) –: 12/26 (46%)	+: 36/68 (53%) –: 32/68 (47%)	$\chi^2 = 0.01$ $P = 0.94$
Number of working hours per week (hours)	Mean: 15.3 SD: 18.3 Range: 0–50	Mean: 12.0 SD: 15.5 Range: 0–50	$t = 0.88$ $P = 0.38$

SD, standard deviation.

Table 2. Univariate binary logistic regression outcomes (odds ratio and 95% CI) of potential risk factors associated with self-reported symptoms of digital ischemia in elite male volleyball players

	Symptomatic group vs reference group
Personal-related risk factors	
Smoking (yes)	OR 1.53 (95% CI 0.43–4.41)
Use of alcohol (yes)	OR 0.36 (95% CI 0.07–1.91)
Family history on cardiovascular disease (yes)	OR 2.26 (95% CI 0.82–6.24)
Sports-related risk factors	
Total years playing volleyball	OR 1.01 (95% CI 0.99–1.18)*
Years playing professional volleyball	OR 1.03 (95% CI 0.93–1.14)
Total practice and competition hours in a week	OR 1.00 (95% CI 0.92–1.07)
Position in the field (attacker)	OR 0.67 (95% CI 0.21–2.17)
Smashing “away from the shoulder” (often/always)	OR 2.05 (95% CI 0.82–5.15)
Type of service (jump service)	OR 1.03 (95% CI 0.38–2.78)
Performing dominant limb weight training in general (yes)	OR 2.42 (95% CI 0.28–21.13)
Frequency of performing dominant limb weight training during warm-up before practice (often/always)	OR 0.84 (95% CI 0.27–2.61)
Number of minutes per week performing dominant limb weight training during warm-up before practice	OR 1.00 (95% CI 0.99–1.02)
Frequency of performing dominant limb weight training during warm-up before competition (often/always)	OR 0.63 (95% CI 0.12–3.16)
Number of minutes per week performing dominant limb weight training during warm-up before competition	OR 1.00 (95% CI 0.95–1.06)
Frequency of performing weight training to increase dominant limb strength (often/always)	OR 2.70 (95% CI 1.05–6.92)*
Number of hours per week performing weight training to increase dominant limb strength	OR 1.53 (95% CI 0.84–2.79)
Frequency of performing weight training to maintain dominant limb strength (often/always)	OR 1.45 (95% CI 0.58–3.62)
Number of hours per week performing weight training to maintain dominant limb strength	OR 1.75 (95% CI 0.73–4.22)
Work-related risk factors	
Perceived heaviness of work (scale 0–10)	OR 0.89 (95% CI 0.65–1.20)
Working with vibrating tools more than 1 h/day (often/always)	OR 0.00 (95% CI 0.00– . . ..)†
Working in a cold environment more than 1 h/day (often/always)	OR 0.00 (95% CI 0.00– . . ..)†
Performing repetitive work with the arms more than two times per minute (often/always)	OR 0.76 (95% CI 0.19–3.00)
Working above shoulder height more than 1 h/day (often/always)	OR 0.00 (95% CI 0.00– . . ..)†
Performing work with tools heavier than 1 kg (often/always)	OR 1.81 (95% CI 0.28–11.48)
Performing work with a computer or mouse more than 4 h/day (often/always)	OR 0.90 (95% CI 0.31–2.61)
Lifting over 15 kg/day (often/always)	OR 2.09 (95% CI 0.43–10.04)
Performing powerful work with the hands (like screwing or kneading) more than 1 h/day (often/always)	OR 0.90 (95% CI 0.09–9.11)

*Significant ($P \leq 0.10$).

†No odds ratio (OR) could be calculated because no volleyball players reported being exposed to this risk factor.

CI, confidence interval.

Sports-related risk factors

On average, volleyball players in the symptomatic group had played volleyball for 16 years and in the reference group for 13 years. This difference was significant ($t = 1.85$, $P = 0.07$). A significant difference was also found for the frequency of performing weight training to increase dominant limb strength (65% vs 41%; $\chi^2 = 4.42$, $P = 0.04$; Appendix). For the other sports-related risk factors, both groups did not differ significantly. An overview of these risk factors is shown in Appendix.

