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BRIEF REPORT

Effect of Ski Mountaineering Track on Foot Sole Loading Pattern

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Objective.—Ski mountaineering is becoming a popular sport. The ascending techniques (tracks) can be divided into 3 different groups: flat field, direct ascent, and traversing. This study examines the relationship between different mechanical loads on the foot and the 4 different mountaineering ascending techniques.

Methods.—All subjects used the same pair of ski boots and the same skis while performing the 4 different ascending techniques. An in-shoe dynamic pressure measuring system was used to measure the mechanical load on the foot soles of each ski mountaineer. The foot sole was divided into 6 anatomic sections to measure the different loads in each section.

Results.—Thirteen men with an average age of 29 years were enrolled in the study. The results showed small, not significant differences in the mechanical foot load in the flat field or in the direct ascent. The average mechanical foot load was highest on the valley side foot while traversing (179 kPa to 117 kPa). The higher load forces were in the medial ball of the foot and the longitudinal aspect of the foot side closer to the hill.

Conclusions.—The higher impact placed on the valley side foot and the concentration of force placed on the medial ball of the valley side foot suggested the influence of the track on the load pattern of the foot sole. This higher impact may result in upward forces that affect the force distribution in the ankle and knee joints.

Key words: ski mountaineering, mechanical foot load, ski mountaineering techniques, dynamic measuring system

Introduction

Ski mountaineering is becoming a popular sport. In ski mountaineering, the athlete gains vertical height with special skis prepared with skins under the ski that prevent backsliding during ascent. The ski mountaineer is free to choose the level of exertion used to perform the maneuvers required for this sport. After reaching the highest point of the ascent, the athlete removes the skins and uses the skis to descend.

There are essentially 3 different techniques used while ski mountaineering. The first is in a flat field without gaining any height (Figure 1A), the second is directly ascending the slope to gain height as quickly as possible (Figure 1B), and the third is traversing the slope with or without gaining any height (Figure 1C).

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Patients we have seen in our orthopedic department who have complained of knee pain have mentioned that pain increases during ski mountaineering, specifically during traversing. In response to these patient complaints, we reviewed the literature and found no published information on the role of foot load in ski mountaineering. We report here on the first of 3 studies we conducted to examine the relationship between lower limb joint pain and foot loading during varying ski mountaineering ascending techniques. This first study attempts to establish the different mechanical loads on the foot in healthy subjects that occur during ski mountaineering.

Methods

STUDY POPULATION

All subjects were male, and all skiers had performed at least 5 ski tours during the last 2 years so they did not need help to perform the skiing techniques asked of

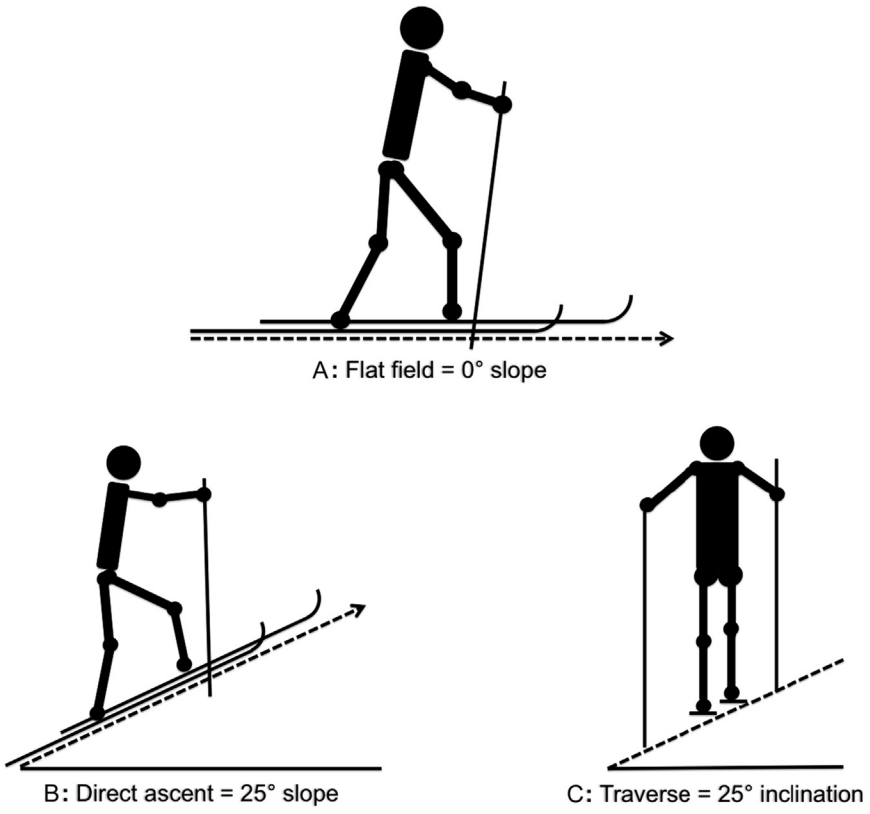

Figure 1. Different types of ski mountaineering: A) flat field, B) direct ascent, and C) traverse.

them. No study subjects were in treatment for or had been treated before the study for any orthopedic pathologies that might influence performance. The foot lengths for all subjects ranged between 267 mm and 286 mm. These subjects were chosen because, in spite of having slightly different foot lengths, they all wore the same size ski boot for ski mountaineering and were, therefore, all able to comfortably wear the exact same pair of ski boots used for load testing.

STUDY DESIGN

In this experimental study, the mechanical load on the foot soles was evaluated. The subjects performed the 3 different ski mountaineering tracks: flat field, direct ascent, and traversing. The subjects repeated each track 10 times. Only 5 complete repeats in the middle (4 to 8) were analyzed to allow time for each subject to accelerate to a steady pace and subsequently decelerate. The foot sole was divided into 6 sections (Figure 2): medial ball of the foot, lateral ball of the foot, medial midfoot, lateral midfoot, medial heel, and lateral heel.

The mean of the maximal pressure in each section across all steps was calculated. Three tracks and 4 techniques were analyzed: in plane level and fall line the movement for each foot was the same, so the average for the left and right foot was calculated. Owing to the different heights of the steps, the movement of the uphill leg and the downhill leg are different when traversing, so all uphill foot data (left and right foot) and downhill foot data (left and right foot) were combined. The unit used for pressure was kilopascal (kPa).

The subjects performed all techniques using the same ski boots (Dynafit ZZero-4 2008; Salewa Oberalp AG, Bozen, Italy) size 43 (US 9.5), on the same 170-cm skis (Bergrettungsski; Skitrab srl, Bormio, Italy), and on the same bindings (Dynafit TLT Vertical; Salewa Oberalp AG, Bozen, Italy). All measurements were performed at Seegrube within the Nordkettenbahn skiing area in March 2011.

Because the measurements were performed on healthy persons during the course of their normal sporting activity, this study was exempt from Ethics Board review. All participants provided written consent before participating in the study.

INSTRUMENTS

The mechanical load of foot soles was measured by the in-shoe dynamic pressure measuring system Pedar-x/E3 (Novel GmbH, Munich, Germany). In that system, a 1.9-mm-thick