Profiles of Trunk and Thigh Muscularity in Youth and Professional Soccer Players

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Abstract

Kubo, T, Muramatsu, M, Hoshikawa, Y, and Kanehisa, H. Profiles of trunk and thigh muscularity in youth and professional soccer players. *J Strength Cond Res* 24(6): 1472–1479, 2010—The present study aimed to examine the influence of lateral dominance for ball kicking on the cross-sectional areas (CSAs) of thigh and trunk muscles in Japanese elite youth and professional soccer players, and to clarify the difference between the 2 groups in the muscle CSAs of the 2 body segments in relation to that in lean body mass (LBM). The CSAs of 4 (rectus abdominis, oblique, psoas major, and erector spinae) and 3 (quadriceps femoris, hamstrings, and adductors) muscle groups located in the trunk and thigh, respectively, were determined in 18 youth players (16.8 $\pm$ 0.6 years) and 17 professional players (23.7 $\pm$ 3.1 years) using magnetic resonance imaging. In youth and professional players, no significant effect of lateral dominance was found in the CSA of any muscle group. In all muscle groups except for the erector spinae, the CSAs were significantly greater in the professional players than in the youth players. The CSA of every muscle group was significantly correlated to the two-thirds power of LBM ($LBM^{2/3}$). In terms of the ratio of CSA to $LBM^{2/3}$, only the psoas major was significantly greater in the professionals. In conclusion, Japanese youth and professional soccer players did not exhibit bilateral asymmetry in the CSAs of thigh and trunk muscles, and the professional players had more developed psoas major muscle as compared with youth players even when matched for whole-body lean tissue mass. The current results suggest that for soccer players with bilateral asymmetry in the muscularity of the thighs and trunk, personalized strength programs for developing symmetry are recommended, and exercises involving hip flexion should be incorporated progressively into individual strength and conditioning programs.

Key Words lateral dominance, CSA, lean body mass, bilateral asymmetry, age-related difference

Introduction

Soccer requires a unipedal posture to perform different technical movements such as shooting and passing (28). In addition, the game frequently involves physical contact with other players including intentional pushing, side-to-side cutting, pivoting, or sudden starts and stops (12). Under these conditions, the players must maintain balance as they run at high speed, change direction rapidly, and powerfully kick the ball to pass or shoot (12). Notably, they are often required to support their body mass with 1 leg when kicking a ball (25). Consequently, soccer players have a superior ability to maintain a stable 1-legged stance, as compared with basketball players, swimmers, and untrained individuals (25). Furthermore, high-level professional soccer players demonstrate better postural control than regional-level soccer players (27). For soccer players, therefore, strengthening the trunk muscles is assumed to be essential for improving competitive performance, because trunk muscles have a critical role in the maintenance of stability and balance when performing movements with the extremities (1), and a strong and stable trunk provides a solid foundation for the torques generated by the limbs (4,20). However, little information on the profiles of the trunk muscularity of soccer players is available.

Most soccer players have a preferred foot for kicking and receiving the ball (30). In relation to lateral dominance, Masuda et al. (24) failed to find a significant difference between the preferred and nonpreferred sides in the cross-sectional area (CSA) of the iliopsoas muscle in university soccer players, despite small but significant differences between the 2 sides in the CSAs of hamstrings and adductor muscles in specific portions of the thigh. On the other hand, Hides et al. (13) reported that the CSA of the psoas muscle was significantly greater ipsilateral to the kicking leg in elite Australian Football League players. With regard to asymmetry in the CSA of a specific muscle group located in the trunk, we cannot explain the discrepancy between the results

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of the 2 studies. However, a prior study using an electromyographic approach on soccer place kicks provided evidence that the iliopsoas muscle was active during the entire kicking motion, even in the period when the thigh was decelerating (10). Moreover, Wong et al. (34), who examined the profiles of plantar pressure during 4 movements: running at 3.3 $m \cdot s^{-1}$, sideward cutting, 45° cutting, and landing from a vertical jump, suggested a tendency of the preferred foot for higher motion force and of the nonpreferred foot for a greater role in body stabilization. These findings tempt us to assume that, in relation to footedness for kicking, professional players, who have participated in long-term soccer training, would show asymmetry, which is related to the preferred foot, in not only thigh but also in trunk muscularity. On the other hand, it has been suggested that a bilateral leg strength difference can be a factor inducing sport-related injuries (21,35). Training sessions for elite soccer players appear to have imposed a strength balance for the right and left body sides (36). Zakas (36) did not identify any influence of lateral dominance on knee extension and flexion strength in professional soccer players. In addition, even at a young age, well-trained soccer players show less effect of footedness on muscle strength (32). These findings contradict the assumption mentioned above. In any case, it is not clear whether elite soccer players exhibit thigh and trunk muscularity related to their lateral dominance for ball kicking.

