The Helical Extension Theorem: Psoas–Ligament Coupling and Rotational-to-Axial Work Conversion in Hip Hyperextension

Concept Note

Abstract

Standard descriptions of the iliopsoas emphasize its role as a hip flexor and trunk stabilizer, and the hip joint is often modeled as a simple ball-and-socket or hinge for teaching purposes. In extreme ranges of motion, however (e.g. deep backbends such as Urdhva Dhanurasana, martial front splits, or maximal sprint extension), the anterior hip capsule and spiral ligaments become fully tensioned. In this regime, the hip behaves like a screw constrained within a helical capsule. We propose a simple kinematic and energetic model showing how an external rotation torque driven by psoas can indirectly contribute to extension work through psoas–ligament coupling, without requiring the psoas to change sign from flexor to extensor.

1 Introduction

Anatomy texts commonly describe psoas major as a powerful hip flexor that may also contribute to external rotation and trunk control. The hip joint itself is a synovial ball-and-socket joint reinforced by strong capsular ligaments, notably the iliofemoral (Y) ligament. These ligaments are arranged in a spiral fashion from pelvis to proximal femur and tighten in hip extension, with additional tightening reported in combined extension and external rotation (a "screw-home" mechanism).

In functional movement disciplines such as yoga and martial arts, practitioners observe that certain spiral activation patterns around the hip seem to improve lift, stability, and force transmission in extreme positions (e.g. Wheel pose or loaded stances), even though psoas is typically classified as an antagonist to hip extension. This note proposes a mechanical explanation: in a "helical constraint regime" near terminal extension, rotation and extension are kinematically coupled by ligament geometry, so that external rotation work can manifest as effective extension work at the system level.

2 Anatomical and Mechanical Background

2.1 Rigid bodies and constraints

We model the system with three primary rigid bodies:

- the pelvis and trunk (treated as a single body),
- the femur,
- the ground (feet fixed; closed kinetic chain).

The hip joint is modeled as a ball-and-socket with additional passive constraints arising from:

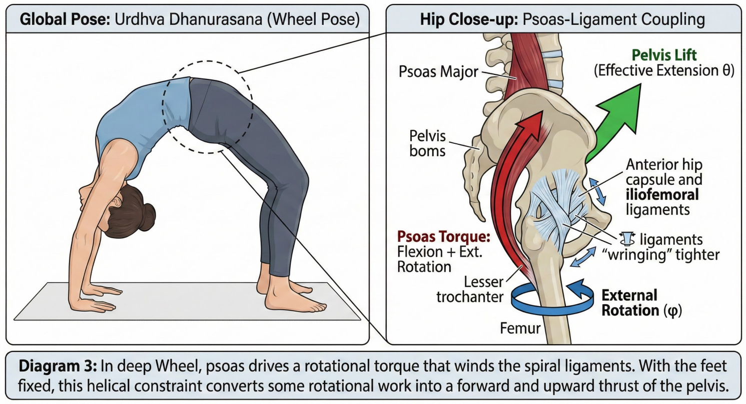

Figure 1: Conceptual illustration of deep Wheel pose with rotational torque and muscle force pathways.

- the iliofemoral, pubofemoral, and ischiofemoral ligaments,
- the anterior joint capsule and zona orbicularis.

These structures are known to run in a spiral from the acetabulum/ilium to the proximal femur and to tighten in hip extension, with further tightening in some patterns of combined extension and rotation.

2.2 Psoas major

Psoas major originates from T12–L5 vertebral bodies and transverse processes and inserts on the lesser trochanter of the femur. It is classically described as:

- a strong hip flexor,
- a contributor to lumbar flexion and lateral flexion,
- a potential external (lateral) rotator of the hip near neutral,
- an important postural stabilizer of the lumbopelvic region.

More detailed modeling shows that the rotational moment arm of psoas may vary with hip angle, but for the purposes of this concept note we assume that in the extended or near-neutral positions relevant to deep backbending, psoas can generate a net external rotation torque about the hip.

