Whole Body Metabolic Imaging for Sport Science

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[^{18}F]Fluorodeoxy-glucose (^{18}FDG) and three dimensional positron emission tomography (3DPET) is a useful device for clinical and basic medicine that maps physiopathology of organs *in vivo* in humans. ^{18}FDG-3DPET technique assesses the changes in the muscle usage as well as physiology of organs during tasks. Imaging analysis of muscle use difference between trained and non-trained subjects would be helpful for rational body training of future athletes. Inevitably, brain is a vital organ which has a keen participation at physical task evaluated by PET technique. We propose the use of 3DPET for sport science.

Measurement of whole body glucose metabolism for sport science

PET technique assesses the metabolic activity of organs in humans *in vivo* at rest or during task[1-5]. Figure 1 depicts the whole-body ^{18}FDG distribution at one hour after injection while the person was in resting state. The highest uptake is seen in the brain than other organs. During exercise, jogging in this case, ^{18}FDG uptake is dramatically increased in the lower limbs. In this experiment, the subject ran around our university campus for a total of 35 minutes, 15 minutes prior and 20 minutes after the intravenous injection of ^{18}FDG. A group study using seven healthy male volunteers, average age of 32.2 ± 13.5 y (mean±SD) showed redistribution of energy metabolism, i.e., the highest in lower leg muscles while ^{18}FDG uptake was reduced in other organs except in the brain and heart (Fig. 2). Whole-body PET imaging was carried out by a series of 9 to 11 scanning table movements taking 180 sec for each table position. A transmission scan (post injection transmission mode) then followed using the same time schedule as the emission scan using a ^{68}Ge/^{68}Ga external rotating line source to correct tissue photon attenuations for the emission scans. The exercise strength was below the anaerobic threshold and kept constant

(140 to 150 beat/min,) using heart rate as a marker, which was monitored by a wrist pulse monitor (Vantage-XL Polar Electro, Finland). Plasma glucose level was within normal range (103 ± 9.7 mg/dl, mean ± SD), and did not show any change between the beginning and end of the experiment.

ROIs analysis showed that ^{18}FDG uptake by the skeletal muscles of legs increased two folds while abdominal organs, such as the kidneys, liver, and intestines showed reduction in ^{18}FDG uptakes during running compared with the controls as shown in Fig. 2 and Fig. 3**.** These results clearly show the homeostatic control of energy resources, i.e., glucose was sent to the working skeletal muscles from abdominal organs.

Exercise inducing energy metabolism between trained and non-trained subjects

Training integrates and adjusts the skeletal muscle physiology from homogeneous perfusion distributions within muscles[6)]. Although PET has limited time resolution, it can visualize the relative work of all the body muscles utilized in a particular exercise. An example is shown for this evaluation. Two subjects collaborated in this experiment, one is a beginner and the other is a proficient golf player with a handicap of zero. They continuously practiced a total of 240 shots, at the rate of 6 shots/min for 40 minutes with a driver after 40 MBq of ^{18}FDG administration. ^{18}FDG uptake of the proficient golfer was much higher than that of the beginner, except in the brain. The difference was mostly noted in the forearms, hands and leg muscles. Accumulation of ^{18}FDG uptake was more prominent in the posterior compartment of both the legs and the trunk than in the anterior compartment (Fig. 4). These asymmetrical distributions are reasonable since the role of the posterior compartment muscles of the legs is to support the body against gravity, and simultaneously transmit the force of reaction from the ground to the upper part of the body. In case of the beginner, the work exerted by the posterior compartment muscles was not stronger than the anterior compartment muscles. As a result, the beginner could not produce enough power to generate effective shots. This suggests the usefulness of physical training to ameliorate the tissue oxidative metabolism[7,8)].

The role of the brain at physical exercise.

