# Basic biomechanics of the hip

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## Abstract

The basic mechanical principles which govern how the hip joint maintains equilibrium and balance during standing and performing activities is explained along with the consequences when this balanced system is compromised. A description of the movements and forces acting around the hip joint that are expected during activities of daily living is offered and also how these movements are affected following total hip replacement, with particular reference to femoral offset and leg length inequality.

**Keywords** activities of daily living; femoral offset; hip biomechanics; leg length inequality; total hip replacements

## Introduction

An understanding of the mechanics of the hip joint is important background knowledge for a number of disciplines, whether these are for the diagnosis and treatment by a clinician, or for the surgeon who is performing hip surgery. It is important to understand how the mechanics of the hip change when a person is static, compared to when dynamic, what anatomical structures interact and how these enable movement and maintain stability within these mechanical principles. It is also important to understand what the normal function of the hip is during activities of daily living and how these are changed when hip surgery has been performed.

## Hip anatomy

The hip joint is surrounded by a mass of musculature that produces desired movements at both the hip and the knee, and prevents unwanted movements from the inertial forces caused by the large moving masses. The resulting joint reaction force at the hip can thus exceed many times our body weight demonstrating the importance of soft tissue support.[1,2]

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Muscles, however, are not the only important soft tissue structures which influence the integrity of the hip joint. The hip joint has a strong joint capsule and is surrounded by a complex ligamentous structure. The joint capsule has a protective role to restrain the movement of the femur articulating around the acetabulum and to prevent dislocation. The extracapsular ligaments comprise the iliofemoral (IF) pubofemoral (PF) and ischiofemoral (ISF) ligaments. The iliofemoral ligament is a Y-shaped ligament which extends anteriorly from the ilium, attaching to the intertrochanteric line of the femur; the IF ligament prevents hyperextension of the hip. The PF ligament attaches to the obturator crest and superior ramus of the pubis and blends with the articular capsule; the PF ligament prevents excessive abduction and extension of the hip. The ISF ligament is located on the posterior aspect of the hip, originating from the ischium and inserting on the intertrochanteric line of the femur; the ISF ligament resists hip hyperextension and excessive internal rotation.

Ligaments are passive structures and act more like a resistance band, thus it is very difficult to quantitatively measure when and how they work. In contrast, muscular activity can be measured through methods such as electromyography (EMG). Because of this, in comparison to studies orientated around muscle function, there is far less research around the mechanical influence of the ligaments. Researchers have used cadaveric hips to measure the contribution of each ligament using range of motion (ROM) testing, by measuring the reduction in measured torque when the ligaments had been removed.[3] In this manner, the IF and ISF ligaments were found to have an essential role in restraining rotational hip movement. Thus to maintain correct hip mechanics following surgery it is important that the function/tension of the individual ligaments is considered. To truly understand the role that soft tissues play it is important to look at how the hip joint functions as a supportive and mobile structure.

## Mechanics of the hip joint

The human body is a well engineered structure where bone and soft tissues interact in both static and dynamic situations to maintain balance and generate movement. Statics is a branch of mechanics which models and analyses load on a physical system, where structures are motionless or moving at a constant velocity. Such models would include the hip joint when standing still.

During static standing the combined forces acting on any component, measured in Newtons (N), must be zero in all in all axes (Figure 1), thus for translational static equilibrium:

$$\sum F_{x,y,z} = 0 \quad (1)$$

where $F$ = force and $x$, $y$, $z$ are the axis of rotation.

Torque, measured in units of Newton.metres (Nm), at the hip joint is also experienced and is the consequence of a load acting at a distance. For rotational static equilibrium the sum of the moments needs also to be zero[4]:

$$\sum M_{x,y,z} = 0 \quad (2)$$

where $M$ = moments.




