Short Report

Anatomical differences in the psoas muscles in young black and white men

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ABSTRACT

The anatomy of the psoas major muscle (PMA) in young black and white men was studied during routine autopsies. The forensic autopsies included 44 fresh male cadavers (21 black, 23 white) with an age span of 14 to 25 y. The range for weight was 66–76 kg and for height 169–182 cm. The PMA was initially measured in its entire length before measuring the diameter and circumference at each segmental level (L1–S1). At each segmental level, the calculated anatomical cross-sectional area (ACSA) was more than 3 times greater in the black group compared with the white ($P < 0.001$). The psoas minor muscle (PMI) was absent in 91% of the black subjects, but only in 13% of the white subjects. These data show that the PMA is markedly larger in black than white subjects. The marked race specific difference in the size of the PMA may have implications for hip flexor strength, spine function and race specific incidence in low back pathology, and warrants further investigation.

Key words: Skeletal muscle; racial variation.

INTRODUCTION

The psoas major muscle (PMA) is a fusiform muscle lateral to the lumbar region of the vertebral column and the pelvis (Agur, 1991). It attaches by slender fasciculi cranially to the medioventral surface of the vertebral body and disc, and caudally to the ventrocaudal borders of the lumbar transverse processes (Agur, 1991). The PMA passes anterior to the sacroiliac joint caudally, deep to the inguinal ligament and anterior to the upper part of the hip joint (Ferner & Staubesand, 1982). It inserts on the lesser trochanter of the femur together with the iliacus muscle to form the iliopsoas muscle.

Anatomical variations and anomalies of the psoas muscles have been described (Bergman et al. 1988; Clarkson & Rainy, 1889). The 12th rib, the iliolumbar ligament, the ventral sacroiliac ligament and the diaphragm have been described as accessory origins of the PMA, this component having been referred to as the psoas accessorius muscle (Rickenbacker et al. 1985). The psoas minor muscle (PMI) attaches on the anterior surface of the 12th thoracic and the first lumbar vertebrae (Williams et al. 1995), and may be absent in 50% of subjects (Rickenbacker et al. 1985). The only study of racial discrepancies in the psoas muscles reported the PMI to be absent in 50% of the studied body-halves in Orientals, 57% of body-halves in whites, and 67% of body-halves in blacks (Seib, 1934).

In general, the size of a muscle is often a indicator of its strength. In a computerised tomographic (CT) study the PMA reached a maximum anatomical cross-sectional area in men at age 30 y and then declined to about two thirds by the age of 40 y (Imamura et al. 1983). On the other hand, women only showed a

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decline in the size of the muscle at age 40. These data suggest that age related changes in the size and presumably strength of the PMA is age and sex specific.

The PMA has been suggested to contribute to several functions: hip flexion (Bogduk et al. 1992), lumbar extension (Basmajian & Greenlaw, 1968; Rab et al. 1977; Basmajian & De Luca, 1985), flexion moment force between the ilium and the sacrum (Hamilton, 1972; Woodburne & Burkel, 1988), lateral lumbar flexion (Romanes, 1981), general stabilisation of the lumbar spine (Nachemson, 1966, 1968; Crisco & Panjabi, 1990; Bogduk & Twomey, 1997) and a power source in walking (Gracovetsky & Farfan, 1986). Also, contraction of the PMA increases the stress on the lumbar intervertebral discs (Nachemson, 1966). Clinically, patients with weak abdominal muscles display the psoas paradox (Rasch & Burke, 1978), or spinal hyperextension during a 'sit-up': the PMA hyperextends the lumbar spine because the force of the rectus abdominis is inadequate as an antagonist (Rasch & Burke, 1978; Janda, 1983).