The brain is a vital organ that regulates the functional behaviour of rest of the body[9)]. Meanwhile, brain would have a keen participation in the regulation of physical exercise. PET with certain tracers such as ^{18}FDG or ^{15}O-H2O are useful in evaluation of brain function at rest or physical exertion[10,11)]. Figure 5 shows the activated brain areas during field running using statistical parametric mapping analysis (SPM-96)[12]. The results show that the posterior parietal, occipital, premotor cortices and the cerebellum are the principal brain areas working during field running. Activation of the occipital cortex was more prominent than those of sensori-motor brain areas. This suggests that main task of the brain during running is to process visual information, while the control of the body movement itself is rather automatic and requires less attention. Indeed, the visual information processing of the external environment is crucial for runners to go forward quickly and smoothly. Another important role of the brain during running is the integration of both visual and spatial information and motor control. The parietal brain, which is known for this integration of motor control and visual information, was also active during the task.

Conclusion

High sensitivity 3DPET is a unique imaging modality to map regional whole-body energy metabolism during any task. A whole body mapping of muscle work would make the ^{18}FDG-3DPET technique suitable to create a database of famous athletes' muscle usage for future research**.** We propose the application of ^{18}FDG-3DPET method for sport science.

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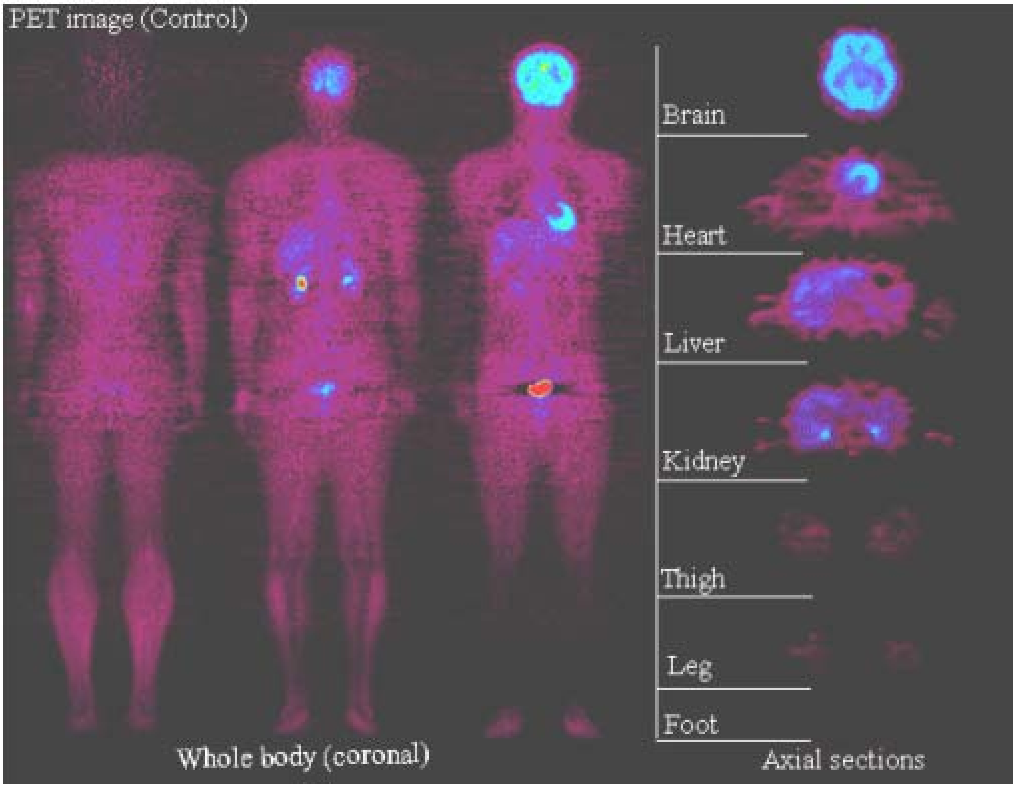

Figure 1. Whole body coronal PET images from one of the controls with representative axial images (right panel) are illustrated. Images are viewed from back (left of the figure) to the front (toward right).

