Changes in muscle activity after performing the FIFA 11+ programme part 2 for 4?weeks

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Authors:

Yasushi Takata[1], Junsuke Nakase[1], Anri Inaki[2], Takafumi Mochizuki[3], Hitoaki Numata[1], Takeshi Oshima[1], Seigo Kinuya[2], Hiroyuki Tsuchiya[1]

[1]*Department of Orthopaedic Surgery, Graduate School of Medical Science Kanazawa University, 13-1 Takaramachi, Kanazawa 920-0934, Japan*

[2]*Department of Nuclear Medicine/Biotracer Medicine, Graduate School of Medical Science Kanazawa University, 13-1 Takaramachi, Kanazawa 920-0934, Japan*

[3]*Kanazawa Advanced Medical Center, 13-1 Takaramachi, Kanazawa 920-0934, Japan*

Corresponding author:

Junsuke Nakase

13-1 Takaramachi, Kanazawa 920-0934, Japan

Tel: +81-76-265-2374

Fax: +81-76-234-4261

E-mail: nakase1007@yahoo.co.jp

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Abstract

Changes in muscle activity were evaluated by positron emission tomography-computed tomography (PET-CT) after performing part 2 of the Fédération Internationale de Football Association's 11+ program (11+) for 4 weeks. Eleven males performed part 2 of the 11+ for 20 min before and after 37 MBq of ^{18}F-fluorodeoxyglucose (FDG**)** was injected intravenously. PET-CT images were obtained 50 min after FDG injection. The subjects were then instructed to perform part 2 of the 11+ 3 times per week for 4 consecutive weeks, after which another set of PET-CT images was obtained following the same procedure. Regions of interest were defined within 30 muscles. The standardized uptake value (SUV) of FDG by muscle tissue per unit volume was calculated, and FDG accumulation was compared between pre and post-training PET-CT results. Performing part 2 of the 11+ for 4 weeks increased mean SUV in the sartorius, semimembranosus, biceps femoris, abductor hallucis, and flexor hallucis brevis muscles ($P<0.05$). In conclusion, routinely performing part 2 of the 11+ for 4 weeks increased glucose uptake related to muscle activity in the hamstrings and hallux muscles. We speculate that there is some possibility of this change of muscle activity contributing to a decrease in sports-related injuries.

Keywords: FIFA 11+; Fluorodeoxyglucose, F18; Positron-emission tomography; sports injury prevention

Introduction

Many top athletes incur sports injuries during athletic participation. Prevention of sports injuries is thus a key concern in sports medicine. Most sports injury prevention training programs include plyometric, balance, and agility training. Studies have been conducted on the effects of such training programs in various athletes. Although the subjects and details of the training programs differed, the results generally demonstrated a decreased incidence of sports injuries regardless of sport activity level, sex, and age (Rössler et al., 2014; Olsen, Myklebust, Engebretsen, Holme, & Bahr, 2005; Myer, Ford, Brent, & Hewett, 2006).

The Fédération Internationale de Football Association (FIFA) Medical and Assessment Research Centre (F-MARC) has recently developed, in cooperation with the Oslo Sports Trauma Research Centre and the Santa Monica Orthopaedic and Sports Medicine Research Foundation, the 11+, an advanced version of the previous training program called “The 11” (www. F-marc.com/11plus). A cluster-randomized controlled trial has shown that the 11+ is effective in reducing injuries by 30% to 50% in teams practicing the program at least twice per week (Silvers-Granelli et al., 2015; Hammes et al., 2015; Soligard et al., 2008). The entire 11+ consists of 3 parts: a running exercise (part 1); 6 exercises with 3 levels each of increasing difficulty that develop strength, balance, muscle control, and core stability (part 2); and advanced running exercises (part 3). As opposed to the parts 1 and 3 of the 11+, which are focusing on running exercise, the part 2 of the 11+ focuses on core and leg strength, balance, and plyometrics. In a previous study, whole-body positron emission tomography-computed tomography (PET-CT) was used to examine where glucose uptake occurs in the skeletal muscles after a single performance of part 2 of the 11+. This previous study was undertaken to clarify the activation of the “core muscles” in the deep part of the trunk by performing part 2 of the 11+. Contrary to expectations, activity was observed in the hip abductor and abdominal rectus muscles and no significant acute change in the “core muscles” when part 2 of the 11+ was performed (Nakase et al., 2013).