Apart from the influence of lateral dominance on trunk muscularity, Peltonen et al. (29) found the CSAs of the psoas major and multifides plus erector spinae muscles, adjusted with body mass, to be significantly greater in adolescent female athletes (age range: 13.7 – 16.3 years) than in an age-matched nonathletic population. This report implies that chronic participation in sport training during adolescence can increase trunk muscularity beyond the level achieved by natural growth. On the other hand, Kubo et al. (22) observed that the CSAs of the rectus abdominis and psoas major muscles were significantly greater in senior than junior elite wrestlers. In their results, however, there were no significant differences between the 2 age groups in the CSAs of oblique, quadratus lumborrum, and erector spinae muscles. In addition, no significant difference was found between subelite senior and junior elite wrestlers in the CSA of any of the trunk muscles. Considering these findings, it may be assumed that, for an athletic population, the development of trunk muscularity from the junior to senior stage differs among muscles in relation to individual competitive levels. In the prior study cited above, however, the absolute CSA value was used to examine the age-related difference. It is known that the CSAs of limb muscles are highly correlated to lean body mass (LBM) (17). In addition, Lee et al. (23) indicated that muscle CSA obtained from a single slice at the L4–L5 level was a strong marker of whole body skeletal muscle mass. Therefore, even if the CSAs of muscle groups located in either the limbs or trunk differ between junior and senior athletes, there is a possibility that the difference will be attributed to that in the total mass of lean tissues in the whole body. No study has tried to clarify this point.

The main aims of the present study were to examine the influence of lateral dominance for kicking on the CSAs of thigh and trunk muscles in youth and professional soccer players, and to elucidate whether the muscle CSAs of 2 segments differ between the 2 groups even when the difference in lean body mass is taken into consideration.

Methods

Experimental Approach to the Problem

In the present study, to obtain data on muscle CSA for elite soccer players at the youth and senior levels, subjects were recruited from academy trainees (under 18) of one of the most successful soccer clubs in Japan, and from professionals playing in the first division of the Japan League. Lateral dominance was defined by players' reports with regard to the leg preferentially used for kicking and confirmed by an experimenter observing the subjects play during official games. Using magnetic resonance imaging, the CSAs of trunk muscles and thigh muscles of the preferred and nonpreferred legs were determined in youth and professional soccer players. A 2-way analysis of variance (ANOVA [side, muscle, and interaction]) with repeated measures was used to examine the effects of side (preferred side and nonpreferred side) on the CSA variables for each of the 2 groups. Furthermore, a symmetry index (34) was calculated. In addition to CSA measurements, LBM was also determined by an air-displacement plethysmograph technique to examine whether the difference in muscle CSA between the 2 groups can be related to that in LBM. Muscle CSA was expressed relative to the two-thirds power of LBM ($LBM^{2/3}$) to reduce the possible influence of the difference in total lean tissue mass between the youth and professional players on the comparison between the 2 groups in muscle CSA. A 2-way ANOVA (group, side, and interaction) was used to examine the effects of group (youth and professional players) on the CSA variables for each of the muscle groups.

Subjects

Eighteen academy trainees for soccer (age: 16.8 ± 0.6 years, body height: 1.72 ± 0.05 m, body mass: 66.4 ± 4.9 kg, mean ± *SD*) and 17 professional soccer players (age: 23.7 ± 3.1 years; body height; 1.78 ± 0.03 m; and body mass: 72.0 ± 4.1 kg) participated in the study. In the present study, the academy trainees were referred to as youth players. As compared with the youth players, the professional players were significantly taller ($p = 0.0005$) and heavier ($p = 0.0007$). All subjects were field players. The goalkeeper was not used. Sixteen of the youth players and 14 of the professional players were right footed. The remaining players were left footed. The testing was carried out in the second week of the preseason period. The professional players had more experience of high-resistance and ballistic training as part of their muscular fitness programs. As a part of the training schedule, however, preceding the testing, the professional players had performed at least 5 physical training sessions in addition to 10–12 soccer training sessions (each session lasting for 1.5–2 hours). The physical training program at the first week mainly consisted of aerobic running with combined anaerobic–aerobic exercises (middle distance running, and interval training). The youth players had been engaged in organized soccer training for at least 4 years and recently underwent physical and soccer training programs $3h \cdot d^{-1}$, $6\ d \cdot wk^{-1}$. The physical training for the youth players was mainly long-distance running, interval training, and circuit training using their own body masses as a load. All measurements were performed with intervals of more than 24 hours after the completion of a training session. Daily food intake was supervised by experts in nutrition. In addition, none of the subjects was dehydrated and dieting. This study was approved by the Office of Sports Photonics Laboratory, Hamamatsu Photonics KK, and was consistent with the institutional ethical requirements for human experimentation in accordance with the Declaration of Helsinki. The subjects and parents for youth players were fully informed of the study procedures, the experimental risks, and the purpose of the study, and gave their written informed consent before the investigation.

