FOOT AND ANKLE BIOMECHANICS IN ALPINE SKIING

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I. Introduction

A. Biomechanics in Sports: The study of the muscular, joint and skeletal actions of the body during the execution of a given sports task, skill or technique, including the interaction between the performer, their equipment and the environment.

B. Ski Biomechanics and the Foot:

1."The feet are the foundation for edging and stance. In ski biomechanics, the laws of mechanics are used to study foot/ankle movements to better understand ski performance, ski safety and injury prevention in our teaching program." -*Telluride Ski Biomechanics Program*

2. "Most articulations of the foot involve displacements beyond the neutral envelope of the architecture of the foot. Any significant interference to these displacements can disrupt the flow of the dynamic chain." - *David McPhail: "Skier's Manifesto"*

C. Goal of Presentation: Review normal foot and ankle function and introduce new insights into the role of foot and ankle movement in alpine skiing. Study the causes of impaired function which lead to poor ski performance. Examine ski equipment devices whose variable and anatomically restrictive components may be contributing to the continued high injury rate in alpine skiing. Propose responsibility to the ski industry to advance the importance of normal foot and ankle function in promoting ski safety, skier education and effective ski performance.

II. Foot anatomy + motion dynamics

III. Ankle anatomy + motion dynamics

IV. Combined Foot and Ankle Dynamics (Working Together)

A. Foot and Ankle coupling

B. Open chain vs. closed chain leg rotation (video)

C. Foot-leg Coupling: three integrated movements. Block one, block them all!

1. Ankle dorsiflexion

2. Internal rotation of leg

3. Foot eversion

D. Muscle synergism and postural response

V. Foot Dynamics in Ski Edging

A. Center of Mass (CoM) - point of average total body mass in space relative to body movement with no point of application.

B. Center of Pressure (CoP) - point of vertical ground reaction force (GRF) as body contacts ground (balance point).

C. Mechanics of one-footed stance - active normal pronation is crucial

D. One-foot balance with pronation essential in skiing, ice skating, all cutting sports

VI. Foot Dynamics in Turn Transition

A. CoP moves from neutral to inside foot pronation, outside foot supination

B. Railroad tracks edge control drill isolating foot movement

VII. Edge Control Movements

A. Foot tipping - initiates tipping

B. Body tipping - enhances tipping while achieving balance

1. inclination

2. angulation

C. MYTH: edge control by using only the leg to exert force against the side of a ski boot
D. Contributions to edge control outcomes relative to degree of edge engagement. The foot is the dominant contributor!
1. Sliding
2. Slipping
3. Skidding
4. Carving

E. Foot tipping and edging - video: in boot inversion, eversion
F. Mikaela Shiffrin: Inside foot turn initiation (demo slide + video)
G. Foot contribution to inclination/angulation: initiates edging; I & A ineffective if outside foot inverted

VIII. Ski Boot Structure and Alignment - effect on stance and foot/ankle mechanics
A. Ankle dorsiflexion crucial to stance and balance
B. Structural vs. functional fore/aft imbalance
C. History of the heeled shoe and effect on stance and balance
D. Ski stance changes with heel lifts, boot ramp and binding delta angle
E. Tight heel cord - an overlooked common problem
F. Excessive ramp angle: a stance killer?
1. Ski stance and heel elevation
2. Boot Ramp angles
3. Binding Delta angles
4. Net Ramp Angle (NRA)
5. Effects of foot/boot size on NRA
6. The enigma of ski industry boot-binding variations
    a. Is NRA critical or irrelevant?
    b. If critical, why is it so variable?
    c. If irrelevant, why does it exist?

G. Foot/ankle movement interference
1. Boot tongue block
2. Rigid orthotics and footbeds
3. Pronation vs. "captured" foot

IX. Slip-Catch Edge Control Deficiency - injury potential
1. Definition: Skier loses edge control on the outside ski (inversion) during turning which then drifts away from the body's center of mass. While extending the outside knee to regain edge engagement (eversion), the inside edge of the outside ski catches abruptly, forcing the knee into valgus and internal rotation.
2. ACL tear mechanics in slip-catch edging (video Carlo Janka)

X. Conclusions
1. Current biomechanics research is generating new insight into the role of the foot and ankle in alpine skiing.
2. Foot and ankle function is significantly modified by ski boot structure and ski bindings.
3. Wide variation in boot/binding effects on foot and ankle mechanics requires a detailed study by equipment manufacturers.
4. The increasing incidence of knee injury demands continued skier education and equipment innovation.
5. The entire ski industry must advance the importance of normal foot and ankle function in promoting ski safety, skier education and effective ski performance.