Electromyogram had been used to observe the activity of superficial muscles; however

surface and needle electromyogram are limited in their ability to observe the activity of the skeletal muscle located in the trunk and the deep parts of the limbs. Furthermore, their results are often shown in terms of relative intensity of the maximum muscle strength, and the activity of each muscle could not be directly compared. Therefore the study on current sports injury prevention training progresses with the most basic part being unknown. We think that it is only at present PET that can observe effect by the training of on skeletal muscles which is present in the trunk and deep parts of, the limbs. Because the PET is the device which can observe the activity of the biological tissue noninvasively, and permits a three-dimensional image construction is possible, it is clinically used for a cancer examination, and the investigation of brain function, and, blood flow or metabolic measurement of the heart. As glucose is one of the energy sources of skeletal muscle, the use of 18F-fluorodeoxyglucose (FDG) permits the observation of glucose metabolism throughout the body's skeletal muscle during exercise confirmed the reliability as the index that the carbohydrate metabolism measured by FDG-PET shows activity intensity (Ohnuma, Sugita, Kokubun, Yamaguchi, & Rikimaru, 2006) and is highly correlated with muscle activity (Fujimoto et al., 2003; Kemppainen et al., 2002). Additionally, to our knowledge it is the only method that can compare the activity between muscles for an index to capture cumulative muscle activity, which has been an ongoing problem in current sports injury prevention training.

In recent years, various effects resulting from routinely performing the entire 11+ have been reported, including a reduction in the incidence of sports injuries. Impellizzeri et al. (2013) reported that neuromuscular control and strength of muscle flexors improved in amateur soccer players when part 2 of the 11+ was performed 3 times per week for 9 weeks. Daneshjoo et al. reported that static and dynamic balance improved when the entire 11+ was performed for 2 months (Daneshjoo, Mokhtar, Rahnama, & Yusof, 2012). Performing a single session of part 2 of the 11+ was previously shown to activate the hip abductor and abdominal rectus muscles (Nakase et al., 2013). However, it is unknown how skeletal muscle metabolism changes in response to activity associated with routinely performing part 2 of the 11+. This study investigated the changes in muscle activity after performing part 2 of the 11+ for 4 weeks.

Methods

Eleven healthy males (5 amateur and 6 recreation level football players, mean ± standard deviation [SD] age, 29.0±4.2 years old; height, 173±6 cm; weight, 68±5 kg) were included in this study. Based on a previous study, we assumed there would be a 1.5-fold increase of muscle glucose uptake after continued performance of part 2 of the 11+ for 4 weeks. To determine the sample size, we set an α value 0.05, power 0.95 and effect size of 1.20 and calculated a sample size of 11. None of the subjects was taking any medications, and based on their medical history and physical examination, all were considered healthy. The purpose and potential risks of this study were explained to each subject, who provided written informed consent to participate. The study design was approved by the ethics committee of Kanazawa University Hospital and Kanazawa Advanced Medical Center.

All subjects refrained from eating and drinking for at least 6 hours before FDG-PET assessment, and strenuous physical activity was avoided for at least 1 day before the experiment. The plasma glucose level of each subject was confirmed to be in the normal range (70–100mg/dl), subjects then performed part 2 of the 11+ for 20 min, and 37 MBq of FDG was injected intravenously. Part 2 of the 11+ was performed again for 20 min, after which subjects rested for 25 min in a sitting position. According to a previous study, the influence of the exercise is well reflected by performing the 11+ twice (before and after FDG injection) (Nakase et al., 2013). Subjects were verbally encouraged to generate maximal force during exercise. PET-CT images were obtained 50 min after FDG injection. Subjects were subsequently placed in a supine position on a scanning bed that facilitated longitudinal placement into the gantry of the PET-CT system (Discovery PET/CT 690; GE Healthcare, Milwaukee, WI, USA). Scanning was performed with a 60-cm axial field of view and a transaxial resolution of 6.4 mm (full-width at half-maximum at the centre of the field of view without a scattering medium). Before emission scanning, an unenhanced low resolution CT scan was performed for attenuation correction and anatomical orientation. Emission scanning was performed in 3-dimensional mode 50 min after FDG administration. The

