

Research article

## Microcirculation under an Elastic Bandage during Rest and Exercise – Preliminary Experience with the Laser-Doppler Spectrophotometry System O2C

Björn Sommer<sup>1</sup>✉, Gereon Berschin<sup>2</sup> and Hans-Martin Sommer<sup>2</sup>

<sup>1</sup>Department of Neurosurgery, University of Erlangen-Nuremberg, Erlangen, and <sup>2</sup>Department of Sports Science and Motology, Philipps-University Marburg, Marburg, Germany

### Abstract

There is an abundance of studies on the influence of rest and exercise as well as external compression on cutaneous, subcutaneous and muscle tissue blood flow using different measurement techniques. As a novel approach, we simultaneously examined the influence of a custom-made elastic thigh bandage on cutaneous and subcutaneous venous blood oxygenation ( $SO_2$ ), post-capillary venous filling pressures ( $rHb$ ) and blood flow ( $flow$ ) using the non-invasive laser-Doppler spectrophotometry system “Oxygen-to-see(O2C)”. Parameters were obtained in 20 healthy volunteers in 2 mm and 8 mm tissue depth during rest, 5 and 10 minutes of moderate bicycle exercise following a 10-minute recovery period. Without the bandage, results matched the known physiological changes indicating higher blood backflow from superficial and deep veins. Underneath the elastic bandage, we observed lower post-capillary filling pressures during exercise. However, after the bandage was removed in the post-exercise period, all obtained parameters of microcirculation remained increased, indicating a higher amount of local venous blood volume in this area. Our observations might be the result of external compression, thermoregulatory and exercise-dependent vascular mechanisms. With the O2C device, a promising new non-invasive technique of measuring local microcirculation in soft tissue exists. This study gives new insights in the field of non-invasive diagnostics with special regard to the influence of elastic bandages on local microcirculation.

**Key words:** External compression, blood flow, non-invasive diagnostics, lower extremity, exercise.

### Introduction

Elastic bandages and compression stockings are widely used as a basic treatment of chronic venous insufficiency of the lower extremity and for the prevention of deep venous thrombosis as well as lymphedema (Aschwanden et al., 2008; Nehler et al., 1993). Both orthopaedic devices have a mutual mechanical and proprioceptive benefit on joint stabilization (Beynon et al., 2002; Hassan et al., 2002). However, circular compression creates an elevated hydrostatic pressure in the tissue beneath the brace (Styf, 1999). As a consequence, there is an elevation of intramuscular pressure at rest and during exercise, which impairs muscle blood flow and transportation of metabolites leading to premature muscle fatigue (Man and Morrissey, 2005; Styf, 1990; Styf et al., 1992; 1994). Since many patients’ microcirculation is impaired after knee or foot injury, external compression by elastic bandages and braces could have potential detrimental effects during the

healing process.

Invasive and non-invasive methods of measuring cutaneous and subcutaneous tissue perfusion are well established. Venous occlusion plethysmography and radionuclide techniques are the most commonly used invasive methods that allow a quantitative description of local and regional blood flow (De Graaff et al., 2003; Sejrsen and Bülow, 2009; Martin et al., 2011). However, microtrauma can cause false positive and negative results and invasive measurements require an elaborate experimental setup. When using radionuclides, tracer biokinetics such as isotope affinity to fat tissue and diffusibility are known to bias blood flow values of the terminal capillary system (Swain and Grant, 1989). The high sensitivity to movement artifacts is one major problem of the assessment of regional blood flow using venous occlusion plethysmography during moderate upright exercise (Rowell, 1983). Laser-Doppler spectrophotometry is a promising new non-invasive tool which measures qualitative changes in capillary and venous microcirculation. The combination of backscattering-spectroscopy and laser-Doppler flowmetry allows real-time determination of venous oxygen saturation, haemoglobin saturation and blood flow. The monitoring device used in this study (“Oxygen-to-see(O2C)”, LEA Medizintechnik, Giessen, Germany), has been proven to be a reliable and valid tool in various conditions such as transplant and plastic surgery (Knobloch et al., 2003; Hölzle et al., 2010), Achilles tendon and ankle microcirculation (Knobloch et al., 2006a; Knobloch et al., 2006b), or wound tissue microperfusion in pressure and diabetic foot ulcers (Reenalda et al., 2009; Beckert et al., 2004).

