

Biomechanical Performance Diagnostics in Elite Sports



Hermann Schwameder

Josef Kröll – Stefan Lindinger –
Thomas Stöggli – Ulli Benko –
Erich Müller

Outline

- General considerations
- Relevance of performance diagnostics within the training process
- Purposes of performance diagnostics
- Methodology of performance diagnostics

General considerations

- Performance related factors
 - Biomechanical factors
 - Metabolic factors
 - Mental factors
 - Emotional factors
 - Others

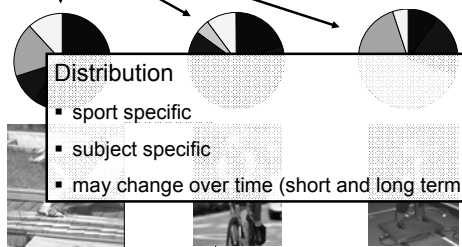
General considerations

Performance

- Biomechanical factors
- Metabolic factors
- Mental & emotional factors
- Others

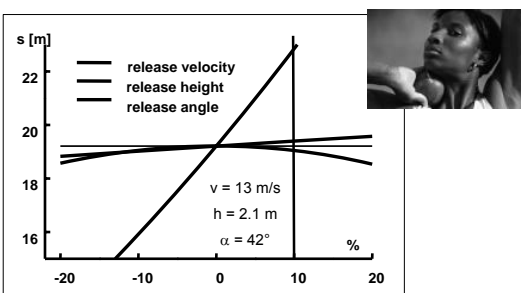
Distribution

- sport specific
- subject specific
- may change over time (short and long term)



General considerations

Example: Shot put mechanically determined $d = f(v, \alpha, h)$



General considerations

- Athletes' level of performance: very high
- Several world records every year
- Enhancements and developments
- Quantity of training
 - risking negative effects (overtraining or injuries)
- Improve quality of training
 - evaluation (performance diagnostics)

Relevance of performance diagnostics

General

Quality of training
 → evaluation (performance diagnostics)

Relevance

- Proper parameters → validation
- Accurate parameters → reliability

Purposes

- Specific regarding
 - conditioning
 - technique
 - subject

Methods

- Boundary conditions
 - Simulation exercises
 - Measuring system

Purposes of performance diagnostics

General

- Identification of biomechanical parameters related to performance
- Determination of subject specific deficits
- Determination of subject specific characteristics
- Assessment of training effects
- Assessment of individual performance development
- ...

Relevance

Purposes

Methods

Identification of parameters related to performance

General

Example: Ski-jumping
 Simulated take-offs

Relevance

hill jumps

Purposes

Methods

Determination of subject specific deficits

General

Simulated take-offs in ski-jumping (4 subjects)

Relevance

Purposes

Methods

Determination of subject specific characteristics

General

Simulated take-offs in ski-jumping (4 subjects)

Relevance

subject specific characteristics ?

Purposes

Methods

Assessment of training effects

General

1992 m VTV

Relevance

Purposes

Methods

Benko et al., 2004

Assessment of individual performance development

Dept Sport Science & Kinesiology
Simulated Take-offs - ski-jumping H.M. 17.09.2004

Test protocol:
 Simulated take-offs in ski-jumping

current performance
 comparison (group)
 development

Datum	Name	K	V	m	l	V	h	F _{peak}	F _{max}	ExpD	Mean
				(m)	(m)	(m/s)	(cm)	(kN)	(kN)	(kN)	(kN)
17.09.2004	H.M.	A	1	67.5	0.426	3.08	40.3	1290	2.10	5.0	-0.372
17.09.2004	H.M.	A	2	67.5	0.436	3.11	41.5	1406	2.12	4.1	-0.370
17.09.2004	H.M.	A	3	67.5	0.444	3.10	39.9	1400	2.12	5.0	-0.365
17.09.2004	H.M.	A	67.5	0.425	3.10	40.0	1401	2.12	4.7	-0.370	
24	Matthias	A	65.4	0.399	2.90	33.7	1434	2.19	5.0	-0.354	
	Philipp	A	39	0.37	2.8	34	139	2.0	5.0	-0.3	
16.05.2003	H.M.	A	70.5	0.410	2.78	32.5	1380	1.99	5.2	-0.361	
25.07.2003	H.M.	A	69.1	0.403	3.02	38.9	1461	2.15	5.4	-0.354	
17.12.2003	H.M.	A	68.2	0.373	3.10	42.0	1459	2.24	6.3	-0.321	
20.06.2004	H.M.	A	70.2	0.388	3.08	38.7	1430	2.20	6.3	-0.353	
17.09.2004	H.M.	A	67.5	0.425	3.10	40.6	1401	2.12	4.7	-0.370	

