Espírito Santo Federal University
Center of Physical Education and Sport
Motion and Breathing Biomechanics Laboratory

Biomechanics contributions to para-cycling performance improvement

Karine Jacon Sarro, PhD

Para-cycling

Tandem

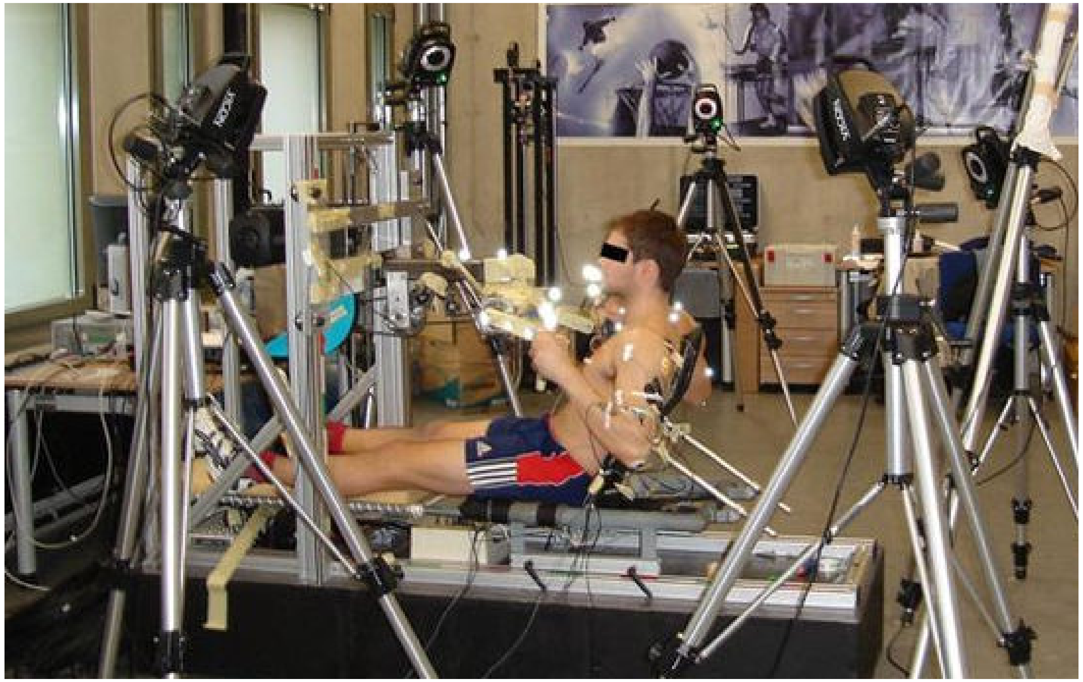
Handcycle

Tricycle

Bicycle

Biomechanics of handcycling

- combination of physiological and biomechanical analyses to assess the efficiency, health/safety



- movement pattern and force generation strategies during handcycling can be important to further optimize hand cycling from a performance as well as a health perspective

Cyclus2 performance diagnostic and training - Handbike test station (TU Munich)
http://www.cyclus2.com/en/applications/special-usage/handbike-project.htm

How findings of research in biomechanics may contribute to handcycling performance improvement?

- Methods used to measure performance
- What influences performance
- Limitations
- Possibilities

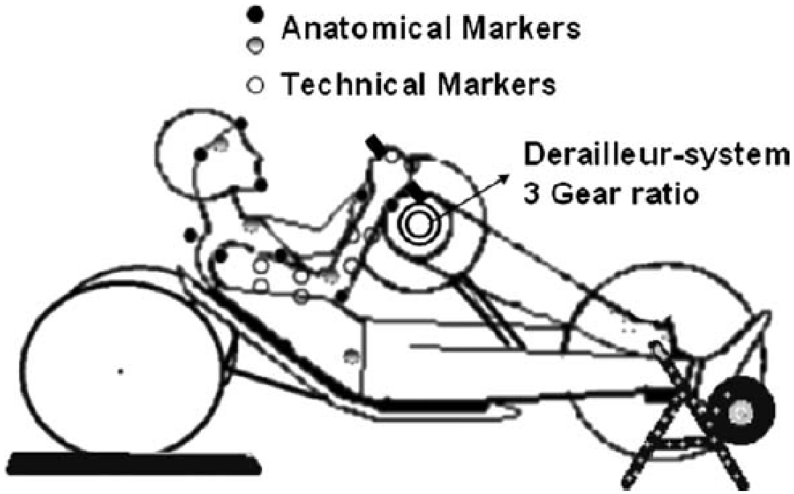
- **Methods used to measure performance**
- What influences performance
- Limitations
- Possibilities

Movement pattern and force generation strategies

How performance was measured via biomechanics methods

Kinematics

- Optoelectronic System
- Surface markers
  - Angles and angular acceleration of upper limb joints and trunk
  - Laboratory environment