In this study, the O2C device is used for the first time to evaluate local venous microcirculation of the thigh in skin and subcutaneous tissue depths. Apart from the physiological reactions to circulatory activity, the aim of this study was to examine if a custom-made thigh bandage had a positive or negative impact on soft tissue microperfusion during rest and exercise conditions in healthy volunteers.

### Methods

#### Subjects

Twenty healthy non-smoking male volunteers [mean  $\pm$  SD: 27.1  $\pm$  7.7 years] participated in this study. Regarding sports activity, 11 participants performed endurance training on a regular basis (7.6  $\pm$  4.1 h per week) and 9 par-

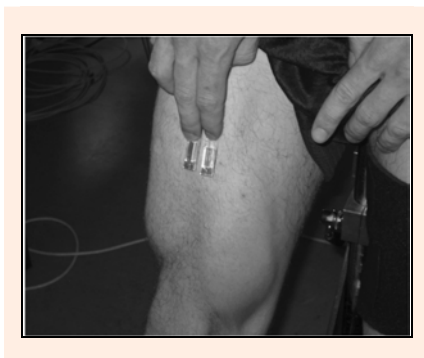
participants fitness training with power lifting ( $9.6 \pm 1.7$  h per week). All subjects were free of any injuries of the lower extremities and proved full functionality of the hip, knee and ankle joints under physical investigation. Anthropometric data for the subjects were: body mass  $82.1 \pm 9.8$  kg and height  $183 \pm 8$  cm. The circumference of the thigh (measured 15 cm above the superior border of the patella) was  $50.2 \pm 2.8$  cm.

This study complied to the laws of the Federal Republic of Germany and followed the Declaration of Helsinki. Subjects gave written informed consent before the tests.

### Experimental setup

We used a modified open, non-blinded crossover-study design. Each participant completed two exercise trials, one with and one without wearing an elastic bandage. The trials were arranged in random order and at least 72 hours apart. External factors such as ambient room temperature ( $20.0 \pm 1^\circ\text{C}$ ), air humidity (20%), air pressure (1013 hPa) and no direct illumination were kept constant in our laboratory.

At the beginning of each session the participants were seated in an upright position on the ergometer bicycle. The Oxygen-to-see probes were placed on the most distal part of the *M. rectus femoris* and gently strapped with tape (Leukoplast<sup>®</sup> hospital, BSN medical, Hamburg, Germany) as shown in Figure 1. Standardization of the probe position was achieved with additional reference to the bone structures (patella, medial and lateral femoral condyles). The tape application had no effect on the measured values.



**Figure 1.** Probe position on the right thigh.

The pre-exercise parameters (condition “pre-exercise”) venous oxygen saturation ( $SO_2$ ), postcapillary venous filling pressures ( $rHb$ ) and microcirculatory blood flow ( $flow$ ) were measured at two distinct tissue depths (2 mm and 8 mm) after resting 10 minutes on the ergometer bicycle. Pre-study examinations showed that after this period of time, all parameters remained in a steady condition. This measurement was made in both recording sets.

Thereafter, subjects started cycling in the first set, while in the second set the elastic bandage was adjusted. The custom-made bandage (width 13.7 cm, material: mixture of neoprene and polyurethane foam) was wrapped around the right thigh 15 cm above the superior border of the patella, a similar position to that of commonly used elastic knee bandages (e.g. Bauerfeind, 2011).

The bandage could be adjusted to the individual size of the leg by tightening two straps with a defined tensile force of 25 N, which was measured by a tensiometer (Lehrmittelbau MAEY, Bonn, Germany). We chose the dimension of tensile force according to the results of Lundin and Styf (1998), who discovered that the participants’ preferred level of tightening the thigh straps of a knee brace showed similar effects on intramuscular pressure compared to a tensile force of 25 N.

