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Asymmetry in muscle weight and one-sided dominance in the human lower limbs

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The fact that the right upper limb is stronger than the left in virtually all persons who are born right handed is well known. Although no specific reports are available, it can be safely presumed that in these persons muscles of the right upper limb are heavier than those of the left. This does not apply, however, to persons who are born left handed and are subsequently trained to use the right hand in writing. Such persons continue to use the left limb for all acts requiring strength and in them it can be demonstrated that the left limb is more developed than the right. Muscular development is, therefore, a more reliable index of inherited upper limb dominance than preferential use of the hand.

It is common knowledge that right handed persons prefer to kick with the right foot, and this has been correlated with dominance of the contralateral cerebral hemisphere. However, several observations recorded by Singh (1968) suggest that in the majority of both right handed and left handed persons the left lower limb is more used than the right. These observations include greater wear on the left shoe, a marked tendency to put the left foot forward first on starting to walk, and ability to apply greater pressure with the left foot. It has also been shown that in most instances the left femur is heavier than the right. In view of these observations it has been considered pertinent to compare muscle weight on the right and left sides, to further study the possible presence of one sided dominance in the lower limbs.

MATERIAL AND METHODS

The investigation was carried out in ten cadavers. In three cadavers (3, 4 and 9 in Table 1) the left upper limb was dominant (as indicated by muscular development) while in the remaining seven the right side was dominant. Muscular development of the upper limbs was assessed by measuring limb girth at three points, viz., 1 in. above the distal crease of the wrist, $\frac{1}{2}$ in. below the level of the head of the radius, and midway between the tip of the acromion and the lateral epicondyle of the humerus. The validity of this method of determining dominance in the upper limbs has been established by making similar measurements in a large number of living persons in whom detailed information regarding preferential use of limb was available (a detailed report is being published separately). It was found that dominance (as indicated by preferential use in acts requiring strength) could be safely predicted from the set of measurements listed above in over 90% of subjects studied. When the sum of these measurements favoured the left side, left sided dominance was invariable. The

right limb was dominant in all subjects in which the sum of the measurements on the right side exceeded those on the left by more than 6 mm. Using these criteria the issue was not in doubt in any of the cadavers used in the present study.

Following removal of the abdominal viscera the lower limbs were separated from the trunk by a transverse cut at the level of the highest part of the iliac crest. Subsequently, the two lower limbs were separated by an exact midline cut and weighed. The following muscles were dissected out and weighed: (*a*) quadriceps, (*b*) sartorius, (*c*) gracilis, (*d*) biceps femoris, semitendinosus and semimembranosus, (*e*) gastrocnemius and soleus, (*f*) deep muscles of the back of the leg, (*g*) muscles of the anterior compartment of the leg, (*h*) peronei.

The femur, tibia and fibula were denuded of all soft tissues and weighed. Care was taken to ensure that unequal dehydration by drying did not vitiate the comparison between the right and left sides.

OBSERVATIONS

Table 1 compares the total limb weight, and the weights of various muscle groups and of the femur, tibia and fibula, on the right and left sides. The results are recorded as right heavier (R), left heavier (L) or equal (E). A difference of less than 1 % of the weight of the heavier muscle or bone has been ignored.

Table 1. *Comparison of muscle and bone weight on right and left sides*

(The left upper limb was dominant in cases marked*.)

Weight compared	Case number									
	1	2	3*	4*	5	6	7	8	9*	10
Total limb weight	R	R	R	L	L	L	L	L	L	L
Quadriceps	R	R	R	R	L	E	R	L	L	L
Sartorius	R	E	R	L	R	R	R	L	R	L
Gracilis	E	R	R	R	L	R	R	L	E	L
Biceps femoris + semimembranosus + semitendinosus	R	R	L	R	R	L	L	L	L	E
Gastrocnemius + soleus	R	E	L	L	L	L	L	L	L	L
Deep muscles of back of leg	R	R	E	L	L	R	L	E	—	L
Anterior compartment of leg	R	L	R	L	E	R	L	R	L	L
Peronei	E	R	R	R	R	L	L	R	L	L
Femur	L	R	L	E	L	E	L	L	L	L
Tibia	R	L	E	R	R	L	R	L	L	L
Fibula	R	E	L	L	R	R	R	R	R	L
'R' score (−)	9	7	6	5	5	5	5	3	2	0
'L' score (+)	1	2	4	6	6	5	7	8	8	11
Net score	−8	−5	−2	+1	+1	0	+2	+5	+6	+11

R = Right heavier; L = Left heavier; E = Weight equal.

