WHOLE-BODY ENERGY CONSUMPTION MAP CONSTRUCTED BY POSITRON EMISSION TOMOGRAPHY OF MEN AFTER RUNNING

Toshihiko Fujimoto, Masatoshi Ito*, Manabu Tashiro*, Ryoichi Nagatomi, Akira Tamagawa, Hiroaki Ohmori.

Department of Medicine and Science in Sports and Exercise, School of Medicine, Tohoku University Sendai, Japan, and Cyclotron Radioisotope Center, Tohoku University*

INTRODUCTION

Positron emission tomography (PET) is used to visualize tissue metabolism in vivo in humans subjects. $^{18}$F-fluoro-deoxy-glucose (FDG) has been used to measure regional levels of function of organs such as brain and heart as indices of tissue energy consumption levels. Recent technological advances have opened a new area of this field: whole-body, three-dimensional (3D) data acquisition. In such data acquisition, electronic coincidence detection between all opposing photon-sensitive crystals is extended from plane (2D) to volume (3D), thus, yielding higher sensitivity (approximately 5 fold for detectors with a 15 cm axial length and approximately 10 fold for ones with a 20 cm axial length as in our case). While some difficulties in the absolute quantification of isotope distribution due to the scattering events occurring in the body are an issue, the high sensitivity should compensate for this problem. The decreases in the level of exposure to radiation and the increases in image quality are major benefits. Whole-body imaging with injection of only 40-75 Mbq (one or two mCi) or less amount of FDG is now possible. We propose the use of 3D-FDG-PET technique in sports medicine for non-invasive mapping of the working strength of all the muscles in the body.

METHODS

The subjects were seven healthy male volunteers, aged 20-40 years, FDG (1.0-2.3 mCi) was injected into the vein of the subjects while they were running, 15 minutes after they started running. The total running time was 35 minutes for each subject. The running intensity was maintained at a level at which the heart rate was maintained at between 140 and 150 beats per minute, as measured by heart rate monitoring system Vantage XL (Polar Electro Co, Finland). PET measurements were started at 40 minutes after injection using an SET2400W whole-body tomography system, (Shimadzu Co, Japan), with an intrinsic spatial resolution of 3.9 mm. The tomography system has 32 rings of BGO crystals separated by axial intervals of 3.15 mm covering an axial field of 20 cm.

Correction for tissue attenuation was made after the emission acquisition (post-injection transmission) with a needle $^{68}$Ge/Ga source. The tomographic images were obtained from the regions of the foot, 10 cm up the medial malleolus, to the maximal girth of the leg and thigh, the greater trochanter, the 4th lumbar vertebra and the 7th thoracic vertebra. We measured the FDG uptake of 39 muscles present in these regions. The localization of individual muscles were verified by comparison with the tomographic images with magnetic resonance imaging (MRI).

RESULTS

FDG counts per second (cps) indicate the extent of FDG accumulation in muscle tissues and were corrected in terms of the injected radioisotope dose in each subject. On the whole, more than two times more FDG accumulated in foot and leg, and slightly more FDG accumulated in the quadriceps femoris and gluteal muscles than in the thoracic, back, abdomen and arm muscles. Figure A sjiows the amount of FDG accumulated in the lateral gastrocnemius (LG) and medial gastrocnemius (MG) which act synergistically in plantar flexion. Greater amount of FDG accumulated in MG than in LG (P<0.05). Similar difference in the local deposition of FDG in synergistic muscles was also observed in the thigh muscles (Figure B). Smaller amount of FDG accumulated in the rectus femoris (RF) than in the vastus lateralis (VL), vastus intermedius (VI) and vastus medialis (VM), respectively (p<0.01). 

DISCUSSION

Muscles which have similar muscle fiber type distributions are expected to have similar glucose uptake abilities. Although VL and gastrocnemius have similar fiber type distributions (type I + fl a vs. type II b), two times more FDG accumulated in the gastrocnemius than in the VL in the present study. Therefore it was considered that the difference between the amount of
FDG accumulated in the gastrocnemius and that accumulated in the VL reflects a difference in the intensity of muscle contraction or in the manner of muscle use during running. Johnson et al. reported on the fiber type distribution in thirty-six human muscle samples collected at autopsy. They found no marked differences in the fiber type distribution among most of the muscles examined except for several muscle such as soleus. Thus, though we need further consideration on fiber type composition, we conclude that the amount of FDG accumulated in each muscle roughly indicates the contraction intensity and/or the manner of use of each muscle during the running in this experiment. The results of his experiment suggest that leg and foot muscles were used most during the low-intensity running.

LG and MG act synergistically in plantar flexion of the ankle joint, and have similar fiber type distributions. However, the amount of FDG accumulated in these muscles differed significantly in the present study, and similar difference in the accumulation of FDG in the synergistic muscles. This suggests that the synergistic muscles, although they movement, were not subjected to the same load during the low-intensity running.

In conclusion, our results indicate that PET can identify the muscles used in any physical activity via markers of the whole body energy consumption level. The amount of radioactivity required for imaging can probably be reduced to less than 1.0 mCi. This amount corresponds to a whole body radiation dose of around 0.5 mSv, equivalent to one-half the exposure dose in a conventional abdominal x-ray examination. PET mapping of muscle activity may provide data useful not only in sports medicine but also in rehabilitation medicine.

**Figure A** FDG counts per second (cps) in the lateral gastrocnemius and medial gastrocnemius corrected in terms of the injected radioisotope dose. LG: lateral gastrocnemius. MG: medial gastrocnemius. Asterisks (*) indicate significant difference (p<0.05).

**Figure B** FDG counts per second (cps) in the quadriceps femoris. RF: rectus femoris. VM: vastus medialis. VI: vastus intermedius. VL: vastus lateralis. Daggers (†) indicate significant differences (p<0.01).

**References**