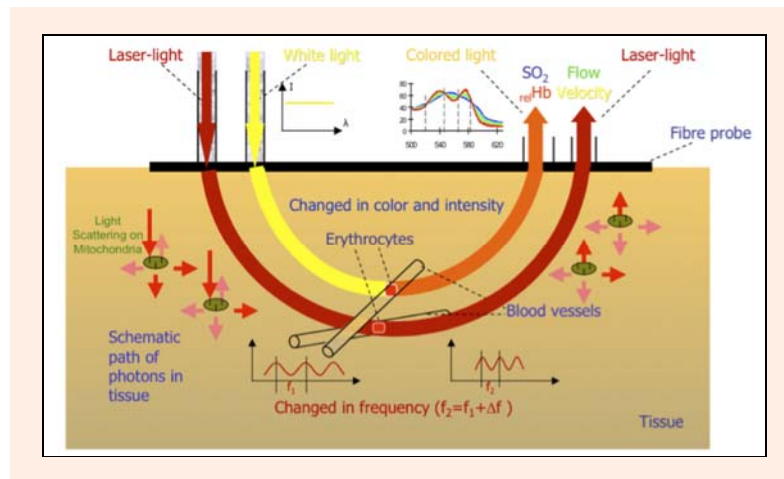
During exercise, we performed real-time measurements after 5 and 10 minutes of cycling in both sets. In the last recording (“post-exercise”), exercise was stopped and subjects had to rest in an upright position on the ergometer for ten minutes. After this time span, parameters in participants without the bandage were measured in the first set, while in the second set, participants who wore the bandage had to remove it before parameters were obtained. Due to the known physiological changes in the vasomotor tone of skin and subcutaneous blood vessels during initiation of exercise, the first 5-10 minutes and the post-exercise period (Johnson, 1992; Roddie, 1983), we chose to focus our data collection to four distinct moments rather than using the complete data set.

Throughout the examination, the heart rate was transmitted to the ergometer (Lifecycle<sup>®</sup> 9500HR, Life-Fitness, Brunswick Corporation, Schiller Park, Illinois, U.S.A.) by a chest strap (Polar T31<sup>®</sup>, Polar Electro Oy, Kempele, Finland). The ergometer used an electromagnetic brake system to adjust pedal resistance according to the individual training condition. Subjects had to perform the test with a steady heart rate of 130 bpm, which is considered as “moderate intensity” of endurance-type activity (Pollock et al., 1998).

### Determination of blood circulation

Two flat probes were connected to the laser-Doppler spectrophotometry system “Oxygen-to-see (O2C)”, the first measuring the microperfusion to a depth of 2 mm, which represented cutaneous tissue (“superficial probe”), the other probe collected data to a depth of 8 mm, which represented subcutaneous tissue (“deep probe”). The white light source was calibrated with a definite raw haemoglobin spectrum before each measurement. All data were recorded in real-time at 50 Hz, which allowed pulsed synchronous measurements. The technology of this device combines two types of measuring components, backscattering-spectroscopy and laser-Doppler flowmetry. Since these optical methods have been described in detail elsewhere (Frank et al., 1989; Knobloch et al., 2003; 2006b), we give only a brief overview in the following passage.

Light that is sent through tissue will be reflected i.e. by blood cells at certain wavelengths, depending on their haemoglobin content and oxygen saturation (Figure 2). Through the specific absorption spectra it is possible to determine local oxygen supply parameters and the amount of local haemoglobin relative postcapillary filling pressures by a spectrophotometer (Knobloch et al. 2006b). At the same time, the integrated laser-Doppler flowmeter uses the Doppler principle to measure the relative velocity of moving particles. Here, laser light of 830