3 Kinematic Model of the Helical Constraint

Definition 1 (Joint coordinates)**.** *Let*

- *θ denote the hip extension angle measured from neutral standing ($\theta = 0^\circ$ in neutral, $\theta > 0^\circ$ in extension/hyperextension),*
- *ϕ denote the external rotation angle of the femur at the hip ($\phi > 0$ for external rotation),*

- $L(\theta, \phi)$ *denote an effective length of the anterior capsular/ligamentous complex between pelvis and femur.*

Assumption 1 (Helical constraint regime)**.** *There exists a range of motion near terminal extension in which:*

1. *the anterior capsular ligaments (including the iliofemoral ligament) are fully tensioned and act as a primary constraint on motion,*
2. *further motion of the hip approximately preserves L, so that*
$$L(\theta, \phi) \approx L_0,$$
with L_0 constant over small variations of (θ, ϕ),
3. *L is differentiable in θ and ϕ.*

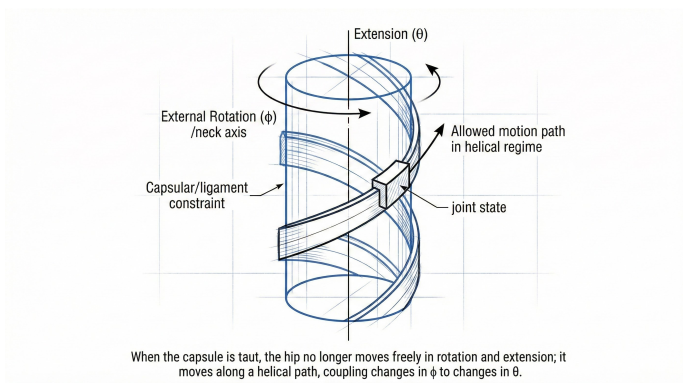

Figure 2: Helical force model emphasizing the spiral orientation and tensioning of the anterior hip capsule.

Differentiating the constraint $L(\theta, \phi) = L_0$ yields

$$\frac{\partial L}{\partial \theta}\, d\theta + \frac{\partial L}{\partial \phi}\, d\phi = 0. \tag{1}$$

Provided $\partial L/\partial \theta \neq 0$ in this regime, we obtain the local coupling relation

$$\frac{d\theta}{d\phi} = -\frac{\partial L/\partial \phi}{\partial L/\partial \theta} =: \lambda, \tag{2}$$

where λ is an effective helical pitch that characterizes the coupling between external rotation and extension near the chosen configuration.

Assumption 2 (Sign of the helical pitch)**.** *Empirically, the spiral orientation of the capsular ligaments and their reported tightening in combined extension and external rotation suggest that in the relevant end-range regime, a small increase in external rotation is associated with a small increase in extension. We therefore assume $\lambda > 0$ locally.*

Under these assumptions, small changes obey

$$\Delta\theta \approx \lambda\, \Delta\phi \tag{3}$$

for sufficiently small variations around a fixed extended configuration.

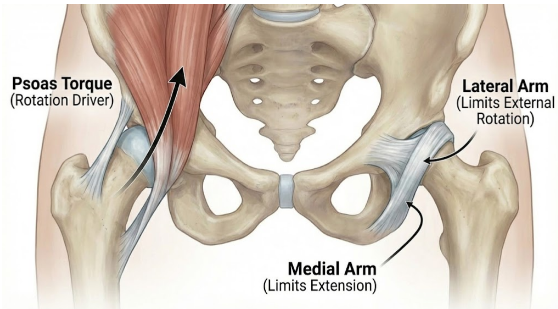

Figure 3: Schematic of rotational-to-axial coupling in the helical hip model.

4 Energetic Contribution of Psoas Rotation Torque

Let $\tau_{\phi,\mathrm{psoas}}$ denote the torque about the hip's rotational axis generated by psoas in the external rotation direction.

The incremental work done by psoas in the rotational coordinate is

$$dW_{\mathrm{psoas}} = \tau_{\phi,\mathrm{psoas}}\, d\phi. \tag{4}$$

Using the kinematic coupling $d\theta = \lambda\, d\phi$, we may write

$$d\phi = \frac{1}{\lambda}\, d\theta, \tag{5}$$

and therefore

$$dW_{\mathrm{psoas}} = \tau_{\phi,\mathrm{psoas}}\, \frac{1}{\lambda}\, d\theta. \tag{6}$$