Methodology of performance diagnostics

- Identification of biomechanical parameters related to performance
- Determination of parameters during simulation exercises
- Determination of parameters in 'reality'
- Feedback training during simulation exercises
- Feedback training – 'reality'
- Measurement during competitions

Methodology of performance diagnostics

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Identification of parameters related to performance

- Isolated and complex parameters
 - Force
 - Force rate (explosive force)
 - Power
 - ...
- Correlation & regression analysis
- Performance related group analysis
- Validation

Identification of parameters related to performance

Correlation analysis

Ski-jumping

simulated take-offs isometric leg press

take-off velocity

F_{peak} 90°, 110°, 130°
 F_{ex} 90°, 110°, 130°

Schwameder et al., 2004

Identification of parameters related to performance

Correlation analysis

Isometric leg press: correlations with jump height

67%

peak force explosive force

Schwameder et al., 2000

Identification of parameters related to performance
Multiple regression analysis


General

Relevance


Purposes

Methods

Example: ski-jumping (hill)



R = 0.89
vertical release velocity
peak knee angle velocity
angular momentum during take-off
angle body axis - ski after 20 m



Schwameder & Müller, 1995

all parameters
Factor analysis
Factors (selected variables)
Multivariate regression
Relevant parameters

Identification of parameters related to performance
Performance related group analysis



General

Relevance

Purposes

Methods

Fistball: Velocities of segments (hitting arm)

Söser, 2004

Identification of parameters related to performance
Performance related group analysis

General

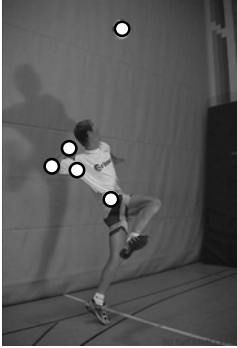
Relevance

Purposes

Methods

Fistball: Velocities of segments (hitting arm)

National team (high level)
Provincial team (medium level)
Junior team (low level)



Identification of parameters related to performance
Performance related group analysis

General

Relevance

Purposes

Methods

velocity (m/s)

hip shoulder elbow wrist fist ball

high (n=4)
medium (n=8)
low (n=7)

p < 0.00
p < 0.02
p < 0.00
p < 0.00
p < 0.00
p < 0.00

Söser & Schwameder, 2005

Identification of parameters related to performance
Validation



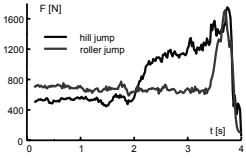
General

Relevance

Purposes

Methods

Comparison of hill jumps and simulated take-offs

Schwameder & Haim 2001

Identification of parameters related to performance
Validation

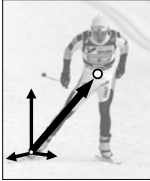
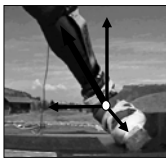

General

Relevance

Purposes

Methods

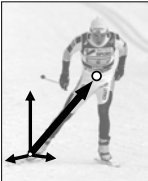
Cross-country skiing – Skating simulator






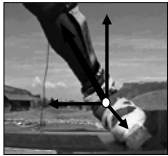

Lindinger, 2001

Identification of parameters related to performance
Validation

General: Cross-country skiing – Skating simulator

Relevance: 

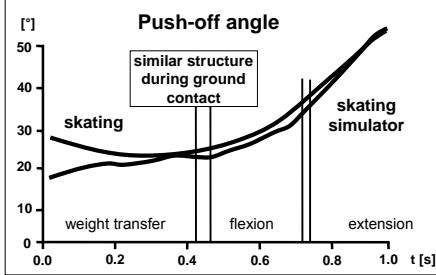
Purposes: 


Methods:  


Lindinger, 2001

Identification of parameters related to performance
Validation

General: Cross-country skiing – Skating simulator

Relevance: 

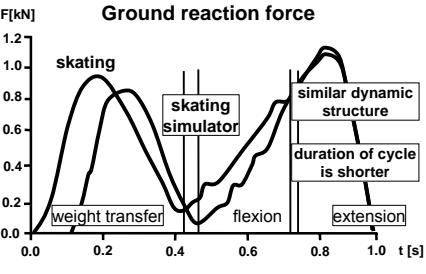
Purposes: 


Methods: 


Lindinger, 2001

Identification of parameters related to performance
Validation

General: Cross-country skiing – Skating simulator

Relevance: 

Purposes: 

Methods: 


Lindinger, 2001


Identification of parameters related to performance
Validation

General: Cross-country skiing – track vs. treadmill

Relevance:

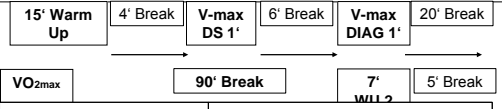
- Biomechanical parameters
- Physiological parameters

Purposes: 

Methods: 


Stöggl et al., 2005


Identification of parameters related to performance
Validation

General: 

Relevance:

Correlation coefficient (Pearson)	Sprint performance (heat, -heat _s)	
	r	p
double poling v_max	0.93	< 0.001
diagonal v_max	0.87	< 0.001
# pole plants	-0.77	< 0.01
# double poling kicks	0.58	< 0.05
frequency	-0.05	>> 0.05

Purposes: 

Methods: 

HEAT 3 Open → 8' Rest → 15' Treadmill (8km/h 0.5%) Stöggl et al., 2005

Methodology of performance diagnostics

General:

- Identification of biomechanical parameters related to performance
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- Measurement during competitions

Determination of parameters during simulations

Ski-jumping – simulated take-offs

Schwameder & Eitzlmair, 2002

Determination of parameters during simulations

Cross-country skiing – rollerboard

Stöggli et al., 2004

Methodology of performance diagnostics

- Identification of biomechanical parameters related to performance
- Determination of parameters during simulation exercises
- Determination of parameters in ‚reality‘
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- Measurement during competitions

Determination of parameters in ‚reality‘

Ski-jumping

kinematics dynamics electromyography

Determination of parameters in ‚reality‘


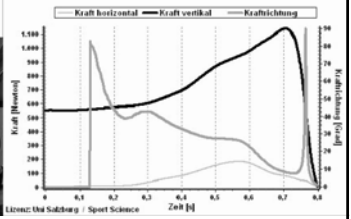
Schwameder & Müller, 1995

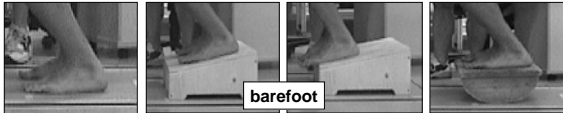

Determination of parameters in ‚reality‘

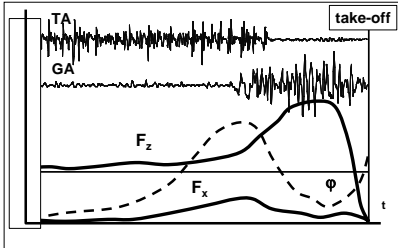

Fistball – velocities of segments

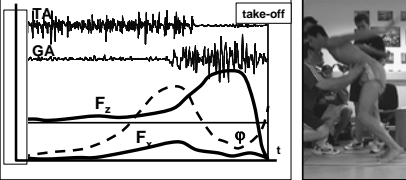
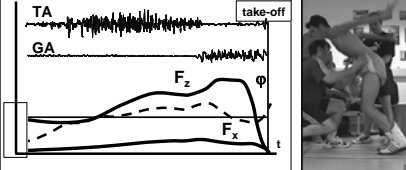
Söser & Schwameder, 2005


Methodology of performance diagnostics	
General	<ul style="list-style-type: none"> ▪ Identification of biomechanical parameters related to performance
Relevance	<ul style="list-style-type: none"> ▪ Determination of parameters during simulation exercises
Purposes	<ul style="list-style-type: none"> ▪ Determination of parameters in ‚reality‘ ▪ Feedback training during simulation exercises
Methods	<ul style="list-style-type: none"> ▪ Feedback training – ‚reality‘ ▪ Measurement during competitions

Feedback training – simulation exercises	
General	
Relevance	
Purposes	
Methods	

Feedback training – simulation exercises	
General	Ski-jumping simulated take-offs - diverse conditions
Relevance	 <p style="text-align: center;">barefoot</p>
Purposes	 <p style="text-align: center;">jumping boots</p> <p style="text-align: center;">standard standard, 11° 11°, heel 'seesaw'</p>
Methods	Haim & Schwameder, 2001

Feedback training – simulation exercises	
General	Ski-jumping simulated take-offs – standard, barefoot
Relevance	
Purposes	
Methods	Haim & Schwameder, 2001

Feedback training – simulation exercises	
General	
Relevance	 <p style="text-align: right;">standard barefoot</p>
Purposes	 <p style="text-align: right;">standard jumping boots</p>
Methods	Haim & Schwameder, 2001

Feedback training – simulation exercises	
General	Alpine skiing – gliding
Relevance	
Purposes	
Methods	Kröll et al., 2004