Measurements of Muscle Cross-Sectional Areas

Magnetic resonance images for both the thighs and trunk were obtained using a 0.2-T scanner (Signa Profile, General Electric Medical System, Milwaukee, WI, USA) with a body coil. The subjects were scanned while supine with the knee and hip joints extended and arms folded over the chest. For the thigh, longitudinal images were obtained to identify the greater trochanter and lower edge of the femur. Then, transverse scanning of T1-weighted images with a thickness of 10 mm was performed from the greater trochanter to the lower edge with a 10-mm gap (repetition time [TR] 350 ms, echo time [TE] 21 ms, matrix 256 × 256, field of view [FOV] 40 cm × 40 cm, 2 number of exitations [NEX]). Similar to the method of an earlier study (15,24), images located nearest to 30% (proximal knee joint), 50 and 70% of the femur's length, from the lower edge of the femur to the greater trochanter, were selected for the determination of thigh muscle CSAs on both sides. For the trunk, after longitudinal scans to identify the portion of the lumbar vertebrae, transverse scanning of T1-weighted images 10 mm thick was performed at the midlevel of L2–L3, L3–L4, and L4–L5 (TR 250 ms, TE 20 ms, matrix 224 × 128, FOV 30 × 30 cm, 4 NEX). For each transversal image, a single experienced observer, who did not know the subjects' characteristics, outlined the areas of

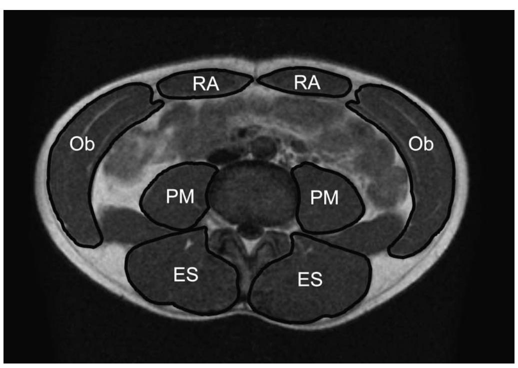

Figure 1. A transverse image of the trunk muscles obtained at the L3–L4 level. RA = rectus abdominis muscle; Ob = internal and external oblique muscles; PM = posoas major muscle; and ES = erector spinae muscle.

