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The Distribution of Muscle and Bone Weight in Swamp Buffalo (*Bubalus bubalis*), *Bos indicus* and *Bos taurus* Steers

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ABSTRAK

Penyebaran berat otot dan tulang 15 ekor kerbau (Bubalus bubalis) *jantan dibandingkan dengan 15 ekor lembu jantan masing-masingnya daripada baka Angus, Hereford dan Brahman. Penyebaran berat otot dan tulang kerbau menunjukkan peralihan ke arah bahagian hadapan badan. Bahagian yang terlibat ialah servital, toraks dan tulang kaki hadapan dan "piawia tumpulais otot" 5, 7 dan 9. Brahmans menunjukkan penyebaran otot yang sama tetapi tidak setanding dengan kerbau. Skapula di bahagian belakang kerbau juga berlainan. Ianya hipotrofi dibandingkan dengan baka yang lain dengan pembesaran otot* supraspinatus *dan otot* infraspinatus *tetapi otot* subscapularis *yang ringan. Adalah dicadangkan bahawa perbezaan penyebaran itu mencerminkan "traction" masa lampau kerbau dan Brahmans.*

ABSTRACT

The muscle weight distribution and bone weight distribution of 15 buffalo (Bubalus bubalis) *steers were compared with that of 15 steers from each of three breeds of cattle, Angus, Hereford and Brahman. For both muscle weight distribution and bone weight distribution, buffaloes showed a "shift" towards the forequarter. This involved the cervical, thoracic and forelimb bones and standard muscle groups 5, 7 and 9. Brahmans showed a similar but less pronounced distribution to that of the buffaloes. The scapula was an exception in the forequarter of the buffaloes. It was lighter relative to the other breeds with clearly enlarged mm.* supraspinatus *and* infraspinatus *but a lighter m.* subscapularis. *It is suggested that these distribution differences reflect the traction history of buffaloes and Brahmans.*

INTRODUCTION

Cattle were domesticated about 4000 to 6000 years B.C. (Zeuner 1963) although carbon-dated Jericho discoveries suggest that domestication may have occurred as early as 10,000 years B.C. (Boston 1963). The earliest domestication was in Mesopotamia and North West India.

Ploughing and the haulage of two-wheeled carts were practiced in the Mohenjodaro area about 3000 years B.C. and Banjaras carried merchandise on pack bullocks (Von Fürer-Haimendorf 1963). Rouse (1972) and Porter (1991) noted that the muscular power of cattle, particularly zebus, was used for transport and ploughing on most of the Indian sub-continent. Zeuner (1963) produced evidence that *Bos primigenius namadicus* had been in India before early Man and it showed several features in common with the zebu. The muscle power of cattle, particularly zebus, has been used for raising water, draft, cultivation, transport and haulage. Innumerable descendants of zebu native stock have found their way to Africa and South East Asia where they have been used as beasts of burden (Wheaton-Smith 1963).

The Buffalo has a 5000 year history, authenticated on seals struck in the Indus Valley, suggesting that by then, it had already been domesticated (Anon 1981). It was in use, in China, 4000 years ago where its legendary strength was used to supply farm power. It is now used as a "living tractor" in South China, Thailand, Indonesia, Philippines, India and Pakistan. In Egypt, it is the most important domestic animal (Anon 1981).

In the rice fields, the swamp buffalo (*Bubalus bubalis*) is generally preferred to cattle (oxen) as a draft animal because of its slow, steady capacity for work (Rouse 1972). The animal is used for ploughing, harrowing and hauling loaded carts.

The yoke on the working buffalo in Asia has changed very little in the last 1500 years (Anon 1981). This hard, wooden yoke presses on a very small area, about 200 square centimetres, on top of the animal's neck, which probably has not enabled it to exert its full pulling power.

In the current study, the muscle weight distribution and bone weight distribution of the carcass are examined in castrated male swamp buffaloes (*Bubalus bubalis*) and compared with the distributions in *Bos indicus* and *Bos Taurus* steers.