The PMA is clearly an important muscle that may play a role in the function both of the trunk and the extremity. However, few studies have addressed its normal size, shape, and possible anatomical variation. Further, studies have typically disregarded age, which is accompanied by skeletal muscle atrophy secondary to inactivity and/or disease. Also investigations of embalmed cadavers may cause distortion of soft tissue (Reid et al. 1994). During other studies of the lumbosacral region (Hanson & Magnusson, 1998) size differences in the psoas major muscle were observed. This study therefore investigated possible differences in morphology of the psoas muscles in fresh young male white and black cadavers.

MATERIAL AND METHODS

The psoas muscles were studied in conjunction with routine autopsies at the Arkansas State Crime Laboratory, Little Rock, Arkansas, USA and at the Department of Forensic Medicine, University of Lund, Sweden. A total of 44 male subjects were used in this study, 21 were black and 23 were white. The subjects were defined as black or white both from the records of the coroner or physician who declared the subject dead, and then by records from the Medical Examiner's office. These people were unfamiliar with the study at hand and, therefore, any investigator bias was eliminated. Subjects were aged between 14 and 25 y, between 66 and 76 kg and between 169 and

Table 1. *Age, sex, weight and height distribution (mean, ±S.D.) of subjects*

	Age (y)	Height (cm)	Weight (kg)
Black ($n = 21$)	19.9 ± 4.2	177.2 ± 6.7	73.9 ± 3.9
White ($n = 23$)	21.2 ± 4.9	173.7 ± 7.6	74.6 ± 3.6

No significant differences existed between the groups with respect to age, height and weight.

182 cm in height (Table 1). All subjects available, matching the inclusion criteria for weight, height, age, and sex during the period of the study (1994–97), were included in the study. The causes of death are not listed since they were all due to trauma unrelated to the area to which this study was aimed. No visible muscle bulk differences or other anatomical variations could be detected in other muscles of the lumbosacral region.

After incising through the anterior side of the body, and removing the viscera, the psoas major muscle (PMA) and the psoas minor muscle (PMI) could be visualised. The attachments of the PMI were determined before to removal to study the PMA accurately. The length of the PMA was measured from the most cranial attachment on the T12 vertebra to the lesser trochanter of the femur. The width and thickness of the PMA was measured at each segmental level from L1–L2 to L5–S1 with a digital vernier caliper. The width of the PMA is defined as the diameter of the muscle in the coronal plane. The thickness is defined as the diameter of the muscle in the sagittal plane. Recognising that the cross-sectional shape of the PMA is approximately an ellipse, the anatomical cross-sectional area (ACSA) was calculated using the area formula for an ellipse, πab, where a is half the width and b is half the thickness.

The vertebral attachments of the muscle were then cut at the levels of each segment to measure its circumference, which was used as an independent measure of size. Finally, the PMA was divided in cross section, and remeasured with a ruler, to verify the width and thickness of the measurements with the vernier caliper. All measurements were taken prior to the calculations of the ACSA. The vernier caliper, the measuring tape, and the ruler measured to an accuracy of ± 1 mm.

The Spearman correlation coefficient was used to examine the strength of the relationship between the 2 independent measures of size, i.e. the circumference measurement and the calculation of the cross-sectional area based on the width and thickness. The Mann-Whitney U test and Wilcoxon matched-pairs

signed-ranks test (2-tailed) (Conover, 1980) were used for nonpaired and paired analysis, respectively. An alpha level of $P < 0.05$ was accepted as significant.

RESULTS

In the black group the PMI was present in 2 subjects (9%). In both cases the PMI was present only on one side of the body. In the white group the PMI was present on both sides in all except 3 cases (87%). There was therefore a significant difference in the occurrence of the PMI between the black and the white groups ($P < 0.001$). In 1 of these 3 cases the PMI was completely absent. In the remaining 2 subjects, the PMI was absent on one side of the body. Further, on visual inspection, the PMI in the black subjects appeared as a slight thickening of the fascia surrounding the PMA, rather than an actual muscle. In contrast, in the white group the PMI was a well defined muscle positioned anterior to and separate from the PMA fascia. In all instances the PMI attached via a thin membrane to the bodies of the T12 and L1 vertebrae superiorly and to the pubic bone inferiorly.