total emission time ranged from 39 to 42 minutes. Images were reconstructed using a 3-dimensional ordered-subset expectation maximization algorithm with 2 iterations and 16 subsets. After reconstruction, a 6.4-mm full-width at half-maximum Gaussian post-filter was applied.

After the first PET-CT examination, subjects were asked to perform 1 set of part 2 of the 11+ for 15 minutes, 3 times per week for 4 consecutive weeks from February to May 2013. We instructed subjects in how to perform part 2 of the 11+ according to the FIFA 11+ manual (the number of repetitions, number of sets/duration, and rest duration of each exercise) only on the day in which the pre-training PET-CT was obtained, and they performed part 2 of the 11+ on an individual basis with their usual sports activity for 4 consecutive weeks. As part 2 of the 11+ consists of 3 different levels of difficulty, we asked subjects to perform at a higher difficulty level when an exercise could be performed without difficulty for the specified duration and number of repetitions. Following 4 consecutive weeks, PET-CT images were acquired in the same manner described previously.

One experienced nuclear medicine specialist (A.I.) defined all regions of interest using plain CT images. Regions of interest were manually segmented in 30 skeletal muscles located in 5 areas of the body as follows: (1) trunk, at the inferior border of the fourth lumbar vertebrae for the abdominal rectus as well as for the abdominal external oblique, abdominal internal oblique, transverse abdominal, greater psoas, lumbar quadrate, and erector spinae muscles; (2) pelvis, at the superior border level of the acetabular roof for the gluteus maximus as well as at the gluteus medius, gluteus minimus, and piriformis muscles; (3) thigh, at the centre of the inferior border of the femoral lesser trochanter, the femoral condyle for the quadriceps femoris muscle, the sartorius, gracilis, semimembranosus, semitendinosus, and biceps femoris muscles, and the adductor muscle complex; (4) lower leg, at the centre of the tibia for the anterior tibial muscle as well as the long flexor muscles of the toes, the great toe, the posterior tibia, triceps surae, and peroneus muscles; and (5) foot, at the centre of the navicular for the abductor hallucis muscle, the centre of the metatarsal bone for the interosseous muscles, and the plantar quadrate, flexor digitorum brevis, abductor digiti minimi, and flexor hallucis brevis muscles.

The standardized uptake value (SUV) was calculated by overlapping of the defined Regions of interest and fusion images. Large vessels were avoided when the muscle areas were outlined. The SUV was calculated to quantitatively examine the FDG uptake of the muscle tissue per unit volume according to the equation: SUV = {mean Regions of interest count (counts per second/pixel) × calibration factor (counts per second/Bq)}/{injected dose (Bq)/body weight (g)}. Regions of interests were defined for the right and left sides of the aforementioned skeletal muscles. The mean SUV was calculated using the following equation: mean SUV = ([left mean SUV × left muscle area] + [right mean SUV × right muscle area])/(left muscle area + right muscle area). FDG accumulation was compared between the first and second PET-CT examinations.

All data are presented as means and standard deviations. A Shapiro-Wilk test was performed to ensure a normal distribution. Differences in values were analyzed by paired t-test. SPSS for Windows ver. 19.0 (SPSS Inc., Chicago, IL, USA) was used for the analysis. The minimum significance level was set at $P < 0.05$.

Results

Figures 1 and 2 illustrate typical whole-body PET images acquired from the first and second PET-CT scan, respectively. Tables I and II show the mean SUVs before and after training and the 95% confidence interval, effect size and *P* value of all the muscles. The mean SUVs before and after training were normally distributed, allowing for use of the paired t-test.