The univariate binary logistic regression revealed significant associations for the following two sports-related risk factors: total years playing volleyball (OR = 1.01; 95% CI 0.99–1.18), and the frequency of performing weight training to increase dominant limb strength (OR = 2.70; 95% CI 1.05–6.92; Table 2). For the other sports-related risk factors, the univariate binary logistic regression revealed no significant associations like years playing professional volleyball (OR = 1.03; 95% CI 0.93–1.14) or total practice and competition hours in a week (OR = 1.00; 95% CI 0.92–1.07; Table 2).

Work-related risk factors

The chi-square test and independent *t*-test revealed no significant differences between both groups regarding the work-related risk factors. An overview of these risk factors is shown in Appendix. Also, no significant associations were revealed in the univariate binary logistic regression analyses (Table 2).

Multivariate regression outcomes

The multivariate binary logistic regression revealed significant associations for two sports-related risk factors: total years playing volleyball with OR 1.11 (95% CI 1.01–1.21) and the frequency of performing weight training to increase dominant limb strength with OR 3.56 (95% CI 1.26–10.11; Table 3). After categorizing the total years playing volleyball in four categories (0–10 years, 11–13 years, 14–17 years, and 18–30 years) as well as the frequency of performing weight training to increase dominant limb strength (never, sometimes, often, and always), the multivariate binary logistic regression revealed a significant association for the subcategory 18–30 years playing volleyball with OR 6.70 (95% CI 1.12–29.54). A nonsignificant result was found for often/always performing weight training to increase dominant limb strength with an OR 3.41 (95% CI 0.64–18.18) and OR 3.96 (95% CI 0.70–22.56), respectively. For the other subcategories, the multivariate binary logistic regression also revealed no significant differences.

Table 3. Multivariate binary logistic regression outcomes (odds ratio and 95% confidence interval) of two sports-related risk factors: total years playing volleyball and frequency of performing weight training to increase dominant limb strength

	Symptomatic group vs reference group
Total years playing volleyball	OR 1.11 (95% CI 1.01–1.21)
0–10 years ($n = 25$)	Reference
11–13 years ($n = 22$)	OR 1.88 (95% CI 0.41–8.70)
14–17 years ($n = 23$)	OR 1.63 (95% CI 0.35–7.56)
18–30 years ($n = 22$)	OR 6.70 (95% CI 1.12–29.54)
Frequency of performing weight training to increase dominant limb strength	OR 3.56 (95% CI 1.26–10.11)
Never ($n = 16$)	Reference
Sometimes ($n = 33$)	OR 0.85 (95% CI 0.16–4.58)
Often ($n = 27$)	OR 3.41 (95% CI 0.64–18.18)
Always ($n = 18$)	OR 3.96 (95% CI 0.70–22.56)

CI, confidence interval; OR, odds ratio.

Discussion

The main finding of this questionnaire survey among 99 elite male volleyball players is that the total years playing volleyball and the frequency of performing weight training to increase dominant limb strength were identified as risk factors associated with self-reported symptoms of digital ischemia. Regardless of the cause of these apparently innocuous complaints, the identification of these risk factors could serve as a first step in prevention.

Risk factors and etiology

These two sports-related risk factors might be related to (a) repetitive blunt trauma to the forearms and hands, and (b) repetitive rotary movements of the shoulder girdle, both possibly resulting in an overload and deterioration of vascular structures. It has been suggested that vascular trauma is likely to be sustained during extreme hours of practice (McIntosh et al., 2006), and that reduction in training duration and intensity should result in less overload of the dominant limb, thereby providing a greater opportunity for tissue recovery (Reeser et al., 2006).

Studies among athletes exposed to repetitive blunt trauma to the forearms and hands have reported ischemia-related symptoms of the hand as a result of forearm vessel aneurysms (Kostianen & Orava, 1983), hypothenar hammer syndrome (Massada et al., 2011), digital arterial pathology (Buckhout & Warner, 1980; Ho et al., 1981; Sugawara et al., 1986; Itoh et al., 1987), and Raynaud-like vasospasm of the digital arteries (McCarthy et al., 1989). Studies among athletes who practice repetitive rotary movements of the shoulder girdle have reported ischemia-related symptoms of the hand as a result of arterial thoracic outlet syndrome (Reeser, 2007), quadrilateral space syndrome (Reeser, 2007), and aneurysms of the axillary artery (Jackson, 2003) or its branches, like the posterior circumflex humeral artery (PCHA). Aneurysms of the PCHA have been reported in elite volleyball players (Reekers et al., 1993; Reekers & Koedam, 1998; Stänz et al., 2001;

Vlychou et al., 2001; McIntosh et al., 2006; Atema et al., 2012; van de Pol et al., 2012) and baseball pitchers (McCarthy et al., 1989; Nuber et al., 1990; Durham et al., 1995; Kee et al., 1995; Todd et al., 1998; Schneider et al., 1999; Arko et al., 2001).