The measurement between the cranial and caudal attachments revealed that the overall length of the PMA did not vary significantly between the black and white groups. However, the size of the PMA differed considerably between the groups (Table 2). The thickness and width of the PMA in the black group was on average approximately twice that of the white group at each segmental level ($P < 0.001$). Similarly, the circumference in the black group was more than twice that of the white group ($P < 0.001$). Consequently, calculations of the cross-sectional area in the black group was almost 4 times that of the white group ($P < 0.001$). The correlation coefficients (r_s) for the circumference measurement and the calculation of the cross-sectional area for all levels ranged between 0.93–0.99.

DISCUSSION

The main findings of the present study are that the PMA in the black group was considerably larger than that of the white group. Further, it was shown that the PMI was present in 9% of the black subjects, and in 87% of the white subjects.

The PMA has been described as attaching on the anterolateral aspect of the lumbar spine, and descending to the lesser trochanter (Williams et al. 1995; Bogduk & Twomey, 1997). These attachment sites correspond well to those of the present study in both the black and white group. Previous studies have described the PMI to be absent bilaterally in 41% subjects (Anson, 1966), or over 50% (Williams et al. 1995). In contrast, the present study showed the PMI to be absent in 91% of black subjects, but only in 13% of white subjects, demonstrating variation according to race.

The strong relationship between the independently measured circumference and the calculated anatomical cross-sectional area (ACSA) suggests that the circumference is a valid estimate of ACSA. As 86–98% of the calculated ACSA can be explained by the circumference measure. The maximal contraction force of a muscle is closely related to the physiological cross-sectional area (PCSA) (Lieber, 1992). In muscles with a pennation angle of zero degrees, the ACSA corresponds to the PCSA. The fibre pennation angle of the PMA has been reported to be zero degrees (White, 1989) and 7° (Hoy et al. 1990) and accordingly the ACSA and the PCSA must be almost identical for the PMA. Although it remains to be established, it is likely that black individuals are capable of producing greater hip flexion force than white individuals of similar age, height and weight. This observation may have functional implications since the PMA is the largest of the hip flexor muscles (Bogduk et al. 1992). It has been shown that the iliopsoas muscle is maximally activated during a soccer place kick, and

Table 2. *Racial differences (mean ± S.D.) in psoas muscles*

	Black				White		
Level	Thickness (mm)	Width (mm)	CSA (mm²)		Thickness (mm)	Width (mm)	CSA (mm²)
L1–L2	24.4 ± 1.5	30.3 ± 1.6	582.8 ± 66.1*		13.0 ± 1.2	15.1 ± 1.2	155.6* ± 27.9
L2–L3	34.4 ± 1.5	40.1 ± 1.6	1092.6 ± 73.8*		19.9 ± 1.3	22.3 ± 1.2	349.9 ± 41.7
L3–L4	48.9 ± 1.5	53.8 ± 2.0	2067.9 ± 118.6*		29.0 ± 1.3	30.2 ± 1.2	688.2 ± 56.9
L4–L5	43.9 ± 1.5	49.5 ± 1.8	1708.6 ± 100.1*		20.8 ± 1.1	22.1 ± 1.2	361.8 ± 34.0
L5–S1	36.0 ± 1.6	37.7 ± 1.9	1065.7 ± 84.6*		16.8 ± 1.1	17.3 ± 1.1	228.5 ± 26.1

* $P < 0.001$.

contributes to a large hip flexor moment (H. C. Dorge et al. unpublished observations). A large, and therefore a strong PMA, may thus be an advantage in events that require kicking movements and during sprint running, where fast and forceful hip flexion generates the action of the trailing leg (Mann & Sprague, 1980; Simonsen et al. 1985).

