FUNCTIONAL ANATOMY OF THE HIP

By J. M. WALKER, M.N.Z.S.P., Dip.T.P.,
Lecturer, Sub-Department Physiotherapy, University of the Witwatersrand

A review of recent literature, with emphasis on the role of the Hip Abductors.

It has been said that "orthopaedic surgeons worship at the shrine of the Quadriceps"[11], the object of worship at the hip should fall to the abductor group, which however do not receive the same attention. The same attitude often applies to many physiotherapists.

Hip Abductor Function

The hip abductors are Gluteus Medius, Minimus and Tensor Fascia Lata. Anatomists give the action of the abductors as primarily abduction of the hip, that is, abduction of the free femur on the fixed pelvis and secondarily, to control the lateral pelvic tilt when standing on one leg. That is, describing the action, in the first instance in the tradition, that muscles arise by a fleshy belly, insert by a tendon and in shortening approximate the insertion towards the origin; abduction of the femur on the fixed pelvis. This action is however, not commonly performed in everyday life (some occasions, moving sideways, getting in and out of a car, getting on a horse, vaulting) and is rarely performed against any significant resistance other than the weight of the limb. The real function of the abductors, controlling and moving a considerable load is abduction of the mobile pelvis, on the fixed femur and prevention of adduction of the pelvis on the weight bearing hip under the superincumbent body weight[10]. This occurs every time weight is taken on one leg.

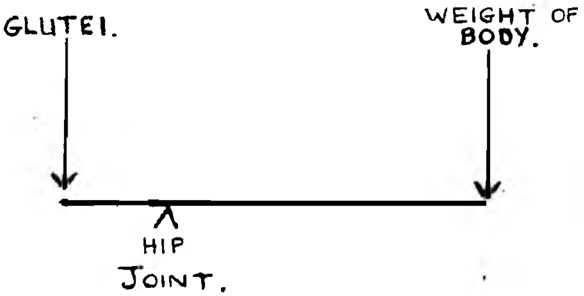


Fig. 1. The lever principle of the hip joint.

The Hip Joint as a Fulcrum

To fully appreciate the role of the abductors it is important to realise that the hip joint acts as a fulcrum of an unequal lever system, the long arm of which supports the body weight, the short arm of which being controlled by the gluteal muscles (see Fig. 1). Due to the differences in the length of the lever arms the abductors have to exert considerable force to obtain this balance. When standing on one leg, the line of gravity, weight transmission, falls commonly on the medial side of the hip. This has been calculated to be four inches from the centre of the joint. It has also been calculated from determining a resultant line of force for the abductor group (see Fig. 2) that gluteal force acts at a distance of two inches from the centre of the joint. The ratio of the lever arms is therefore 4: 2, so that when a person is standing on one leg and weighs 150 lbs. (minus the weight of the supporting limb) a gluteal force of 300 lbs. at least is required to maintain coronal balance (see Fig. 3, where x equals gluteal force).

It should be noted that the force acting through the head of femur is not just the body weight but that the hip joint is in fact subjected to the summation of these two forces' body weight and gluteal force (see Fig. 4). It has thus been calculated that the forces acting on the head of femur are at least twice the body weight. The force transmitted by the hip is the sum of the total supported body weight plus the tension in the balancing muscles, which is not solely produced by the abductors. When a person stands on one leg (in this instance the left), maintaining a level pelvis, as the line of gravity is medial to the pivot the pelvis tends to rotate

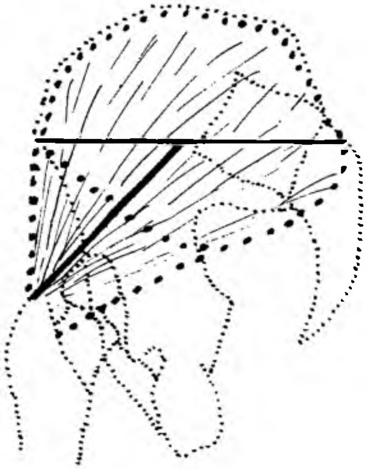


Fig. 2. Postero-lateral aspect of the hip, showing attachment of the glutei and resultant line of force of hip abductors.