During a volleyball player's career, exposure to blunt trauma to the forearms and hands increases gradually because of the numerous spikes, serves, passes, and other movements required in elite volleyball (Reeser et al., 2006). This cumulative effect might explain why a volleyball career of more than 17 years is associated with a significant 6.7-fold increased risk on ischemia-related complaints in the dominant hand. Furthermore, as a result of often/always performing weight training to increase dominant limb strength, the volleyball player might acquire more power in his strokes. This could lead to more vigorous spikes and serves resulting in an increased moment of impact of the ball on the dominant hand and thus more blunt trauma to local vascular structures. In addition, also the type of weight training might be stressful for vascular structures. However, we have no data about the type of kinetics performed. Again, there seems to be a cumulative effect as often/always performing this type of weight training is associated with a significant 2.7-fold higher risk of ischemia-related complaints in the dominant hand compared with never and sometimes performing this training. Our results suggest that especially strength-increasing weight training, and not weight training itself, results in an increased risk.

Other potential risk factors assessed in this study did not lead to a significant result. For instance, the number of practice and competition hours per week could have been a contributing factor. Some studies have suggested a reduction in training intensity (Reeser et al., 2006) and guidelines for number of smashes, practice, and competition hours per day (McIntosh et al., 2006), in order to prevent dominant limb overload. Although a relation between reported symptoms and the number of practice and competition hours per week seemed plausible, our study did not reveal this relation. The same was true for position in the field as suggested by Rosi et al. (1992) and McIntosh et al. (2006). Regarding work-related risk factors, working with vibrating tools was thought to be a potential risk factor. Studies have demonstrated that these activities could lead to digital artery occlusion (Conn et al., 1970) and to acute reductions in finger blood flow (Ye et al., 2012). van der Worp et al. (2011) concluded that volleyball players with physically demanding jobs have an increased risk of developing patellar tendinopathy. A similar increased work-related risk might have been present for hand injuries in volleyball players working with vibrating tools and performing repetitive work with the arms above shoulder height (Conn et al., 1970; Sluiter et al., 2001; Melchior et al., 2006; Descatha et al., 2009; Ye et al., 2012). However, our results did not provide evidence for this relation in Dutch elite male volleyball players with blue and pale digits.

Relevance for clinical sport practice

At the moment, the existing literature on the prevention of volleyball injuries and its risk factors is relatively sparse (Reeser et al., 2006). However, a number of studies have addressed this topic in the past (Bahr et al., 1997; Augustsson et al., 2006; van der Worp et al., 2012; Visnes & Bahr, 2013). Given the high prevalence of complaints raising the suspicion of digital ischemia in young, healthy athletes, the identification of the sports-related risk factors – playing volleyball for more than 17 years and often/always performing weight training to increase dominant limb strength – might be a first step in prevention. The overview of the other potential risk factors should also make it possible to monitor or modify these factors at an early stage in those volleyball players experiencing apparently innocuous symptoms. In this way, the onset or worsening of thromboembolic complications and irreversible damage to the digits might be understood and prevented (Schneider et al., 1999; McIntosh et al., 2006). With regard to the years playing volleyball, it is clear that this is a non-modifiable risk factor. However, this result implies that in surveillance, for instance using a screening questionnaire (van de Pol et al., 2012), extra attention should be given to players who have played volleyball for more than 17 years.

A weakness of the present study is that, although an association between performing weight training to increase dominant limb strength and reported ischemia-related symptoms in the dominant hand was found, the specifics of this strength training were not defined. Therefore, before recommendations regarding potentially more suitable exercises can be made, a better insight into a player's strength exercise routines should be obtained. Biomechanical factors, like the exact type of movements and range of motion, and training characteristics like intensity, frequency, and duration might be relevant. Another weakness is the lack of proof of actual digital ischemia in elite male volleyball players, although the reported symptoms are very suggestive. However, we believe that, regardless of the cause of these symptoms, we have identified significant risk factors for these symptoms, making prevention possible.

