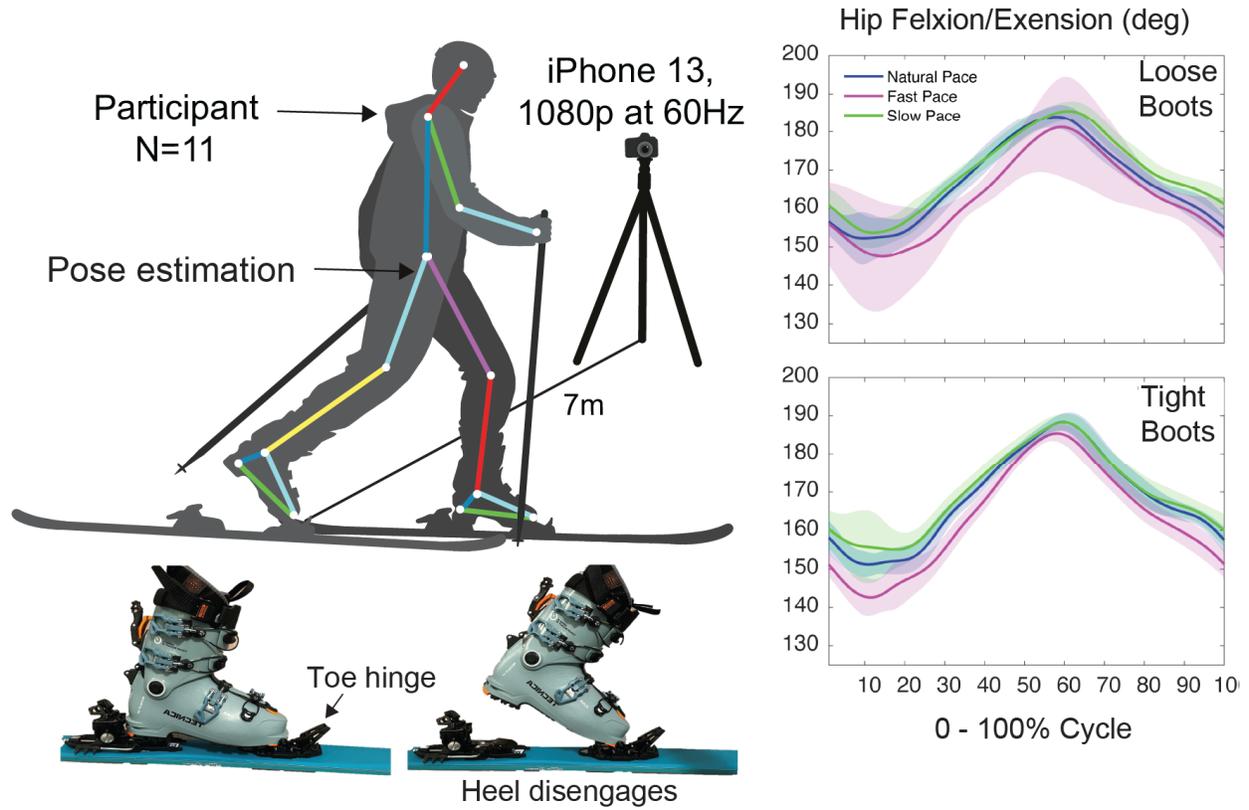


Field-based biomechanical analysis of ski mountaineering using smartphone video and open-source pose estimation

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Introduction:

Ski mountaineering debuts at the 2026 Milano-Cortina Winter Olympics, yet we know remarkably little about how athletes actually move in mountain environments. Unlike downhill skiing, ski mountaineers spend most of their time ski touring: walking uphill with skis attached, using specialized bindings that release the heel and skins that grip the snow to prevent backward sliding. During ski touring, athletes also loosen their boots to allow greater ankle mobility. This ascending phase is physically demanding and technically complex, yet nearly all biomechanical research relies on laboratory treadmills and roller skis that cannot replicate snow properties or glide characteristics. We used smartphone video and open-source pose estimation to demonstrate that meaningful kinematic analysis of ski touring is feasible in natural mountain environments.

Methods:

We recruited 11 participants (ages 22-54, intermediate to expert) and recorded video using an iPhone 13 (1080p, 60 Hz) in the mountains of Squamish (Squamish), British Columbia, Canada. Participants ski toured under six conditions varying speed (slow, natural, fast) and boot configuration (loose touring mode vs. tight skiing mode). We extracted body landmarks using a general pose estimation algorithm (BlazePose) and then estimated hip, knee, and ankle joint angles, trunk inclination, and ski stride rate across segmented ski strides.

Results:

Using this free, and easily implemented method, we found consistent hip and knee joint angle patterns across the ski stride cycle. Boot configuration altered how participants moved: tight boots reduced hip range of motion (both $p < 0.001$) but increased knee range of motion ($p \leq 0.025$), suggesting participants compensated for restricted ankle mobility through greater knee flexion. Participants also leaned further forward as stride rate increased. However, our pose estimation algorithm struggled to well track ski boot landmarks, producing inconsistent ankle angles.

Discussion:

To our knowledge, this represents the largest in-field ski touring biomechanics dataset collected to date. We demonstrate that smartphone-based pose estimation can detect meaningful kinematic patterns and condition differences in natural environments. Future work will focus on improving landmark tracking on ski equipment and validate results against wearable systems such as inertial measurement units.