MATERIALS AND METHODS

Fifteen swamp buffalo (*Bubalus bubalis*) steers and fifteen steers each of Angus, Hereford and Brahman breeds were slaughtered, dressed and chilled at 3°C. A side from each carcass was dissected into individual muscles, bones or bone groups, fat and connective tissue using the technique described by Butterfield (1963). Individual muscles were combined into nine "standard" muscle groups (SMG's) and the bones into 11 bones or bone groups as shown in Tables 1 and 2.

Some details of the carcasses are shown in Table 3.

Tests of significance were conducted for the distribution of muscle and bone among the four groups of steers.

TABLE 2

Bone or bone groups	Approximate proportion of total bone weight (%)*
Ossa coxa	11
Patella	0.7
Femur	11
Tibia + tarsus	10
Lumbar vertebrae and 3 ribs	10
Scapula	5.3
Humerus	9
Radius/ulna + carpus	8
Sternum + costal cartilages	7
Cervical vertebrae	7
Thoracic vertebrae + 10 ribs	21

*Johnson, Charles and Baker, from 100 total anatomical dissections

RESULTS

The differences in muscle weight distribution of each Standard Muscle Group (SMG) are shown in Table 4. Buffalo and Brahman steers had less muscle in the spinal (SMG 3) and abdominal (SMG4) groups than Angus and Hereford steers. Buffaloes generally, had a greater weight of muscle concentrated in the forequarters, particularly the shoulder (SMG 5), thorax to shoulder (SMG 7) and intrinsic muscles of the neck (SMG 9). Brahman steers generally, had more muscle concentrated in the proximal hind limb (SMG 1), neck to shoulder (SMG 8) and intrinsic muscles of the neck (SMG 9). Relative to the Herefords, Angus steers showed a lower proportion of hind leg muscles (SMG 1 and SMG 2)

TABLE 1

Standard muscle group (Butterfield 1963)	Description	Approximate proportion of total muscle weight (%)*
1	Muscles of the proximal pelvic limb	32
2	Muscles of the distal pelvic limb	4.5
3	Surrounding spinal column in thorax and lumbar regions	12
4	Abdominal muscles	10
5	Muscles of proximal forelimb	11
6	Muscles of distal forelimb	2.5
7	Muscles of thorax attaching to forelimb	10
8	Muscles of neck attaching to forelimb	7
9	Intrinsic muscles of neck and thorax	10

* Johnson, Charles and Baker, from 100 total anatomical dissections

TABLE 3
Details* of *Bubalus bubalis, Bos taurus* and *Bos indicus* carcasses

Description	Buffalo	Angus	Hereford	Brahman
Chilled carcass	169 - 260	176 - 390	95 - 273	46 - 347
weight (kg)	208.6	271.2	163.7	266.5
	(27.4)	(68.3)	(49.7)	(53.1)
Age (months)	24 - 46	16 - 42	15 - 22	12 - 38
	29.4	25.9	18.7	23.7
	(5.0)	(9.8)	(2.5)	(10.6)
Carcass Composition				
Muscle	58.3 - 69.7	51.4 - 63.3	50.2 - 65.5	55.3 - 65.5
	64.8	57.1	61.5	60.8
	(3.6)	(3.6)	(4.5)	(3.1)
Bone	13.3 - 18.0	10.6 - 17.1	12.6 - 22.0	12.1 - 23.1
	15.3	12.8	16.1	15.4
	(1.4)	(1.7)	(2.8)	(3.2)
Fat	8.6 - 25.5	20.1 - 36.4	9.1 - 35.3	13.4 - 30.3
	17.0	28.1	19.7	21.7
	(5.1)	(5.0)	(7.3)	(5.1)

* Range and mean with standard deviation shown in parenthesis

TABLE 4
Muscle weight distribution of the standard muscle groups

Standard muscle group	Muscle weight distribution (%)			
	Angus	Hereford	Brahman	Buffalo
1	31.6^{a}	321^{a}	33.3	31.7^{a}
2	4.4^{b}	4.8^{a}	4.5^{bc}	4.7^{ac}
3	12.5^{a}	12.6^{a}	12.1	10.5
4	10.5	9.4^{b}	8.7^{a}	9.1^{ab}
5	11.2^{b}	11.5^{a}	11.2^{ab}	12.4
6	2.5^{b}	2.7^{a}	2.6^{ab}	2.7^{a}
7	10.1^{ab}	9.8^{b}	9.1	10.1^{a}
8	7.0^{b}	6.9^{b}	7.6^{a}	7.3^{ab}
9	9.5^{b}	9.3^{b}	10.1^{a}	10.2^{a}

Means with the same superscript are not significantly different ($P<0.05$)

and forelimb muscles (SMG 5 and SMG 6), but a greater proportion of abdominal (SMG 4) and thorax to shoulder (SMG 7) muscles.

