Seminar - Post Olympic Winter Games 2018

Thursday 28th and Friday 29th of June 2018

Vuokatti Sport Olympic Training Center – Finland

PARALYMPIC NORDIC SKIING

Classification research project & performance/race analysis in Nordic Sit-skiers (PyeongChang 2018)

Stefan J. Lindinger

Eligible type of impairment

Impairment should impact performance!

Challenge is to know how much exactly the functional limitations influence e.g. race time in a complex sport!

Ten egligible impairments

Sports specific Classification

The Paralympic Movement offers sport opportunities for athletes with physical, visual and/or intellectual impairments that have at least one of the following 10 eligible impairments:

Impairment	Explanation
Impaired muscle power	Reduced force generated by muscles or muscle groups, may occur in one limb or the lower half of the body, as caused, for example, by spinal cord injuries, spina bifida or poliomyelitis.
Impaired passive range of movement	Rar… anently. Join… n, joint inst… sidered elig…
Limb deficiency	Tot… or as a con… tion) or illn…
Leg length difference	Bor…
Short stature	Rec… ones of upp… oplasia or growth hormone dysfunction.
Hypertonia	Abnormal increase in muscle tension and a reduced ability of a muscle to stretch, which can result from injury, illness or a health condition such as cerebral palsy, brain injury or multiple sclerosis.

Ten egligible impairments

Sports specific Classification

Ataxia	Lack of co-ordination of muscle movements due to a health condition, such as cerebral palsy, brain injury or multiple sclerosis.
Athetosis	Generally characterised by unbalanced, uncontrolled movements and a difficulty in maintaining a symmetrical posture, due to health conditions such as cerebral palsy, brain injury or multiple sclerosis.
Visual impairment	Vision is impacted by either an impairment of the eye structure, optical nerve/pathways or the part of the brain controlling vision (visual cortex).
Intellectual Impairment	A limitation in intellectual functioning and adaptive behaviour as expressed in conceptual, social and practical adaptive skills, which originates before the age of 18.

The presence of an eligible impairment must be proven by means of medical diagnostic information that must be presented no later than at the time of athlete evaluation.

IPC project

FOCUS ON PARA SKIING & SPINAL CORD INJURY

Impairment	Explanation
Impaired muscle power	Reduced force generated by muscles or muscle groups, may occur in one limb or the lower half of the body, as caused, for example, by spinal cord injuries, spina bifida or poliomyelitis.

CLASSIFICATION, performance, training

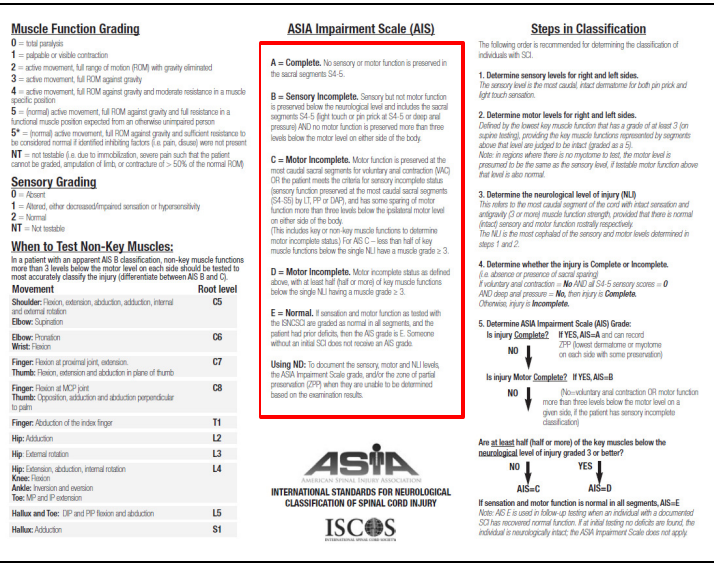
*Big **DIVERSITY** of SKIING CLASSES*

Goal:
Evidence based classification ⇒
*project start with **Nordic sit-skiers***

1 Medical Classification in SCI patients

based on rules of the **American Spinal Injury Association (ASIA)**

http://asia-spinalinjury.org/



Muscle Function Grading

0 = total paralysis
1 = palpable or visible contraction
2 = active movement, full range of motion (ROM) with gravity eliminated
3 = active movement, full ROM against gravity
4 = active movement, full ROM against gravity and moderate resistance in a muscle specific position
5 = (normal) active movement, full ROM against gravity and full resistance in a functional muscle position expected from an otherwise unimpaired person
5* = (normal) active movement, full ROM against gravity and sufficient resistance to be considered normal if identified inhibiting factors (i.e. pain, disuse) were not present
NT = not testable (i.e. due to immobilization, severe pain such that the patient cannot be graded, amputation of limb, or contracture of > 50% of the normal ROM)

Sensory Grading

0 = Absent
1 = Altered, either decreased/impaired sensation or hypersensitivity
2 = Normal
NT = Not testable

When to Test Non-Key Muscles:

In a patient with an apparent AIS B classification, non-key muscle functions more than 3 levels below the motor level on each side should be tested to most accurately classify the injury (differentiate between AIS B and C).

Movement	Root level
Shoulder: Flexion, extension, abduction, adduction, internal and external rotation **Elbow:** Supination	C5
Elbow: Pronation **Wrist:** Flexion	C6
Finger: Flexion at proximal joint, extension. **Thumb:** Flexion, extension and abduction in plane of thumb	C7
Finger: Flexion at MCP joint **Thumb:** Opposition, adduction and abduction perpendicular to palm	C8
Finger: Abduction of the index finger	T1
Hip: Adduction	L2
Hip: External rotation	L3
Hip: Extension, abduction, internal rotation **Knee:** Flexion **Ankle:** Inversion and eversion **Toe:** MP and IP extension	L4
Hallux and Toe: DIP and PIP flexion and abduction	L5
Hallux: Adduction	S1

ASIA Impairment Scale (AIS)

A = Complete. No sensory or motor function is preserved in the sacral segments S4-5.

B = Sensory Incomplete. Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-5 (light touch or pin prick at S4-5 or deep anal pressure) AND no motor function is preserved more than three levels below the motor level on either side of the body.

C = Motor Incomplete. Motor function is preserved at the most caudal sacral segments for voluntary anal contraction (VAC) OR the patient meets the criteria for sensory incomplete status (sensory function preserved at the most caudal sacral segments (S4-S5) by LT, PP or DAP), and has some sparing of motor function more than three levels below the ipsilateral motor level on either side of the body.
(This includes key or non-key muscle functions to determine motor incomplete status.) For AIS C – less than half of key muscle functions below the single NLI have a muscle grade ≥ 3.

D = Motor Incomplete. Motor incomplete status as defined above, with at least half (half or more) of key muscle functions below the single NLI having a muscle grade ≥ 3.

E = Normal. If sensation and motor function as tested with the ISNCSCI are graded as normal in all segments, and the patient had prior deficits, then the AIS grade is E. Someone without an initial SCI does not receive an AIS grade.

Using ND: To document the sensory, motor and NLI levels, the ASIA Impairment Scale grade, and/or the zone of partial preservation (ZPP) when they are unable to be determined based on the examination results.

ASIA
AMERICAN SPINAL INJURY ASSOCIATION
INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY
ISCOS

Steps in Classification

The following order is recommended for determining the classification of individuals with SCI.

1. Determine sensory levels for right and left sides.
The sensory level is the most caudal, intact dermatome for both pin prick and light touch sensation.