The mean SUVs of the “core muscles” including transverse abdominal and greater psoas showed no statistical difference between pre- and post-training results. The mean SUV increased significantly in the sartorius, semimembranosus, biceps femoris, abductor hallucis, and flexor hallucis brevis muscles after continued performance of part 2 of the 11+ for 4 weeks. We observed a weak (but not statistically significant) tendency toward reduction of muscle glucose uptake in the gluteus maximus, gluteus minimus, and quadriceps femoris after 4 weeks of training. Additionally, the long flexor muscle of the toes, posterior tibial, long flexor muscle of the great toe, and triceps surae demonstrated increased (but not statistically significant) glucose uptake after 4 weeks of

training. There was no significant difference in the glucose uptake of the trunk muscles after performing part 2 of the 11+ for 4 weeks.

Discussion

The results of this study indicate that performing part 2 of the 11+ for 4 weeks changed glucose uptake in various skeletal muscles throughout the body owing to their activity. Increased glucose uptake occurred in the sartorius, semimembranosus, biceps femoris, and hallux muscles. We speculate that this increase in glucose uptake reflects muscle activity and activated muscles because continued performance of part 2 of the 11+ for 4 weeks is one of the key mechanisms explaining the association of the 11+ with a decrease in sports-related injuries.

Muscle activity during exercise has been examined previously by PET with FDG (Fujimoto, Itoh, Kumano, Tashiro, & Ido, 1996; Ohnuma et al., 2006; Bojsen-Møller et al., 2006). FDG taken up by muscle cells is not metabolized and remains in the cells as FDG-6-phosphate after phosphorylation. Thus, FDG accumulation in the muscle can be used as a parameter of glucose uptake by the muscle and is an indicator of muscle activity. Fujimoto et al. (1996) and Tashiro et al. (1999) used PET to evaluate muscle activity during running in the first PET-based studies on muscle activity during exercise. Other studies have investigated tissue glucose uptake with PET during tasks such as isometric muscle contractions (Bojsen-Møller, Kalliokoski, Seppanen, Kjaer, & Magnusson, 2006) and dynamic strength exercises (Pappas, Olcott, Drace, 2001) as well as during more complex tasks requiring endurance such as walking (Oi et al., 2003), running (Tai, Liu, Kuo, Hsu, & Chen, 2010), and double poling (Bojsen-Møller et al., 2010). Bojsen-Møller et al. (2010) proposed that PET imaging might be a promising adjunct modality or alternative compared to more traditional methods for investigating muscle activity during complex human movements. These studies showed that glucose uptake by skeletal muscle during exercise intensity up to 55% maximal oxygen consumption closely reflected muscle activity as assessed by PET. In a previous study, this characteristic of FDG-PET was used to examine the skeletal muscle activity when part 2 of the 11+ was performed once (Nakase et al., 2013).

In the present study, we focused on the changes in skeletal muscle activity to assess the effect of routine performance of part 2 of the 11+. Reichkendler et al. (2013) reported that the increase in skeletal muscle glucose uptake rate paralleled the increase in whole-body glucose uptake as well as the increase in skeletal muscle glucose transporter-4 (GLUT4) expression in healthy sedentary men who performed daily aerobic exercise for 11 weeks. The fact that exercise increases glucose uptake and utilization through increasing GLUT4 in the skeletal muscle is well known (Richter, & Hargreaves, 2013). An increase in skeletal muscle GLUT4 levels is a fundamental adaptation to exercise training (Reichkendler et al., 2013). By comparing the FDG accumulation of each muscle before and after the training period, we could identify activated muscles and fundamental adaptation to the exercise training.

