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CASE REPORT

Sport-related femoral artery occlusion detected by near-infrared spectroscopy and pedal power measurements: a case report

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ABSTRACT

Objectives: Approximately one in five professional cycling athletes will eventually develop a sport-related vascular problem. However, detecting such flow limitation is a diagnostic challenge as the sensitivity of the currently available standard diagnostic tools is limited.

Methods: Here we present an athlete with exercise-induced pain and weakness of the left leg. During the physical examination, pulsations of the femoral artery were palpable but less prominent. He was analyzed in an ongoing research project aimed at improving methods detecting sport-related leg flow limitations.

Results: During functional testing, the ankle-brachial index of the left leg was moderately lowered. However, results of near-infrared spectroscopy and pedal power measurements were largely abnormal suggesting a severe flow limitation.

Conclusion: Combining post-exercise ankle-brachial index, near-infrared spectroscopy, and pedal power measurements as routine diagnostic functional testing suggested a severe arterial flow inflow limitation. Conventional diagnostics encompassing duplex-Doppler echography and magnetic resonance angiography confirmed a femoral artery occlusion.

Clinical trial registration: https://www.trialregister.nl/ identifier is Trial NL8557.

Abbreviations: NIRS: Near-Infrared Spectroscopy; PPM: Pedal Power Measurements; ABI: Ankle Brachial Index; PSV: Peak Systolic Velocity

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Case report; near-infrared spectroscopy; pedal power measurements; arterial occlusion; exercise testing

Introduction

Approximately one in five endurance cycling athletes is faced with a sports induced leg blood flow limitation in the iliac arterial axis [1,2]. Such blood flow limitations are caused by endofibrotic thickening, functional kinking, or a combination of both. A diminished oxygen delivery may result in pain, powerlessness, and cramps in one or more leg muscles that emerge during near-maximal effort and lessens several minutes after cessation of exercise [2]. A major complaint of patient athletes is the loss of power in the affected leg. Therefore, pedal power measuring (PPM) is a technique that is potentially able to quantify these complaints and may support this diagnosis. Near-infrared Spectroscopy (NIRS) is an innovative technique that measures muscle oxygenation indirectly. This technique is able to monitor the oxygenation state resulting from the vascular O_2 delivery and metabolic O_2 usage [3]. Recent proof-of-concept studies suggested that both techniques were possibly useful tools in these patients [4,5]. The exact diagnostic threshold for NIRS parameters is currently investigated (not yet published).

In the present case report, we describe a patient who was analyzed in an ongoing research project aimed at increasing the diagnostic accuracy of functional testing in this sport-related entity. He was found to have a common femoral artery occlusion. This abnormality is occasionally encountered as the end stage of a sport-related iliac artery flow limitation. The aim of this contribution is to discuss a set of extraordinary response patterns using NIRS and PPM associated with a severe arterial inflow blockage.

Case report

The patient is a 50-year-old male, with a length of 169 cm and 58 kg (BMI = 20.3 kg/m^2, 12.3% fat [6]) who reported pain in his left leg related to exercise intensity of cycling and walking stairs for over a year. This pain prevented him from staying aerobic fit. He did not have any other medical conditions, no relevant family history, and no previous treatments. He had raced intensively during his life, initially on the national competitive level and the last 12 years on the recreative level. In 42 years he had cycled over 500 000 km. The pain was also elicited following normal hip flexion. He was an ex-smoker with 30 packyears and had stopped smoking a month prior to his visit. He was included in a large ongoing research project investigating the validity of NIRS and PPM as the current set of functional diagnostic tools lack sensitivity [Trail NL8557]. The

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subject provided oral and written informed consent for the present case study whereas the protocol was approved by the hospital's medical ethical committee. The study was reported according to CAse REport (CARE) guidelines [7]. The study was conducted in accordance with the declaration of Helsinki [8].

On physical examination, pulsations of the left femoral artery were palpable but less prominent compared to the right leg. As an arterial flow restriction was considered, a maximal exercise test on an electronically braked ergometer (Lode Excalibur Sport, Lode BV, Groningen, The Netherlands) in a competitive cycling posture was performed. This cycle ergometer allows for obtaining a continuous PPM signal through strain gauges connected to each crank. In addition, ventilatory and gas exchange parameters were measured breath-by-breath (Quark CPET, Cosmed, Rome, Italy). On each leg, a 10 Hz NIRS device (PortaMon, Artinis, Elst, The Netherlands) was placed on the muscle belly of the vastus lateralis muscle 15 cm proximal from the patella edge. The cycling protocol consisted of cycling on a 10% predicted maximal workload. The workload was increased in a ramp protocol aimed at reaching maximal exhaustion within 8–12 minutes [9].

The subject was instructed to cycle until maximal exhaustion. The maximal attained workload was defined as the peak workload.