2. Determine motor levels for right and left sides.
Defined by the lowest key muscle function that has a grade of at least 3 (on supine testing), providing the key muscle functions represented by segments above that level are judged to be intact (graded as a 5).
Note: in regions where there is no myotome to test, the motor level is presumed to be the same as the sensory level, if testable motor function above that level is also normal.

3. Determine the neurological level of injury (NLI)
This refers to the most caudal segment of the cord with intact sensation and antigravity (3 or more) muscle function strength, provided that there is normal (intact) sensory and motor function rostrally respectively.
The NLI is the most cephalad of the sensory and motor levels determined in steps 1 and 2.

4. Determine whether the injury is Complete or Incomplete.
(i.e. absence or presence of sacral sparing)
*If voluntary anal contraction = **No** AND all S4-5 sensory scores = **0** AND deep anal pressure = **No**, then injury is **Complete.***
*Otherwise, injury is **Incomplete.***

5. Determine ASIA Impairment Scale (AIS) Grade:
Is injury Complete? If YES, AIS=A (and can record ZPP (lowest dermatome or myotome on each side with some preservation))
NO ↓
Is injury Motor Complete? If YES, AIS=B
NO ↓
(No=voluntary anal contraction OR motor function more than three levels below the motor level on a given side, if the patient has sensory incomplete classification)
Are at least half (half or more) of the key muscles below the neurological level of injury graded 3 or better?
NO ↓ AIS=C
YES ↓ AIS=D
If sensation and motor function is normal in all segments, AIS=E
Note: AIS E is used in follow-up testing when an individual with a documented SCI has recovered normal function. If at initial testing no deficits are found, the individual is neurologically intact; the ASIA Impairment Scale does not apply.

XC-skiing specific classification

1 Medical documentation – **2 Functional testing** – 3 Observation

Status: Functional testing ?

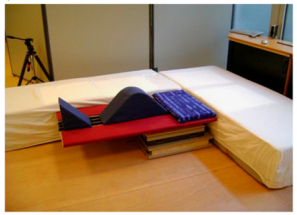
Test Table Test

(IPC; Protocol according to Pernot et al. (2011)

- The Test-Table-Test Board consists of a medium density fibre board padded with specially designed standardized cushions also supporting the legs.
- The position of these cushions can be adapted to the person's anthropometrics.
- Velcro straps over the hip joints, knees and ankles are used to secure legs during testing.

a

b



Test Table Test

Class	TTT score
LW 10	0-2
LW 10,5	3-6
LW 11	7-10
LW 11,5	11
LW 12	12

Test 3 The athlete is asked to perform a maximum rotation of the trunk in the long-sitting position in both directions while keeping the arms fully abducted.	**Score 0: No function** The athlete cannot sit with the arms abducted
	Score 1: Weak function The athlete only uses the arms when trying to rotate
	Score 2: Fair function The athlete rotates the upper body, but one side is better than the other, or lumbar spine is not following in the rotation
	Score 3: Normal function Normal trunk rotation
Test 4 The athlete is asked to bimanually lift a 1-kg medicine ball over the head from the left to the right and back. Leaning on the ball has to be avoided.	**Score 0: No function** The athlete cannot lift the medicine ball
	Score 1: Weak function The athlete can lift the medicine ball, but cannot hold it with both hands, nor lift it over the head. The athlete uses one hand for stability
	Score 2: Fair function The athlete leans on the medicine ball when putting it down
	Score 3: Normal function Normal function

(*LW* is an *abbreviation* for "Locomotor Winter")

Test- table-test (TTT)

From: Pernot et al. Validity of the test–table–test for Nordic skiing: in: Spinal Cord (2011) 49, 935–941.

(*LW* is an *abbreviation* for "Locomotor Winter")

class	Impairment	Muscle activity (ASIA classification*)	TTT
LW 10	Lower limb and trunk	**Unable to sit** without strapping	**0-2**
LW 10,5	Lower limb and trunk	**sit statically** without arm support	**3-6**
LW 11	Lower limb and trunk	**Retained** abdominal muscles and trunk extensor	**7-10**
LW 11,5	Lower **limb (s)** and trunk	Near to **normal** trunk muscles activation	**11**
LW 12	Lower **limb (s)**	**Normal** trunk function	**12**

Problem:
Functional testing **not evidence** based & **sport-specific enough**!

How much the impairment really impacts performance in sit-skiing?
Do classes reflect this?

(International Paralympic Nordic Skiing Committee) and are being published in Internet on IPC official website.

ation

3 Observation

class	% race time
LW 10	86
LW 10,5	90
LW 11	94
LW 11,5	96
LW 12	100

PROJECT START & PROJECT GROUP

EVIDENCE BASED CLASSIFICATION RESEARCH in **NORDIC PARA-SKIING**

IPC project

Since 2012/13: **Classification,** performance & training in **Paralympic Skiing** – **"Nordic Sit-skiing classification projects"** – a model for spinal cord injury/classification research

Vesa Linnamo & team
Department of Biology Physical Activity, University of Jyväskylä, Finland
Laura Gastaldi, Valeria Rosso
Department of Mechanical and Aerospace, Politecnico di Torino, Italy
Walter Rapp
Department of Sport and Sport Sciences, University of Freiburg, Germany
Magdalena Karczewska-Lindinger
Józef Piłsudski University of Physical Education in Warsaw, Poland
Yves Vanlandewijck
Department of Movement & Rehabilitation Sciences, Katolieke Universiteit Leuven, Belgium
Stefan Lindinger,
Center of Health and Performance at the Dep. of Food and Nutrition and Sport Science, University of Gothenburg, Sweden & Department of Sport Science and Kinesiology, University of Salzburg, Austria

class	impairment	Muscle activity (ASIA classification*)	% race time
LW 10	Lower limb and trunk	Unable to sit without strapping, (muscle activity score 2)	86
LW 10,5	Lower limb and trunk	Able to sit without arm support, (muscle activity score 3)	90
LW 11	Lower limb and trunk	Retained abdominal muscles and trunk extensor	94
LW 11,5	Lower limb and trunk	Retained abdominal muscles and trunk extensor activation	96
LW 12	Lower limb (s)	Normal trunk function	100

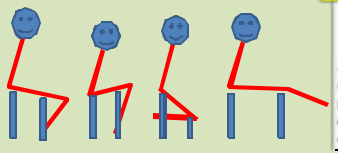
VISION/GOAL =

NEW CLASS-DISTRIBUTION!?

NEW %-TIME SYSTEM!?

STEP 1

UNDERSTANDING THE SPORT



1a *Understand* ***the sport***

STEP 1

1a)
Lab-tests abled skiers: "Effect of sitting posture on ***sit-skiing economy, muscle activity*** *and* ***force production*** *in non-disabled athletes"*

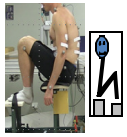
Effect of **sitting posture** on sit-skiing performance, **economy** & biomechanical patterns in **non-disabled** athletes

LAB:

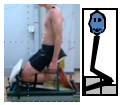
Concept 2

Double poling simulator

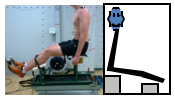
P1
normal



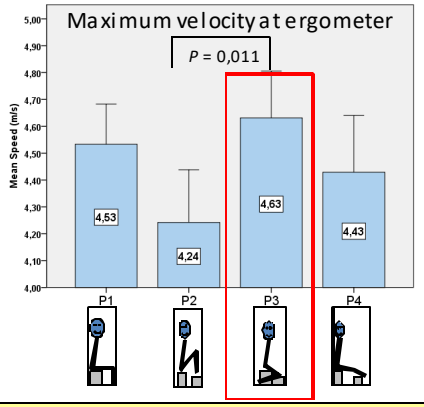
P2
knee high



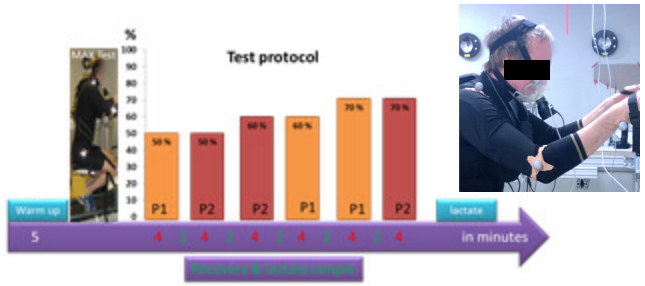
P3
kneeing



P4
long sit



- Significantly **higher maximum velocity** in kneeling position



- 10 experienced (VO_2max 73 ± 5 ml/min/kg) xc skiers
- 3 x 4 min loading in both postures - 50, 60 and 70 % of the max speed

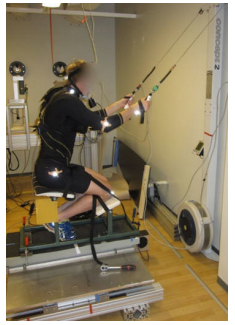
- **Physiological** variables
  - Respiratory gases (VO2, VCO2)
  - Blood lactate concentration
  - Heart rate
- Biomechanical variables
  - Poling forces
  - Cycle characteristics
  - Joint angle changes

Results:

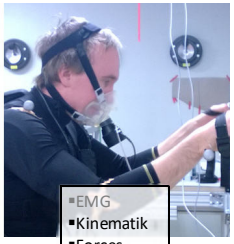
Physiological *(economy) + biomechanical data*

(Kimmo Lajunen, Bachelor Thesis, Univ. Jyvä.FIN)

e.g. Knees-high (P2)



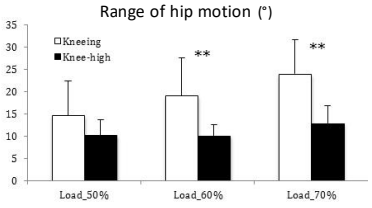
e.g. Kneeing (P3)

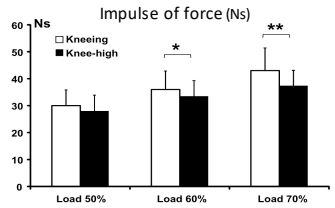


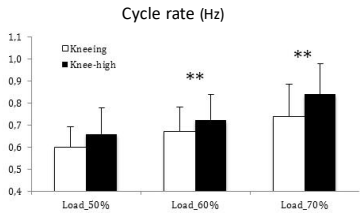
- EMG
- Kinematik
- Forces

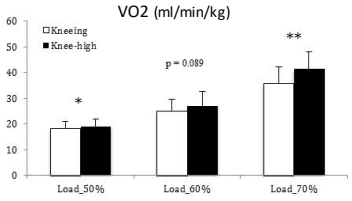
➢VO2
➢Lactate
➢Heart rate

(Lajunen et al. 2018; submitted)





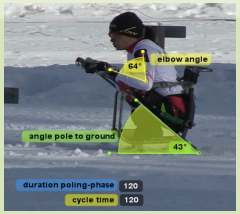


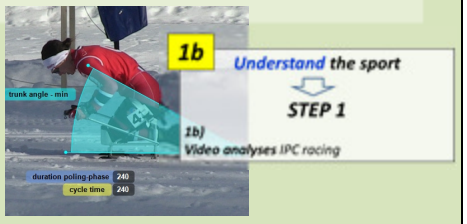


(Lajunen et al. 2018; submitted)

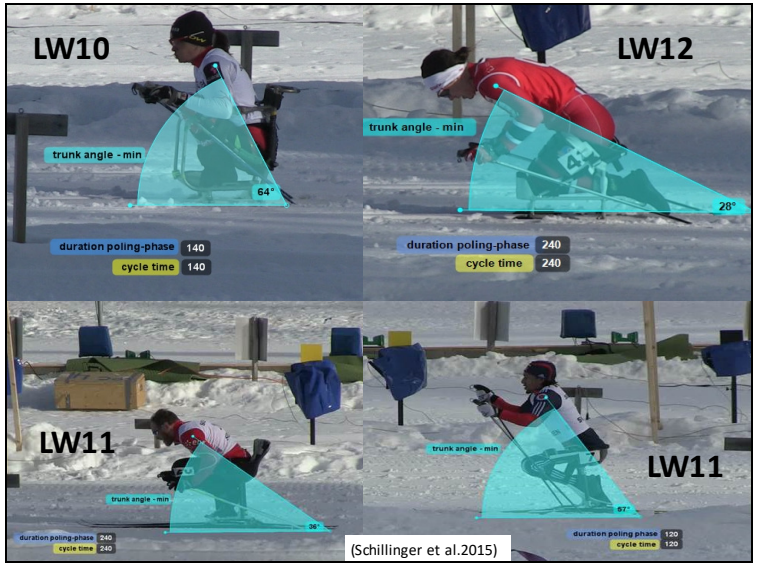
Physiological effects (disadvantages)

A descriptive video analysis of classified Nordic disabled sit-skiers during the Nordic World Championships 2013 – a pilot study



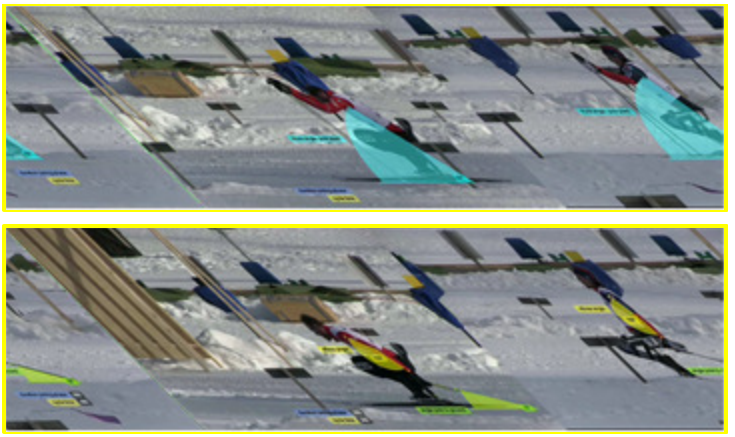


IPC NORDIC SKIING



(Schillinger et al.2015)

Info on: *pole angle, elbow angle, trunk angle, cycle characteristics*



Data pool of analysed video files

flat men	flat women	uphill men	uphill women	curve men	curve women
LW10	LW10	LW10	LW10	LW10	LW10
LW10.5	LW10.5	LW10.5	LW10.5	LW10.5	LW10.5
LW11	LW11	LW11	LW11	LW11	LW11
LW11.5	LW11.5	LW11.5	LW11.5	LW11.5	LW11.5
LW12	LW12	LW12	LW12	LW12	LW12

STEP 2

DESIGN OF NEW LAB TESTS:

- ERGOMETER TEST (DP SIMULATION) (VS SNOW SKIING)
- PERTURBATION (CORE STABILITY) TEST (ON MOVING PLATFORM)
- F-MAX TEST (ISOMETRIC)

FIELD ANLYSES ON SNOW

(SKI TUNNEL; FIN)

Ergo vs ski

Journal of Electromyography and Kinesiology 32 (2017) 15–21

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Biomechanics of simulated versus natural cross-country sit skiing