When the changes in glucose uptake were examined, FDG accumulation was increased in the sartorius, semimembranosus, and biceps femoris muscles. This finding indicates that when part 2 of the 11+ is routinely performed, these muscles adapt to the training method, and their metabolism increases. Training of the sartorius, semimembranosus, and biceps femoris muscles occurred because part 2 of the 11+ exercises the group of muscles known collectively as the hamstrings. The hamstrings are most commonly affected by injuries in professional football with a reported prevalence of 37% of all muscle injuries in a large prospectivecohort, accounting for 12% of all injuries (Ekstrand, Hagglund, & Waldén, 2011). Thus, activation of the hamstrings by performing part 2 of the 11+ is one of the key mechanisms explaining the association of the 11+ with a decrease in sports-related injuries.

Some studies have shown that routinely performing the entire 11+ increases knee flexor strength (Impellizzeri et al., 2013; Daneshjoo, Mokhtar, Rahnama, & Yusof, 2013; Daneshjoo, Mokhtar, Rahnama, & Yusof, 2012). However, this finding is thought to reflect the effects on the sartorius, semimembranosus, and biceps femoris muscles. Interestingly, this study showed no significant change in glucose uptake owing to muscle activity in the semitendinosus and gracilis muscles among other knee flexors. However, some subjects in the present study demonstrated increased glucose uptake in the semitendinosus and gracilis muscles upon performing part 2 of the

11+ for 4 weeks. Mendiguchia et al. reported a difference in the changes among hamstring muscles before and after Nordic hamstring exercise detected using MRI measurements (Mendiguchia et al., 2013). By dividing each hamstring muscle into 15 sections, they found that the biceps femoris short head demonstrated a proximal damage pattern (section 10) compared with distal (sections 12 and 14) and nondominant-limb biceps femoris long head (section 10) and semitendinosus (sections 8 and 10), which demonstrated a distal recruitment pattern during Nordic hamstring exercise. This finding suggests that the damage patterns of each hamstring muscle are nonuniform. In the present study, FDG uptake was measured at an arbitrary site on the target muscle, and thus, it may not reflect the uptake of the entire muscle. Therefore, we may not have found differences in some hamstring muscles because measurements were not performed at the appropriate site. It may also be possible that the muscles activated to perform part 2 of the 11+ within hamstrings vary across individuals.

One of the determining factors of knee injuries is the muscle balance between the hamstrings and quadriceps muscles (Morgan & Oberlander, 2001; Rahnama, Lees, & Bambaecichi, 2005). Some studies have shown that knee flexor strength is increased by the entire 11+ (Impellizzeri et al., 2013; Daneshjoo et al., 2012; Brito et al., 2010). Although much is known about these factors, the results of our study suggest that the sartorius, semimembranosus, and biceps femoris muscles might have a major effect on increased knee flexor strength. Part 2 of the 11+ is thought to be a reasonable training regimen for knee flexor strength in order to decrease sports-related injuries.

There have been no reports on the incidence of muscle injury in the foot among football players, but as reported in previous studies (Impellizzeri et al, 2013; Daneshjoo et al., 2012), the intrinsic muscles of the foot are thought to greatly improve balance. In particular, studies have reported that impaired hallux muscle strength was related to increased postural sway (Nix, Vicenzino, & Smith, 2012; Sadra et al., 2013). Kelly, Kuitunen, Racinais, and Cresswell (2012) reported that intrinsic foot muscles such as the abductor hallucis are particularly important in controlling mediolateral sway. Hallux plantar flexion weakness is a risk factor for falls in older people (Menz, Morris, & Lord, 2006; Mickle, Munro, Lord, Menz, & Steele, 2009). Hashimoto et

al. reported that intrinsic muscle strength training significantly improved muscle strength scores and movement performance (Hashimoto, & Sakuraba, 2014). In this study, the changes in glucose uptake were examined in the abductor hallucis and flexor hallucis brevis muscles. Training the hallux muscles by part 2 of the 11+ aids in good balance and movement performance, which may also play a role in preventing injury.

