

## Učinki standardne cilindrične manšete in prototipa manšete z asimetrično razporeditvijo tlaka na oksigenacijo in aktivacijo mišice kvadriceps femoris

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**Uvod:** Vadba z zmanjšanim pretokom krvi z aplikacijo napihljivih manšet skozi aktivne mišice (ishemična vadba) se uporablja kot alternativa standardni vadbi s težkim bremenom. Za povzročitev žilne okluzije se uporabljajo različne napihljive manšete in sistemi za regulacijo tlaka. Tehnične podrobnosti so slabo opisane in tudi optimalni parametri za ishemično vadbo niso znani. Namen te študije je primerjati delovanje dvoprekatne manšete z asimetričnim tlakom (DMAT) in enoprekatne manšete s simetričnim tlakom (EMST) na spodnjih udih v mirovanju in med vadbo. **Metode:** Novo oblikovana DMAT (širina 14 cm) in EMST (širina 10 cm) sta bili preverjeni na 17 zdravih prostovoljcih (starost  $27,3 \pm 5,2$  leta). Učinkovitost manšet v mirovanju smo primerjali na obeh stegnih pri štirih različnih tlakih (120, 160, 200 in 240 mm Hg). Izmerili smo obseg stegna in kožno gubo, navor maksimalne hotene izometrične kontrakcije (MIVC) mišice kvadriceps, čas izometrične kontrakcije do hotene odpovedi pri 40-odstotni sili MIVC v ishemičnih in kontrolnih pogojih, kardiovaskularne odzive (EKG in arterijski krvni tlak), intenzivnost bolečine in spremembe kinetike hemoglobina v mišici vastus lateralis z infrardečim laserskim spektrometrom (NIRS). **Rezultati:** Obseg stegna ( $L = 57,3 \pm 3,7$  cm,  $D = 57,1 \pm 3,8$  cm) in navor MIVC ( $L = 230 \pm 77$  Nm,  $D = 233 \pm 77$  Nm) se med nogama nista razlikovala. V mirovanju je intenzivnost bolečine pomembno ( $p = 0,03$ ) naraščala z manšetnim tlakom, vendar se med manšetama ni pomembno razlikovala. Opazna je bila pomembna ( $p = 0,009$ ) razlika v hitrosti spremembe koncentracije skupnega hemoglobina med manšetama ( $v\Delta$  [tHb] =  $0,028\mu\text{M/s}$  z DMAT,  $v\Delta$  [tHb] =  $0,056\mu\text{M/s}$  z EMST) pri tlaku 160 mm Hg. Čas do hotene odpovedi med izometrično kontrakcijo je bil  $-11\%$  krajši ( $p = 0,033$ ) v ishemičnem pogoj, vendar brez razlike med manšetama. Aktivacija in oksigenacija mišice se nista pomembno razlikovali med pogojema in manšetama. **Zaključki:** Iz razlike v  $v^-$  [tHb] sklepamo, da je bila z DMAT arterijska okluzija povzročena že pri manšetnem tlaku  $\sim 160$  mmHg, medtem ko je bila z EMST dosežena šele pri  $\sim 200$  mmHg. To kaže, da lahko z novo DMAT povzročimo ishemijo mišice v mirovanju z nižjim tlakom pri enaki intenzivnosti bolečine kot z EMST. Učinek obeh manšet na oksigenacijo in aktivacijo mišice je bil razmeroma majhen, kar pripisujemo konstantno povečanemu medmišičnemu tlaku med izometrično kontrakcijo. V prihodnje bi bilo smiselno preučiti vpliv ishemije med dinamičnimi kontrakcijami.

**Ključne besede:** ishemija, mišična aktivacija, manšetni tlak, dvoprekatna manšeta.

## Effects of standard cylindrical tourniquet and asymmetrical countoured tourniquet on oxygenation and activation of quadriceps femoris muscle

**Introduction:** Blood flow restricted resistance exercise (BFRRE) is commonly used to gain muscle mass and strength. The most efficient technique of blood-flow restriction for muscle conditioning has not been identified yet. During rest, width of the tourniquet and limb circumference has been shown to substantially influence pressure distribution to the tissues. Thus the aim of this study was to further optimize tourniquet characteristics for restriction of limb muscles blood flow. **Methods:** Newly designed double-compartment tourniquet cuff with asymmetric pressure distribution (DCAP, 14 cm wide) and standard single-compartment tourniquet cuff with symmetric pressure distribution (SCSP, 10 cm wide) were tested on 17 healthy volunteers (27.3±5.2 years) during rest. Thigh circumference and skinfold were determined for each leg. Efficiency of tourniquets was compared bilaterally on proximal thighs at four occlusion pressures (OP = 120, 160, 200 and 240 mmHg). Changes in haemoglobin kinetics in *v. lateralis* muscle (near-infrared spectroscopy), cardiovascular responses (ECG and ABP), isometric endurance, maximal voluntary isometric contraction (MIVC) torque and pain intensity (visual analogue scale, VAS) were analyzed. **Results:** Lean thigh circumference did not differ between legs (L= 57.3±3.7 cm, R=57.1±3.8 cm). VAS scores did not differ between tested tourniquets, but did significantly increase ( $p=0.03$ ) at OP 200 mmHg and higher. Difference ( $p = 0.009$ ) in slope of total haemoglobin concentration change ([tHbs]) was found between the tourniquets at OP 160 mmHg (DCAP=0.028 $\mu$ M/s, SCSP=0.056 $\mu$ M/s). Mean ABP was significantly increased ( $p=0.02$ ) at OP 120 mmHg compared to baseline values, whereas change in heart rate was detected. MIVC did not differ between legs (L=230 ± 77 Nm, R=233 ± 77 Nm). Shorter time to exhaustion (-11%;  $p=0.003$ ) was found in ischemic condition compared to control condition, while no difference was found between tested tourniquets. **Discussion:** Based on differences in [tHbs], arterial occlusion was induced at OP  $\geq 160$  mmHg with DCAP, whereas OP  $\geq 200$  mmHg was required with SCSP. Given that higher pressure may cause damage to underlying tissues and increases discomfort, it is concluded that novel tourniquet design allows safer and more efficient blood flow restriction at a given tourniquet pressure and discomfort during rest. Whether the same is achieved during BFRRE, needs further investigation.

**Key words:** ischemia, isometric, muscle activation, tourniquet characteristics.