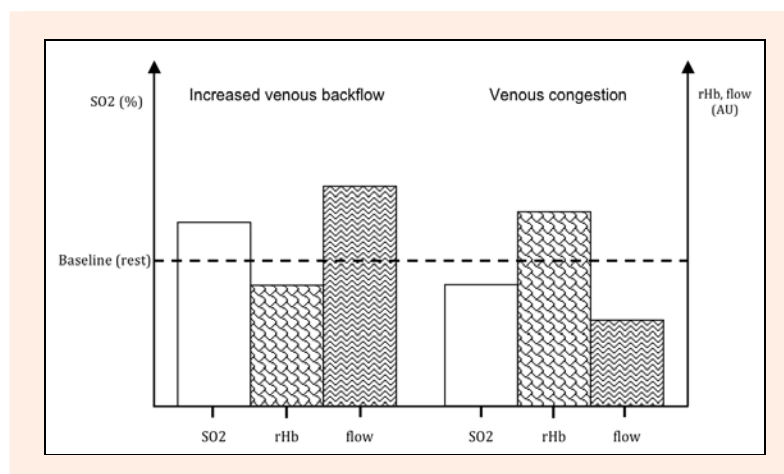
**Figure 2.** Schematic illustration of the path of light photons through tissue, which are emitted by the O2C device from two sources (laser light and white light source). The white light is scattered and returned to the detectors of the O2C probe. Depending on the degree of blood cell oxygenation, specific spectra of backscattered light can be measured and the local amount of blood can be calculated from this method. By applying the Doppler principle, the backscattered laser light gives additional information about the movement of the erythrocytes, which determines blood flow. With kind permission of LEA Medizintechnik, Germany.

nm wavelength is sent through a fiber-optic cable. If photons are backscattered by moving blood cells, they undergo a frequency shift, which is collected by the same probe (Eyre et al., 1988; Bonner and Nossal, 1990). Using the Doppler frequency shift formula, the velocity of blood cells and, as a combination of velocity and quantity, relative blood flow can be determined (Michelson et al., 1996; Seifalian et al., 1994).

The O2C system uses arbitrary units ("AU") to describe the quantity of haemoglobin amount. The manufacturer introduced this unit because measured values are derived from electrical units. To calculate the blood flow in millilitres per minute, the electrical signals have to be compared to a corresponding method, i.e. coloured microspheres (Walter et al., 2002) and have to be calibrated for each measured organ. Measurements with the O2C system reflect mainly the capillary-venous compartment of the microcirculation, because about 80% of the haemoglobin is located in the capillary and post-capillary system of the microvascular bed (Gaethgens, 2000; Abboud et

al., 1976). Since light is absorbed completely if the vessel diameter is greater than 100µm, the O2C system measures only the blood parameters in nutritive, microvascular vessels (Gandjbakhche et al., 1999).

Since the capillary-venous vessel bed is serving as a volumetric store, it guarantees that the same amount of blood volume is transported through the venous system at low pressure as it is in the corresponding high pressure arterial system in order to maintain blood flow (Sinaasappel et al., 1999). Under physiological conditions, a rise of venous oxygen saturation and microcirculatory blood flow is expected in both tissue depths during exercise, while postcapillary venous filling pressures decrease due to higher venous outflow. An inhibited venous capillary outflow would produce a decrease in  $SO_2$  and  $flow$  with an increase of  $rHb$  (Figure 3), because of the accumulation of blood volume through insufficient blood transportation to the deep veins (Hanna et al., 1997; Hölzle et al., 2010; LEA, 2007). The reliability and intrasubject variability of the laser-Doppler system has been examined in



**Figure 3.** Interpretation of O2C parameters: Relative distribution of venous blood oxygenation (SO2), postcapillary venous filling pressures (rHb) and blood flow (flow) during an increased venous backflow (left) and inhibition of venous capillary outflow (right). Baseline (dashed) indicates initial parameters while the subject is resting.

**Table 1.** Physiological reactions in venous blood oxygenation (SO<sub>2</sub>), haemoglobin saturation (rHb) and blood flow (flow) in skin and subcutaneous tissue during pre-exercise, 5 and 10 minutes of moderate exercise, and post-exercise without compression. Data are represented as means (± SD).

