

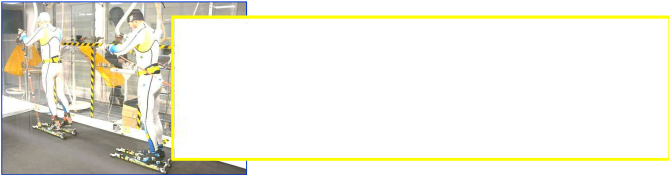
Benefits of *drafting* in double poling in cross-country skiing





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FROM OVER TO

Lienz (Tyrol) Salzburg (24 yrs) Gothenburg (SWE)


(Jyväskylä/Vuokatti; Oslo; Östersund)











Resisting forces in cross-country skiing



- **Gravitational force** (F_G) = $mg \sin \alpha$
where
 - m is the mass of the skier and equipment
 - g is acceleration due to gravity
 - α is the inclination or declination of the surface
- **Frictional force** (F_μ) = $\mu N = \mu mg \cos \alpha$
where
 - μ is the friction coefficient between skis and snow
 - in roller skiing, μ is replaced by a rolling resistance coefficient ($\mu_R = \mu$)
- **Aerodynamic drag** (F_D) = $\frac{1}{2} C_D A \rho v^2$
where
 - C_D is the drag coefficient
 - A is the projected frontal area
 - ρ is the air density
 - v is the air velocity

Earlier research of F_D in xc-skiing



- **Effect of drafting on work intensity in classical cross-country skiing.** (1995) *Int J Sports Med.*, Bilodeau B., Roy B., Boulay M. R.
 - **Methods**
On-snow skiing (2 km course). Diagonal stride and double poling techniques. Paired skiers (n= 10), leader and drafter. After 30 min recovery the skiers switched positions and repeated the protocol.
 - **Results**
Heart rate significantly different ($\Delta HR = 7$ b/min, 172 vs 165 b/min, $p < 0.05$)
- **Effect of drafting on heart rate in cross-country skiing** (1994) *MSSE*.
Bilodeau B., Roy B., Boulay M. R.
 - **Methods**
On-snow skiing (2 km course). Gears 2, 3 and 4. Paired skiers (n= 6), leader and drafter. After 30 min recovery the skiers switched positions and repeated the protocol.
 - **Results**
Heart rate significantly different ($\Delta HR = 9$ b/min, 163 vs 154 b/min, $p < 0.05$)



Earlier research, cont.



- **Drag area of a cross-country skier** (1988). *Int J Sport Biomech.*
Spring E., Savolainen S., Erkkilä J., Hämäläinen T., Pihkala P.
 - **Methods**
Roller skis on asphalt surface. Skiers (n=3) rolling in different postures and clothing. Calculations of air drag and drag area from measured velocities.
 - **Results**
Calculations of air drag and drag area from measured velocities.
- **Effects of body position on slide boarding performance by cross-country skiers** (2006). *MSSE*
Leirdal S., Saetran L., Roeleveld K., Vereijken B., Bråten S., Löset S., Holtermann A., Ettema G.
 - **Methods**
Wind tunnel. Force plate. Skiers (n=6) imitating ski-skating movements on a sliding board. Low, moderate (gear 5?) and high positions (gear 3?)
 - **Results**
Aerodynamic drag, VO_2 , heart rate, power



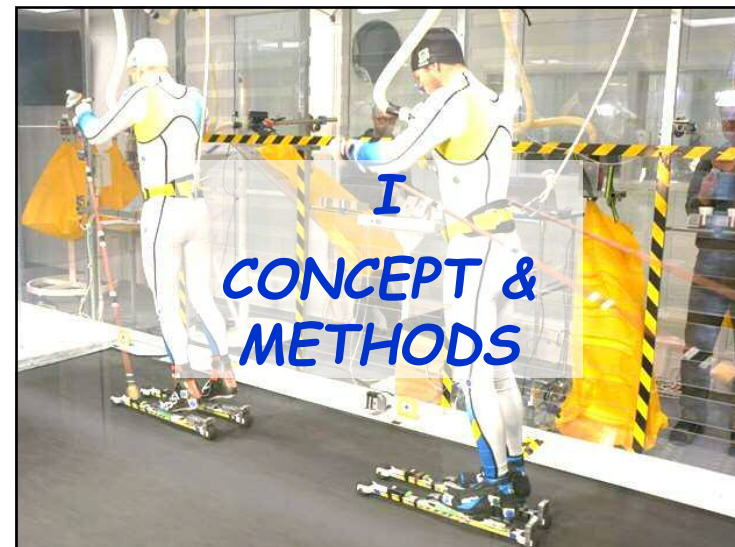
Aim of this study



- Changed techniques and velocities
- Lack of integrative physiological-biomechanical view on the "problem"
- Increased importance of tactics in World Cup and Ski Classic
- Improved technology in controlled conditions (LAB)




The aim of this part study was to investigate the **effects of drafting in double poling cross-country skiing**



Wind tunnel experiments

Design and development of a climatic wind tunnel for physiological sports experimentation