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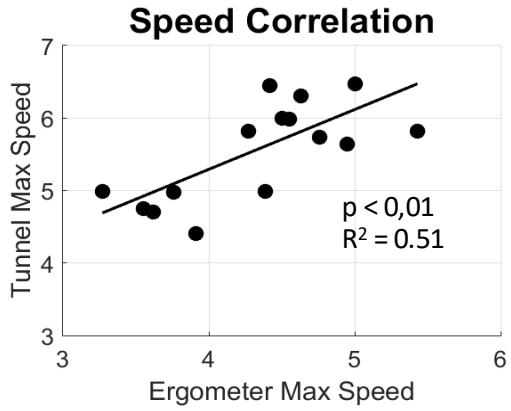
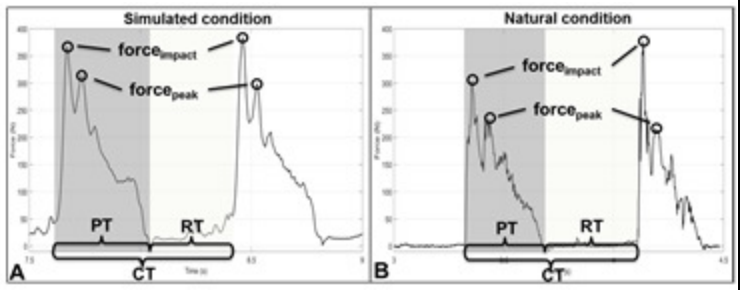
[d] Department of Sport Science and Kinesiology, University of Salzburg, Austria
[e] Department of Rehabilitation Sciences, KU Leuven, Belgium

- 5 females and 8 males
- LW10 N=1, LW10.5 N=1, LW11 N=3, LW11.5 N=4, LW12 N=4
- Ergometer resistance 7.5/10
- 16m of 2.5° incline in ski tunnel

Maximal speed

- Ergo 4.3 ± 0.6m/s
- Tunnel 4.6 ± 0.7 m/s (P<0,05)



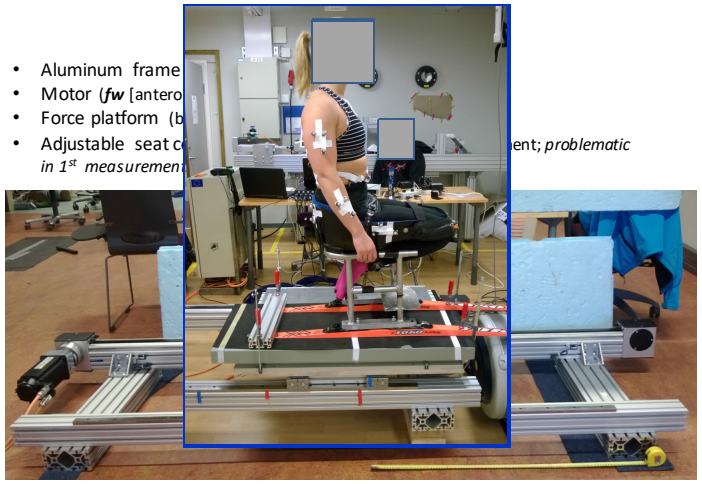


- No significant differences in force characteristics (force impact, force peak,….)

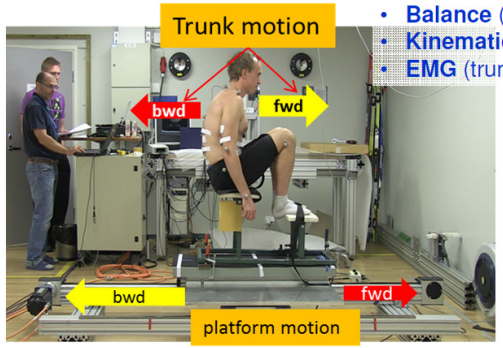
Development / design:
Core stability /perturbation test under dynamic conditions – new classification standard?

Development / design:
Max. force production test – new classification standard?

- Aluminum frame
- Motor (***fw*** [antero
- Force platform (b
- Adjustable seat c ent; *problematic in 1st measuremen*

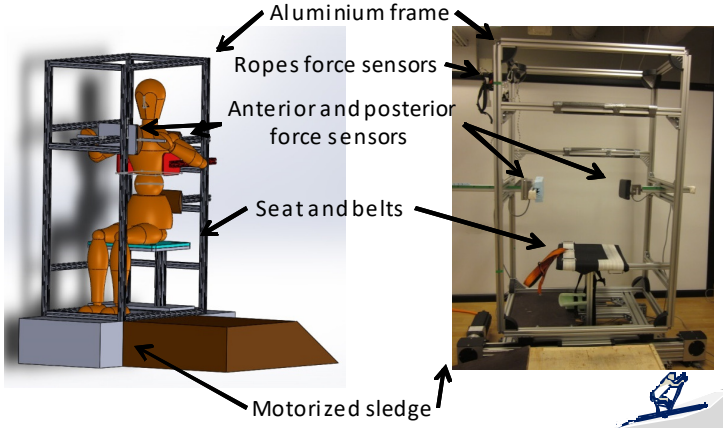


6 forward and 6 backward
6 medio-lateral (left/right)
stimuli in randomized order



- **Balance** (Amti)
- **Kinematics** (Vicon)
- **EMG** (trunk, arms, legs)

*NEW VERSION **PERTURBATION** TESTS & F_max tests*

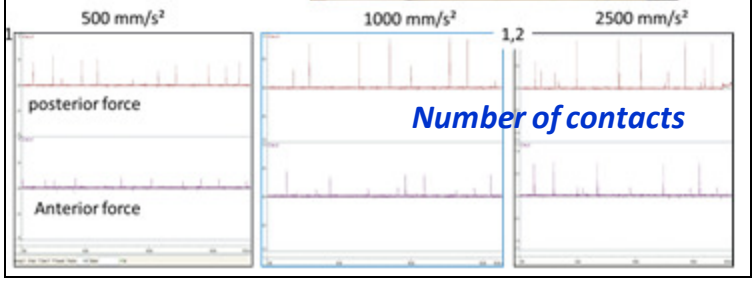


Perturbation test: New, safer device

Trunk angle *and* ***force generated*** *during* ***perturbation***

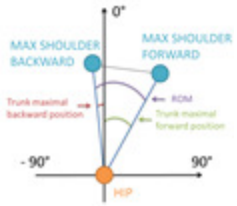
acceleration
slow (500 mm/s²),
medium (1000 mm/s²),
fast (2500 mm/s²)

5 forward , 5 backward in randomized order.