In conclusion, playing volleyball for more than 17 years and often/always performing weight training to increase dominant limb strength were significantly associated with self-reported blue or pale digits in the dominant hand during or immediately after practice or competition in elite male volleyball players. No significant other sports-, personal-, or work-related risk factors were found.

Perspectives

The identification of the sports-related risk factors – playing volleyball for more than 17 years and often/always performing weight training to increase dominant

limb strength – is the first step in signaling and preventing apparently innocuous symptoms of digital ischemia.

A better insight into the dominant limb weight training among elite male volleyball players might result in more safe strength training without an association with symptoms of digital ischemia.

Elite male volleyball players, playing volleyball for more than 17 years, warrant regular surveillance for symptoms of digital ischemia possibly due to thromboembolic complications.

This way, sports medicine specialists can be more proactive in helping prevent possibly irreversible damage to the digits among elite male volleyball players.

Key words: volleyball, digital ischemia, risk factors, upper extremity.

References

Arko FR, Harris EJ, Zarins CK, Olcott C 4th. Vascular complications in high-performance athletes. J Vasc Surg 2001: 33: 935–942.

Atema JJ, Unlu C, Reekers JA, Idu MM. Posterior circumflex humeral artery injury with distal embolisation in professional volleyball players: a discussion of three cases. Eur J Vasc Endovasc Surg 2012: 44: 195–198.

Augustsson SR, Augustsson J, Thomeé R, Svantesson U. Injuries and preventive actions in elite Swedish volleyball. Scand J Med Sci Sports 2006: 16: 433–440.

Bahr R, Lian O, Bahr IA. A twofold reduction in the incidence of acute ankle sprains in volleyball after the introduction of an injury prevention program: a prospective cohort study. Scand J Med Sci Sports 1997: 7: 172–177.

Block JA, Sequeira W. Raynaud's phenomenon. Lancet 2001: 357: 2042–2048.

Buckhout B, Warner M. Digital perfusion of handball players: effects of repeated ball impact on structures of the hand. Am J Sports Med 1980: 8: 206–207.

Conn J, Bergan J, Bell J. Hypothenar hammer syndrome: posttraumatic digital ischemia. Surgery 1970: 68: 1122–1128.

Descatha A, Roquelaure Y, Chastang JF, Evanoff B, Cyr D, Leclerc A. Description of outcomes of upper-extremity musculoskeletal disorders in workers highly exposed to repetitive work. J Hand Surg Am 2009: 34: 890–895.

Durham JR, Yao JS, Pearce WH, Nuber GM, McCarthy WJ 3rd. Arterial injuries in the thoracic outlet syndrome. J Vasc Surg 1995: 21: 57–69.

Grens K. Artery injury signs common in pro volleyballers. Reuters. September 8, 2012. Available at http://in.reuters.com/article/2012/09/07/us-artery-volleyball-idINBRE88617T20120907?feedType=RSS&feedName=health (accessed 19 June 2013).

Ho P, Dellon A, Wilgis E. True aneurysms of the hand resulting from athletic injury. Am J Sports Med 1981: 13: 136–138.

Itoh Y, Wakano K, Takeda T, Murakami T. Circulatory disturbances in the throwing hand of baseball pitchers. Am J Sports Med 1987: 15: 264–269.

Jackson MR. Upper extremity arterial injuries in athletes. Semin Vasc Surg 2003: 16: 232–239.

Kee ST, Dake MD, Wolfe-Johnson B, Semba CP, Zarins CK, Olcott C 4th. Ischemia of the throwing hand in major league baseball pitchers: embolic occlusion from aneurysms of axillary artery branches. J Vasc Interv Radiol 1995: 6: 979–982.

Kostianen S, Orava S. Blunt injury of the radial and ulnar arteries in volley ball players. A report of three cases of the antebrachial–palmar hammer syndrome. Br J Sports Med 1983: 17: 172–176.

Massada M, Aido R, Magalhaes C, Puga N. Hypothenar hammer syndrome in a middle blocker – a case report and brief review. Br J Sports Med 2011: 45: 549.