Buffaloes showed a shift in their musculature towards the shoulder, thorax and cervical regions. Brahman steers showed a similar, but less spectacular shift, towards the neck and shoulder region. They also showed an increase of about 1.5% in the muscles of the proximal pelvic limb where some of the carcass's most expensive cuts are located.

Table 5 shows the significantly different individual muscle weight distributions among the four steer groups, listed according to the SMG.

The lowered distribution of SMG 3 and SMG 4 in the buffaloes and Brahmans was supported by the individual muscle weight distribution study. Buffaloes had much less *m. longissimus thoracis et lumborum* (1.3% to 1.7%). *psoas* muscles and *mm. scalenus dorsalis, multifidus dorsi* and *quadratus lumborum.* Brahmans had less *m. longissimus thoracis et lumborum* and less *mm. scalenus dorsalis, iliocostalis* and *spinalis dorsi.*

In SMG 4, buffaloes had generally less of four major muscles (*mm. obliquus internus abdominis, obliquus externus abdominis, transversus abdominis* and *rectus abdominis*). The Brahman steers, like the buffaloes, had less *mm. obliquus*

TABLE 5
Significant differences in individual muscle distribution among *Bubalus bubalis*, *Bos taurus* and *Bos indicus* steer carcasses

Muscle	Breed means			
	Buffalo	Angus	Hereford	Brahman
SMG 1				
Tensor fasciae latae	1.37a	1.29ab	1.29b	1.36ab
Biceps femoris	8.09	7.27a	7.20a	7.41a
Gluteus medius	3.59a	3.70a	3.76a	4.11
Gluteus accessorius	0.45	0.29a	0.29a	0.28a
Gluteus profundus	0.33b	0.35b	0.39a	0.39a
Vastas lateralis	2.84	2.32a	2.43a	2.57
Rectus femoris	2.34	1.99a	2.07a	2.05a
Vastus medialis	0.53	0.72ab	0.75a	0.69b
Vastus intermedius	0.50	0.64a	0.71	0.62a
Gracilis	1.08	1.31a	1.30a	1.45
Sartorius	0.30bc	0.34ab	0.35a	0.29c
Semimembranosus	4.05	5.02a	5.06a	5.42
Adductor femoris	1.40	1.71a	1.80a	1.92
Pectineus	0.50c	0.53bc	0.59a	0.55ab
Gemellus	0.07a	0.07a	0.09	0.08a
Quadratus femoris	0.06a	0.05a	0.07	0.05a
Iliacus	1.05	0.77	0.87a	0.84a
Articularis genu	0.05b	0.06b	0.08a	0.08a
Sacrococcygeal	0.09a	0.13	0.10a	0.08a
SMG 2				
Gastrocnemius + soleus	2.15	1.85b	1.97b	1.94b
Superficial flexor (plantaris)	0.28	0.42ab	0.46a	0.39b
Extensor group	0.53	0.62a	0.70	0.64a
Extensor digitorum lateralis	0.27a	0.20a	0.22b	0.25a
Tibialis anterior	0.13a	0.11bc	0.12ab	0.11c
Tibialis posterior	0.14	0.10b	0.11ab	0.11a
Popliteus	0.34	0.24a	0.27a	0.31
Flexor digitorum longus	0.14b	0.20a	0.20a	0.15b
Flexor hallicus longus	0.60a	0.60a	0.61a	0.54
SMG 3				
Psoas minor	0.29b	0.28b	0.31ab	0.35a
Psoas major	1.29	1.56a	1.58a	1.56a
Quadratus lumborum	0.15b	0.17a	0.16ab	0.17a
Scalenus dorsalis	0.21b	0.29	0.25a	0.22ab
Iliocostalis	0.51a	0.45b\	0.48ab	0.40
Longissimus thoracis et lumborum	5.23	6.93a	6.78ab	6.54b
Spinalis dorsi	1.84a	1.78a	1.82a	1.62
Multifidus dorsi	0.79	0.99a	1.02a	1.06a
SMG 4				
Retractor costae	0.03b	0.05a	0.04ab	0.03b
Obliquus internus abdominis	1.67a	1.99	1.86	1.67a
Obliquus externus abdominis	2.15a	2.49	2.24a	1.88
Transversus abdominis	1.00	1.27	1.16a	1.12a
Rectus abdominis	1.88	2.31a	2.18a	2.14a
Cutaneus trunci et omobrachialis	1.58bc	1.82a	1.64ab	1.45c