Simultaneous ankle and arm blood pressure measurements during a five-minute recovery phase allowed for calculating an ankle brachial index (ABI). Unlike measuring ABI in supine posture in patients with intermittent claudication in rest, our patients with sport-related blood flow limitation are measured immediately after exercise in competitive posture. The normal value for this examination is >0.54 [10]. The values of NIRS and PPM were obtained throughout this test. This exercise protocol, analysis of data, and signal analysis were executed as recently reported [4,5].

In addition to this set of functional testing, the patient underwent a standard iliac and common femoral artery duplex-Doppler echography (Terason T3000, Burlington, MA, USA) on the same day. This examination visualizes vascular abnormalities and obtains peak systolic velocity measurements to grade the severity. A magnetic resonance angiogram (Achieva, Philips, release 3.2.3.2, Best, The Netherlands) was performed some weeks later for objectively imaging the arterial circulation.

Results

The patient described a progressive pain in his left quadriceps femoris with radiation to his calf from a 120 Watts workload on and eventually stopped at a maximal workload of 161 Watts due to pain and exhaustion. At this point, the VO_2/kg was 37.9 ml/min/kg and a respiratory exchange ratio of 1.28 suggesting maximal exhaustion. His left ABI in the competitive cycling posture decreased to 0.41 but was normal on the right side (0.81). In addition, the pressure difference at ankle level was 76 mmHg (normal, <23 mmHg) [10].

Pedal power measurement (PPM)

Figure 1(a) depicts the relationship between a progressive workload (x-axis) and the power (y-axis) that is generated by the right leg (upper blue line) and the leg left (lower red line) indicating a huge difference (middle green line). The formula that is applied for the diagnosis of a one-sided arterial problem [5]

$$\left(\frac{|\Delta mean\ power\ at\ 95\%\ of\ maximal\ test|}{Maximal\ workload}\right) * 100$$

yielded a score of 38 (normal, <5.4 [5]) indeed strongly suggesting a unilateral arterial inflow restriction. Figure 1(b) indicates a large power difference between the two legs and illustrates the instantaneous 10 cycles averaged crank power at 95% of the maximal test, where the mean power is used for the above equation.

Near-infrared spectroscopy (NIRS)

During recovery following the maximal test while remaining seated in competitive posture, no reoxygenation was observed in the left leg (red line) also suggesting a severe arterial flow limitation (Figure 1(c)) [4]. Interestingly, changing posture to an upright position ensured immediate reoxygenation suggesting compensatory collateral circulation.

Duplex-Doppler echography

On the left side, an occlusion was found in the distal portion of the common femoral artery with minor kinking of the external iliac artery. Interestingly, the peak systolic velocity (PSV) measurements in the proximal external iliac artery were normal with extended hip, flexed hip, and during psoas contraction [10]. In addition, minor intimal thickening abnormalities in the right common iliac artery with functional kinking in the right proximal external iliac were found that were also documented by an increased PSV with a flexed hip.

Magnetic resonance angiography

In accordance with the duplex-Doppler echography, the left distal external iliac artery, and the common femoral artery were occluded whereas the remaining portion of the femoropoplitteal axis was normal (Figure 2). The right side showed an unobstructed common, external, and femoral iliac artery. A few centimeters distal to the origo, non-significant plaque formation is found in the superficial femoral artery. Some significant stenosis is found in the distal peroneal artery.

Intervention

The patient chose for a pharmacological intervention using Carbaspirin Calcium (80 mg once a day). During his following visit, he was able to resume his work and sport activities as the complaints had decreased.

Discussion

This case report is the first to discuss severe abnormal responses of NIRS and PPM reflecting an endofibrotic occlusion of the common femoral artery in endurance athletes. Most often abnormalities in these patients are located in the