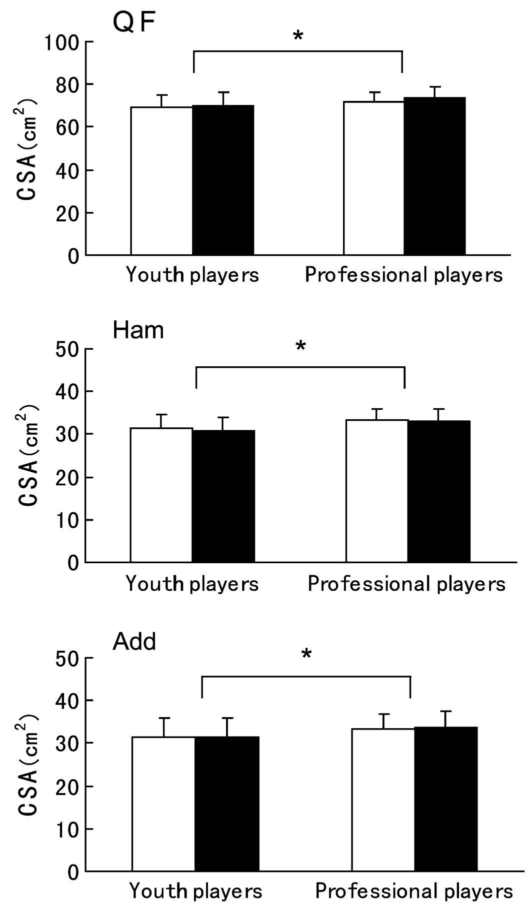

Figure 2. Comparisons of the cross-sectional areas (CSAs) of the 3 thigh muscles between the preferred and nonpreferred sides within the same group and between the youth ($n = 18$) and professional ($n = 17$) players within the same muscle. QF = quadriceps femnoris muscle; Ham = hamstring muscle; and Add = adductor muscle. Open and closed bars indicate the mean and *SD* for the preferred and nonpreferred sides, respectively. A 2-way ANOVA with repeated measures (3 muscle groups and 2 sides) indicated that the effect of side on muscle CSA was not significant, without significant interaction between muscle group and side. A 2-way ANOVA (2 groups and 2 sides) showed that the difference in CSA of every muscle group was significantly ($p < 0.05$) greater in the profession players than in the youth players.

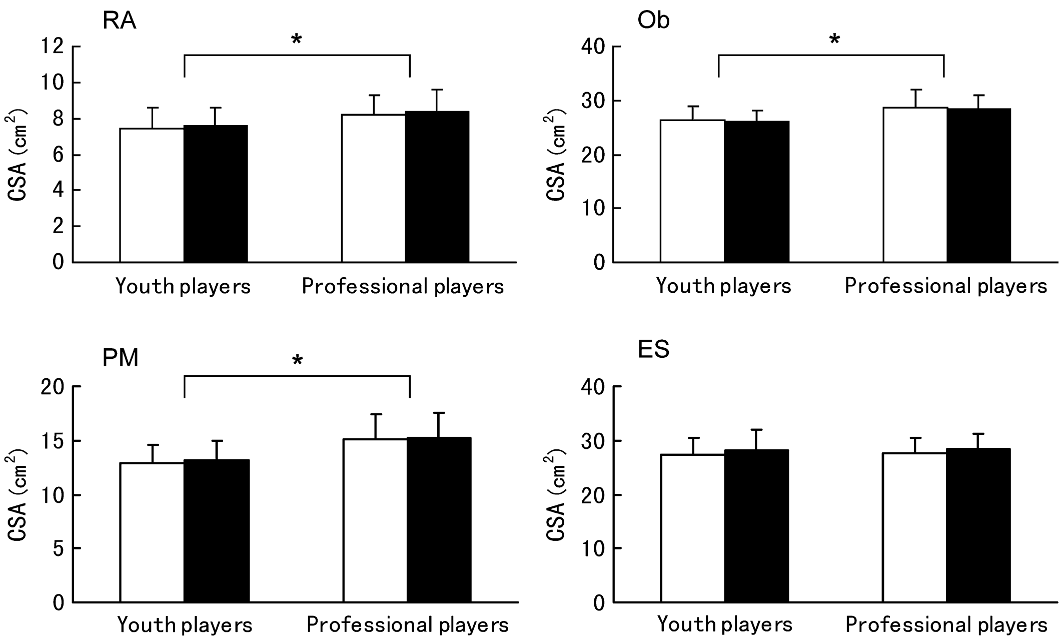

Figure 3. Comparisons of the cross-sectional areas (CSAs) of the 4 trunk muscles between the preferred and nonpreferred sides within the same group and between the youth ($n = 18$) and professional ($n = 17$) players within the same muscle. RA = rectus abdominis muscle; Ob = internal and external oblique muscles; PM = posoas major muscle; and ES = erector spinae muscle. Open and closed bars indicate the mean and *SD* for the preferred and nonpreferred sides, respectively. A 2-way ANOVA with repeated measures (3 muscle groups and 2 sides) indicated that the effect of side on muscle CSA was not significant, without significant interaction between muscle group and side. A 2-way ANOVA (2 groups and 2 sides) showed that the CSAs of all muscle groups except for ES were significantly ($p < 0.05$) greater in the professional players than in the youth players, without significant interaction between group and side.

muscle compartments on each side in the 2 body segments using a computer mouse. For the thigh, the areas of 3 muscle groups were analyzed: the quadriceps femoris (rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius), hamstrings (biceps femoris, semitendinosus, and semimembranosus), and adductors (adductor brevis, adductor longus, adductor magnus, and adductor minimus). For the trunk, the areas of 4 muscle groups were analyzed: the rectus abdominis, oblique (internal and external oblique), psoas major, and erector spinae muscles (Figure 1). Then, the CSAs were calculated by summing the pixels surrounded by the outlines. In a preliminary study of 16 young adult men, we examined the repeatability of the CSA measurements. The subjects participated in the CSA measurements on 2 separate days. A paired Student's *t*-test showed that there was no significant difference between the CSA values of the 2 measurements for any muscle. The mean of the coefficient of variation (%CV) and intracorrelation (ICC R) coefficient for the CSA measurement of each muscle were less than 2.0% and more than 0.977, respectively.