We undertook this study to clarify the activation of the “core muscles” in the deep part of the trunk by performing part 2 of the 11+. Impellizzeri et al. reported a statistically significant improvement in core stability in subjects who performed part 2 of the 11+ compared to controls. The trunk stabilization exercises included in part 2 of the 11+ have been claimed to activate the deep abdominal muscles such as the transversus abdominis (Bjerkefors, Ekblom, Josefsson, & Thorstensson, 2010). Contrary to our expectation, we found no significant difference in the glucose uptake of the trunk muscles after performing part 2 of the 11+ for 4 weeks. We speculate that the duration and intensity of the exercise may be one reason for this result. Further study of the glucose uptake of these muscles in association with injury prevention is planned to assess the effects of performing part 2 of the 11+ over a longer period of time.

We also found a slight (but not significant) tendency for decreased glucose uptake in the gluteus maximus, gluteus minimus, and quadriceps femoris after 4 weeks of training. These muscles demonstrated large SD values, indicating that there may be individual differences in the effect on these muscles. It is also possible that the 11+ training strength was insufficient to aggravate the activity of the quadriceps femoris muscle or gluteus muscles. Since quadriceps femoris muscle injury is a frequent muscle injury among footballers, who require hyperactivity of these muscles, the review of this program may be necessary. Additionally, the long flexor muscle of the toes, posterior tibial, long flexor muscle of the great toe, and triceps surae demonstrated increased (but not statistically significantly) glucose uptake after 4 weeks of training. The effect size in these muscles was small to medium (0.435–0.680). The effect of training with part 2 of the 11+ for 4 weeks may not have been sufficient to generate significant differences.

This research has some limitations. First, the duration of training in this study was only 4

weeks, which may be considered relatively short. In general, approximately 6 to 8 weeks of training is thought to be necessary to stimulate muscle hypertrophy. In a review of studies reporting the acute or chronic effects of the FIFA 11+ on performance and physiological measures in football players, the shortest intervention periods were 9–10 weeks (Barengo et al., 2014). However, skeletal muscle changes occur after 2 weeks of training (Staron et al., 1994), and our aim was to investigate the effectiveness of the 11+ over a short term period. In this study, we found significant differences in the mean SUV of the hamstrings and hallux muscles after performing the 11+ part 2 for 4 weeks. Thus, the 11+ training may be effective in changing muscle activity over shorter-term training periods. However, we also remain interested in more long-term effects, and further studies are needed to examine long-term changes in skeletal muscle activity. A second limitation of this study is that the FDG-PET method reflects only muscle glucose uptake. Other substrates such as free fatty acids, muscle glycogen, and lactate are metabolized in active muscle cells. Nonetheless, glucose oxidation increases with exercise intensity, and glucose uptake increases, to some extent, in proportion to glycogen utilization when exercise intensity increases (Staron et al., 1994). A third limitation of this study was the method used to define Regions of interest. As FDG uptake was measured at an arbitrary site on the target muscle, it did not reflect the uptake of the entire muscle. It will be necessary to further investigate this issue in future studies. Fourth, the sample size was limited because of the concern for radiation exposure. The effect size of mean SUV of the biceps femoris was 1.393, which was greater than the level of 1.2 that we expected and on which we based the calculation of sample size before the investigation. Thus, the sample size (n=11) of this investigation was appropriate. Despite these limitations, no other study has used PET-CT to examine the effect of routinely performing part 2 of the 11+. Thus, we believe our study is novel and significant in this respect.

Conclusion

The results of this study indicate that performing part 2 of the 11+ for 4 weeks increases glucose uptake via muscle activity. Contrary to expectations, the mean SUVs of the “core muscles”

including transverse abdominal and greater psoas showed no statistical difference between pre- and post-training results. Increased uptake occurred in the sartorius, semimembranosus, and biceps femoris muscles as well as in the hallux muscles of the feet. We speculate that there is some possibility of this change in muscle activity contributing to the decrease in sports-related injuries.