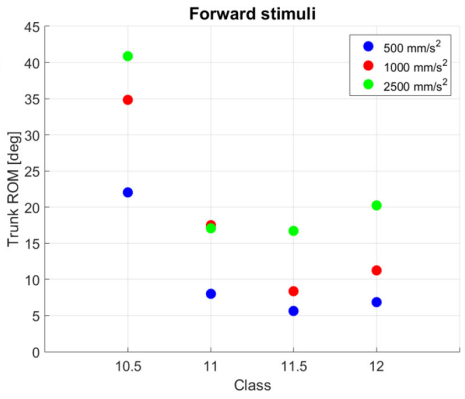


posterior force
„platform forward“

Subject „SK“ (LW12, female; high speed)



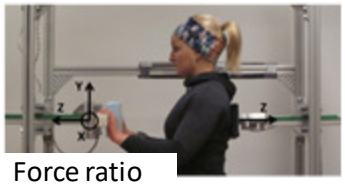
Trunk ROM - Forward and backward stimuli



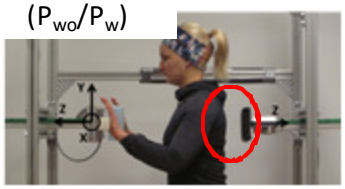
Rosso et al. (2016)

F_max - test: same device

FORCE PRODUCTION



Force ratio (P_{wo}/P_w)

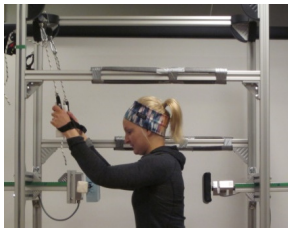


Simulated bench press by pushing **with** back support (P_w):
- P_w anterior
- P_w posterior

Simulated bench press by pushing **without** back support (P_{wo}):
- P_{wo} anterior

Rosso et al. (2016)

FORCE PRODUCTION



Simulated poling by pulling couple of ropes (P):
- P ropes

Rosso et al. (2016)

REPEATABILITY

High repeatability

Consistent measurement c…

The …

…ung

Is there a **relationship** between **force production** (simulated bench press and simulated poling) and **trunk control** (unpredictable stimuli)?

IMPAIRMENT …

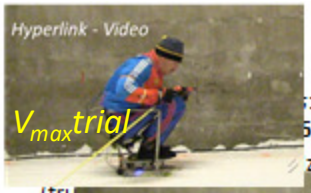
r… fo… 10.5-11

Important role of trunk muscles

The new device can separate athletes in different groups

Rosso et al. (2016)

FIELD ANALYSES – Sit-skiing on snow – VUOKATTI Ski tunnel

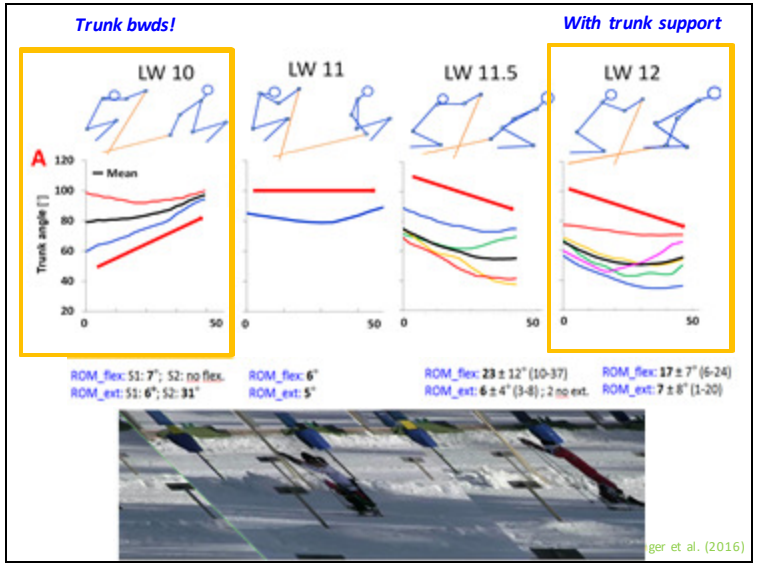


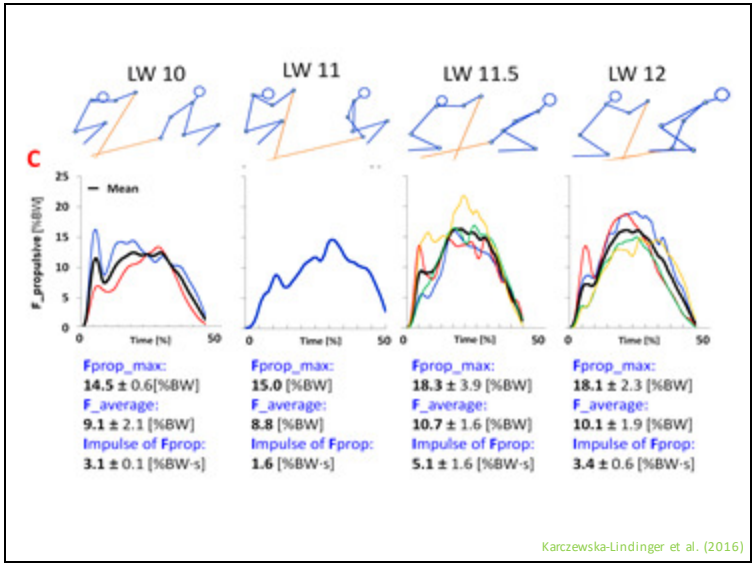
…: **12 male elite** sit-skiers (2-LW**10**, **0**-…6; 5-LW**12**)

…z; APAS-System-USA): **Joint kinematics** (tru…

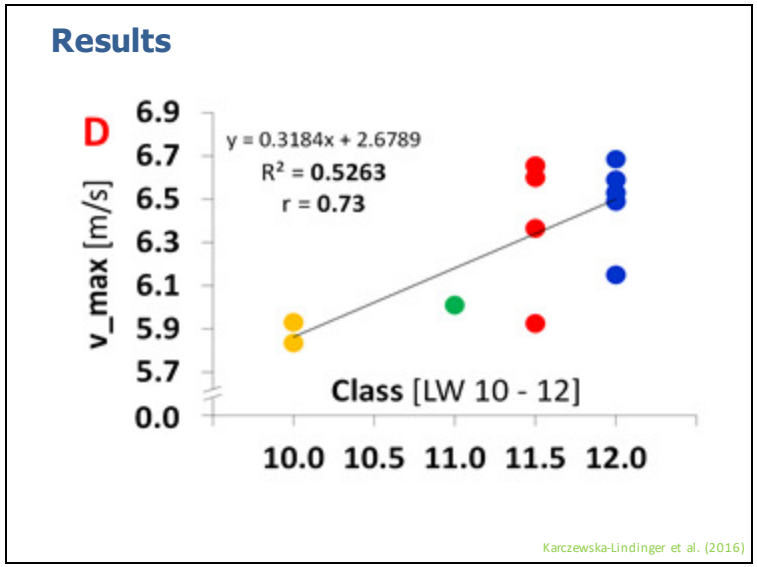
• **Pol**… force var…

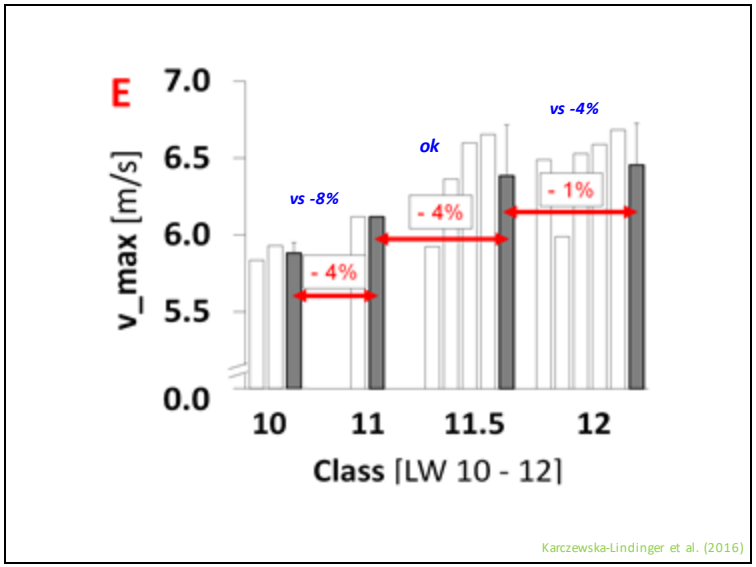
…mall *n* in …s …es are …d …vely. …ons …culated …x.