McCarthy WJ, Yao JS, Schafer MF, Nuber G, Flinn WR, Blackburn D, Suker JR. Upper extremity arterial injury in athletes. J Vasc Surg 1989: 9: 317–327.

McIntosh A, Hassan I, Cherry K, Dahm D. Posterior circumflex humeral artery aneurysm in 2 professional volleyball players. Am J Orthop 2006: 35: 33–36.

Melchior M, Roquelaure Y, Evanoff B, Chastang JF, Ha C, Imbernon E, Goldberg M, Leclerc A, Pays de la Loire Study Group. Why are manual workers at high risk of upper limb disorders? The role of physical work factors in a random sample of workers in France. Occup Environ Med 2006: 63: 754–761.

Nuber GW, McCarthy WJ, Yao JS, Schafer MF, Suker JR. Arterial abnormalities of the shoulder in athletes. Am J Sports Med 1990: 18: 514–519.

Reekers JA, den Hartog BM, Kuyper CF, Kromhout JG, Peeters FL. Traumatic aneurysm of the posterior circumflex humeral artery: a volleyball player's disease? J Vasc Interv Radiol 1993: 4: 405–408.

Reekers JA, Koedam N. Re: volleyball-related ischemia of the hand. Cardiovasc Intervent Radiol 1998: 21: 261.

Reeser JC. Diagnosis and management of vascular injuries in the shoulder girdle of the overhead athlete. Curr Sports Med Rep 2007: 6: 322–327.

Reeser JC, Verhagen E, Briner WW, Askeland TI, Bahr R. Strategies for prevention of volleyball related injuries. Br J Sports Med 2006: 40: 594–600.

Rosi G, Pichot O, Bosson JL, Calabrese G, Carpentier P. Echographic and Doppler screening of the forearm arteries in professional volleyball players. Am J Sports Med 1992: 20: 604–606.

Schneider K, Kasparyan NG, Altchek DW, Fantini GA, Weiland AJ. An aneurysm involving the axillary artery and its branch vessels in a major league baseball pitcher. A case report and review of the literature. Am J Sports Med 1999: 27: 370–375.

Sluiter JK, Rest KM, Frings-Dresen MH. Criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders. Scand J Work Environ Health 2001: 27: 1–102.

Stänz K, Wedler V, Köpfli P, Künzi W, Pfammatter T. Compression syndrome of the arteria circumflexa humeri posterior in a volleyball player [Article in German]. Vasa 2001: 30: 229–232.

Sugawara M, Ogino T, Minami A, Ishii S. Digital ischemia in baseball players. Am J Sports Med 1986: 14: 329–334.

Todd GJ, Benvenisty AI, Hershon S, Bigliani LU. Aneurysms of the mid axillary artery in major league baseball pitchers – a report of two cases. J Vasc Surg 1998: 28: 702–707.

van de Pol D, Kuijer PPFM, Langenhorst T, Maas M. High prevalence of self-reported symptoms of digital ischemia in elite male volleyball players in the Netherlands: a cross-sectional national survey. Am J Sports Med 2012: 40: 2296–2302.

van der Worp H, van Ark M, Zwerver J, van den Akker-Scheek I. Risk factors for patellar tendinopathy in basketball and volleyball players: a cross-sectional study. Scand J Med Sci Sports 2012: 22: 783–790.

van der Worp H, Zwerver J, Kuijer PP, Frings-Dresen MH, van den Akker-Scheek I. The impact of physically demanding work of basketball and volleyball players on the risk for patellar tendinopathy and on work limitations. J Back Musculoskelet Rehabil 2011: 24: 49–55.

Visnes H, Bahr R. Training volume and body composition as risk factors for developing jumper's knee among young elite volleyball players. Scand J Med Sci Sports 2013: 23: 607–613.

Vlychou M, Spanomichos G, Chatziioannou A, Georganas M, Zavras GM. Embolisation of a traumatic aneurysm of the posterior circumflex humeral artery in a volleyball player. Br J Sports Med 2001: 35: 136–137.

Wigley FM. Clinical practice. Raynaud's phenomenon. N Engl J Med 2002: 347: 1001–1008.

Ye Y, Mauro M, Bovenzi M, Griffin MJ. Acute effects of mechanical shocks on finger blood flow: influence of shock repetition rate and shock magnitude. Int Arch Occup Environ Health 2012: 85: 605–614.