Measurements of Body Composition

Lean body mass was determined using an air-displacement plethysmograph (Bodpod; model 2000A, Life Measurement Instrument, Concord, CA, USA), with a protocol described previously (7). Briefly, the subjects wore only a tight-fitting swimsuit and swim cap during this measurement. After a body mass measurement to within an accuracy of 0.01 kg on a calibrated electronic scale, the subjects sat quietly in the fiberglass chamber with normal respiration while their body volume was determined. This measurement was performed 2 times, and the average volume was adopted for the LBM calculation. To determine thoracic gas volume, the subjects were connected to a breathing circuit within the system via a breathing tube, fitted with a nose clip and instructed to continue breathing normally. The subject's tidal breathing was recorded and displayed on a computer monitor, and after 2–3 cycles of a pattern, the airway was occluded. Then, the subjects were signaled by the investigator and puffed against the closed airway for about 3 seconds. Body density was calculated by dividing body mass (g) by body volume (cm^3). Once body density was known, the percentage of fat mass (%fat) was calculated using the equation developed by Brožek et al. (6): %fat (%) = (4.570/body density − 4.124) × 100. Lean body mass was obtained by subtracting fat mass from total body mass. The reliability of the body composition measurements was certified in a prior study (16).

Statistical Analyses

For every muscle group analyzed on each of the preferred and nonpreferred sides, the CSAs obtained from the 3 images for the thigh and trunk, respectively, were averaged for use as

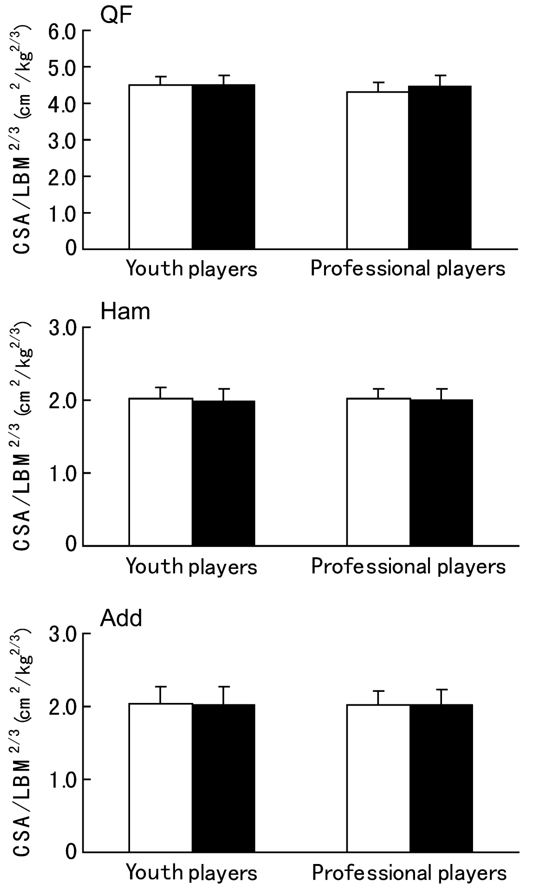

Figure 4. Comparisons of the ratios of cross-sectional area to two-thirds power of lean body mass (CSA/$LBM^{2/3}$) of the 3 thigh muscles between the preferred and nonpreferred sides within the same group and between the youth ($n = 18$) and professional ($n = 17$) players within the same muscle. QF = quadriceps femnoris muscle; Ham = hamstring muscle; and Add = adductor muscle. Open and closed bars indicate the mean and *SD* for the preferred and nonpreferred sides, respectively. A 2-way ANOVA with repeated measures (3 muscle groups and 2 sides) indicated that the effect of side on CSA/$LBM^{2/3}$ was not significant, without significant interaction between muscle group and side. A 2-way ANOVA (2 groups and 2 sides) showed that the group difference in the CSA/$LBM^{2/3}$ of each muscle group was not significant, without significant interaction between group and side.

a representative value. In addition, a symmetry index was calculated using the following formula (34): symmetry index (%) = {2 × (preferred side − nonpreferred side)/(preferred side + nonpreferred side)} × 100. It has been shown that body mass is a function of length to the third power in line with the dimensional relationship (3). In the present study, therefore, LBM was expressed as $LBM^{2/3}$ to convert it into the same dimension as the CSA measurements. Using this index, we conducted a linear regression analysis with CSA measurements. Moreover, muscle CSA was expressed relative to $LBM^{2/3}$ (CSA/$LBM^{2/3}$) to reduce the possible influence of the difference in body size between the professional and youth players on the comparison between the 2 age groups.