The following conclusions can be derived from this table:

(1) The right and left lower limbs of the individuals studied are not equally developed. Using total limb weight as a criterion of better physical development (and hence of greater use) it is seen that in seven out of the 10 persons studied the left limb is dominant. A 't' test comparing the weights of the dominant limb with the other shows that the difference is highly significant ($P < 0{\cdot}001$).

(2) Most muscle groups and bones show a variation in weight between the right and left sides, but this does not always correspond with the difference in total limb weight. The lowest three rows of Table 2 give the score in favour of right or left and the net score (in favour of left) in each individual. It is seen that while the degree of one sided dominance (indicated by the score) is highly variable, the net score is in each case consistent with dominance in total limb weight. In the description that follows subjects one, two and three are, therefore, regarded as showing right sided dominance and the remaining ones are regarded as showing left sided dominance.

(3) There is no obvious relationship between dominance in the upper and lower limbs. Dominance of the right upper limb can be seen in association with dominance of the right lower limb (subjects 1, 2) or with dominance of the left lower limb (subjects 5, 6, 7, 8, 10). Similarly dominance of the left upper limb may be associated with dominance either of the left (subjects 4, 9) or of the right (subject 3) lower limb.

Table 2. *Comparison of mean weight of various muscle groups on the dominant and non-dominant sides*

Muscle group	Dominant side		Non-dominant side	
	Mean weight (g)	Standard error	Mean weight (g)	Standard error
Quadriceps	830·7	89·08	807·3	87·40
Gracilis	38·2	5·60	38·1	5·66
Sartorius	54·0	8·71	49·4	8·51
Biceps femoris + semimembranosus + semitendinosus	333·4	28·25	329·2	30·81
Gastrocnemius + soleus	359·0	29·57	339·7	29·99
Deep muscles of back of leg	109·2	9·36	104·7	10·43
Muscles of anterior compartment of leg	114·1	12·35	105·6	12·51
Peronei	58·1	7·57	56·9	6·56

Table 2 presents a comparison of the mean weights of the muscles studied, on the dominant and non-dominant sides. It is seen that in each muscle group the mean weight is greater on the dominant side. The difference is statistically significant ($P < 0{\cdot}05$). When weights of individual muscle groups are compared a statistically significant difference is found for two muscles, namely the gastrocnemius-soleus and the sartorius. Differences in the other groups, and in the weights of the bones, are not significant, but this appears to be attributable, in some cases at least, to the small size of the sample.

DISCUSSION

The finding that the left lower limb of the majority of individuals—both right handed and left handed—is dominant (Singh, 1968, and present investigation) raises the problem of the relationship of limb dominance to cerebral dominance.

The traditional concept of a cerebral hemisphere dominant for the contralateral hand and foot (De Jong, 1958; Adams, 1962) would appear to need revision in the light of these findings.

SUMMARY

1. The weight of the right and left lower limbs, and of muscles and bones therein, has been studied in ten cadavers.

2. The left lower limb was heavier in seven and the right in three cadavers. This difference in weight is believed to be the result of functional dominance of one limb over the other (as in the upper limb). The difference in weight between the dominant and non-dominant sides was highly significant ($P < 0{\cdot}001$).

3. The mean weights of the muscle groups studied were greater on the dominant side ($P < 0{\cdot}05$).

4. The gastrocnemius-soleus and sartorius showed a statistically significant difference in weight between the dominant and non-dominant sides ($P < 0{\cdot}05$).

5. These findings confirm the view that one sided dominance similar to that in the upper limbs is also to be seen in the lower limbs. However, no correlation has been observed between dominance in the upper and lower limbs.

The greater part of the practical work on which this paper is based was done by S.R.C. I.S. is responsible for the planning of the investigation and its presentation.

REFERENCES

ADAMS, R. D. (1962). In T. R. Harrison, *Principals of Internal Medicine*, 4th ed. p. 375. New York: McGraw-Hill.

DE JONG, R. N. (1958). *The Neurologic Examination*, 2nd ed. p. 793. London: Pitman.

SINGH, I. (1968). Right and left footedness. Paper read before Anatomical Society of India, New Delhi, Dec. 1968.