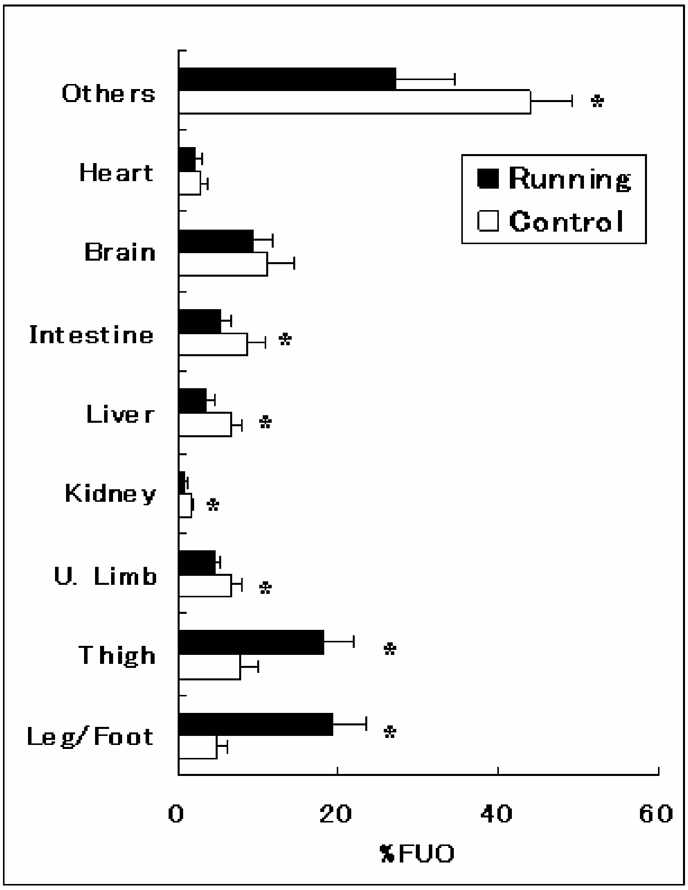

Figure 2. %FUO values of 14 male subjects as controls (N = 7) and running (N = 7) were shown as mean with their standard deviation. %FUO values presented statistically significant at *p<0.05 among control and runners.

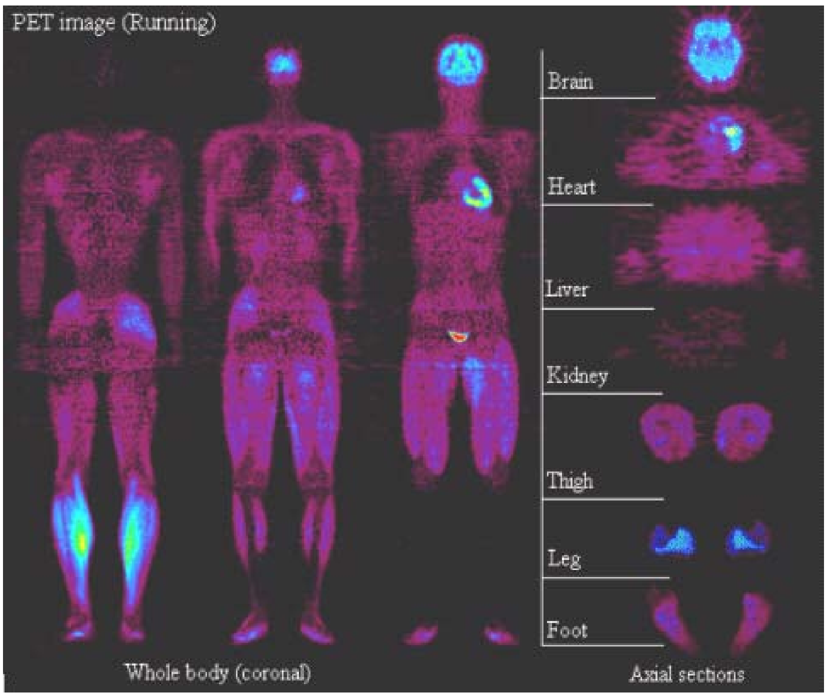

Figure 3. Whole body coronal PET image from a typical running subject with representative axial images on the right panel are illustrated. Leg/foot and thigh showed increases of ^{18}FDG uptake.