Descriptive data were presented as means and *SD*s. A simple linear regression analysis was used to calculate the coefficients of the correlation between $LBM^{2/3}$ and CSA and between the symmetry indices of the thigh and trunk muscles. A 2-way ANOVA with repeated measures and a Scheffe test was used to examine the effects of side (preferred side and nonpreferred side), muscle group (3 muscle groups for the thigh and 4 muscle groups for the trunk), and their interactions on the CSA variables for each of the youth and professional groups. Moreover, a 2-way ANOVA with a Scheffe test was used to examine the effects of group (youth and professional players), side (preferred side and nonpreferred side), and their interactions on the CSA variables for each of the muscle groups examined. Significance was set at $p \leq 0.05$.

Results

There was no significant difference in %fat between the youth (8.4 ± 3.3%) and professional (7.0 ± 1.8%) players. Lean body mass was significantly greater in the professional players (67.0 ± 4.2 kg) than in youth players (60.8 ± 4.3 kg), even relative to height: 37.7 ± 1.9 vs. 35.3 ± 2.2 $kg \cdot m^{-1}$.

Figures 2 and 3 indicate the descriptive data on the CSA measurements of the thigh and trunk, respectively. In both youth and professional players, the 2-way ANOVA with repeated measures showed that there was no significant effect of side on CSA for any muscle group of the thigh or trunk. The professional players showed significantly greater CSA values than the youth players in all muscle groups examined, with the exception of the erector spinae, whose CSAs were similar between the 2 groups on both sides of the body.

The average value of the symmetry index for each muscle group of the thigh and trunk ranged from −3.0 to 2.0% for the youth players and from −2.3 to 1.9% for the professional players, with no significant difference between the 2 groups. In addition, the symmetry index for each muscle group of the trunk was not significantly correlated to that of the thigh in regression analyses for the pooled data of youth and professional players ($r = -0.214$ to 0.306, n.s.).

In both segments, the CSA of every muscle group on the preferred and nonpreferred sides was significantly correlated to $LBM^{2/3}$ in regression analyses for the pooled data of the youth and professional players; $r = 0.465$ ($p = 0.004$) to 0.697 ($p < 0.0001$) for the trunk muscles and $r = 0.634$ ($p < 0.0001$) to 0.692 ($p < 0.0001$) for the thigh muscles. For the thigh muscle groups, no significant difference was found in CSA/$LBM^{2/3}$ between the youth and professional players (Figure 4). For the trunk, however, the CSA/$LBM^{2/3}$ of the psoas major was significantly higher in the professional players than in the youth players, and that of the erector spinae, vice versa (Figure 5).