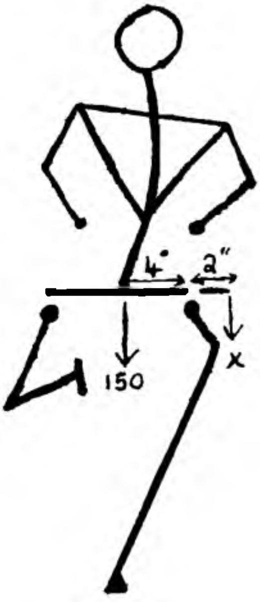
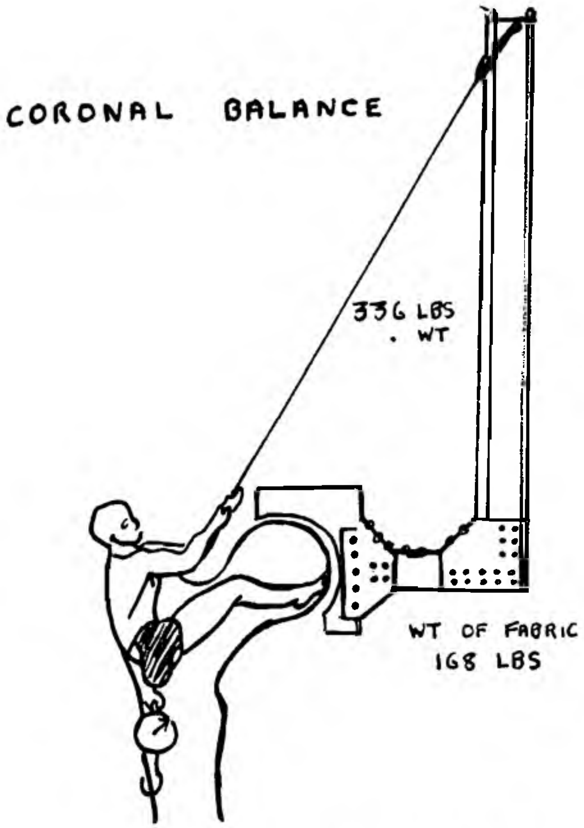


Fig. 3

$$150 \times 4 = x \times 2$$
$$x = 300$$
$$\text{Joint Pressure} = 150 + 300$$
$$= 450 \text{ lbs.}$$



CARTOON to illustrate the compression load Gluteus medius & minimus impose on the Neck of Femur.

Fig. 4

clockwise about the supporting hip and this is counteracted by an anti-clockwise force produced in part by the pull of the abductors and in part, by the considerable force which is contributed by the passive tension of the fascia lata and the ilio tibial tract[6]. Fascial structures play a large part in assisting and sparing the hip muscles. It is interesting to note that, excluding Gluteus Maximus, the actual combined mass of the Gluteus Medius, Minimus and Tensor Fascia Lata is only 15.3 per cent of the total mass about the hip[6].

If an abductor force graph (see Fig. 5) is examined it can be seen that the highest recording from the abductors occurs when the non-weight-bearing buttock is elevated and a pelvic tilt of 10-15 per cent towards the weight-bearing side is present. If the pelvis is allowed to sag, 10-20 per cent to the non-weight-bearing side, light activity only occurs in the abductors. At this point fascial structures, particularly the fascia lata are taut and are acting under load[6].

Factors which affect the Ratio of the Lever Arms

The load on the abductors and thus the force they are then required to produce to maintain coronal balance and counteract the rotatory tendency of the body weight about the supporting hip is very much influenced by the ratio in the length of the lever arms and in the amount of body weight (see Fig. 6), which illustrates how an increase in body weight requires a corresponding increase in gluteal force. Fig. 7 illustrates how, if there is shortening of the femoral neck, as is seen following fractures of the neck, or in the presence of an adduction deformity of the hip, as in osteoarthritis, the distance at which the gluteal muscles have to exert their force on the hip is reduced and a much greater force is then required to maintain balance. Clinically, patients with these factors present, which require increased strength of the abductors to obtain pelvic balance, such as the overweight osteoarthritic patient, usually present with weakness of the abductors and a gluteus medius limp, the trunk swaying over the supporting hip with each step. Insufficient abductor force and thus an unbalanced lever system.