TABLE 5 cont'd
Significant differences in individual muscle weight distribution among *Bubalus bubalis*, *Bos taurus* and *Bos indicus* steer carcasses

SMG 5				
Deltoideus	0.60	0.49a	0.52	0.47a
Infraspinatus	2.19a	2.17ab	2.16ab	2.06b
Supraspinatus	1.90	1.50b	1.55ab	1.58a
Subscapularis	1.05	1.15a	1.13a	1.16a
Triceps brachii (caput laterale)	0.68ab	0.67ab	0.69a	0.65b
Triceps brachii (caput longum)	3.75	3.17a	3.15a	3.33
Triceps brachii (caput mediale)	0.11a	0.09b	0.10a	0.08b
Tensor fascia antibrachii	0.13b	0.15a	0.15a	0.14ab
Teres minor	0.18a	0.18a	0,20	0.17a
Teres major	0.47	0.41a	0.42a	0.42a
Biceps brachii	0.67a	0.60c	0.62bc	0.64ab
Coracobrachialis	0.13a	0.13a	0.13a	0.15
Brachialis	0.55	0.43	0.46a	0.46a
SMG 6				
Extensor carpi radialis\	0.78	0.72a	0.73a	0.73a
Extensor digiti tertii	0.15	0.12b	0.12ab	0.13a
Extensor digitorum communis	0.10	0.08a	0.08a	0.08a
Extensor digiti quarti	0.17	0.12	0.14a	0.13a
Extensor carpi ulnaris	0.32	0.26	0.29a	0.30a
Extensor carpi obliquus	0.03	0.03a	0.03a	0.03a
Flexor carpi radialis	0.10b	0.10b	0.11a	0.10ab
Flexor carpi ulnaris	0.10	0.13b	0.13ab	0.14a
Flexor digitorum profundus	0.54b	0.60a	0.63a	0.55b
Anconaeus	0.11a	0.09	0.11a	0.11a
SMG 7				
Serratus ventralis thoracis	1.70a	1.58ab	1.55b	1.25
Pectoralis profundus	3.53	3.81ab	3.89a	3.70b
Pectoralis superficialis	1.50a	1.69	1.42a	1.54a
Latissimus dorsi	2.73	2.24a	2.24a	2.02
Trapezius thoracis	0.67a	0.79	0.70a	0.59
SMG 8				
Trapezius cervicalis	0.48a	0.52a	0.50a	0.29
Omotransversarius	0.68	0.57a	0.56a	0.60a
Brachiocephalicus	1.88	1.56a	1.55a	1.59a
Rhomboideus	1.23a	1.37a	1.29a	2.03
Serratus ventralis cervicalis	3.02ab	2.94b	3.21a	3.10ab
SMG 9				
Serratus dorsalis cranialis	0.20	0.14a	0.12a	0.13a
Cervicohyoideus	0.09	0.02a	0.02a	0.04
Splenius	1.09a	0.81b	0.77b	1.05a
Complexus	1.57	1.68a	1.69a	1.69a
Scalenus ventralis	0.51a	0.44b	0.45b	0.49ab
Rectus capitis ventralis major	0.32	0.18a	0.19a	0.19a
Longissimus capitis et atlantis	0.23	0.33a	0.30a	0.31a
Intertransversarius colli	0.81	0.59b	0.61ab	0.67
Rectus capitis dorsalis major	0.14ab	0.12b	0.13b	0.16a
Obliquus capitis caudalis	0.40a	0.33	0.36b	0.38ab
Rectus thoracis	0.14	0.12a	0.13a	0.12a
Transversus thoracis	0.20ab	0.22a	0.21ab	0.20b
Longus colli	0.91a	0.78b	0.73b	0.98a
Intercostales	2.67b	2.58a	2.76ab	2.84ab

Means with the same superscript are not significantly different ($P<0.05$)

internus abdominis, obliquus externus abdominis and cutaneous trunci et omobrachialis.