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Table I. Muscle SUVs during pre- and post-training in the trunk through the thigh region

Body area	**Muscles**	**Pre-training SUV**	**Post-training SUV**	***Confidence interval***	***Effect size***	***P* value**
Trunk	Abdominal rectus	0.76±0.16	0.79±0.28	[-0.15, 0.22]	0.131	0.698
	Abdominal external oblique	0.59±0.03	0.57±0.11	[-0.04, 0.01]	0.248	0.223
	Abdominal internal oblique	0.61±0.12	0.58±0.06	[-0.11, 0.05]	0.316	0.438
	Transverse abdominal	0.58±0.11	0.58±0.12	[-0.05, 0.06]	0	0.886
	Greater psoas	0.74±0.11	0.73±0.05	[-0.07, 0.06]	0.117	0.890
	Lumbar quadrate	0.58±0.07	0.57±0.04	[-0.07, 0.04]	0.175	0.578
	Erector spinae	0.67±0.07	0.69±0.06	[-0.03, 0.08]	0.306	0.316
Pelvis	Gluteus maximus	1.14±0.62	0.91±0.26	[-0.57, 0.11]	0.483	0.168
	Gluteus medius	2.24±0.76	2.30±0.77	[-0.77, 0.89]	0.078	0.872
	Gluteus minimus	4.61±2.31	4.40±1.15	[-1.70, 1.28]	0.115	0.757
	Piriformis	2.87±1.78	2.78±1.27	[-1.01, 0.83]	0.058	0.821
Thigh	Quadriceps femoris	0.95±0.44	0.84±0.28	[-0.21, 0.17]	0.298	0.214
	Sartorius[a]	**0.54±0.09**	**0.80±0.37**	**[0.01, 0.50]**	**0.965**	**0.041**
	Gracilis	0.77±0.27	0.77±0.35	[-0.31, 0.31]	0	0.996
	Semimembranosus[a]	**0.56±0.05**	**0.80±0.30**	**[0.03, 0.44]**	**1.115**	**0.028**
	Semitendinosus	0.77±0.31	0.76±0.28	[-0.27, 0.27]	0.033	0.986
	Biceps femoris[a]	**0.53±0.06**	**0.88±0.35**	**[0.11, 0.59]**	**1.393**	**0.008**
	Adductor complex	0.66±0.08	0.62±0.09	[-0.12, 0.03]	0.469	0.223

[a]Data shown in bold font indicate that the mean SUV was significantly increased ($P < 0.05$). SUV, standardized uptake value

Table II. Muscle SUVs during pre- and post-training in the lower leg and foot regions

Body area	**Muscles**	**Pre-training SUV**	**Post-training SUV**	***Confidence interval***	***Effect size***	***P* value**
Lower leg	Anterior tibial	0.99±0.42	1.04±0.32	[-0.30, 0.38]	0.133	0.793
	Long flexor muscle of toes	0.86±0.24	1.03±0.30	[-0.08, 0.42]	0.625	0.166
	Posterior tibial	1.12±0.40	1.39±0.78	[-0.25, 0.78]	0.435	0.274
	Long flexor muscle of great toe	1.41±0.62	1.79±0.83	[-0.17, 0.92]	0.518	0.160
	Peroneus	1.02±0.43	1.10±0.44	[-0.37, 0.53]	0.183	0.704
	Triceps surae	1.01±0.34	1.27±0.42	[-0.11, 0.64]	0.680	0.142
Foot	**Abductor hallucis**[a]	**1.19±0.55**	**1.58±0.92**	**[0.03, 0.75]**	**0.514**	**0.036**
	Plantar quadrate	0.99±0.27	1.03±0.25	[-0.13, 0.23]	0.153	0.567
	Flexor digitorum brevis	1.17±0.54	1.21±0.53	[-0.31, 0.38]	0.074	0.841
	Abductor digiti minimi	0.97±0.56	1.10±0.57	[-0.21, 0.47]	0.230	0.411
	Flexor hallucis brevis[a]	**1.63±0.78**	**2.42±1.47**	**[0.02, 1.57]**	**0.671**	**0.044**
	Interosseous	1.50±0.71	1.45±0.58	[-0.37, 0.26]	0.077	0.700

[a]Data shown in bold font indicate that the mean SUV was significantly increased ($P < 0.05$).

SUV, standardized uptake value

Figure Legends

Figure 1. Representative whole-body positron emission tomography images acquired before routine performance of the 11+.