Trunk bwds!
With trunk support
LW 10
LW 11
LW 11.5
LW 12
A
Mean
Trunk angle [°]
ROM_flex: S1: 7°; S2: no flex.
ROM_ext: S1: 6°; S2: 31°
ROM_flex: 6°
ROM_ext: 5°
ROM_flex: 23 ± 12° (10-37)
ROM_ext: 6 ± 4° (3-8) ; 2 no ext.
ROM_flex: 17 ± 7° (6-24)
ROM_ext: 7 ± 8° (1-20)
ger et al. (2016)


LW 10
LW 11
LW 11.5
LW 12
C
Mean
F_propulsive [%BW]
Time [%]
Fprop_max:
14.5 ± 0.6[%BW]
F_average:
9.1 ± 2.1 [%BW]
Impulse of Fprop:
3.1 ± 0.1 [%BW·s]
Fprop_max:
15.0 [%BW]
F_average:
8.8 [%BW]
Impulse of Fprop:
1.6 [%BW·s]
Fprop_max:
18.3 ± 3.9 [%BW]
F_average:
10.7 ± 1.6 [%BW]
Impulse of Fprop:
5.1 ± 1.6 [%BW·s]
Fprop_max:
18.1 ± 2.3 [%BW]
F_average:
10.1 ± 1.9 [%BW]
Impulse of Fprop:
3.4 ± 0.6 [%BW·s]
Karczewska-Lindinger et al. (2016)

Results


D
y = 0.3184x + 2.6789
R² = 0.5263
r = 0.73
v_max [m/s]
Class [LW 10 - 12]
Karczewska-Lindinger et al. (2016)


E
v_max [m/s]
vs -8%
- 4%
ok
- 4%
vs -4%
- 1%
Class [LW 10 - 12]
Karczewska-Lindinger et al. (2016)

PROBLEM IN ALL STUDIES

- *Problem of small N of skiers in different existing classes and in general (~55 sit.skiers in WC)?*
- *More skiers (and SCI-athletes from other sports) to enable a proper cluster analyses after specific functional biom.-physiol. testing ► new classes/clusters*

STEP 3

RACE ANALYSES
(MORE ATHLETES)

Where do athletes with **different impairments** **gain** and **loose** time**?**

CHP CENTER FOR HEALTH AND PERFORMANCE

RACE ANALYSES for BETTER PERFORMANCE, TRAINING & classification/fairer competitions

Section-time & speed analyses *during racing (Paralympic Games & World Cups in elite Nordic sit & standing skiers with physical impairment*

CHP CENTER FOR HEALTH AND PERFORMANCE

Basic idea:
to provide coaches & athletes a

a)
Detailed (functional track sections) **split time analyses**: (also shooting range biathlon) during **Paralympics & WCs** in season 17/18

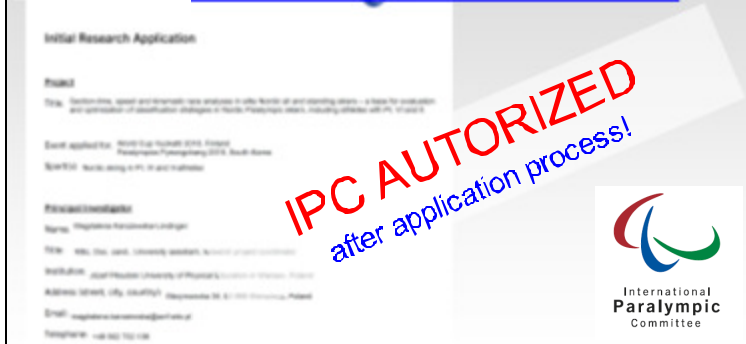
+

b)
a highly accurate **position & speed / acceleration over time** (speed-time-curves) analyses during all races – speed distribution and acceleration patterns on entire track

CHP CENTER FOR HEALTH AND PERFORMANCE

Project authorized/allowed by IPC

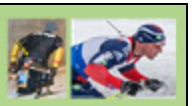
Written allowance given from IPC:



IPC AUTORIZED after application process!

International Paralympic Committee

I



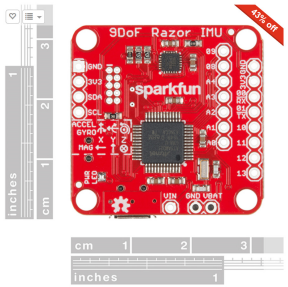
SPLIT TIME ANALYSES by leight weight **mini Magneto sensor** (independent)

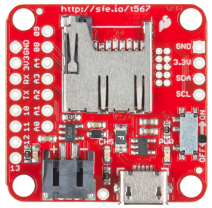
Accurate Screening of many/optional split times on track

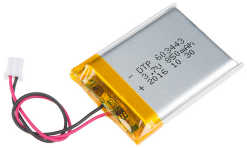
(much more detailled compared to timing company during a race)
(see/read in detail PDF file Korea application)

TECHNOLOGY: MINI-MAGNETO-SENSORS (RECEIVER) + MAGNETS (SENDER) IN SNOW

SparkFun 9DoF Razor IMU M0
SEN-14001

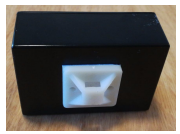


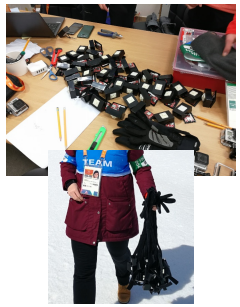




TECHNOLOGY: MINI-MAGNETO-SENSORS (RECEIVER) + MAGNETS (SENDER) IN SNOW

SparkFun 9DoF Razor IMU M0
SEN-14001

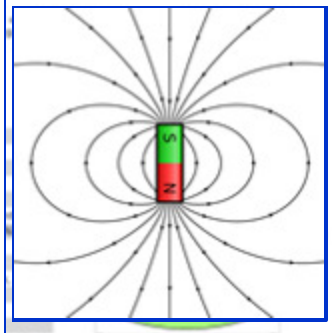




*„No“ weight (15g)
*Small
*Easy to mount
(plastic band fixed)
*„No“ interference with athlete
*100 Hz

TECHNOLOGY:

MINI-MAGNETO-SENSORS +
MAGNETS IN SNOW



Data sheet

Technical data

1. Technical inf

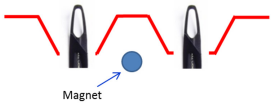
Residual magn … 2900-13200 G, 1.29-1.32 T

strength … pprox. 13 kg (approx. 127 N

CONCEPT

Miniatur Magneto-Sensor on sledge close to track;
+ low cost magnet below snow surface!

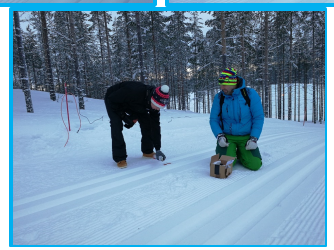
Fig. 10: Mounted miniature Magneto-Sensor (left side), magnets (right side), and embedded magnet below snow surface in the classic track (below):



Magnets have to be placed at the desired split time places along the track after each grooming, which is not very "invasive" and simply done. The cylinder with filled magnets can be placed aside the track with the disadvantage of weaker signal quality.

