Effect of muscle architecture on oxygenation in knee extensor during isometric contraction

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Introduction

Muscle architecture is dramatically changed during exercise. In the human vastus lateralis, one of the pennate muscles, Fukunaga et al. (1997) and Ichinose et al. (1997) presented that muscle architecture, i.e. fascicle length and pennation angle were changed with joint angle and/or muscle fibers develop force in vivo. From the point of view of energy (oxygen) supply in order to perform exercise, these changes in muscle architecture may lead to some disadvantages. Previous studies reported that the relationship between external torque and intramuscular pressure was linear during static action (Sadamoto et al., 1983; Sjøgaard et al., 1986). When a muscle contracts isometrically the blood flow is obstructed by elevated intramuscular pressure (Sadamoto et al., 1983). The blood flow is also affected by extended fiber length (Poole et al., 1997). These may affect the muscle oxygen utilization during muscle action. However the relationship between muscle architecture and muscle oxygenation during exercise has been not clarified. The purpose of the present study was to clarify the effect of muscle architecture on muscle oxygenation during static action at a given intensity. For this purpose, the fascicle length and pennation angle were measured in vastus lateralis muscle (VL) by ultrasonography and thigh muscles oxygenation were measured by near-infrared spectroscopy (NIRS).

Method

Seven healthy men (age 23.3 ± 2.8 yr, height 175.2 ± 4.5cm, body mass 74.6 ± 10.7kg; mean ± SD) participated after giving their informed consent.

After a 3min pre-exercise control period, 30sec of isometric knee extension at 25% and 50% of the predetermined maximal voluntary contraction (MVC) were performed at knee joint angle 50° and 100° (full extension; 0°), respectively. Knee extension torque was measured using isokinetic dynamometer (Cybex®II; U.S.A). To give visual feedback of force output by subject, the line corresponding to the required level was displayed on a storage oscilloscope (DCS-7020; KENWOOD, Japan). A near infrared spectrometer (NIRO-300; Hamamatsu Photonics, Japan) is used to measure changes in oxy (Δoxy-Hb), deoxy (Δdeoxy-Hb), total (Δtotal-Hb) Hb and tissue oxygenation index (TOI) for vastus lateralis muscle (VL) during isometric action. Δoxy-Hb, Δdeoxy-Hb and Δtotal-Hb were indicated as change from resting value. NIRS probe was placed over VL belly which was corresponded to 50% of the thigh length. After
these measurements, to observe changes in muscle architecture, longitudinal muscle tissue images of VL using an ultrasonic apparatus with a linear probe (5MHz, Echo Camera SSD-500; Aloka Co, Japan) were obtained at rest and during contraction at both joint angles. Fascicle length and pennation angle were measured from these images (Fukunaga et al., 1997).

Results & Discussion
Maximal knee extension torque did not differ significantly between both joint angles, i.e., $217.4 \pm 30.7$ Nm at 50°, $221.3 \pm 24.2$ Nm at 100°. When the knee extensor muscle (VL) was contracted the pennation angle increased and fascicle length decreased significantly, compared to resting condition. The fascicle lengths at 50° were shorter than at 100° flexed position during contraction, accompanying with higher pennation angles (Figure 1). This result agreed with previous study (Ichinose et al., 1997). When the subjects exerted knee extension torque isometrically for 30 sec the TOI in VL decreased more at longer fascicle length (100°) than at shorter one (50°), indicating significant higher deoxygenation in tissue at longer fascicle length (Figure 2). Changes in $\Delta$oxy-Hb, $\Delta$deoxy-Hb and $\Delta$total-Hb at 50% MVC were indicated in Figure 3. In previous study it was observed when blood vessels in muscle were stretched a flow velocity of red cell in capillaries decreased (Poole et al 1997). Thus, it may be considered that when the knee was flexed in the present study the fiber in knee extensor was stretched, causing decrement of blood flow and increment of deoxygenation. The present results suggest that muscle oxygenation during isometric contraction in human is affected by changes in muscle fiber length even though same contraction level.

![Figure 1](https://example.com/figure1.png)

**Figure 1**: Pennation angle (a) and Fascicle length (b)
References