Diagnostic properties of the SPIQuestionnaire to detect Posterior Circumflex Humeral Artery Disease in elite volleyball players: a cross-sectional study

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Research article

Objective: Sports related aneurysmal degeneration and thrombosis of the Posterior Circumflex Humeral Artery (PCHA) has been known to cause symptoms of digital ischemia (DI) in elite volleyball players. Studies have reported symptoms of DI in as much as 28% of the elite indoor volleyball players. The purpose of this study was to determine the diagnostic value of the Shoulder PCHA Pathology and digital Ischemia – Questionnaire (SPI-Q) for detection of sports related PCHA disease using ultrasound data as the standard of reference.

Methods: The SPI-Q was completed by elite indoor volleyball players from the highest and single highest Dutch volleyball division and by elite beach volleyball players participating in the 2014 Grand Slam Beach Tournament The Hague (GSBTH). Ultrasound assessment of the dominant shoulder was performed on-site using the SPI-US protocol. The SPI-Q sensitivity, specificity, positive – and negative predictive value and positive – and negative likelihood ratios, and the diagnostic odds ratio were calculated for detection of sports related PCHA disease, using ultrasound as the standard of reference.

Results: Two hundred twenty-four elite male indoor volleyball players from the Dutch division were included in this study and 62 elite male and female beach volleyball players participating in the GSBTH; a total of 278 players. Thirty-five percent of the players reported symptoms of DI. The prevalence of PCHA disease was 6.1%. For the SPI-Q we found a sensitivity of 18% (95% CI 4–43), specificity of 64% (95% CI 58–70), positive predictive value of 3% (95% CI 0.7–8.9) and negative predictive value of 92% (95% CI 87–96), positive likelihood ratio of 0.50 (95% CI 0.18–1.40), negative likelihood ratio of 1.28 (95% CI 1.01–1.62) and a diagnostic odds ratio of 0.39 (95% CI 0.11–1.38).

Conclusions: The diagnostic value of the SPI-Q to detect PCHA disease in elite volleyball players is poor, which makes it unsuitable as a diagnostic instrument for sports related PCHA disease specifically. However, it can be used to assess all-cause symptoms of DI and raise awareness within athletes and sports physicians, which is important for preventing ischemic complications.

1. Introduction

A number of volleyball players, playing in the highest and second highest national division in The Netherlands presented themselves in our hospital with complaints of cold, pale and blue digits in the dominant hand (Fig. 1). These complaints are associated with digital ischemia (DI) amongst elite volleyball players [1–5]. Digital Subtraction Angiography (DSA) of the affected hand showed discontinuation of digital and palmar arteries, presumably due to micro emboli, and aneurysm formation of the Posterior Circumflex Humeral Artery (PCHA) in the ipsilateral (dominant) shoulder [3,6].

It is assumed that repetitive vigorous overhead movements in volleyball such as serving and spiking (hitting the ball forcefully from a position near the net so that it moves downward into the opposite court) – causes chronic vessel wall injury and aneurysm formation as a result of positional traction and compression of the proximal PCHA (Fig. 2) [2,6,7]. Aneurysm thrombosis might lead to distal embolisation 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 [1,8,9,2]. The standardised SPI-US (Shoulder...
and reported a 28% prevalence of DI symptoms [12]. The purpose of this study was to determine the diagnostic value of the SPI-Q for detection of sports related PCHA disease, using ultrasound as the standard of reference.

2. Materials and methods

2.1. Study design

A cross sectional study was performed in line with the STARD Statement for Reporting Studies of Diagnostic Accuracy [13] among elite male volleyball players participating in the highest or second highest division of volleyball in the Netherlands and beach volleyball players participating in the Grand Slam Beach Tournament The Hague 2014 (GSBTH) to determine the diagnostic accuracy of the SPI-Q to diagnose PCHA disease. Official approval for this study was granted by the Institutional Review Board (METC 2013.92#B2013461).

2.2. Participants

2.2.1. Recruitment

We targeted the same population as recruited in an earlier study on volleyball players and sports related PCHA disease [1] and expanded this population with beach volleyball players, as they reported the same symptoms [12,14]. Inclusion criteria were: (i) playing volleyball in the highest or second highest national division or participating in the Grand Slam Beach Tournament The Hague 2014; (ii) active as player at time of testing; (iii) written informed consent. Exclusion criteria were: (i) being diagnosed with Raynaud’s phenomenon; (ii) injury or surgery of blood vessels in the dominant shoulder; (iii) using cardiovascular medication at the time of testing.