		Pre-exercise	5 minutes	10 minutes	Post-exercise
Skin tissue	SO <sub>2</sub> (%)	59.3 (20.4)	61.2 (18.5)	65.4 (14.8)	60.2 (15.3)
	rHb (AU)	69.3 (9.3)	66.5 (8.8)	66.4 (10.3)	69.5 (8.4)
	flow (AU)	209.0 (82.6)	299.4 (33.7) ***	313.2 (35.7) ***	216.1 (53.4) ###
Subcutaneous tissue	SO <sub>2</sub> (%)	72.9 (13.4)	71.2 (12.3)	76.1 (11.3)	75.8 (9.2)
	rHb (AU)	49.4 (13.9)	43.6 (11.4)	45.1 (12.0)	47.1 (13.5)
	flow (AU)	275.2 (231.7)	309.3 (113.7)	358.9 (142.8)	337.9 (233.2)

AU: arbitrary unit. Post hoc \*\*\*p < 0.001 with respect to “pre-exercise” condition. Post hoc ### p < 0.001 with respect to “10 minutes” condition.

several studies and proved sufficient under standardized testing conditions (Brell et al., 2005; Ghazanfari et al., 2002; Walter et al., 2002; Wunder et al., 2005).

### Statistical analyses

Results are given as mean values and one standard deviation (SD). With a sampling rate of 0.5 per second of the O<sub>2</sub>C device, we calculated the average from 15 sample values over 30 seconds for each of the four recordings. Changes were assessed by a two-way analysis repeated measures analysis of variance (ANOVA) with time (“pre-exercise, 5 minutes, 10 minutes, post-exercise”) and condition (with/without bandage) as factors. To meet the requirements for a normal distribution, we examined each variable independently by a KOLMOGOROV-SMIRNOV-Test. For homogeneity of variances, a Levenetest was used. Bonferroni’s post-hoc tests for multiple comparisons were used when differences reached statistical significance. The average intrasubject variability of the blood flow parameters is 5 %, whereas the reproducibility of these values did not show significant changes within or between different days (Ghazanfari et al., 2002). Significance was accepted when *P* was less than 0.05. The SPSS statistical software package 15.0 for Windows (SPSS Inc., Chicago, Illinois) was used for statistical analysis.

### Results

Results are shown in Tables 1 and 2. In summary, we made the following observations:

a) Without wearing an elastic bandage, we observed an increase in *SO<sub>2</sub>* and *flow* during exercise while *rHb* decreased slightly in cutaneous and subcutaneous tissue. The skin blood flow shows a 50% higher increase compared to subcutaneous blood flow (Table 1). Once exercise was stopped, mean values of cutaneous *SO<sub>2</sub>*

b) and flow decreased to pre-exercise levels, whereas in subcutaneous tissue, there was a tendency to higher levels for both parameters (statistically not significant). The postcapillary filling pressures (*rHb*) rose slightly in both tissues, which could be an expression of higher venous pooling according to Figure 3.

c) While wearing an elastic thigh bandage at rest and during ergometer exercise, we observed a similar reaction of microperfusion parameters compared to the physiological condition without the bandage in both tissue depths. Once physical activity stops, however, the reduction in cutaneous blood flow of the bandaged thigh is less compared to the physiological condition (Table 2). In subcutaneous tissue, *flow* is not reduced, but shows a trend for elevation after 10 minutes of rest (Table 2), and so is *SO<sub>2</sub>* in both tissue depths.

We compared the results of both sessions (“inter-subject differences”) and found a statistically significant difference between the venous blood amount (*rHb*) in both skin and subcutaneous tissue. While subjects were wearing the elastic bandage, *rHb* was lower in skin (Table 2) and subcutaneous tissue (Table 2) during *pre-exercise* measurements. After 5 minutes of cycling, skin *rHb* was 59.3 ± 20.4 AU compared to 66.5 ± 8.8 AU without the bandage (*p* = 0.009), whereas there were no significant differences in 8 mm detection depth (*p* = 0.093). Besides that, cutaneous *flow* was significantly (*p* = 0.001) higher underneath the bandage (Table 2) in the post-exercise period, whereas the corresponding values showed no difference in subcutaneous tissue (Table 2). In all other measurements, no difference could be detected.