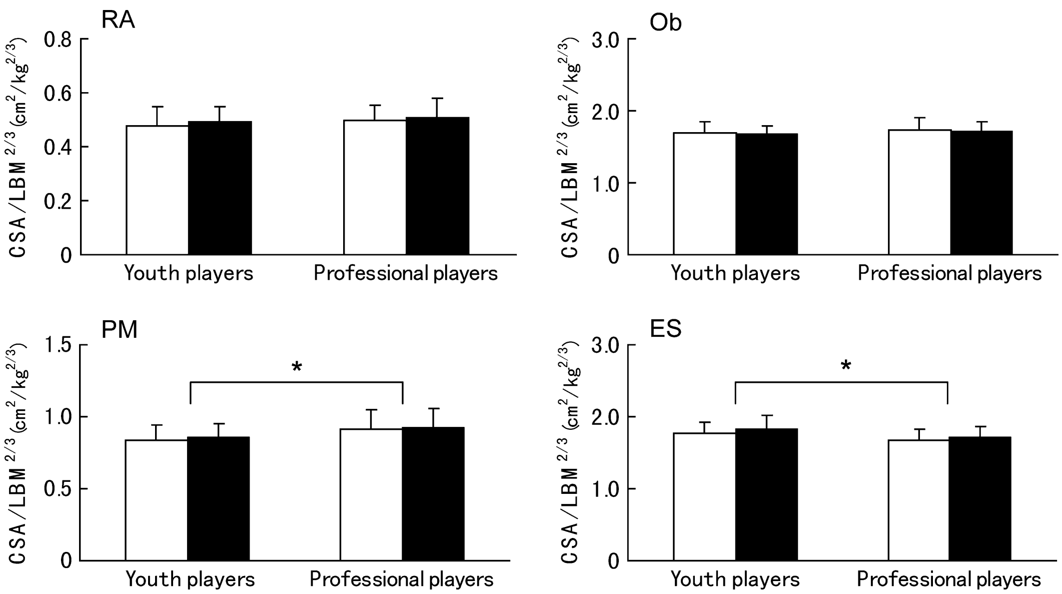

Figure 5. Comparisons of the ratios of cross-sectional area to two-thirds power of lean body mass (CSA/LBM$^{2/3}$) of the 4 trunk muscles between the preferred and nonpreferred sides within the same group and between the youth ($n = 18$) and professional ($n = 17$) players within the same muscle. RA = rectus abdominis muscle; Ob = internal and external oblique muscles; PM = posoas major muscle; and ES = erector spinae muscle. Open and closed bars indicate the mean and *SD* for the preferred and nonpreferred sides, respectively. A 2-way ANOVA with repeated measures (3 muscle groups and 2 sides) indicated that the effect of side on muscle CSA was not significant, without significant interaction between muscle group and side. A 2-way ANOVA (2 groups and 2 sides) showed that the CSA/LBM$^{2/3}$ of the psoas major was significantly ($p < 0.05$) higher in the professional players than in the youth players, and that of the erector spinae vice versa, without significant interaction between group and side.

Discussion

The current results indicate that muscle groups located in not only the thigh but also in the trunk have no lateral dominance in CSA, related to footedness for ball kicking, in youth and professional players. In addition, the symmetry index of each muscle group of the trunk was not significantly related to that of the thigh. This suggests that the interindividual variation in the side-to-side difference in trunk muscle CSA cannot be influenced by that in thigh muscle CSA, and vice versa.

Various sport events have different movement patterns, energy requirements or training regimens. Consequently, athletes exhibit specific adaptations in the size of muscles located in the limbs (17–19,24) and trunk (9,13,14), which can be related to their own competitive styles and training regimens. Kearns et al. (19) reported that the medial gastrocnemius muscle was thicker in the preferred than in the nonpreferred leg in junior soccer players. Moreover, Masuda et al. (24) found small but significant differences between the preferred and nonpreferred legs in the CSAs of hamstrings and adductor muscles proximal to the knee joint and of the midthigh, respectively, in university soccer players. With regard to the trunk muscles, Hides et al. (13) observed an asymmetry related to the kicking leg in the CSA of the psoas muscle in Australian Football players. In addition, Engstrom et al. (9) showed a greater asymmetry of quadratus lumborum CSA in fast bowlers as compared with swimmers. Similarly, Hides et al. (14) also reported that, for cricketers, the CSAs of the quadratus lumborum and erector spinae plus multifides were larger on the side ipsilateral to the dominant arm. These findings indicate that athletes exhibit an asymmetry in the CSAs of certain muscles located in the limbs or trunk as a result of a combination of their lateral dominance and the profiles of competitive activities. Therefore, in the soccer players examined here, too, it was expected that not only thigh but also trunk muscles would show asymmetry in the CSA, which could be related to footedness for kicking. However, the present results indicate that both the youth and professional players exhibited symmetry in CSA between the preferred and nonpreferred sides for ball kicking in every muscle group located in the 2 body segments.

As described earlier, a bilateral leg strength difference can be a factor inducing sport-related injuries (21,35). Consequently, training sessions for elite soccer players appear to have imposed a strength balance for the right and left body sides (36). This concept is widely accepted among top players and their coaches in Japan. In addition, the fact that, for soccer players, running is also a key movement during competitive activities might also explain the observed symmetry in muscle CSA. The average distance covered during a game by national top class and international players is about 10 km, with fairly small differences between positions (8). Both the youth and professional players examined here had regularly performed physical training programs, mainly consisting of aerobic running with combined anaerobic–aerobic exercises (middle distance running and interval training), in addition to soccer training. Running is a unipedal action, in which the legs are used one after the other. Furthermore, Thorstensson et al. (33) reported that lumbar back muscles showed a period of bilateral cocontractions at touchdown in running. Therefore, mechanical loading to the leg and trunk muscles during the running action is considered to be almost the same between the preferred and nonpreferred sides of the body, and consequently, to play a role inducing similar adaptation in the size of muscles located in the thigh and trunk. This idea is supported by the finding of Hoshikawa et al. (15), in which no significant difference was found between the right and left sides in the CSAs of thigh and psoas major muscles for junior sprinters. Therefore, it seems that the physical demands of soccer during competitive activities and the content of physical training performed by the subjects, which are related to running actions, might have led to bilateral symmetry in the CSAs of thigh and trunk muscles.