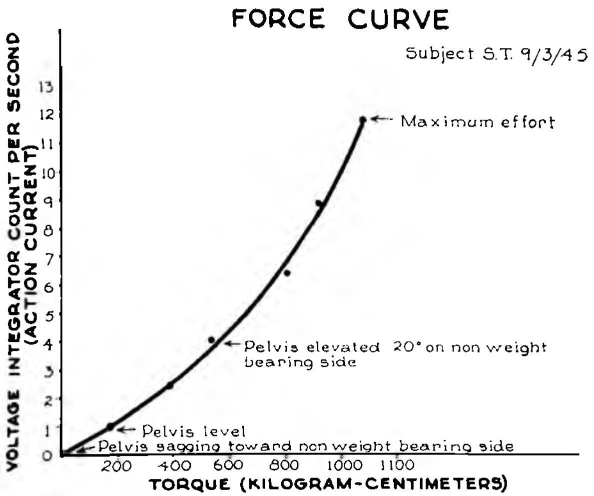


Fig. 5 Abductor Force Graph

In weakness and in the presence of a painful hip condition a gluteus medius limp is seen, the patient tending to reduce the moment of his body weight about the hip by moving his centre of gravity laterally and bringing the line of weight transmission to fall more vertically over the hip. By doing so, the demand on Gluteus Medius is decreased as the unequal length of the lever arms has been reduced. This is illustrated in Fig. 8 where there is now a ratio of 3 : 2. The same effect can be gained surgically, by osteotomy.

Use of a Cane

It has also been shown that the use of a cane, held in the opposite hand affords relief of joint pressure and reduces the work done by the hip muscles quite out of proportion to the thrust exerted on it[11] (see Fig. 9). The body weight, attempting a clockwise turning moment on the hip is counteracted by both the cane and the abductors exerting an anti-clockwise turning moment. 20 inches is the distance the cane is held from the pivot. Where the upward thrust from the cane is 30 lbs. gluteal force is reduced to nil. If the upward thrust from the cane was 20 lbs., instead of 300 lbs. of gluteal force being required only 100 lbs. is necessary, and when the upwards thrust is 10 lbs. only 200 lbs. of gluteal force is required. It has therefore been suggested that one aspect of re-education of the abductors can be achieved by patients using progressively lighter canes, thus progressively increasing the required gluteal force. Further, that as the use of a cane plays such an important part in relieving the joint from strain, its discard should not necessarily be hastened[11, 3]. Remembering that the joint is subjected to the summation of the two forces, body weight and gluteal force, in the first example the joint pressure was calculated at 450 lbs. With the use of a cane, and an upwards

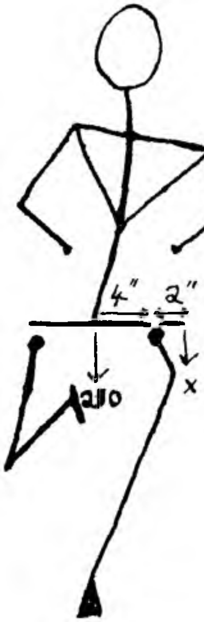
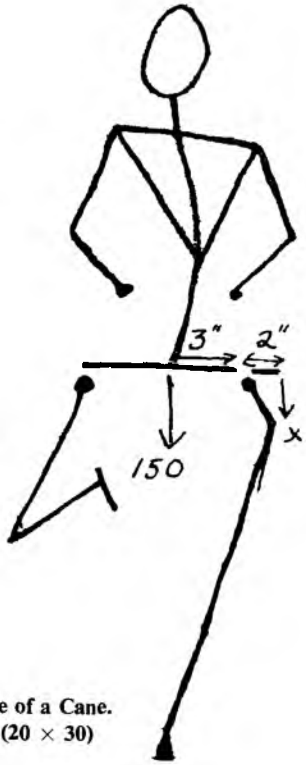


Fig. 6. Increase in Body Weight.

$$200 \times 4 = x \times 2$$
$$x = 400$$
$$\text{Joint Pressure} = 200 + 400$$
$$= 600 \text{ lbs.}$$

Fig. 8. Decrease in distance of supported weight and hip.

$$150 \times 3 = x \times 2$$
$$x \times 225$$
$$\text{Joint Pressure} = 150 + 225$$
$$= 375 \text{ lbs.}$$