We define the *effective extension work* of psoas in the helical regime as

$$W_{\text{ext, eff}} := \int_{\theta_1}^{\theta_2} \tau_{\phi,\mathrm{psoas}}(\theta)\, \frac{1}{\lambda(\theta)}\, d\theta. \tag{7}$$

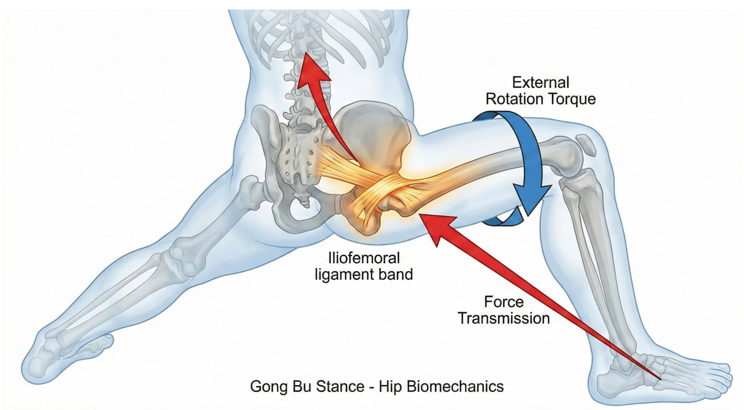

Figure 4: Lower-body hip force model in a closed-chain configuration, illustrating load transfer through the extended hip.

Note that this does *not* imply that psoas has become a mechanical hip extensor in the sagittal plane. Its classical flexion moment arm remains; rather, the geometry of the capsular constraint causes some of the rotational work it performs to appear as axial motion in the extension coordinate.

Helical Extension Theorem 1 (Helical Extension Theorem)**.** *Assume:*

1. *The hip is in a configuration where the anterior capsular ligaments are fully tensioned and impose a differentiable helical constraint* $L(\theta, \phi) = L_0$.
2. *The local helical pitch* $\lambda = d\theta/d\phi$ *is nonzero and positive.*
3. *Psoas generates a nonzero external rotation torque* $\tau_{\phi,psoas}$ *about the hip.*

Then, for any motion respecting the constraint between θ_1 *and* θ_2 *in this regime, the effective extension work of psoas satisfies*

$$W_{ext,\ eff} = \int_{\theta_1}^{\theta_2} \tau_{\phi,psoas}(\theta) \, \frac{1}{\lambda(\theta)} \, d\theta \neq 0$$

whenever $\tau_{\phi,psoas}$ *is not identically zero.*

In a closed kinetic chain (feet fixed on the ground), this extension work corresponds to a forward and upward displacement of the pelvis relative to the feet, so that psoas can indirectly assist the global extension of the body in configurations such as deep backbends.

Remark 1 (Compatibility with classical anatomy)**.** *The theorem does not require psoas to change sign from hip flexor to hip extensor. Locally, its flexion moment arm remains, and net extension requires the dominant action of musculature such as gluteus maximus and hamstrings. The result simply states that in a constrained helical regime, rotational work performed by psoas can contribute indirectly to the extension degree of freedom.*

Remark 2 (Practical interpretations)**.** *In yoga backbends such as Urdhva Dhanurasana, practitioners often report that subtle spiral actions of the femurs and a sense of "drawing into the hip sockets" create more lift and less compression. In martial arts, "screwing" the legs into the ground to load the kua is a similar experiential description. The helical extension model provides a mechanical language for these observations: psoas supplies a controlled external rotation torque that engages the spiral ligaments, and the resulting geometric coupling improves extension support at the system level.*

5 Limitations and Future Work

This concept note is intentionally simplified. Among the limitations:

- The effective ligament length $L(\theta, \phi)$ and helical pitch $\lambda(\theta)$ have not been quantitatively measured in vivo for the extreme positions considered.
- The rotational moment arm of psoas may vary substantially across individuals and hip flexion/extension angles.
- Other muscles (e.g. deep rotators, gluteus maximus) also contribute to external rotation torque and thus may share or dominate the proposed effect.
- The model neglects three-dimensional translations of the femoral head and the complex anisotropic behavior of ligaments and capsule.

Nevertheless, the helical extension theorem offers a useful conceptual bridge between standard anatomy, advanced asana and martial practice, and formal mechanics. It motivates further imaging, modeling, and experimental work to quantify capsular and ligamentous constraints at end-range hip motion.