Appendix

Overview of demographics, personal-, sports-, and work-related risk factors for the symptomatic and reference group of elite male volleyball players

	Answering category	Symptomatic group ($n = 26$)	Reference group ($n = 68$)	Significance
Demographics				
Age	Years	Mean: 25.0 SD: 5.3 Range: 16–38	Mean: 24.0 SD: 4.3 Range: 18–36	$t = 0.98$ $P = 0.33$
Body height	Centimeters	Mean: 196.8 SD: 6.6 Range: 185–210	Mean: 196.0 SD: 7.6 Range: 168–211	$t = 0.49$ $P = 0.62$
Body weight	Kilograms	Mean: 86.0 SD: 7.1 Range: 70–101	Mean: 87.4 SD: 7.4 Range: 70–110	$t = -0.85$ $P = 0.40$
Shoulder injury history	Yes: + No: –	+: 13/26 (50%) –: 13/26 (50%)	+: 23/67 (34%) –: 44/67 (66%)	$\chi^2 = 1.94$ $P = 0.16$
Use of medicine	Yes: + No: –	+: 2/26 (8%) –: 24/26 (92%)	+: 1/67 (2%) –: 66/67 (98%)	$\chi^2 = 2.31$ $P = 0.19$
Paid or unpaid work	Yes: + No: –	+: 14/26 (54%) –: 12/26 (46%)	+: 36/68 (53%) –: 32/68 (47%)	$\chi^2 = 0.01$ $P = 0.94$
Number of working hours per week	Hours	Mean: 15.3 SD: 18.3 Range: 0–50	Mean: 12.0 SD: 15.5 Range: 0–50	$t = 0.88$ $P = 0.38$
Personal risk factors				
Smoking (currently or in the past)	Yes: + No: –	+: 7/26 (27%) –: 19/26 (73%)	+: 13/67 (19%) –: 54/67 (81%)	$\chi^2 = 0.63$ $P = 0.43$
Use of alcohol (currently)	Yes: + No: –	+: 23/26 (89%) –: 3/26 (11%)	+:64/67 (96%) –: 3/67 (4%)	$\chi^2 = 1.55$ $P = 0.34$
Family history on cardiovascular disease	Yes: + No: –	+: 11/23 (48%) –: 12/23 (52%)	+: 15/52 (29%) –: 37/52 (71%)	$\chi^2 = 2.54$ $P = 0.11$
Sports-related risk factors				
Total years playing volleyball	Years	Mean: 15.8 SD: 5.6 Range:7–30	Mean: 13.4 SD: 5.4 Range: 4–28	$t = 1.85$ $P = 0.07$
Years playing professional volleyball	Years	Mean: 4.8 SD: 4.8 Range: 1–18	Mean: 4.2 SD: 4.1 Range: 1–18	$t = 0.61$ $P = 0.54$
Number of practice and competition hours per week	Hours	Mean: 17.1 SD: 5.9 Range: 7–25	Mean: 17.2 SD: 6.1 Range: 5–30	$t = -0.10$ $P = 0.92$
Position in the field	Attacker: + Defender: –	+: 9/16 (56%) –: 7/16 (44%)	+: 27/41 (66%) –: 14/41 (34%)	$\chi^2 = 0.46$ $P = 0.50$
Smashing "away from the shoulder"	Often/always: + Never/sometimes: –	+: 13/26 (50%) –: 13/26 (50%)	+: 22/67 (33%) –: 45/67 (67%)	$\chi^2 = 2.35$ $P = 0.13$
Type of service	Jump service: + Float service: –	+: 9/21 (43%) –: 12/21 (57%)	+: 27/64 (42%) –: 37/64 (58%)	$\chi^2 = 0.00$ $P = 0.96$
Performing dominant limb weight training in general	Yes: + No: –	+: 25/26 (96%) –: 1/26 (4%)	+: 62/68 (91%) –: 6/68 (9%)	$\chi^2 = 0.68$ $P = 0.67$
Frequency of performing dominant limb weight training during warm-up before practice	Often/always: + Never/sometimes: –	+: 5/26 (19%) –: 21/26 (81%)	+: 15/68 (22%) –: 53/68 (78%)	$\chi^2 = 0.09$ $P = 0.76$
Number of minutes per week performing dominant limb weight training during warm-up before practice	Minutes	Mean: 14.0 SD: 22.8 Range: 0–100	Mean: 13.0 SD: 30.8 Range: 0–240	$t = 0.16$ $P = 0.87$
Frequency of performing dominant limb weight training during warm-up before competition	Often/always: + Never/sometimes: –	+: 2/26 (8%) –: 24/26 (92%)	+: 8/68 (12%) –: 60/68 (88%)	$\chi^2 = 0.33$ $P = 0.72$