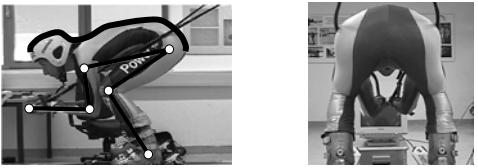
Feedback training – simulation exercises

General

Relevance

Purposes

Methods



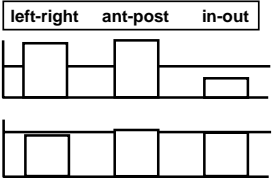
Display

Pre-test off

Training on

Post-test off

left-right ant-post in-out



Kröll et al., 2004

Feedback – simulation exercises

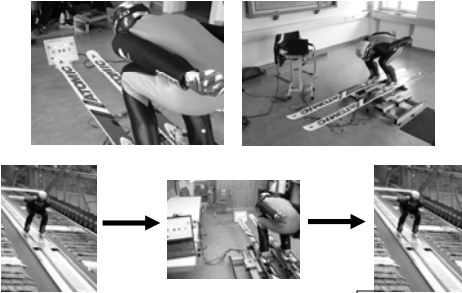
General

Relevance

Purposes

Methods

Ski-jumping – gliding



Schwameder & Kröll, 2005

Methodology of performance diagnostics

General

Relevance

Purposes

Methods

- Identification of biomechanical parameters related to performance
- Determination of parameters during simulation exercises
- Determination of parameters in ‚reality‘
- Feedback training during simulation exercises
- Feedback training – ‚reality‘
- Measurement during competitions

Feedback training – ‚reality‘


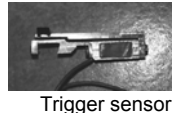
General

Relevance


Purposes

Methods

Shooting stability - targeting

Trigger sensor



Force plate (stability) Noptel (targeting)

Lindinger, 1999

Feedback training – ‚reality‘

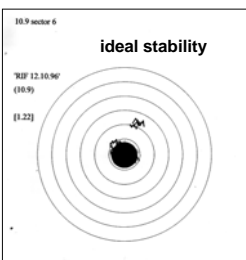
General

Relevance

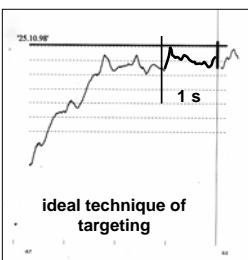
Purposes

Methods

Shooting Noptel - targeting



ideal stability



ideal technique of targeting

Lindinger, 1999

Feedback training – ‚reality‘

General

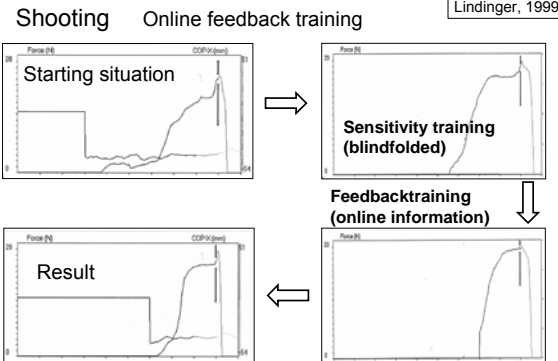
Relevance

Purposes

Methods

Shooting Online feedback training

Lindinger, 1999



Starting situation

Sensitivity training (blindfolded)

Feedbacktraining (online information)

Result

Feedback training – ,reality'

Shooting Optimising standing position

direction

equilibrium (stability)

Lindinger, 1999

Feedback training – ,reality'

Kistler force plates

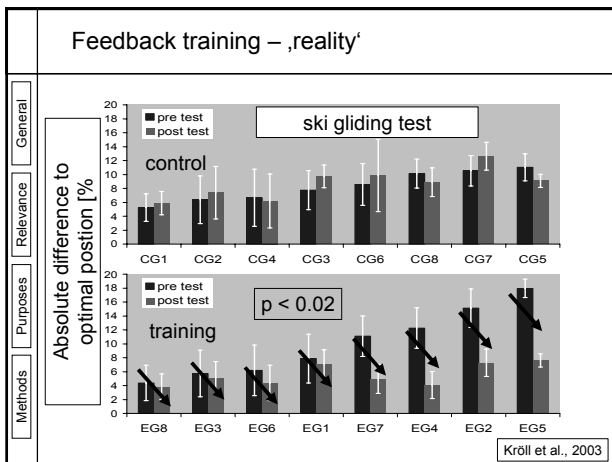
gliding testing

pre-test

training

post-test

Kröll et al., 2003



- Methodology of performance diagnostics**
- Identification of biomechanical parameters related to performance
 - Determination of parameters during simulation exercises
 - Determination of parameters in ,reality'
 - Feedback training during simulation exercises
 - Feedback training – ,reality'
 - Measurement during competitions