2.2.2. Procedure

After approval by the head coach of the different elite volleyball teams, a researcher (D. v. d. P., S. A.) accompanied by a registered vascular technologists (RVT), visited the team in the study period of January 2014 to July 2014 at their training facilities. Participants of the GSBTH were approached during the tournament, held from July 15–20, 2014. After informed consent, participants filled out the SPI-Q and underwent ultrasound assessment of the PCHA and DBA in the dominant arm on-site. Participation was voluntary.

2.3. Test methods

2.3.1. Questionnaire

The SPI-Q was used to assess if participants experienced cold, blue or pale digits during or after volleyball activities. In every of the six questions the answer categories were never, sometimes, often or always [15]. Questions were added to gather demographical information from the participants like sex, age, body height and weight.

2.3.2. Ultrasound

Ultrasound exams were performed by two experienced RVTs and by using a mobile ultrasound device (2006 LOGIQ e, General Electric, Fairfield, Connecticut, United States) on-site and according to the standardised SPI-US protocol (Shoulder vascular Pathology with digital Ischemia–UltraSound protocol) [10,11]. Ultrasound diameter measurements included reference values of normal appearing vessel segments and the maximum diameter value of dilated PCHA vessel segments, if present (Fig. 3). The RVTs were blinded for symptoms. Images were reviewed in a consensus meeting by the RVT involved and a cardiovascular radiologist. Disease of the PCHA was defined as one of the following: (i) a dilatation (ratio exceeding 1), (ii) an aneurysm (ratio of 1.5 or more [15]), (iii) an aneurysm with a visible embolism, or (iv) an occlusion of the vessel using color flow and Doppler flow measurements.
2.4. Data analyses

For data analysis the Statistical Package for the Social Sciences (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0 IBM Corp. Armonk, NY) was used. Data were randomly checked for correct entry by a second researcher (S.A.) with a sample size of 20% (60 cases). This yielded us one incorrect entry, which was corrected.

2.4.1. Participants

Demographics like age, sex, body height and weight were reported for all participants. Questionnaire outcome values were considered positive if the participant reported any symptoms of DI (sometimes, often or always) and negative if no symptoms of DI were reported. Ultrasound outcome was reported positive or negative for the presence of PCHA disease. The participants were divided into four groups based on the questionnaire and ultrasound outcomes and displayed in a two by two cross tabulation conform the STARD Statement (Table 1).

2.4.2. Diagnostic accuracy

We used the data from the ultrasound as a standard of reference to determine the diagnostic properties of the SPI-Q by making a cross tabulation of the results. The accuracy of the positive or negative outcome was expressed as sensitivity, specificity, positive and negative likelihood ratio and positive and negative predictive values of the test and the diagnostic odds ratio was calculated. The diagnostic odds ratio (DOR) is the ratio of the odds of disease in the test positives relative to the odds of disease in the test negatives. The value of the DOR can range from zero to infinity, with higher values indicating better discriminatory test performance [17]. A 95% confidence interval was calculated to quantify uncertainty (Table 2).

3. Results

3.1. Participants

Two hundred and twenty-four (224) elite volleyball players from the highest or second highest Dutch division chose to participate in the study and 63 players that were playing in the GSBTH. In total 286 players participated in the study (Fig. 4). Eight participants were excluded for analyses; four players because they did not play in the highest division at the time of testing; two players because they were diagnosed with Raynaud’s phenomenon; and one player because he was operated on the PCHA; one player who was not an active player at time of testing. Two hundred and seventy-eight (278) participants were included for statistical analyses. Of the included participants 87% was male, the average age was 25 years and at least one of the symptoms of DI was reported in 35% of the participants. Ultrasound revealed a PCHA disease prevalence of 6.1%.

3.2. Diagnostic accuracy

Using ultrasound as the standard of reference the questionnaire resulted in a sensitivity of 18% (95% CI 4.4–43) and specificity of 64% (95% CI 58–70). This would mean that in a group of one hundred players with PCHA pathologi disease being tested, only eighteen players would test positive using the SPI-Q. In a group of hundred players without PCHA disease, only 64 would indeed test negative. The positive predictive value is 3% (95% CI 0.7–8.9), meaning that out of 100 players testing positive 3 would actually have the disease and 97 will not. The negative predictive value is 92% (95% CI 87.4–95.7). This means that out of 100 people testing negative, 92 people actually do not have the disease. The positive likelihood ratio is 0.50 (95% CI 0.18–1.40). This number would mean that after testing positive the chances of having the disease are half of the chance that you had, to have the disease, before testing. The negative likelihood ratio is 1.28 (95% CI 1.01–1.62). This value means that the chances to have the disease after testing negative are increased by 1.28. The diagnostic odds ratio (DOR) was 0.39 (95% CI 0.11–1.38). A DOR < 1 indicates there is a higher percentage of players testing negative in the group with the disease than in the group without the disease [18].

