Obesity Decrease the Eigenvalues of Muscles

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Introduction: Diffusion tensor imaging (DTI) is based on the molecular environment of the water in muscles, and it is used to reflect the structures and blood flow status in muscle tissue. The skeletal muscle cell shrinks with age. Furthermore, the minor axis of the muscle cell decreases and is further replaced with fat tissue. Galban et al reported that the eigenvalues of muscles decrease with age [1]. The minor axis of the muscle cell also decreases with obesity associated with inactivity, resulting in fat tissue accumulation within muscles. In addition, Frisbee et al reported decreased blood flow in the muscles of obese rats [2]. Obesity results in the progression of arteriosclerosis, which affects the function of blood vessel walls. Because DTI is sensitive to both the minor axis of muscle cells and perfusion, it may be able to clarify obesity-induced changes in muscles. This study aims to evaluate the influence of obesity on DTI findings based on the fat fraction and eigenvalues.

Material & Methods: Sixteen healthy volunteers were asked to lie down in the supine position and were subjected to DTI of the lower extremities using the Dixon technique for the fat fraction and single-shot diffusion-weighted echo planar imaging. The Trio Tim 3T (Siemens) and body matrix coil were used for imaging. A body mass index (BMI) of 25 kg/m2, which is a threshold value for slight obesity, was used to divide the subjects into an obesity group (n = 9; BMI, 31.3 ± 5.0) and a normal group (n = 7; BMI, 20.6 ± 1.5). To estimate the accumulation of fat tissue in the muscles, the Dixon value was measured and the fat fraction was presumed. The slice location for calculating the fat fraction was set at 10 cm superior to the edge of the patella. The other scanning parameters for DWI were selected as follows: repetition time (TR)/echo time (TE), 5.28/2.45 ms; field of view, 380 mm × 285 mm; a 320 × 161 matrix; slice thickness/gap, 3/0.6 mm; flip angle, 9°; and number of slices, 40. To estimate the influence of muscle perfusion, low b-value diffusion-weighted imaging (DWI; b = 0, 100, 250 s/mm2) was performed. Six DW images were acquired and measured. The other scanning parameters for DWI were selected as follows: TR/TE, 4000/57.8 ms; FOV, 250 mm × 172 mm; a 128 × 88 matrix; and slice thickness, 5 mm. All measurements were obtained for six regions of interest (ROIs) on femur slices were set at the vastus lateralis (VL), vastus intermedius (VI), vastus medialis (VM), biceps femoris (BF), semitendinosus (ST), and semimembraneous (SM) muscles.

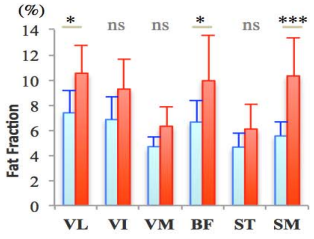

Fig.1. Graph of Fat Fraction

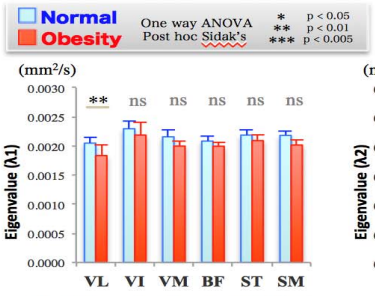

Fig.2. Graph of Eigenvalue(λ1)

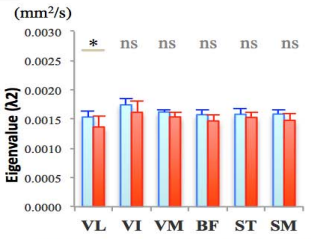

Fig.3. Graph of Eigenvalue(λ2)

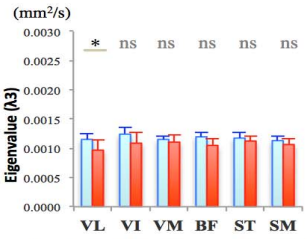

Fig.4. Graph of Eigenvalue(λ3)

Results: Figure 1 shows the results of the fat fraction in each muscle. The fat fraction was higher in the obesity group than in the normal group, with significant differences between the two groups for VL, BF, and SM ($p < 0.05$, $p < 0.05$, $p < 0.005$, respectively). Figures 2–4 show the results of eigenvalues. The lambda 1 value was low value in the obesity group, with a significant difference between groups for VL (Fig. 2, $p < 0.05$). There was no significant difference for the other muscles. The lambda 2 and lambda 3 values were also low in the obesity group, with a significant difference only for VL between the two groups ($p < 0.05$).

Discussion: The fat fraction was significantly different between the obesity and normal groups in this study, indicating fat accumulation in the muscles (Fig. 1). The values in the obesity group were significantly high for VL, BF, and SM. The speed of muscle atrophy varies according to the type of muscle cell, and type II cells are easily replaced with fat tissue. Dehmane et al. reported that the proportion of type II cells is high in BF [3]. Therefore, the differences in fat fraction among muscles may have been affected by the type of muscle cells.

The eigenvalues for VL were significantly lower in the obesity group than in the normal group (Figs. 2–4). Although the precise reason for the lower eigenvalues in the obesity group remains unclear, a decrease in the minor axis of the muscle cells caused by atrophy or the inhibition of diffusion caused by the accumulated fat tissue in the muscles can be possible contributing factors. On the other hand, the b-value used in this study may have been strongly influenced by perfusion. Because a decrease in perfusion affects all eigenvalues, we believe that the results of this study indicate a decrease in muscle perfusion at rest. Furthermore, they may aid in the development of noninvasive muscle screening methods to assess the perfusion of muscles in patients with disorders related to decreased muscle perfusion, such as diabetes.

Reference: [1] Galbán CJ et al., J Gerontol A Biol Sci Med Sci. 2007 Apr;62(4):453-8. [2] Frisbee JC et al., Essays Biochem. 2006;42:145-61. [3] Dahmane R et al., Med Biol Eng Comput. 2006 Nov;44(11):999-1006. Epub 2006 Oct 6.