### Discussion

Many studies exist that describe the influence of external compression on cutaneous, subcutaneous and muscle tissue blood flow using non-invasive measurement

**Table 2.** Venous blood oxygenation (SO<sub>2</sub>), haemoglobin saturation (rHb) and blood flow (flow) in skin and subcutaneous tissue during pre-exercise, 5 and 10 minutes of moderate exercise, and post-exercise while wearing an elastic bandage. Data are represented as means (± SD).

		Pre-exercise	5 minutes	10 minutes	Post-exercise
Skin tissue	SO <sub>2</sub> (%)	59.3 (13.0)	62.6 (10.9)	65.6 (10.6)	68.3 (10.3)
	rHb (AU)	60.0 (8.0)	59.3 (7.9)	61.6 (8.3)	64.8 (7.0)
	flow (AU)	211.3 (50.4)	308.3 (39.5) ***	318.5 (28.0) ***	277.6 (53.6) #
Subcutaneous tissue	SO <sub>2</sub> (%)	71.2 (9.0)	70.6 (10.3)	73.5 (9.0)	79.3 (7.8) *
	rHb (AU)	38.6 (11.0)	37.2 (12.3)	39.8 (14.4)	46.8 (15.1)
	flow (AU)	284.7 (165.6)	274.3 (149.6)	308.4 (208.8)	409.2 (272.9)

AU: arbitrary unit. Post hoc \* *p* < 0.05; and \*\*\* *p* < 0.001 with respect to “pre-exercise” condition. Post hoc # *p* < 0.05 with respect to “10 minutes” condition.

techniques. However, most of them have chosen a reduced experimental setup where “physical activity” is defined as active or passive movement (flexion/extension) of unilateral ankle joints. The obvious methodological consideration is avoiding side effects and create a simplified, standardized experimental setting (Pearson et al., 2011; Stein et al., 2010; Zelis et al., 1969; Zhang et al., 2004), although this does not fully reflect the actual complexity of the influence of circulatory and thermoregulatory mechanisms on local microcirculation, as seen in a more “physiological” type of physical activity such as running or cycling.

Moreover, non-invasive studies that deal with the influence of external compression on skin blood perfusion in rest and exercise conditions are rare (Mayrovitz and Sims, 2003; Styf, 1999; Styf et al., 1992). By trying to avoid side-effects of placing the probe between the bandage-skin interface, some studies performed laser-Doppler investigations beneath the bandage (Mayrovitz et al., 1998) or used single-point laser-Doppler flowmetry (Melhuish et al., 2004) to measure microcirculation under a bandage without removing it. However, in both studies, the results were based on the recording of microcirculatory blood flow *only* with no additional information about the oxygenation or blood volume level. Besides, the circulatory provocation methods were simply defined as an increase in external pressure applied to the calf by an air cast (Mayrovitz et al., 1998).

To the best of our knowledge, no previous study has measured local microcirculation in two different tissue depths using a laser-Doppler spectrophotometer and determined the effects of external compression caused by an elastic bandage on blood perfusion under endurance-type activity.

Our first results when no elastic bandage was worn matched the expected physiological changes. We observed a rise of venous blood oxygenation ( $SO_2$ ) and blood flow ( $flow$ ) in cutaneous and subcutaneous tissue, whereas the blood amount indicated by postcapillary venous filling pressures ( $rHb$ ) was reduced during exercise. Blumberg and colleagues (2005) measured with the O2C system at 2, 8 and 16 mm detection depth while performing a contralateral handgrip exercise. After 10-12 seconds, blood flow increased in all tissues with a clear enhancement on the measurements obtained in skin at 2 mm tissue depth. In our opinion, this is an expression of higher muscle blood flow and increased turnover rates of capillary and post-capillary microperfusion, which leads to a higher venous return to the right ventricle from superficial and deep veins.

