A

Moment of the weight

$$\vec{M}(\vec{W}) = \vec{OW} \times m\vec{g}$$

$$\vec{M}(\vec{W}) = \begin{pmatrix} -mgl\sin\theta\cos\gamma \\ mgl\cos\theta \\ 0 \end{pmatrix}$$

Unit vector normal to the plane of motion

$$\vec{w} = \vec{u} \times \vec{OW}/\|\vec{u} \times \vec{OW}\|$$

$$\vec{w} = \begin{pmatrix} 0 \\ \sin\gamma \\ \cos\gamma \end{pmatrix}$$

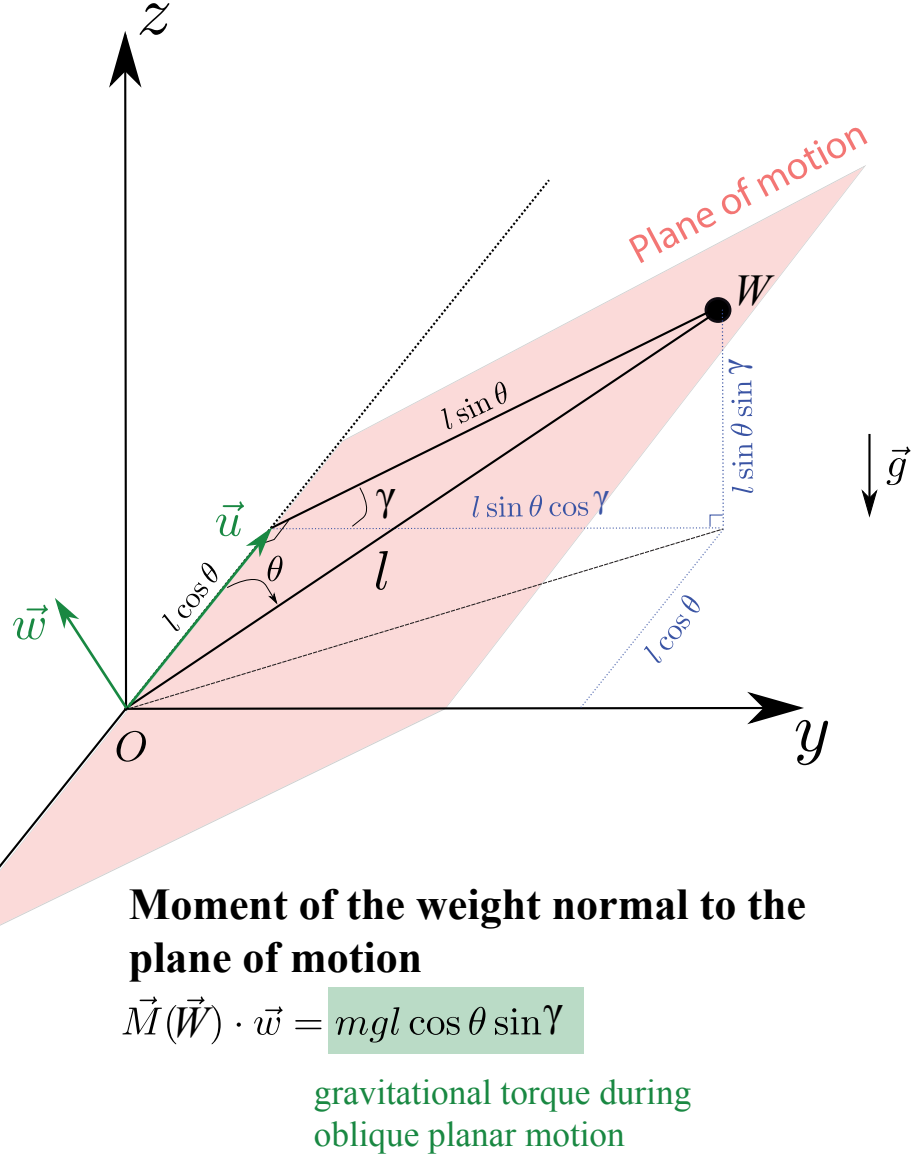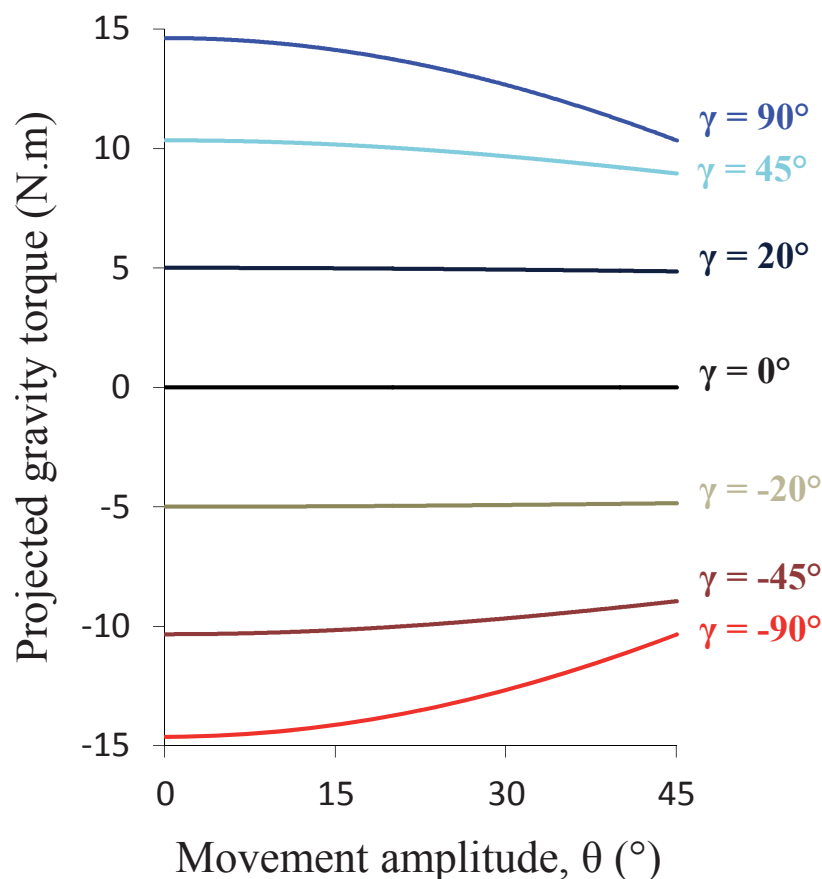**Spherical coordinates of W**