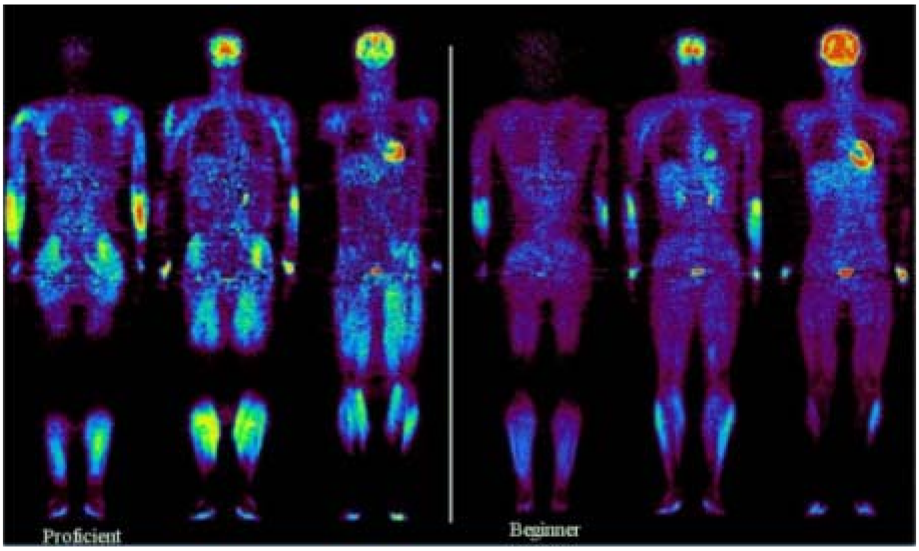

Figure 4. ^{18}FDG uptake was increased in the skeletal muscles of leg, forearm and hands in the proficient golfer.

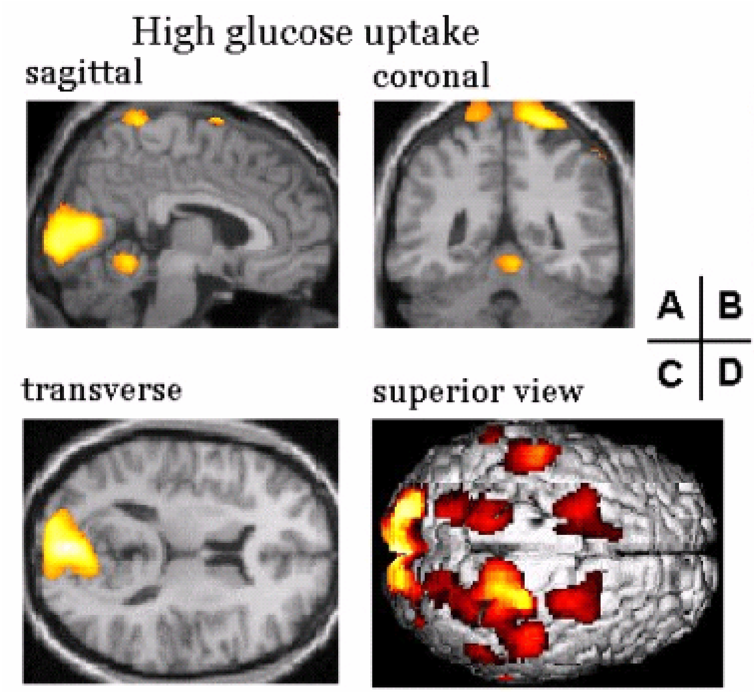

Figure 5. Regional brain ^{18}FDG uptake was statistically compared between running and control subjects, seven in each group, using a statistical parametric mapping (SPM96) software adopting a $p<0.001$ threshold. Significant activation by running was found in the posterior parietal, occipital, cortices and cerebellar vermis. The activated areas are shown over the SPM MRI Template in the sagittal (A), coronal (B), transverse (C) planes, and on rendering (D) (Tashiro et al; 99).