The greater muscle weight distribution in the buffalo forequarter occurred in SMGs 5, 7 and 9. In the latter group, the buffaloes and Brahmans had a similar distribution. In SMG 5, eight muscles were hypertrophied (*mm. deltoideus, infraspinatus, supraspinatus, teres major, brachialis* and all three heads of the triceps group). It should be noted that, concurrent with the relatively lighter scapula, although *mm. infraspinatus* and *supraspinatus* were enlarged, *m. subscapularis* was relatively lighter. In SMG 6, the buffaloes showed a relative enlargement of all six extensor muscles. In SMG 7, the enlarged muscles were *mm. serratus ventralis thoricis and latissimus dorsi.* In SMG 9, the buffaloes showed an enlargement of nine muscles, particularly *mm. splenius* and *intertransversarii cervicis.* Buffaloes and Brahmans, generally, had less of all the major muscles in SMG 4.

The Brahman steers showed a relative enlargement of muscles in SMGs 1, 8 and 9. In SMG 1, they showed increased distribution in *mm. tensor fasciae latae, gluteus medius, gluteus profundus, vastus lateralis* and *rectus femoris.* Most of these are large muscles and clearly explain the superior distribution of the Brahman's proximal hindlimb musculature. In SMG 8, the Brahmans showed an increased distribution in *mm. rhomboideus* and *serratus ventralis cervicis.* In SMG 9, the Brahmans were relatively hypertrophied in six large muscles, *mm. scalenus ventralis, splenius, complexus, longus colli, longissimus capitis et atlantis* and *intercostales.*

Relative to Herefords and Brahmans, Angus showed less muscle in the large muscles of SMG 1 (*mm. biceps femoris, gluteus medius, gluteus profundus, vastus lateralis, rectus femoris, semimembranosus and adductor femoris*); SMG 2 (*m. gastrocnemius et soleus, the extensor group, extensor digitorum lateralis, popliteus* and both *tibial muscles*); SMG 5 (*mm. deltoideus, supraspinatus, biceps brachii, brachialis* and the long and medial heads of the triceps group); SMG 6 (*mm. flexor carpi radialis, flexor carpi ulnaris* and a number of small extensors). Relative to the Herefords and Brahmans, the Angus steers showed a greater proportion of muscle in SMG 4 (*mm. obliquus internus abdominis, obliquus externus abdominis,* and *transversus abdominis*) and SMG 7 (*mm. serratus ventralis thoricis, trapezius thoracis* and both pectoral muscles).

Table 6 shows the significant differences in bone weight distribution among the four groups. Buffaloes showed a lower proportion on bone in the pelvic and lumber areas and a greater proportion of bone in the cervical and thoracic areas, as well as the humerus, radius/ulna and carpus. Although buffaloes had about 1% more muscle in the proximal forelimb, their scapula was significantly lighter than those of the other three groups. Brahmans, like the buffaloes, had a generally lower proportion of bone in the pelvic and lumbar regions but a greater proportion in the limbs (femur, tibia and tarsus, humerus, radius/ulna and carpus). Relative to Herefords, Angus showed a higher proportion of bone in both limbs, in accord with their muscle weight distribution pattern.