$$\vec{OW} = \begin{pmatrix} -l\cos\theta \\ l\sin\theta\cos\gamma \\ l\sin\theta\sin\gamma \end{pmatrix}$$

Moment of the weight normal to the plane of motion

$$\vec{M}(\vec{W}) \cdot \vec{w} = \boxed{mgl\cos\theta\sin\gamma}$$

gravitational torque during oblique planar motion

B

Projected gravity torque (N.m) vs Movement amplitude, θ (°)

$\gamma = 90°$
$\gamma = 45°$
$\gamma = 20°$
$\gamma = 0°$
$\gamma = -20°$
$\gamma = -45°$
$\gamma = -90°$

C

Experiment 1 setup

Target	Plane (γ)	Flexion	Extension	Abduction
0°	90°	-	45°	-
15°	75°	-	43.07°	14.51°
30°	60°	-	37.76°	26.57°
45°	45°	-	30°	35.26°
60°	30°	-	20.70°	40.89°
70°	20°	-	14°	43.22°
80°	10°	-	7.05°	44.56°
85°	5°	-	3.53°	44.89°
90°	0°	-	-	45°
95°	-5°	3.53°	-	44.89°
100°	-10°	7.05°	-	44.56°
110°	-20°	14°	-	43.22°
120°	-30°	20.70°	-	40.89°
135°	-45°	30°	-	35.26°
150°	-60°	37.76°	-	26.57°
165°	-75°	43.07°	-	14.51°
180°	-90°	45°	-	-