Appendix Continued

	Answering category	Symptomatic group ($n = 26$)	Reference group ($n = 68$)	Significance
Number of minutes per week performing dominant limb weight training during warm-up before competition	Minutes	Mean: 3.4 SD: 9.6 Range: 0–40	Mean: 3.3 SD: 7.6 Range: 0–40	$t = 0.03$ $P = 0.98$
Frequency of performing weight training to increase dominant limb strength	Often/always: + Never/sometimes: –	+: 17/26 (65%) –: 9/26 (34%)	+: 28/68 (41%) –: 40/68 (59%)	$\chi^2 = 4.42$ $P = 0.04$
Number of hours per week performing weight training to increase dominant limb strength	Hours	Mean: 0.8 SD: 0.9 Range: 0–4	Mean: 0.6 SD: 0.6 Range:0–3	$t = 1.4$ $P = 0.16$
Frequency of performing weight training to maintain dominant limb strength	Often/always: + Never/sometimes: –	+: 15/26(58%) –: 11/26 (42%)	+: 32/66 (48%) –: 34/66 (52%)	$\chi^2 = 0.63$ $P = 0.49$
Number of hours per week performing weight training to maintain dominant limb strength	Hours	Mean: 0.6 SD: 0.6 Range: 0–2	Mean: 0.4 SD: 0.5 Range: 0–2	$t = 1.2$ $P = 0.21$
Work-related risk factors				
Perceived heaviness of work	Scale 1–10 1 = not heavy at all 10 = as heavy as conceivable	Mean: 1.9 SD: 2.0 Range: 0–5	Mean: 2.5 SD: 2.2 Range: 0–8	$t = -0.79$ $P = 0.43$
Working with vibrating tools more than 1 h per day	Often/always: + Never/sometimes: –	+: 0/26 (0%) –: 26/26 (100%)	+: 1/68 (2%) –: 67/68 (98%)	$\chi^2 = 0.39$ $P = 1.00$
Working in a cold environment more than 1 h per day	Often/always: + Never/sometimes: –	+: 0/26 (0%) –: 26/26 (100%)	+: 1/68 (2%) –: 67/68 (98%)	$\chi^2 = 0.39$ $P = 1.00$
Performing repetitive work with the arms more than two times per minute	Often/always: + Never/sometimes: –	+: 3/26 (11%) –: 23/26 (89%)	+: 10/68 (15%) –: 58/68 (85%)	$\chi^2 = 0.16$ $P = 1.00$
Working above shoulder height more than 1 h per day	Often/always: + Never/sometimes: –	+: 0/26 (0%) –: 26/26 (100%)	+: 1/68 (2%) –: 67/68 (98%)	$\chi^2 = 0.39$ $P = 1.00$
Performing work with tools heavier than 1 kg	Often/always: + Never/sometimes: –	+: 2/26 (8%) –: 24/26 (92%)	+: 3/68 (4%) –: 65/68 (96%)	$\chi^2 = 0.40$ $P = 0.61$
Performing work with a computer or mouse more than 4 h per day	Often/always: + never/sometimes: –	+: 6/26 (23%) –: 20/26 (77%)	+: 17/68 (25%) –: 51/68 (75%)	$\chi^2 = 0.04$ $P = 0.84$
Heavy lifting over 15 kg per day	Often/always: + never/sometimes: –	+: 3/26 (11%) –: 23/26 (89%)	+: 4/68 (6%) –: 64/68 (94%)	$\chi^2 = 0.87$ $P = 0.39$
Performing powerful work with the hands (like screwing or kneading) more than 1 h per day	Often/always: + Never/sometimes: –	+: 1/25 (4%) –: 24/25 (96%)	+: 3/68 (4%) –: 65/68 (95%)	$\chi^2 = 0.01$ $P = 1.00$