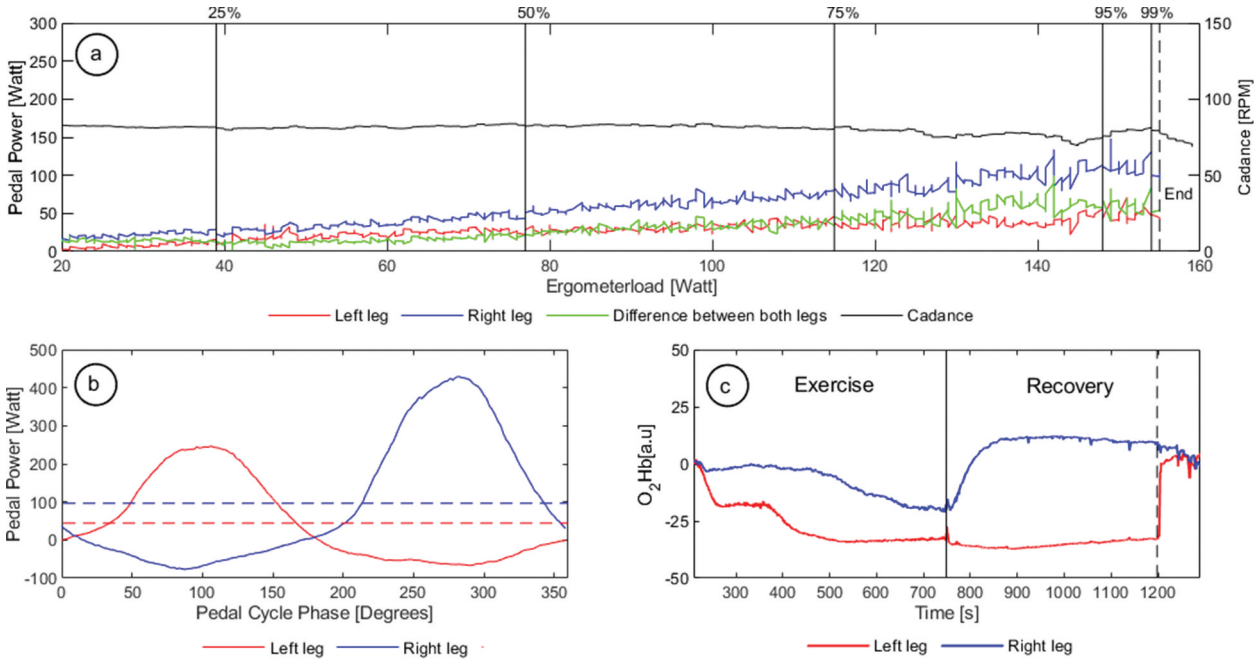

Figure 1. (a) PPM: The pedal power of both legs (red and blue) during a progressive workload. The green line represents the difference between both legs. (b) PPM: Averaged instantaneous 10 cycles averaged crank power at 95% of the maximal workload of the left (red) and right (blue) leg. The dashed lines represent mean power of the whole cycle, which is used for the diagnosis of unilateral flow-limitations [5]. (c) NIRS: O_2Hb signal during and after the test. The solid vertical line at 750 seconds represents the start of the recovery phase. The right leg (blue line) shows a relatively fast reoxygenation compared to the left leg. The left leg (red line) shows no reoxygenation pattern during the recovery suggesting a severe flow limitation. After the dashed line, the patient changed position from competitive cycling posture to upright position. This ensured immediate reoxygenation. We believe that this is caused by both the increased hydrostatic pressure in the upright position in combination with relieve of functional occlusion of collateral circulation in the flexed hip position.

Figure 2. Magnetic resonance angiogram visualized an occluded left common femoral artery. Collateral compensating circulation is visible.

common or external iliac artery. The NIRS technique is advised for measuring muscle tissue oxygenation in patients with, e.g. peripheral vascular disease or chronic heart failure [11,12]. The use of PPM was earlier proposed in studies improving efficiency during cycling and for determining differences in muscular function in patients with a progressive decline in motoric skills [13,14].

The present case is unique as a generally used diagnostic tool such as a post-exercise ABI was only slightly abnormal on the left leg. In addition, a normal PSV proximal and distal to the occlusion was found using duplex-Doppler echography, probably due to an abundant compensatory collateral circulation. On the right side, the ABI was considered normal despite minor intimal thickening abnormalities and functional kinking with increased PSV using duplex-Doppler echography. In contrast to the traditional functional diagnostic method of measuring ABI after exercise, the experimental NIRS and PPM showed substantial abnormalities without extra burden to the patient using normal diagnostic routine potentially increasing the diagnostic accuracy.

The role of PPM may particularly be useful in patients with a one-sided flow limitation as different patterns will be observed in both legs. Using NIRS, the recovery rate is usually related to the oxidative capacity but is now influenced by oxygen delivery impairment. Therefore, the response pattern will also provide important diagnostic clues on the underlying cause. Future studies will establish the potential role of a combination of these techniques in diagnosing and grading the severity of inflow abnormalities in endurance athletes.

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Declaration of interest

The authors declare that they have no conflict of interest.

Ethics approval

The subject is part of a larger ongoing research on improving methods detecting (subtle) sport-related leg flow limitations. The Medical Ethics Review Committee (METC) confirmed that the Medical Research Involving Human Subjects Act (WMO) did not apply to the current study and approved the study protocol (nWMO; N13.12022013).

Consent to participate

The subject provided oral and written informed consent for the present case study.

Availability of data and material

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

M. van Hooff, G. Schep, M. Bender, M. Scheltinga, and H. Savelberg were all contributors to this case-report. G. Schep conducted the duplex-Doppler echography. M. van Hooff conducted the exercise test, performed the data collection, data analysis, and prepared the first draft of the manuscript. All authors agreed with the interpretation of the results. All authors edited and agreed on the final version.

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