Our post-exercise results revealed a reduction in skin blood flow by 31% (from 313.2 to 216.1 AU,  $p < 0.001$ ), while  $SO_2$  had a tendency to decrease and  $rHb$  to increase. In 8 mm tissue depth, all parameters remained constant. This could be a result of the thermoregulatory reflexes mediating a stepwise elimination of thermal energy and metabolites generated by muscular activity.

While subjects were wearing the elastic bandage in the second set, we observed a tendency of higher venous backflow during exercise expressed as lower post-capillary filling pressures. These differences were statisti-

cally significant in skin tissue only and lasted throughout the bicycle exercise period. Changes in the obtained microcirculatory parameters indicate that the amount of venous blood volume in 2 mm and 8 mm depth is less while wearing an elastic bandage during rest and exercise conditions. However, after the bandage was removed in the post-exercise period, all parameters remained increased instead of showing the expected changes (i.e. reduction in  $SO_2$  and  $flow$ , elevation in  $rHb$ ) as one would see in a “physiological” condition without wearing a bandage. Therefore, we conclude that the amount of venous blood volume must be higher under elastic bandages. This is contrary to the above mentioned *reduction* of venous blood volume in both tissue depths, but can possibly be explained by the following mechanisms:

**a)** The observed rise in skin and subcutaneous venous blood oxygenation, which opposes the tendency of physiological decrease of  $SO_2$  after exercise, could be due to a smaller ratio of the venous oxygen extraction rate. This could be caused by a higher post-exercise muscle blood flow, which furthermore evokes faster elimination of metabolites and thermal energy.

**b)** The external pressure mediated through the elastic bandage causes a capillary-venous volume shift, which “rebounds” as the external pressure is released after removal of the bandage. In our study, we chose an external pressure with a tensile strap force of 25 N, which is similar to the expected force of knee braces on the thigh and is expected to create intramuscular pressures up to 36.3 mmHg (Lundin and Styf, 1998). Cutaneous blood flow is already affected at pressures around 20 mmHg (Fromy et al., 1997). Although external compression is used to eliminate venous congestion and contribute to a better local microcirculation (Ramelet, 2002; Aschwanden et al., 2008), it may lead to deterioration of venous outflow distal from the elastic bandage (Mayrovitz and Sims, 2003). Moreover, local pressures exerted on soft tissues vary with different postures (Dai et al., 2012). Our results point to similar effects on cutaneous and subcutaneous microcirculation using a custom-made thigh bandage not only while the subject is resting but most of all after exercise.

Another point is the interaction between pre-capillary constriction evoked by venous congestion and arterial inflow. Oldfield and Brown observed a discrepancy of skin and calf blood flow when the lower limb is subjected to a venous congestion pressure elevation of 50 mmHg (Oldfield and Brown, 2006). The observed blood flow reduction in skin occurred later than in the whole limb, which reflects disparate filling times for deep and superficial veins. Together with the findings of Buckey and co-workers, they concluded that the deep veins receive a proportionately larger blood volume through arterial inflow under external compression (Buckey et al., 1988).

**c)** The isolating properties of the bandage material restrict heat elimination via radiation, convection and sweat evaporation through the skin surface. This causes local heat accumulation, which is known to respond with a further increase of local skin and muscle blood

flow through local vasodilatation of microvasculature (Heinonen et al., 2011; Pearson et al., 2011). Skin tissue is the main recipient of cardiac blood volume distribution during whole body-heating. This could be the reason for the observed increase in venous blood oxygen saturation, postcapillary blood amount and higher blood flow in both tissue depths.

Thus, we conclude that wearing an elastic thigh bandage has an impact on venous blood flow in cutaneous and subcutaneous tissue depths. Our results suggest that there is a higher amount of venous blood volume shift caused by application of an elastic bandage compared to physiological conditions without a bandage.