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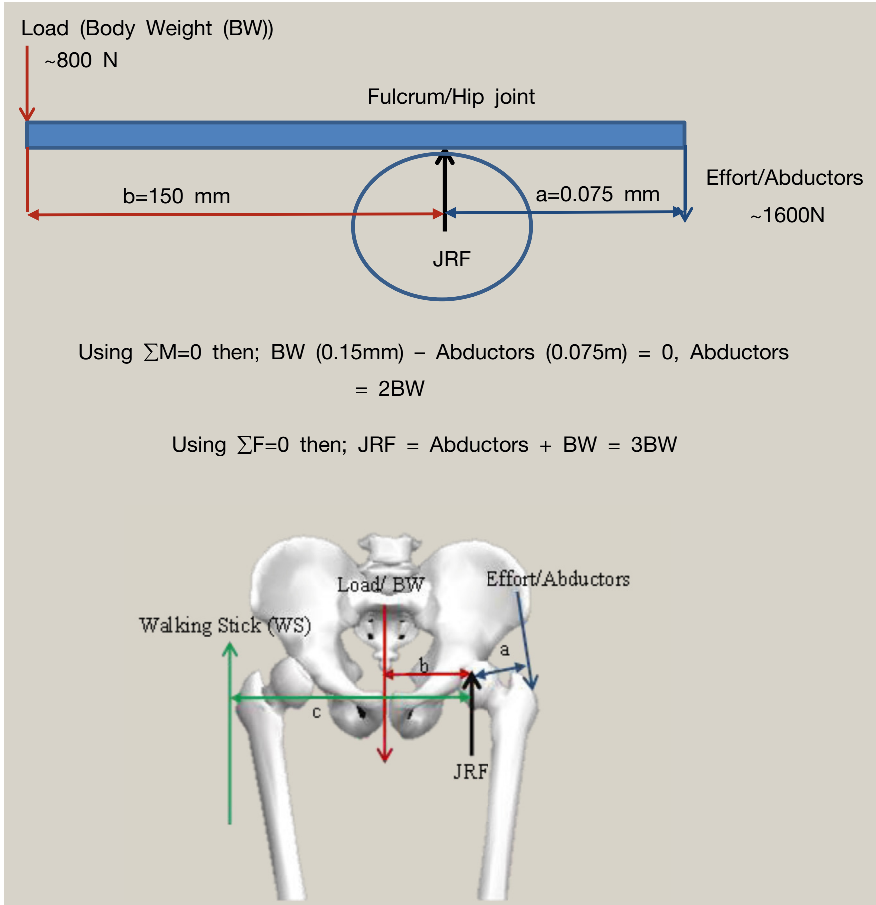


**Figure 1** A simple representation of walking, balancing load and effort. With the load represented by bodyweight on one side of the lever and the effort being applied by the abductor force on the other side, acting around the fulcrum (hip joint centre). With a schematic of the forces overlayed onto a hip model with addition of a walking stick used as aid to alleviate a painful joint (Eq. 4).

During walking the leading leg leaves the ground to step forwards, thus temporarily the body is standing on one leg. The force from our body weight (BW) at this time acts downwards pulling the body to lean over, however, this is balanced by the action of the abductors. Thus the hip behaves much like a lever (Figure 1), with a load/effort acting either side of a fulcrum (femoral head).

During standing, however, BW is supported by both hips, therefore, if the body was perfectly balanced the abductor muscles would not be required and there would be an equal force of ½ BW on each hip. As it is unlikely that the body is ever perfectly balanced the joint reaction force during standing likely varies from ½ BW to 3BW, for the perfectly balanced case and single leg stance case respectively. The abductor muscles are thus very important in balance and pelvic stability, their role becoming more important as motion becomes more dynamic. It is worth noting that although 2D static analysis provides a realistic estimation of forces and moments a number of assumptions are necessary, these are listed in Table 1.

During gait there are two distinctive phases the stance phase, when the foot is contact with the floor and the swing phase when the leg is returning. The role of the abductors is that of balance on the loaded side and managing limb motion on the unloaded side as the leg is brought forward. From the simplistic representation in Figure 1 the abductor muscle force (ABD) on the stance side is equal to body weight multiplied by the ratio of the moment arms of BW (b) and the abductors (a) measured from the hip joint centre (Eq. (3)).

$$ABD = BW \times b/a \qquad (3)$$

where ABD = abductor muscle force; BW = body weight; b = body weight moment arm; a = abductor moment arm.

### The main assumptions made during 2D static analysis of the hip joint

| Main assumptions of 2D static analysis |
|---|
| Bones are completely rigid and do not bend under load |
| Bones and muscles do not absorb any force |
| Forces are only acting in one plane without any rotational and/or translational movements |
| Joints are frictionless |

**Table 1**




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