Figure 2. Representative whole-body positron emission tomography images acquired after routinely performing part 2 of the 11+ for 4 weeks.

Figure.1

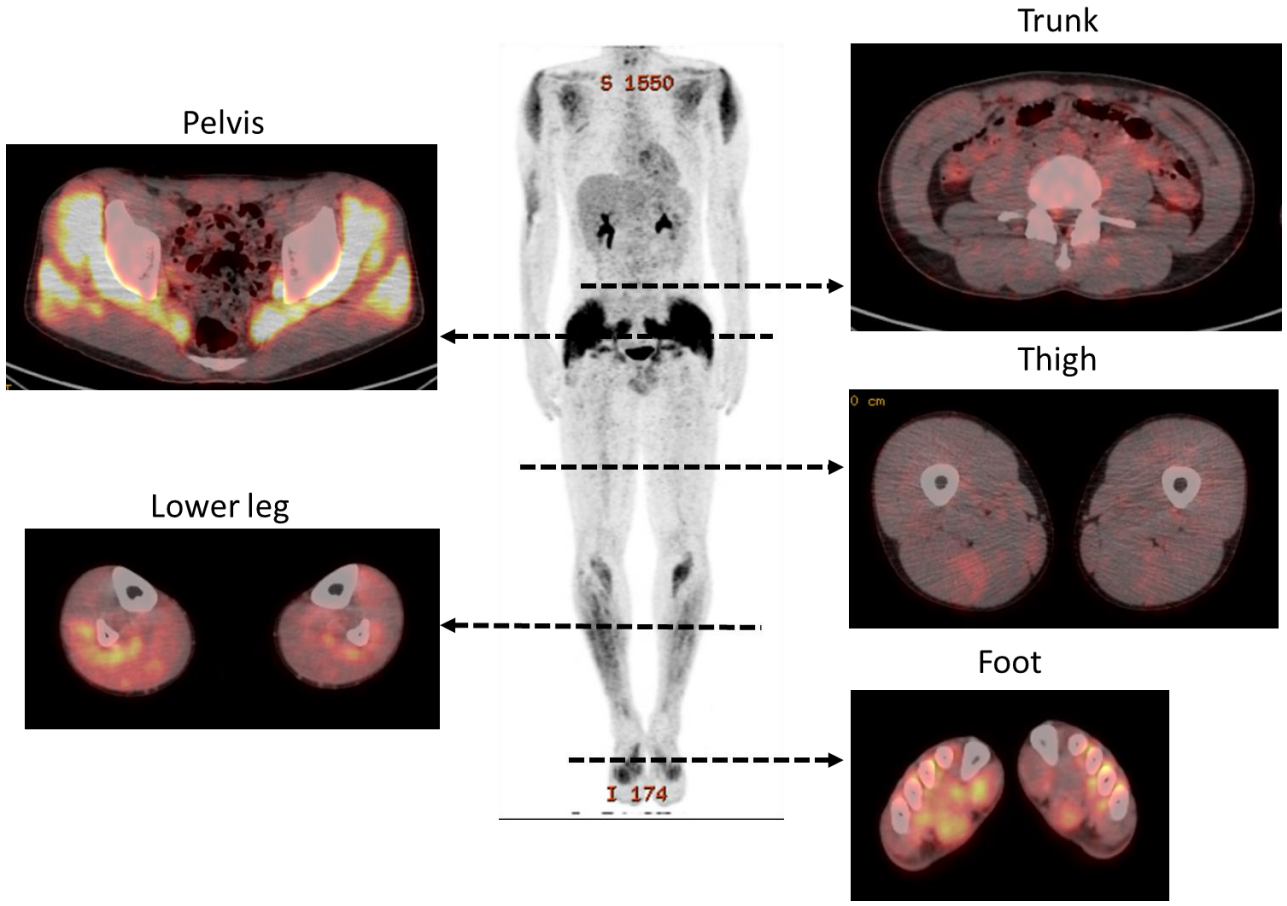

Figure.2