Load-limiting Sports Shoe Sole to Reduce Injuries

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Sports Engineering, Inc.

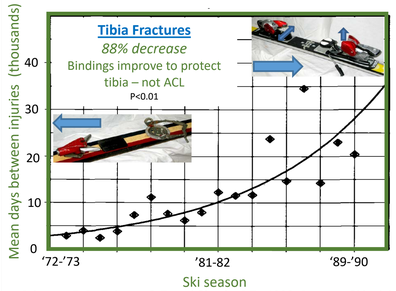
WPI

Objective

Design a new athletic shoe that will reduce ankle and knee injuries, without diminishing performance

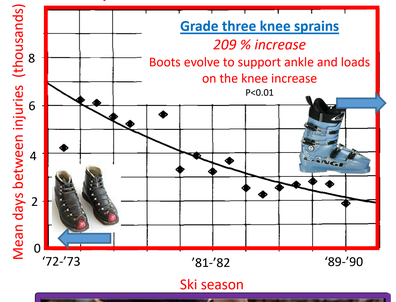
Hypothesis

Injuries caused by loads transmitted through equipment can be mitigated by adsorbing energy in the equipment (e.g., ski bindings and shoes)



Johnson, R.J., Ettinger, C.F. and Shealy, J.E., 1993, January. Skier injury trends—1972–1990. In Skiing Trauma and Safety: Ninth International Symposium. ASTM International.

Throughout the '70s and '80s better ski bindings and stiffer boots were effective at reducing tibia shaft injuries, however grade 3 knee sprains increased dramatically in the same time period.



Ski bindings emphasize release rather than absorption, resulting in inadvertent release and subsequent loss of control and potentially the race.

For floor, court, and field sports, footgear that transfers loads with high fidelity for good performance might also contribute to ankle and knee injuries. Incidences of 0.45 ACL injuries per thousand exposures have been reported for girls' high school basketball.

Prodromos, C.C., Han, Y., Rogowski, J., Joyce, B., Shi, K., 2007. A Meta-analysis of the Incidence of Anterior Cruciate Ligament Tears as a Function of Gender, Sport, and a Knee Injury–Reduction Regimen. Arthroscopy: The Journal of Arthroscopic & Related Surgery.

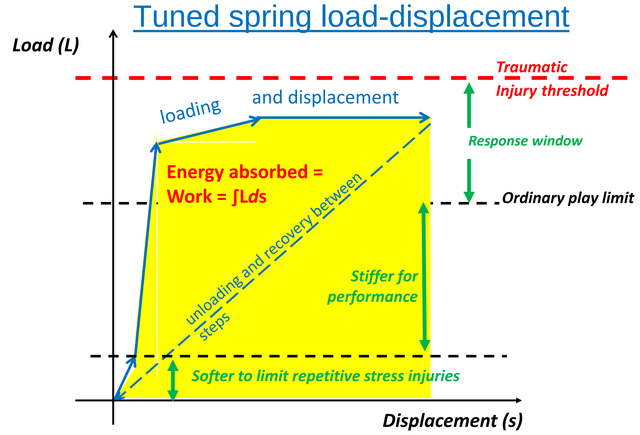
Conventional shoes absorb little energy and reach a limit where injurious loads are transmitted to the ankle and knee

Design Solution

Load-limiting shoe absorbs energy and limits loads to those in ordinary play

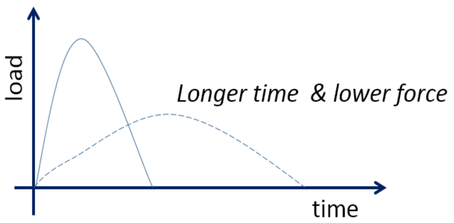
Displacement directions in the horizontal plane