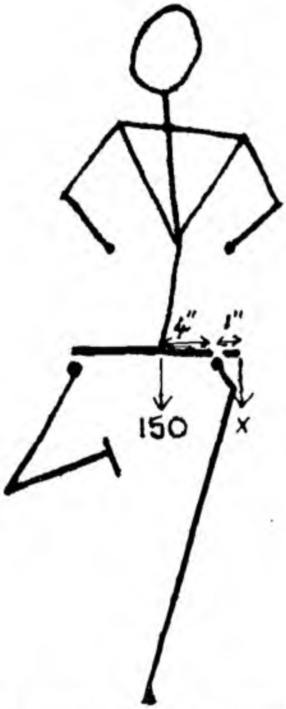
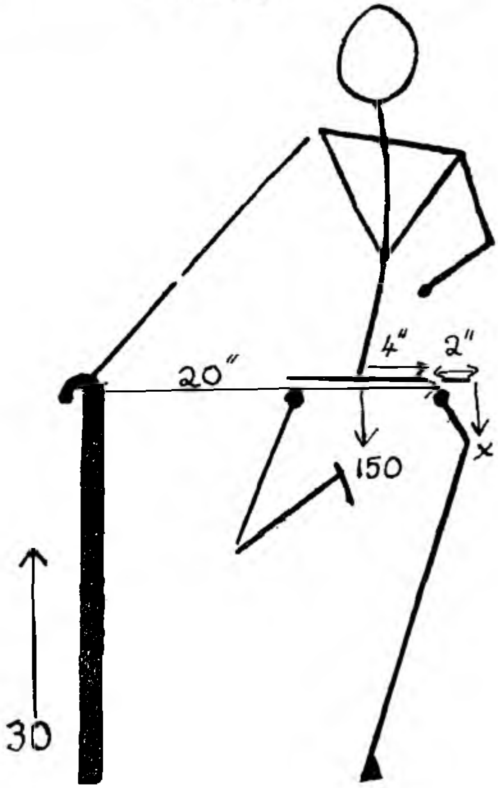


Fig. 7. Decrease in length of Femoral Neck

$$150 \times 4 = x \times 1$$
$$x = 600$$
$$\text{Joint Pressure} = 150 + 600$$
$$= 750 \text{ lbs.}$$

Fig. 9. The Effect of the Use of a Cane.

$$150 \times 4 = (x \times 2) + (20 \times 30)$$
$$x = 0$$
$$\text{Joint Pressure} = 150 - 30$$
$$= 120 \text{ lbs. wgt.}$$



thrust of 30 lbs., joint pressure can be reduced to 120 lbs. It should be noted that these figures are pounds of body weight, if the calculations were to be in pounds per square inch of pressure on the femoral head, the figures would be substantially greater.

Function of Gluteas Maximus

Finally, consider the function of Gluteus Maximus. Anatomists give its action as extension of the hip, that is movement of the femur on the fixed pelvis. Functionally this muscle, of considerable bulk, principally acts to extend the mobile pelvis to the vertical position on a fixed, weight-bearing femur and acts with its greatest force from a position of flexion to the vertical. Actions as lifting a heavy weight, the body from the crouching position. Movement beyond the vertical, in the upright position, is controlled by Ilio-psoas acting to prevent the trunk from falling backwards over the femur[12]. Leaning forwards when going up a steep hill enables us to use Gluteus Maximus with greater effort. Arthritic patients tend to walk with a flexed hip, this may not be solely due to the presence of a hip flexion contracture, as this flexed hip posture allows the patient to use Gluteus Maximus with greater force. It must be noted that this hip flexion must be corrected before the hip abductors can be correctly re-educated.

CONCLUSION

In conclusion, a review of recent literature draws our attention to the facts that:

(i) forces approximately twice the body weight at least pass through the hip joint when standing on one leg.

(ii) the major hip muscles functionally act, with force, against a load, to move the mobile pelvis on the fixed (weight-bearing) femur.

(iii) the hip abductors are normally required to act with a force at least twice the body weight to maintain coronal balance, and in many hip disorders, seen in physiotherapy departments, are required to act with even greater force.

(iv) Gluteus Maximus acts with its greatest force from a position of flexion to the vertical.

As physiotherapists, concerned with obtaining stability round the joint and in establishing an efficient gait pattern more attention should be paid to the strength and functional ability of the hip abductors in controlling the movable pelvis on a fixed femur. The ability of a patient to lift the leg, against gravity in side lying does not indicate sufficient strength to prevent the presence of a gluteus medius limp.

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