EARLY MORNING MAGNET INSTALLATIONS

EARLY MORNING MAGNET INSTALLATIONS



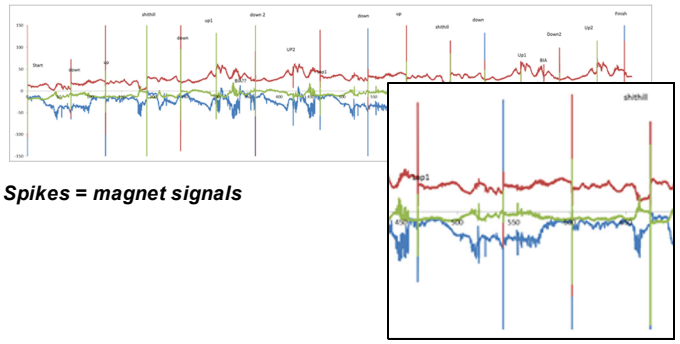
TECHNOLOGY: MOUNTING OF SENSORS

TECHNOLOGY: MOUNTING OF SENSORS

TECHNOLOGY: MAGNETO-SENSORS + MAGNETS IN SNOW

Magnet sensor curves

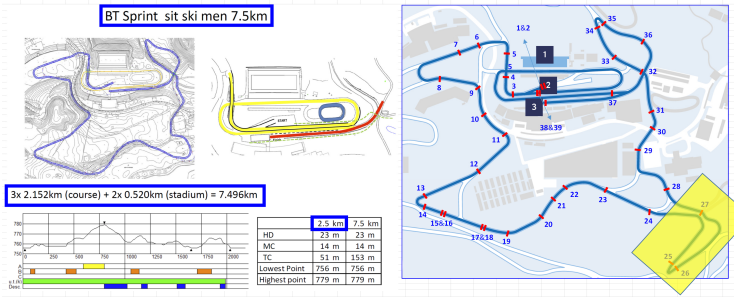
A typical magnetometer signal looks like shown in the following Fig. 12. The spikes given by the magnet to the Magnetometer Sensor is recognized:



Spikes = magnet signals

TRACK PROFILING & TERRAIN DESCRIPTIONS FOR SPLIT TIME SECTIONS

(sections should clearly differ in terrain and power & coordinative demands)



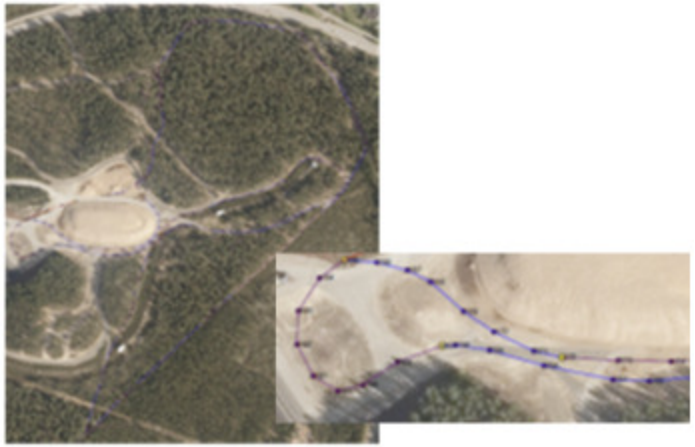
TRACK PROFILING & TERRAIN DESCRIPTIONS FOR SPLIT TIME SECTIONS

3 km TRACK - Sit CC Long Sit Ski men (5x3) & women (4x3) 15 & 12 km

Section	Split Numbers	Magnet set up	Disctance (m)	Climb (m)	Down (m)	Incline (%)	Decline (%)	Verbal characterization	Terrain category/code
1	1-2	1-single; 2-single						short flat straight acceleration section over ~10 m from stand still	
2	2-3	3-single;						straight flat start section	
3	3-4	4-array: 4-5 magnets		x		x		short steep UH + right curve (~90 deg) to bridge 1	
4	4-5	5-arrary: 4-5 magnets						flat straight section on bridge (preperation left curve)	
5	5-6	6-array: 5-6 magnets						left curve (~90 deg) after bridge (~double curve) + short flat part twds mini top	
6	6-7	7-array: 5-6 magnets			x		x	short DH wave (~8 m) to short flat straight part	
7	7-8	8-array: 4 magnets						wide flat left curve	
8	8-9	9-array: 5-6 magnets (in ri curve)		x		x		light-moderate straight UH + small right curve	
9	9-10	10-array: 4 magnets		x		x		short moderate-steep straight UH	
10	10-11	11-array: 4 magnets						"straight" flat section	
11	11-12	12-array: 4 magnets		x		x		ri curve transition to UH + longer steep straight UH 1	
12	12-13	13-array: 4 magnets		x		x		light-moderate straight UH + straight flat part	
13	13-14	14-array: 4 magnets			x		x	fast sharper left curve - transition to straight long DH	
14	14-15	15-array: 4 magnets			x		x	moderate (intermediate) DH part with double poling/getting speed	
								very short 10 m moderate DH part 1:	

TRACK PROFILING:

GPS measurements for exact distances: Longitude, latitude, altitude



TRACK PROFILING:

GPS measurements for exact distances: Longitude, latitude, altitude

7 SIT-SKI RACES (CC & BIA) + 2 STANDING RACES
40-60 SKIERS EACH

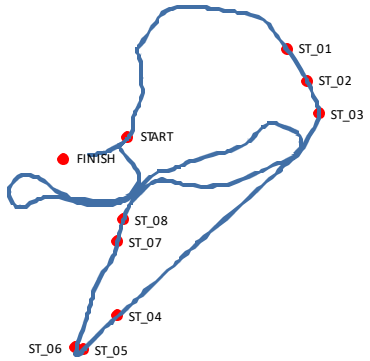
RACE TRACK (SECTION) VIDEO-REPORT:

VIDEO OBSERVATION ON SELECTED SECTIONS (4-5 / DAY)

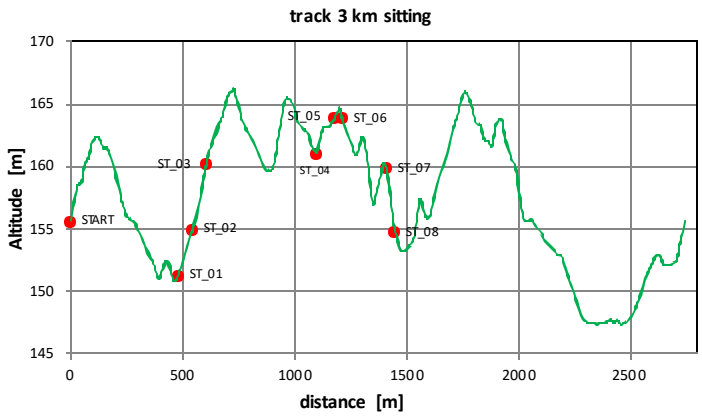
QUALITATIVE

ANALYSES

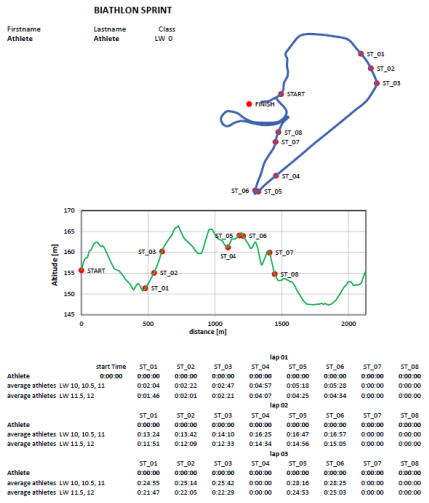
SPLIT TIME DATA PRESENTATION:

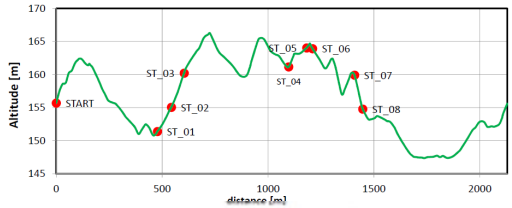


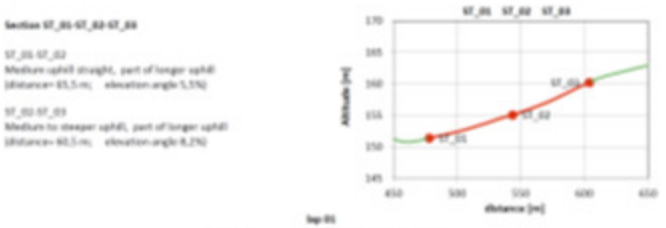
SPLIT TIME DATA PRESENTATION:



SPLIT TIME DATA PRESENTATION:



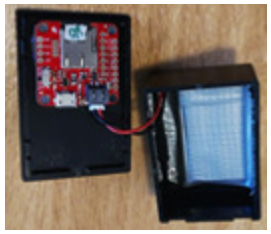


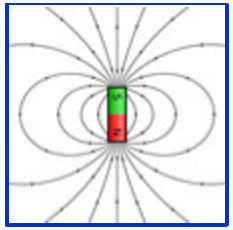


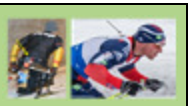
- Absolute and relative differences to own class average (if more than 1 skier in class) and other classes
- Abs. and rel. changes of split times over laps
- Couple similar sections within a race and between races and look at the abs./rel. differences (same kind of terrain - more often)
- Ski test/gliding section: Judge split times relative to gliding properties/speed of each ski/skier-sledge system (glide sections during race without pushing) – optimum = ski test data before race!
- Analyse as many skiers as possible skiers as often as possible over season

LOGISTICS & LIMITATIONS

of the MAGNETO-SENSOR – MAGNET concept?







II

SPEED ANALYSES by super-leight weight mini GNSS system

New, mini,
KINEMATIC GNSS system
for race analyses in **Nordic Parasport**

Naoto Miyamoto
Tohoku University, JAPAN

Configuration – mini precision GNSS (GPS) sensor

*Global Navigation Satellite System"

Accurate positioning system **"kinematic GNSS*"**

Kinematic GNSS

- **Size: 78.5 x 38.5 x 18.5 mm³**
- **Weight: 69 g**
- **Accuracy: a few centimeter**
- Battery: 6 hours
- **Rate: 10 Hz**
- Antenna: integrated

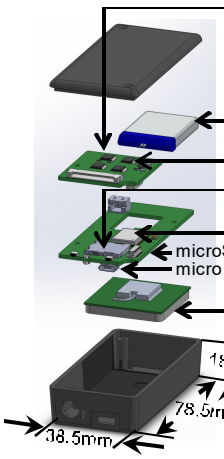
AT-H-02 by Aoba Technologia Inc.

GPS 1200+ by Leica
http://leica-geosystems.com

*„No" weight (69g)
*Small (7.5 cm)
*Easy to mount

- Accuracy of a heavy, huge Leica High End GNSS (see pic right)
- High accurate and **portable mini** measurement system with kinematic GNSS

Configuration - Kinematic GNSS "AT-H-02"



Inertial Measurement Unit
accelerometer, gyroscope

Lithium Polymer Rechargeable Battery
400mAh 6 hours

Analog-to-Digital Converter 24bit ΣΔ
ARM processor 72MHz

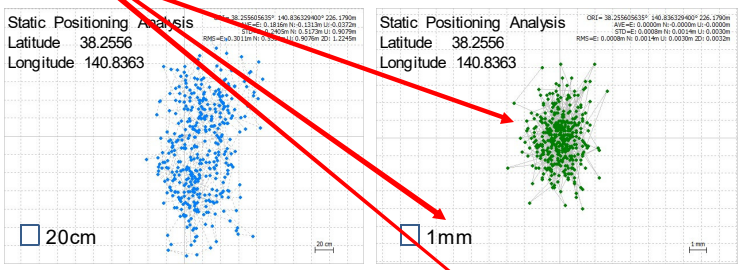
sensor I/F
- heart beat rate
- wind velocity
- snow temperature

GNSS module **10Hz Raw data output**
microSD card 16GB
micro USB connector
GPS, **GLONASS**, Beidou, Galileo, SBAS, QZSS

Integrated active patch antenna
35 x 35 x 6.9 mm³

Advantages
- Precise positioning
- Small size
- Light weight
- Low energy consumption
- All synchronized

Huge accuracy – static positioning analysis



Positioning Accuracy
σ(East-West) 0.2405m
σ(North-South) 0.5173m
σ(Up-Down) 0.9079m

SX BLUE II (GENEQ Inc.)
→ differential GPS

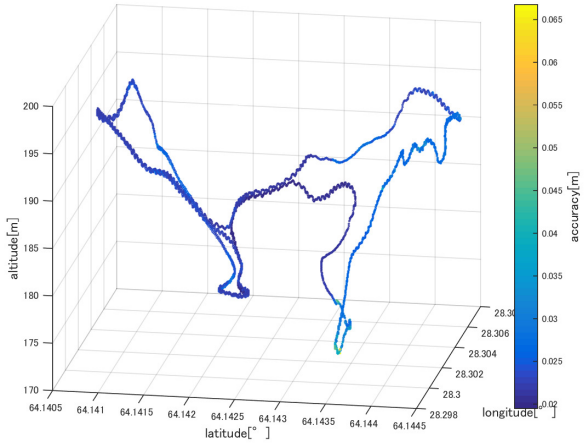
Positioning Accuracy
σ(East-West) 0.0008m
σ(North-South) 0.0014m
σ(Up-Down) 0.0030m

AT-H-02
→ kinematic GNSS

AT-H-02 has millimeter-order static positioning accuracy

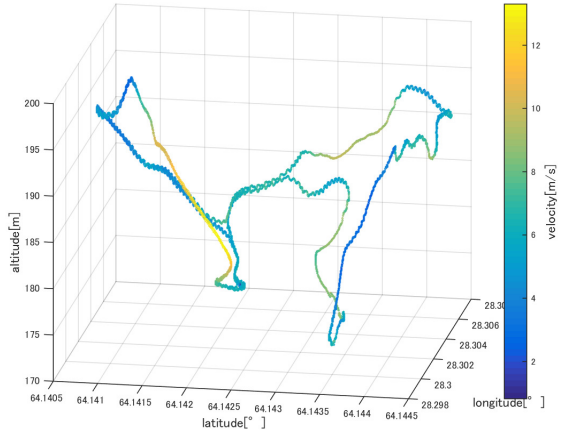
High accuracy during skiing (**below 3 cm** on whole track – see blue colors in curve vs color bar)

Data from **VUOKATTI** (in the specific skiing situation on Vuokatti race track: some forest, some free field) - blue means error of 2-4 cm)



3D velocity curves for a skier ⟶ knowledge about **accelerations** and **speeds over time**

Data from **VUOKATTI** (in the specific situation there: **some forest, some free field**) - based on that speed data around the track)



IMPRESSIONS






IMPRESSIONS

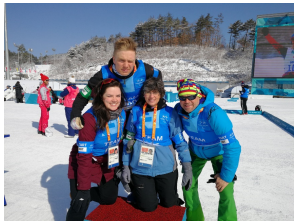



IMPRESSIONS



IMPRESSIONS






Thank you!