Tuned spring load-displacement

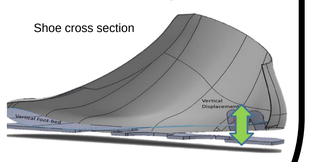


Design Concepts

- Tunable springs in the sole absorb energy and limit loads
- The response of the springs to avoid injury should not interrupt the maneuver
- Instead of releasing like ski bindings, the sole absorbs and recovers to its original configuration before the next step
- It extends the time for the player to respond



Vertical absorption



Axiomatic Design Decomposition

Axiom one – Maintain the independence of the functional elements
Axiom two – Minimize the information content (I =ln(1/p) where p is the probability of success)

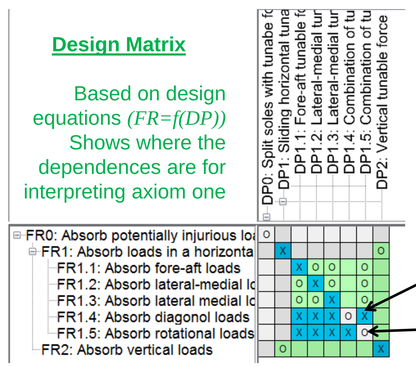
FRs – Functional Requirements that must be accomplished to satisfy Customer Needs

DPs – Design Parameters, physical solutions that fulfill the FRs

#	[FR] Functional Requirements	[DP] Design Parameters
0	Absorb potentially injurious loads to the knee and ankle in a shoe	Split soles with tunabe force spring absorption systems
1	Absorb loads in a horizontal plane	Sliding horizontal tunable force spring system across the horozontal split
1.1	Absorb fore-aft loads	Fore-aft tunable force spring absorption system
1.2	Absorb lateral-medial loads in the forefoot region	Lateral-medial tunable force spring below the forefoot
1.3	Absorb lateral medial loads in the heel region	Lateral-medial tunable force spring below the heel
1.4	Absorb diagonol loads	Combination of tunable springs for fore-aft and lateral-medial loads
1.5	Absorb rotational loads about vertical axes	Combination of tunable springs for fore-aft and lateral-medial loads
2	Absorb vertical loads	Vertical tunable force spring system under the heel controling collaspe

Design Matrix

Based on design equations *(FR=f(DP))* Shows where the dependences are for interpreting axiom one



x indicates a dependence where $\delta FR_i / \delta DP_j \neq 0$

o indicates that $\delta FR_i / \delta DP_j = 0$

Off diagonal x indicates unwanted dependence

On diagonal o indicates unwanted independence

Nam P. Suh, ***Principles of Design*** 1990

Current Prototype

- Modular units with tuned springs
- Spring modules and slidable interface inserted in sliced sole on current basketball shoes

Research and Design Questions

For axiom two – information content and probability of success
- What are the tolerances on the injury loads?
- What are the limits of ordinary playing loads?
- How should the spring strength be determined for individuals?
- How much displacement would limit how many injuries?

Athletes response
- What will the players perceive?
- Can too much displacement be a problem?

Metrics
- How should injury reduction be determined?

Continuing Development

Laboratory test apparatus for measuring and fatigue
- Loads and displacements in any direction
- Torques and rotations about any vertical axis

Axiom one issues
- Best ratios between fore-aft and lateral-medial responses
- Manage coupling between diagonal and rotational responses and the lateral-medial and fore-aft responses

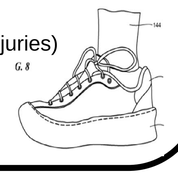
Patents

US Patent 9,730,486 Self-recovering impact absorbing footwear, Christopher Brown, Nicholas Workman, Michael Doyle, Jessica Shelsky

US Patent 9,089,763. Skate boot force absorbing appliance
28 Jul. 2015, Christopher A. Brown, Karin E. Greene, and Devon L. Rehm

US Patent 9,358,447 RAPID RESPONSE SKI BINDING
6-7-16 Christopher A. Brown, John M. Madura

US patent 9,339,719 Ski Binding Plate (to reduce ACL injuries)
5-17-16 Christopher A. Brown, John M. Madura



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