- Measurements during competitions**
- Very tricky task
 - Organisational considerations
 - Methodological restrictions
 - Data of high validity

Measurements during competitions

Ski-jumping, Olympics 2002, K 90 competition

- 3 synchronised video cameras (50 Hz, panned, tilted and zoomed)
- take-off & early flight phase
K 90: 30 m, 1.2 s

camera 1

camera 2

camera 3

K – 90 m

Measurements during competitions

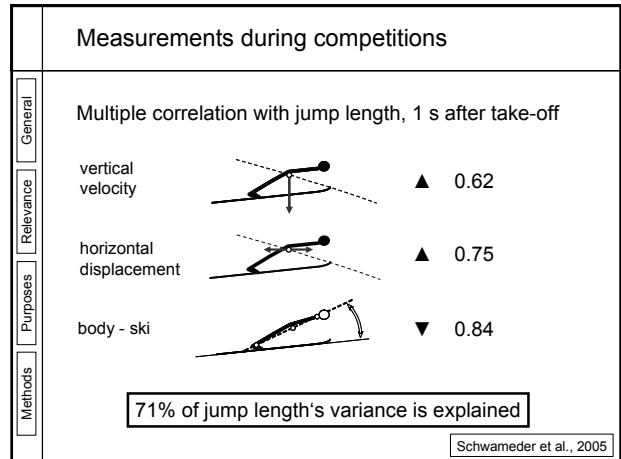
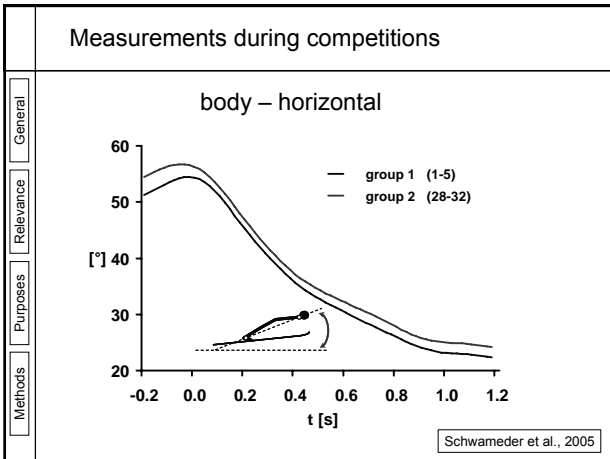
camera 1
camera 2
camera 3

manually digitised, 18 + 4 points
group 1 (ranks 1-5)
group 2 (ranks 28-32)
correlation and multiple regression analysis

General
Relevance
Purposes
Methods

Measurements during competitions

General
Relevance
Purposes
Methods



Considerations and perspectives


- General considerations
- Relevance of performance diagnostics within the training process
- Purposes of performance diagnostics
- Methodology of performance diagnostics

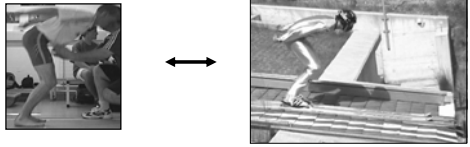
General
Relevance
Purposes
Methods


Considerations and perspectives

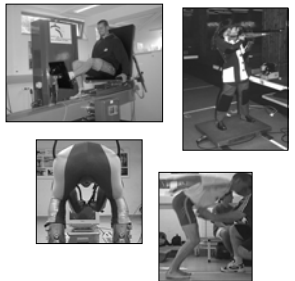
- General considerations
 - Help to use performance diagnostics properly

General
Relevance
Purposes
Methods

Considerations and perspectives			
General	<ul style="list-style-type: none"> ▪ Relevance of performance diagnostics within the training process 		
Relevance	<ul style="list-style-type: none"> ▪ Proper use during the different stages of training 		
Purposes			
Methods			

Considerations and perspectives			
General	<ul style="list-style-type: none"> ▪ Purposes of performance diagnostics 		
Relevance	<ul style="list-style-type: none"> ▪ All purposes of performance diagnostics covered? 		
Purposes			
Methods			

Considerations and perspectives			
General	<ul style="list-style-type: none"> ▪ Methodology of performance diagnostics 		
Relevance	<ul style="list-style-type: none"> ▪ New and most specific measurements ▪ Improvement of measuring devices ▪ Improvement of analysis and statistical methods ▪ Improvement of simulation exercises – closer to ‚reality‘ 		
Purposes			
Methods			

<p>Thank you for your attention</p> 			
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