### Study limitations

Limitations of our study are the non-invasive measurement technique and the lack of intramuscular pressure recordings. Our data was collected in two distinct tissue depths: 2 mm (cutaneous layer) and 8 mm (subcutaneous fat layer). Depending on age, weight and physical condition, average subcutaneous fat thickness of the quadriceps muscle in males is between 4-15 mm (Maurits et al., 2003). With a skinfold thickness of  $7.1 \pm 2.9$  mm at the measurement site, part of the signal from the subcutaneous probe not only resembled subcutaneous, but also muscular blood flow from *M. rectus femoris*. Moreover, subcutaneous tissue oxygenation corresponds directly to the viability of the adjacent muscle tissue and gives an indirect measure of muscle blood flow. This could be the reason that we observed a higher variance expressed as a large standard deviation in *flow* only in subcutaneous tissue depth throughout this study.

### Conclusion

In our study, we were the first to record microcirculatory parameters in skin and subcutaneous tissue depths with the non-invasive combined backscattering-spectroscopy and laser-Doppler flowmetry device “Oxygen-to-see” in healthy subjects under rest and exercise conditions. In the first test regime, we observed a rise in venous oxygenation and blood flow along with a small decrease in venous blood amount as an expression of higher muscular blood flow and venous backflow to the right ventricle from superficial and deep veins. In the second set, we noticed lower post-capillary filling pressures while subjects were wearing a unilateral thigh bandage. This trend might be the result of an increase in venous back flow. However, in the post-exercise period, all parameters remained increased compared to the physiological condition without a bandage, indicating that external compression and thermal isolation caused by the bandage could generate venous blood pooling in both tissue depths. Using a realistic and not simplified laboratory setup, the results of this study underline the possibilities of non-invasive monitoring with a novel technique and the impact of an elastic thigh bandage on skin and subcutaneous microcirculation. In the future, further controlled studies are needed to evaluate and compare these findings with “gold standard” invasive diagnostic methods.

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### Key points

- It can be demonstrated that a novel non-invasive laser-Doppler spectrophotometry system allows the determination of capillary-venous microcirculation in an in-vivo study during exercise-rest cycles.
- The results received with this technique indicate that a) without an elastic thigh bandage, turnover rates of capillary and post-capillary microperfusion in skin and subcutaneous fat tissue increase under physical exertion, b) skin blood flow decreases while subcutaneous blood flow remained constant in the subsequent recovery phase. While wearing the bandage, c) venous back flow during exercise is increased, whereas d) in the recovery phase, microcirculation remained increased in both tissue depths after removing the bandage.
- In conclusion, the elastic bandage has a negative impact on local microcirculation and capillary-venous back flow, which is possibly due to a displacement of blood volume into the deep venous system and heat accumulation impairing the thermo-regulatory response at the same time

### AUTHORS BIOGRAPHY



#### **Björn SOMMER**

##### **Employment**

Resident physician at the Department of Neurosurgery, University of Erlangen-Nuremberg, Erlangen, Germany.

##### **Degree**

MD

##### **Research interests**

Non-invasive diagnostics, Orthotic management of the lower limb, Haemodynamics

**E-mail:** [bjoern.sommer@uk-erlangen.de](mailto:bjoern.sommer@uk-erlangen.de)



#### **Gereon BERSCHIN**

##### **Employment**

PD at the Department of Sports Science and Motology, Philipps-University Marburg, Marburg, Germany

##### **Degree**

PhD

##### **Research interests**

Exercise and Training, Biomechanics, Posture, Rehabilitation

**E-mail:** [berschin@staff.uni-marburg.de](mailto:berschin@staff.uni-marburg.de)



#### **Hans-Martin SOMMER**

##### **Employment**

Professor emeritus of the Department of Sports Science and Motology, Philipps-University Marburg, Marburg, Germany

##### **Degree**

MD

##### **Research interests**

Motor control, Gait and Posture, Pathomechanisms of micro- and macrotraumata in sports

**E-mail:** [hmsommer@t-online.de](mailto:hmsommer@t-online.de)

#### ✉ **Björn Sommer, MD**

Department of Neurosurgery, University of Erlangen-Nuremberg, Schwabachanlage 6, 91054 Erlangen, Germany.