(2017) Review: *J Sports Eng Tech*
 Ainegren M.¹, Tuplin S.², Carlsson P.¹, Render P.²
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DOUGLAS BAG METHOD (VO_2)

- 5 bags front + 5 back



Lactate & HR



POLE FORCES

- *Strain gauge* load cells; aluminium tube; glide box (no cross forces)
 (Univ. Salzburg, AUT)



LEG FORCES • 2Force Binding XC skiing (Univ. Jyväskylä/Vuokatti, FIN)

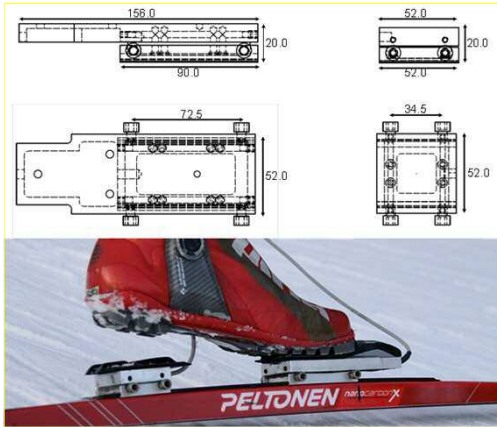
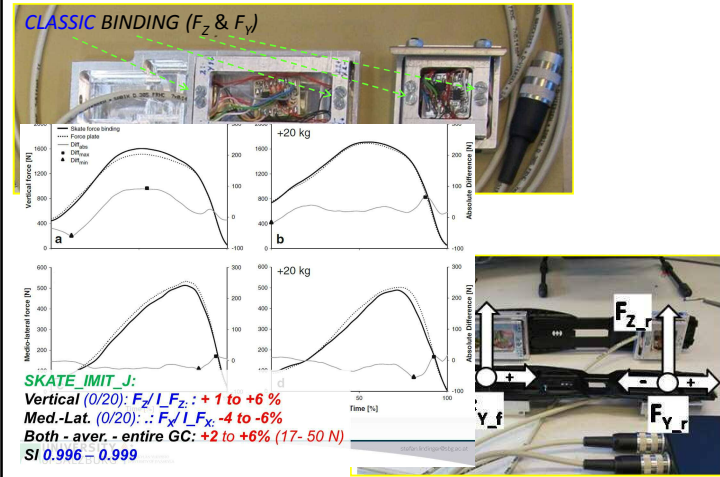


Fig. Photograph and design drawing of the developed multi-dimensional force measurement binding for cross-country skiing with dimensions of the front and rear constructions

LEG FORCES • 2Force Binding XC skiing (Univ. Jyväskylä/Vuokatti, FIN)

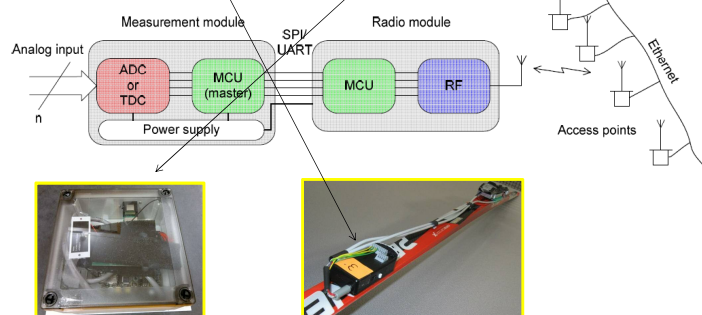


NODE SYSTEM (Vuokatti, Fin)

- Wireless data transmission

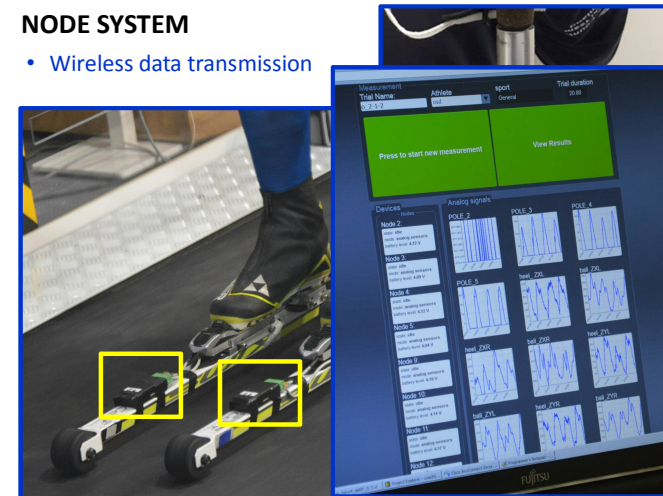
The overview of the developed system

System consists of **mobile nodes (MN)**, gateways, the **server** and the **graphical user interface (GUI)**:



