Surface joint motion - Normal pattern is that femoral head slides across the acetabulum in movements in all 3 planes.

However, in certain circumstances, this normal sliding motion can be disrupted - causing compression or distraction.

For true 3D motions, a single ICR point is not sufficient. Rather, recent studies have attempted to define the orientation and position within various joints. This axis represents (at any given instant) that line about which the body segment is rotating and along which the body is translating all at once.

Kinetics - Large forces are applied to the hip joint area during everyday activities. It is important to understand the factors which influence these forces - especially for rehab choices for patients with hip pathology.

" (First example)

very little muscular activity is needed here. Joint is very stable from joint capsule and the capsular ligaments surrounding the joint. Joint force is mainly a result of compression from weight of the body above the hip. (superincumbent body weight = SBW)

For symmetric standing each hip supports \( \frac{1}{2} \) of this SBW (see Whitmire; Nordin Table A-1 for relative weights of body segments).

Total body weight = W

Each leg \( \times \frac{1}{3} \) W. Two legs - \( \frac{1}{3} \) W, Head + arms + trunk (HAT = \( \frac{2}{3} \) W)

HAT = \( \frac{2}{3} \) W
- force analysis

\[ J = \frac{1}{\sqrt{\Gamma}} \]

\[ \alpha = \tan^{-1}\left( \frac{\Gamma}{\Gamma - 1} \right) \approx 69^\circ \]

\[ \phi = \frac{\pi}{2} - \alpha - 21^\circ \]

Effect of \( \Gamma / b \) ratio on forces in hip joint

see Fig

tends to reduce muscle

to increase \( J \).

Artificially changing moment arms \( c \) and/or \( b \):

- Examples:
  1. Total hip replacement — if you
     moved the greater trochanter this would tend to increase muscle
     moment arm \( c \), or
     
  2. Inserting a prosthetic cup deeper into acetabulum moves center
     of joint closer to the midline, thus decreasing the \( \phi \) of the SBW.
The value of the ratio of the abductor muscle force lever arm (c) to the gravitational force lever arm (b) is plotted against the joint reaction force on the femoral head in units of body weight. Because the line of application of the abductor muscle force (its angle of inclination in the frontal plane) has finite upper and lower limits (10° and 50°), the force envelope is plotted. The curve can be utilized to determine the minimal force acting on the femoral head during a one-leg stance if the ratio of c to b is known. Adapted from Frankel, V.H. (1960). In The Femoral Neck: Function, Fracture Mechanisms, Internal Fixation. Springfield: Charles C. Thomas.

**FIG. 8-11**

**FIG. 8-12**

**FIG. 8-13**


Forces on an instrumented hip prosthesis during walking. The broken line represents the force on the prosthesis, and the solid line represents the ground reaction force. A. Walking speed 0.9 m per second. B. Walking speed 1.3 m per second. An increase in muscle activity at the faster cadence resulted in higher forces on the prosthesis. Adapted from Rydall, N. (1980). Forces in the hip joint. Part II. Intracapsular measurements. In R.M. Kendall (Ed.), Biomechanics and Related Bio-Engineering Topics (pp. 351-357). Oxford: Pergamon Press.
### Table 8-2

**Range of Typical Reported Peak Hip Joint Forces From Selected Studies**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Reported Peak Force BW</th>
<th>Instrumentation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>Instrumented implants</td>
<td>Bergmann et al., 1993, 1995</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kotzar et al., 1991</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>English et al., 1979</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rydell et al., 1966</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paul, 1967</td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>EMG/force plate</td>
<td>Crowninshield et al., 1978</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rohrle et al., 1984</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>van den Bogert et al., 1999</td>
<td></td>
</tr>
</tbody>
</table>

BW, body weight; EMG, electromyography

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7.7. **Hip Joint Loading during Symmetrical and Asymmetrical Lifting**

This example illustrates the effect of the distribution of a burden on hip joint loading. The loading of the hip joint when a suitcase is carried in one hand is compared with the loading when the same type of suitcase is carried in each hand (in other words, when the burden is twice as heavy).

![Diagram](image)

**Figure 7.7** A person is standing on one leg while carrying a 25-kg suitcase in the hand on the side opposite the standing leg (Figure A) and a 25-kg suitcase in each hand (Figure B). The body weight excluding the weight of the standing leg is 500 N. The center of rotation of the hip joint is marked with an X.
7.7A. How large is the joint reaction force (R) in the right hip when a person stands on the right leg while carrying a 25-kg suitcase in the left hand (Figure 7.7A)? Use the following data:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight</td>
<td>600 N</td>
</tr>
<tr>
<td>Weight of the standing leg</td>
<td>100 N</td>
</tr>
<tr>
<td>Moment arm of the weight of the suitcase</td>
<td>0.31 m</td>
</tr>
<tr>
<td>Moment arm of the abductor muscle force</td>
<td>0.05 m</td>
</tr>
<tr>
<td>Moment arm of of the body weight excluding the weight of the standing leg</td>
<td>0.06 m</td>
</tr>
</tbody>
</table>

The abductor muscle force (A) acts at a 70° angle to the transverse plane.

7.7B. How large is the joint reaction force (R) on the right hip joint when a person stands on the right leg while carrying a 25-kg suitcase in each hand (Figure 7.7B)?

The moment arm for the weight of the suitcase in the right hand is 0.14 m, and for the weight of the suitcase in the left hand, 0.31 m. The moment arms of the body weight and of the abductor muscle force are assumed to be the same as in problem 7.7A.
One legged stance examples:  (see problem 7-6)

Carrying one suitcase vs 2 suitcases - 

In hip is reduced when you carry 2 suitcases - one in each hand - compared to one suitcase. This is true even if the total weight carried is more with 2 suitcases than one. Better yet - split up one big suitcase into 2 smaller ones - one in each hand.

Using a cane:  (see problem 7-6)

Cane should be used on the side of the painful hip. This will tend to assist the muscle in balancing the moment of the SBW about the hip joint. This reduces the muscle force and hence reduces the force at the hip.