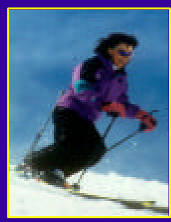
A Biomechanical Analysis of CADS



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Introduction:

"Constant-Force Articulated Dynamic Struts" (CADS) were conceived as a means of alleviating quadriceps muscle fatigue in skiers.

The device consists of cords which run between a pelvic harness (proximally) and thick rubber bands (distally) which are anchored to the ski-boots. Each cord passes over a pulley at the top of a fiberglass rod which articulates with the posterior aspect of the ski-boot. Hence, knee flexion loads the rubber bands.

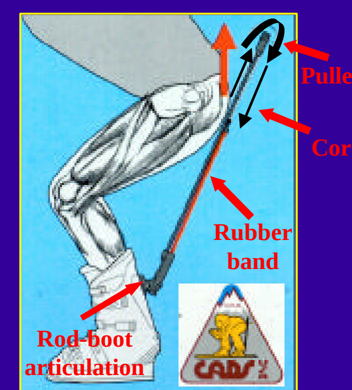
Individuals who use CADS have provided subjective evidence that CADS accomplish their intended goal of reducing quadriceps fatigue. Furthermore, many patients who suffer from osteoarthritis of the knee report that the use of CADS enables them to ski with significantly less knee pain.

Purpose:

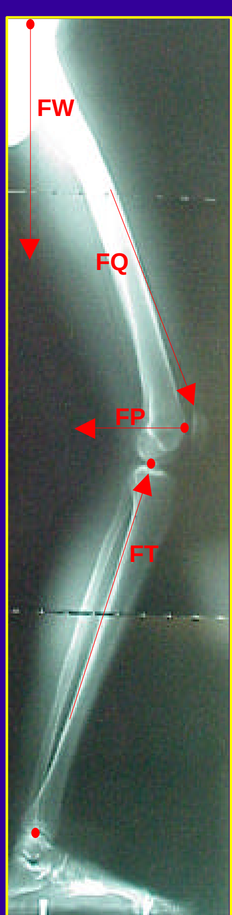
This study was conducted to qualify and quantify how the use of CADS alters knee biomechanics.

Understanding how CADS alter knee biomechanics could provide an explanation for why individuals who use CADS experience less quadriceps fatigue and less knee pain.

We hypothesized that CADS reduce effective body weight and, therefore, decrease the magnitude of quadriceps force required to maintain static flexed-knee stance.



Materials and Methods:



A static free-body analysis was performed upon the lower extremity radiographs of a 6'1", 84.5 kg male subject. Full-length lateral films were obtained with the subject's knees flexed to 20 and 50 degrees. The two positions were chosen to represent different extremes of knee flexion during skiing.

Two conditions were analyzed for each knee position: (1) without CADS; (2) with CADS.

Quadriceps force (FQ), tibio-femoral joint reactive force (FT), and patello-femoral joint reactive force (FP), were calculated according to the methods described by Perry.[1]

FQ = the product of the force of the applied body weight (FW) and its moment arm divided by the moment arm of the quadriceps tendon:

$$FQ = \frac{(FW)(LF)\sin(a)}{(LA)\cos(\phi)}$$

FT = the sum of FW and the vertical component of the quadriceps tension scaled as a function of the angle of the tibia with respect to the vertical axis:

$$FT = \frac{(FW) + (FQ)\cos(\phi)}{\cos(b)}$$

FP = the sum of the horizontal components of the quadriceps and tibial forces:

$$FP = (FQ)\sin(\phi) + (FT)\sin(b)$$

a = the angle of the femur relative to the vertical axis. b = the angle of the tibia relative to the vertical axis.
ϕ = the angle of the quadriceps vector relative to the vertical axis.

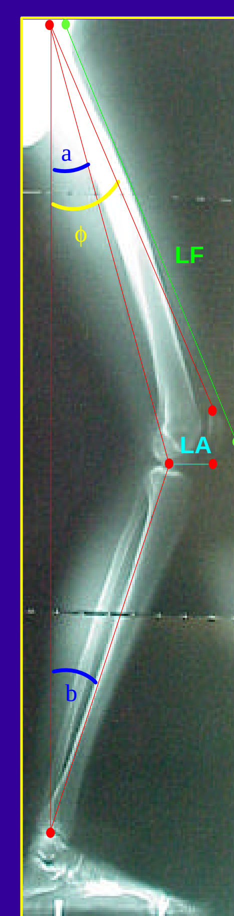
LF = the length of the femur. LA = the patellar lever arm (the horizontal distance between the tibio-femoral contact point and the center of the patella).

For condition (1), FW was calculated based upon the subject's mass. ($FW = mass \times 9.8 m/s^2$)

For condition (2), the subject's <u>effective</u> weight (F_E) was substituted for FW in each of the force equations.
Effective weight (F_E) = true weight (FW) minus the unloading effect (F_U) of the CADS: $F_E = FW - F_U$
Effective weight was measured by a scale with the subject seated upon a CADS simulator.

<u>Note</u>: We assumed two-leg stance with symmetric weight distribution to each ski.
Thus, the subject's weight was divided by a factor of 2 to calculate unilateral values for FW, FQ, FT, and FP.

We also assumed that the articular surfaces were frictionless and that body weight was centered directly over the hip center of rotation in the sagittal plane.



Results:

Knee Flexion 20 Degrees	FW: (Newtons)	FQ: (Newtons)	FT: (Newtons)	FP: (Newtons)
Condition (1): (without CADS)	415	569	975	362
Condition (2): (with CADS)	392	538	922	343
Force Reduction: (1) vs (2)	23 (5.5%)	31 (5.4%)	53 (5.4%)	19 (5.2%)

Knee Flexion 50 Degrees	FW: (Newtons)	FQ: (Newtons)	FT: (Newtons)	FP: (Newtons)
Condition (1): (without CADS)	415	1454	1888	1635
Condition (2): (with CADS)	325	1140	1480	1282
Force Reduction: (1) vs (2)	90 (21.7%)	314 (21.6%)	408 (21.6%)	353 (21.6%)

Discussion & Conclusions:

(1): The quadriceps force required to maintain static equilibrium in a flexed-knee stance is a function of body weight and the angle of knee flexion.

(2): Contact forces at the tibio-femoral and patello-femoral articulations are a function of quadriceps force.

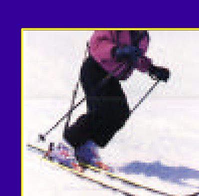
(3): Quadriceps force and joint contact forces are greater at higher degrees of knee flexion.

(4): CADS reduce effective body weight, and, thus, they decrease the magnitude of quadriceps force required to maintain static flexed-knee stance.

(5): The CADS-mediated reduction in quadriceps force decreases both tibio-femoral and patello-femoral joint reactive forces.

(6): Absolute and relative CADS-induced reductions in quadriceps force and joint contact forces are greater at higher degrees of knee flexion.

(7): These biomechanical sequellae of CADS usage provide a scientific rationale for the empiric observation that skiers who wear CADS report decreased quadriceps fatigue and alleviation of knee pain.



<u>References:</u>: (1) Perry, J; Antonelli, D; and Ford, W: Analysis of Knee-Joint Forces during Flexed-Knee Stance. JBJS, 57A:961, 1975.