4. Discussion

The main finding of this study is that the diagnostic value of the SPI-Q for detection of sports related PCHA disease in elite volleyball players is poor which makes it unsuitable as a diagnostic instrument for detection of PCHA disease. However, the SPI-Q, although not valuable for detection of PCHA disease specifically, might be still be a valuable tool for assessment of all-cause symptoms of DI [1].

More awareness and knowledge on sports related PCHA disease, and its concomitant symptoms, among sports physicians is important since this will facilitate early recognition, which is important for preventing serious ischemic complications. One in every 16 elite volleyball players (6.1%) has PCHA disease in the dominant shoulder. Therefore, sports physicians need to have a high index of suspicion when a volleyball player reports symptoms and signs of DI. Since these symptoms might initially seem innocuous to the athlete, it is advisable to use the SPI-Q twice a year to raise awareness and to detect the onset of symptoms of

![Longitudinal B-mode ultrasound image of the aneurysmatic proximal PCHA in a professional volleyball player. AA, axillary arterie; PCHA, posterior circumflex humeral artery [16].](image)

Fig. 3. Longitudinal B-mode ultrasound image of the aneurysmatic proximal PCHA in a professional volleyball player. AA, axillary arterie; PCHA, posterior circumflex humeral artery [16].

<table>
<thead>
<tr>
<th>Ultrasound result for disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Self-reported symptoms</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Table 2: Values of diagnostic accuracy of the questionnaire.

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence – %</td>
<td>6.1</td>
<td>3.6–9.6</td>
</tr>
<tr>
<td>Sensitivity – %</td>
<td>17.7</td>
<td>3.8–43.4</td>
</tr>
<tr>
<td>Specificity – %</td>
<td>64.4</td>
<td>58.2–70.2</td>
</tr>
<tr>
<td>Positive Predictive Value – %</td>
<td>3.12</td>
<td>0.7–8.9</td>
</tr>
<tr>
<td>Negative Predictive Value – %</td>
<td>92.91</td>
<td>87.4–95.7</td>
</tr>
<tr>
<td>Positive Likelihood ratio</td>
<td>0.50</td>
<td>0.18–1.40</td>
</tr>
<tr>
<td>Negative Likelihood ratio</td>
<td>1.28</td>
<td>1.01–1.62</td>
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<tr>
<td>Diagnostic Odds Ratio</td>
<td>0.39</td>
<td>0.11–1.38</td>
</tr>
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</table>
4.1. Considerations

The determined diagnostic properties of the SPI-Q could be influenced by several factors. For one, we only assessed the diagnostic properties of the SPI-Q for detecting sports related PCHA disease. The questionnaire detects symptoms of DI, though it is likely that not all sports related DI is caused by PCHA disease. The symptoms of DI in elite volleyball players can potentially also be explained by other diseases such as thoracic outlet syndrome, axillary artery aneurysm or occlusion, or vasospasms [20]. The repeated action of playing the ball with the forearms and digits could also be a source of the symptoms, for instance, cases of forearm vessel aneurysm and hypothenar hammer syndrome have been reported specifically in volleyball players [21,22]. The diagnostic properties of the SPI-Q were assessed for only one cause of DI. Future studies should determine the diagnostic properties of the questionnaire for these multiple causes of DI.

Furthermore, a known weakness of questionnaires in general is the influence of differences in perception of complaints. Answer categories as ‘sometimes’ and ‘often’ might be interpreted differently by athletes. Also, some athletes might have forgotten about symptoms they experienced earlier on.

Lastly, although symptoms do not seem to be related to PCHA disease in this cross-sectional study, future studies should prospectively assess the reporting of symptoms of DI at regular intervals to reveal a possible association with PCHA disease. This might clarify the onset and course of symptoms in relation to increased seasonal activities (such as the play-offs period). Moreover, in case of sudden onset or aggravation of symptoms, the PCHA could be examined using the SPI-US protocol to assess a possible relation with PCHA pathology and/or the development of intravascular thrombus.

In conclusion, the diagnostic properties of the SPI-Q to detect sports related PCHA disease specifically is poor. However, it can be used to assess all-cause symptoms of DI and raise awareness within athletes and sports physicians which is important for preventing serious ischemic complications.

References

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