Among the muscle groups examined, only the erector spinae showed no significant difference in CSA between the youth and professional players. A similar result was reported by Kubo et al. (22) who compared trunk muscularity between junior and senior wrestlers. In their findings, the CSA of trunk flexors was greater in senior than in junior wrestlers, but the CSA of the erector spinae muscle was similar between the 2 age groups. On the basis of this observation, Kubo et al. (22) suggested that the size of the erector spinae muscle has already developed at the junior stage to the point that it was not a factor in restricting wrestling performance. Whether this explanation can be applied to the present result is unknown. Andersson et al. (1) showed that, in trunk extension strength, there were no marked differences between male athletes including soccer players and untrained subjects. In trunk flexion strength, however, all athletes showed higher values than the untrained subjects. Furthermore, a prior study (2) examining the activities of the paraspinal and abdominal muscles during 16 different therapeutic exercises provided evidence that the activity levels of the lower back muscles during daily life would be higher than those of other skeletal muscle groups located in the abdomen. Considering these findings, it might be assumed that, in the age span from the youth to senior stage, there is less room for increasing the size of the erector spinae muscle, because of the demands of soccer or the training programs, and this might have resulted in the similarity in the CSA of this muscle between the 2 age groups.

The CSA of every muscle group located in the thigh and trunk was significantly correlated to $LBM^{2/3}$. Gatton et al. (11) have suggested that body size did not significantly influence psoas major CSA in men. However, Lee et al. (23) indicated that muscle CSA obtained from a single slice at the L4–L5 level was a strong marker of whole body skeletal muscle mass. The current result is consistent with this report and suggests that, even in individual muscle groups located in the trunk and thigh, size is related to whole-body lean tissue mass. At the same time, this implies that the observed differences in CSAs between the 2 age groups partially relate to differences in whole-body lean tissue mass. In fact, most muscle groups did not show significant differences between youth and professional players in terms of $CSA/LBM^{2/3}$. However, the corresponding values for the psoas major and erector spinae differed between the 2 age groups. This result indicates that the relative distribution of the 2 muscles within the trunk might be specific to the age of the players. Taking together the observed group differences in CSA and $CSA/LBM^{2/3}$ into consideration, we may say that the psoas major muscle is less developed in the youth players than in professional players.

Practical Applications

From the current results, it is concluded that youth and professional soccer players do not show lateral dominance in the CSAs of thigh and trunk muscles, related to the preferred foot for kicking. Unfortunately, we cannot explain how the bilateral similarity in muscle CSA is related to competitive performance in soccer. However, considering the reports of Zakas (36) and Shephard (32), in which any influence of lateral dominance was found in the strength capability of elite soccer players, bilateral similarity in muscular development may be assumed to be a physical background for high competitive performances. In addition, Yamamoto (35) reported that, in a follow-up study of track and field athletes, bilateral imbalance in hip flexion and knee extension strength was related to the occurrence of hamstring strains. In cricket fast bowlers, bilateral asymmetry in quadratus lumborum and/or internal oblique muscles has been shown to be associated with lower back pain (14) and the development of symptomatic unilateral L4 pars lesions (9). Therefore, for soccer players with bilateral asymmetry in the muscularity of the thighs and/or trunk, too, personalized strength programs for developing symmetry will be recommended as a countermeasure to sport-related injuries.

Furthermore, the professional players showed a predominant development of the psoas major as compared with the youth players. So far, no study has tried to elucidate how the muscularity of the psoas major influences soccer performance. However, an electromyographic study has provided evidence that the iliopsas muscle has an important role in kicking. In addition, a soccer player's movements are characterized by a great amount of sprinting and side-to-side cutting, pivoting, and sudden starts and stops (12). In sprinting, a larger hip flexor torque is needed to reverse the hip extension with a larger angular momentum because of a higher angular velocity and to accelerate the leg forward within the shorter swing time available (26). For performing this movement effectively, the psoas major is key because it is the largest of the hip flexor muscles (5). Furthermore, it acts to stabilize the spine and on hip flexion (31). Therefore, it is reasonable to assume that the predominant development of the psoas major muscle in professional compared with junior players guarantees better performances in kicking, sprinting, and the holding of a body position in various competitive scenes of the game. In other words, the present result on the difference in the CSA/LBM$^{2/3}$ between the youth and professional players suggests that, for soccer players, exercises involving hip flexion should be incorporated progressively into individual strength and conditioning programs.

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