NODE SYSTEM

- Wireless data transmission



• COACH TECH system

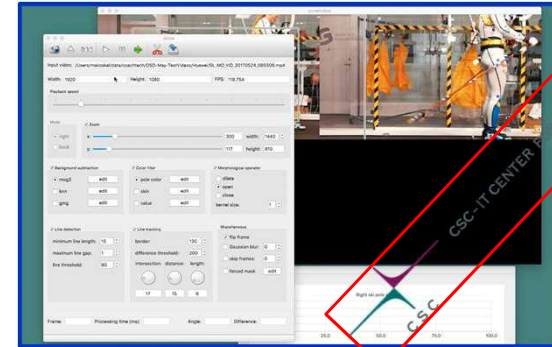
2D KINEMATICS - VIDEO TECHNOLOGY

- High speed cams (smart phones HUWEI; CANON)
- Data processing software – line pixel recognition (CSC Kajaani, FIN) – pole angle \Rightarrow *propulsive* component



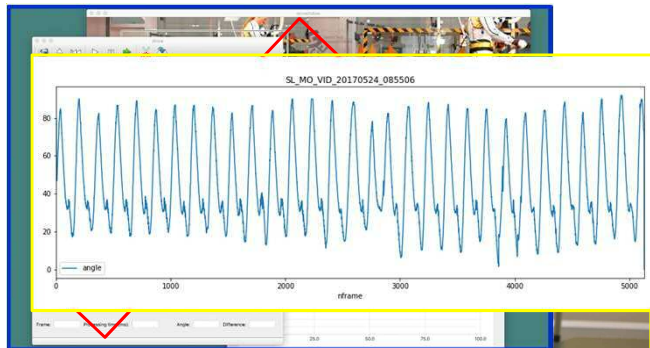
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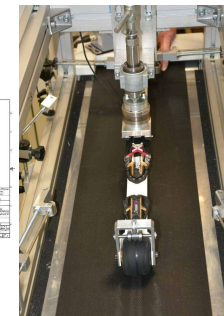
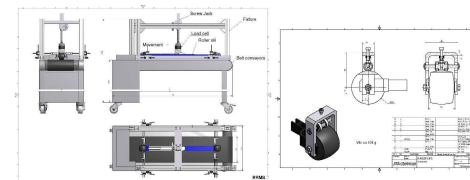
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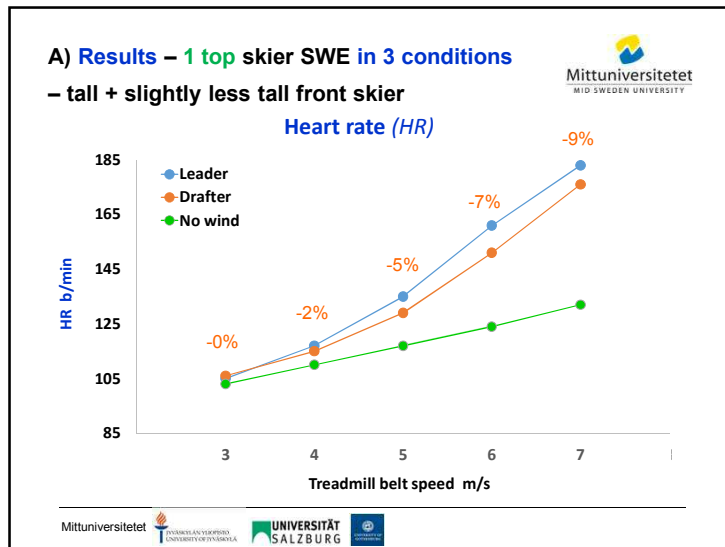
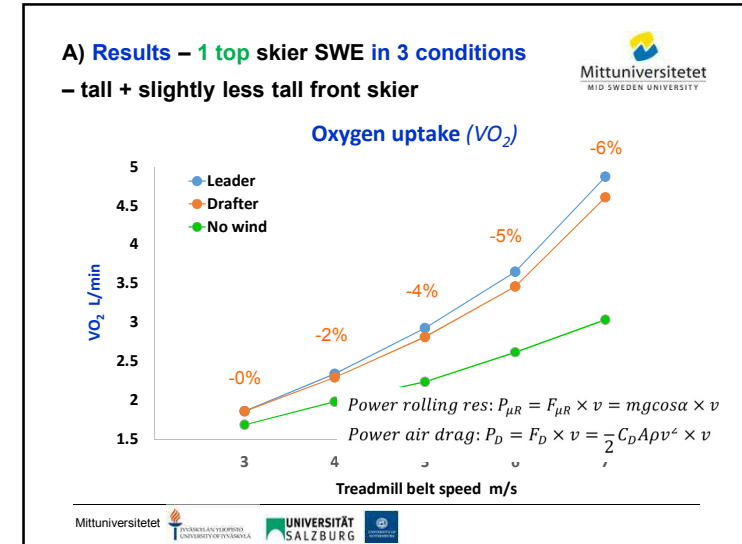


Roller skis

Measurement & standardization of roller skis rolling resistance coefficient

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DISCUSSION & CONCLUSIO



- Tactical strategy – lead or no lead/ if when?
- Adaptation patterns in front position & tactical consequences (aerodyn.)?
- Equal effects in all techniques?
- Antopometry effects (front/rear)?
- Etc.

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OC – team &
Vesa Linnamo (Chair) &
Stef J Lindinger (Co-Chair)

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CONGRESS
ON SCIENCE AND SKIING

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11.-15.3.2019 Vuokatti, Finland

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