The function of the PMA as a general stabiliser of the lumbar spine has been studied extensively (Nachemson, 1966, 1968; Kapandji, 1974; Nordin & Frankel, 1989; Crisco & Panjabi, 1990). Activation of the muscle also results in ipsilateral lateral bending, and contralateral rotation (Kapandji, 1974). Further, the muscle can produce flexion of the lumbar spine relative to the pelvis, and accentuate the lumbar lordosis. Others have questioned the role of the PMA as a prime mover of the lumbar spine, or its involvement in compression and shear loads on the lumbar spine (Bogduk et al., 1992). The PMA has been reported to extend the lumbar spine in the normal lumbar lordosis (Nachemson, 1966; Kapandji, 1974; Rab et al. 1977; Basmajian & De Luca, 1985). The significantly larger PMA in black than in white men shown in present study may indicate that, although unsubstantiated, the above functional capacities could therefore differ with respect to race.

The antagonist muscles to the PMA are the gluteal muscles, which produce hip extension. It has previously been shown that the gluteal region is more prominent in black than in white subjects (Mosner et al. 1989). It is plausible that the greater gluteal prominence in black subjects is a reflection of muscle size. However, it remains to be established if such a race specific size difference also translates into a difference in strength. It was recently shown that the lumbosacral angle is smaller in black individuals, which may be an alternative explanation for the difference in gluteal prominence (Hanson et al. 1998). A smaller sacral angle might enhance the internal moment arm of gluteus maximus and, hence enable production of a larger extensor moment.

Age and sex influence the dimensions of the psoas major significantly. The PMA muscle reaches maximum thickness in men at age 30 y (Imamura et al. 1983). Thereafter, the PMA decreases rapidly to about two-thirds of the original thickness at the age of 40 y. In women, the thickness of the muscle was reported to decrease to half of the original thickness at the age of 40 y (Imamura et al. 1983). The substantial race specific differences in the present study are noteworthy since the study sample was of similar sex, age, weight and height.

Although other studies documenting racial dif-ferences exist, no study has previously described differences in the PMA between black and white people. Only one study, to our knowledge, has presented racial differences with respect to the absence of the PMI (Seib, 1934). The larger gluteal prominence in black subjects compared with white described by Mosner et al. (1989) was named 'apparent lordosis'. No difference in lumbar lordosis, 'the actual lordosis', was shown. Fernand and Fox (1985), on the other hand found no differences in the lumbosacral region between black and white individuals. Most recently differences between young black and white people in the lumbosacral curvature and the sacral angulation have been detected (Hanson et al. 1998). Further, differences in the lumbar anterior longitudinal ligament in black and white people have been shown (Hanson & Magnusson, 1998). Taken together these findings indicate that race is an important factor when studying the anatomy and functions of the lumbosacral region.

From the point of view of pathology, racial differences have frequently been described in the literature. For example, the incidence of spondylolisthesis has been found to vary according to race (Rowe & Roche, 1953; Stewart, 1953; LaFonde, 1962; Turner & Bianco, 1971; Taillard, 1976; Wiltse et al. 1976; Wynne-Davies & Scott, 1979; Bunnell, 1982; Fredrickson et al. 1984). Rowe & Roche (1953) reported the incidence of spondylolisthesis to be 6.4 % in white men, 2.8 % in black men, 2.3 % in white women and 1.1 % in black women. It remains unclear if a larger and stronger PMA can be related to the lower incidence of spondylolisthesis in black people (Turner & Bianco, 1971). Further, it has been reported that the incidence of the intervertebral disc pathology is lower in black people (Levy, 1967; Mennen, 1986), which in part might be explained by a larger, and better stabilising PMA.

In conclusion, the present study investigated the size of psoas muscles in young black and white subjects with similar height and weight. The results show that the PMA is markedly larger in black than white individuals. Albeit unconfirmed, the substantial race specific difference in the size of the PMA may have implications for hip flexor strength, spine function and race specific incidence in low back pathology.

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