TABLE 6
Bone weight distribution

Bone or bone group	Bone weight distribution (%)			
	Angus	Hereford	Brahman	Buffalo
Ossa coxa	11.5a	11.2a	11.2a	10.7
Patella	0.70a	0.75a	0.73a	0.71a
Femur	10.2	11.0a	11.0a	10.8a
Tibia + tarsus	9.7b	10.4a	10.3a	10.1ab
Lumbar Vertebrae + 3 ribs	11.2b	10.6ab	10.3a	10.3a
Scapula	5.3a	5.3a	5.3a	5.0
Humerus	8.2	8.7a	8.8a	9.0a
Radius/ulna + carpus	7.2	7.5b	7.8ab	8.0a
Sternum + costal cartilages	7.5b	6.9ab	6.5a	5.8
Cervical vertebrae	7.3a	7.0a	7.3a	8.1
Thoracic vertebrae + 10 ribs	21.3a	20.5a	20.7a	22.8

Means with the same superscript are not significantly different ($P<0.05$)

DISCUSSION

The Australian water buffalo was introduced from Timor in 1825 (Letts 1972). In South East Asia, the buffalo has long been preferred to cattle as the primary beast of burden. In Australia, over the last 170 years, it has not been used for traction.

Relative to cattle, the buffalo has concentrated more muscle in the forequarter, particularly muscles of the proximal and distal forelimb, thorax to forelimb, and muscles of the neck. This is supported by the bone weight distribution, which shows heavier bone in the cervical and thoracic areas, humerus, radius/ulna and carpus. A notable exception was the scapula, which was lighter in the buffalo than in the three breeds of cattle.

The individual muscle weight distribution study supported the findings of the SMGs, with relatively hypertrophied muscles in the shoulder (eight in SMG 5), distal forelimb (seven in SMG 6), thorax to shoulder (two large muscles in SMG 7) and the intrinsic muscles of the neck (nine in SMG 9). The buffalo showed a reduction in muscle weight distribution in the spinal muscles (four in SMG 3, including a great reduction in m. longissimus et lumborum) and the abdominal muscle group (five expansive muscles in SMG 4). The Brahman steers showed a similar decrease in distribution in these two muscle groups, but an increase in 15 muscles of the three groups, proximal hindlimb (SMG 1), neck to shoulder (SMG 8) and the intrinsic muscles of the neck (SMG 9).

Relative to Herefords and Brahmans, the Angus showed a reduction in muscle weight distribution in 21 muscles of the proximal and distal hindlimb, shoulder and distal forelimb. This group of steers had a markedly increased distribution in the abdominal and thorax to shoulder groups of muscles.

In relation to the shoulder area (SMGs 5 and 7), the buffaloes showed an increased weight distribution in nine muscles including *mm. supraspinatus, infraspinatus, deltoideus, serratus ventralis thoricis, latissimus dorsi* and the two heads of the triceps group, however, *m. subscapularis* was lighter.

Relative to Angus and Hereford steers, Brahmans showed evidence of a shift in muscle and bone weight distribution to the forequarter, although not as pronounced as in the buffalo. The Brahmans had an increased weight of neck to forelimb muscles and intrinsic muscles of the neck. The limb bones of Brahman steers, femur, tibia/tarsus, humerus, radius/ulna and carpus were generally heavier than in the other cattle, particularly the Angus. Brahmans had significantly more muscle (1.2% to 1.7%) in the proximal hind limb than in the other three groups. This is the site of some relatively expensive cuts of meat, thick flank, topside and silverside which confers on this breed a meat production advantage which has been recognized from detailed anatomical studies (Priyanto 1993; Priyanto, Johnson and Taylor unpublished).

Herefords differed from Angus, showing more muscle in the limbs (SMGs 1, 2, 5 and 6) and less in the abdominal group (SMG 4). Angus had heavier bone in the sternum and costal cartilages and in the lumbar vertebrae and last three ribs.

The significantly lighter scapula and *m. subscapularis* in buffaloes may be related to the wooden yoke, which has not changed for at least 1500 years, and this probably prevents the animal from exerting its full pulling power (Anon 1981). It has been estimated that the use of a padded horse collar would allow the buffalo to pull 24% heavier weights. An impeded scapula may have become more compact and lighter while increasing the weight of the muscles clothing the outside of it.

The higher proportion of the weight of muscle in the buffaloes and Brahmans relative to that in Herefords and Angus is possibly a result of their draft animal ancestry. The difference was more pronounced in the buffalo, which has been the preferred beast of burden in China and South East Asia for 4000 years.

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