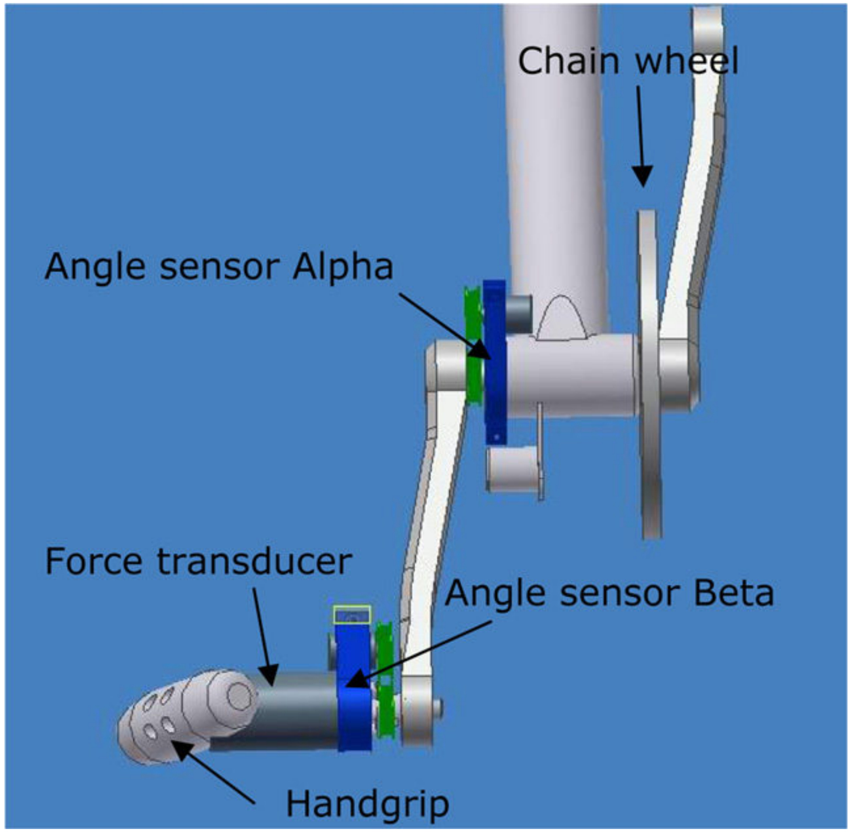
Faupin et al. Clinical Biomechanics. 21, 560–566, 2006
Arnet et al. Clinical Biomechanics. 27, 1-6, 2012

How performance was measured via biomechanics methods

Kinetics

- Strain gauges applied on the handle axis
- Instrumented dynamometric handgrip
  - Forces on the handgrip
  - Crank torque
  - Work

Instrumented handbike



Overview of the angle sensors and the positioning of the force transducer in the stud of the handle.

van Drongelen et al. Medical Engineering & Physics. 33, 1167– 1173, 2011

How performance was measured via biomechanics methods

Torque

- within cycle torque distribution pattern is consistent
- minimally influenced by the exercise intensity
- the pattern for subject A, who is more experienced in hand cycling, was more consistent than for subject B.

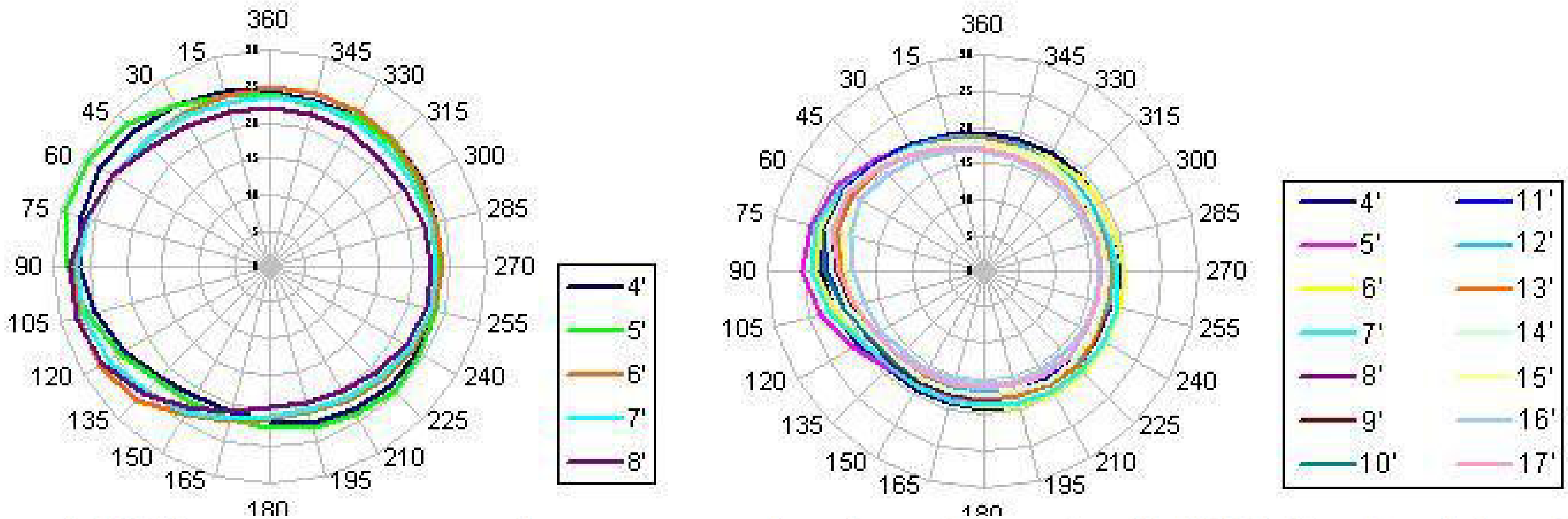


Figure 4: Within cycle torque generation pattern over time for participant A with SCI (left) and participant B (able-bodied - right); cycling direction was clockwise

Verellen et al. European Bulletin of Adapted Physical Activity . 3, 2004

How performance was measured via biomechanics methods

EMG

- Shoulder girdle muscles:
- Shoulder muscles:
  - mm. deltoideus
  - mm. pectoralis major
- Elbow muscles:
  - mm. biceps brachii
  - mm. triceps brachii
- Wrist muscles:
  - mm. extensor carpi ulnaris
- Trunk muscles
  - mm. obliquus externus

- Subjects:
  - Paraplegic with no experience (DeCoster et al., 1999)
  - Able-bodied with no experience (Bafghi et al., 2008; Faupin et al., 2010)

Faupin et al, *Journal of Applied Biomechanics, 2010, 2, 240-245*

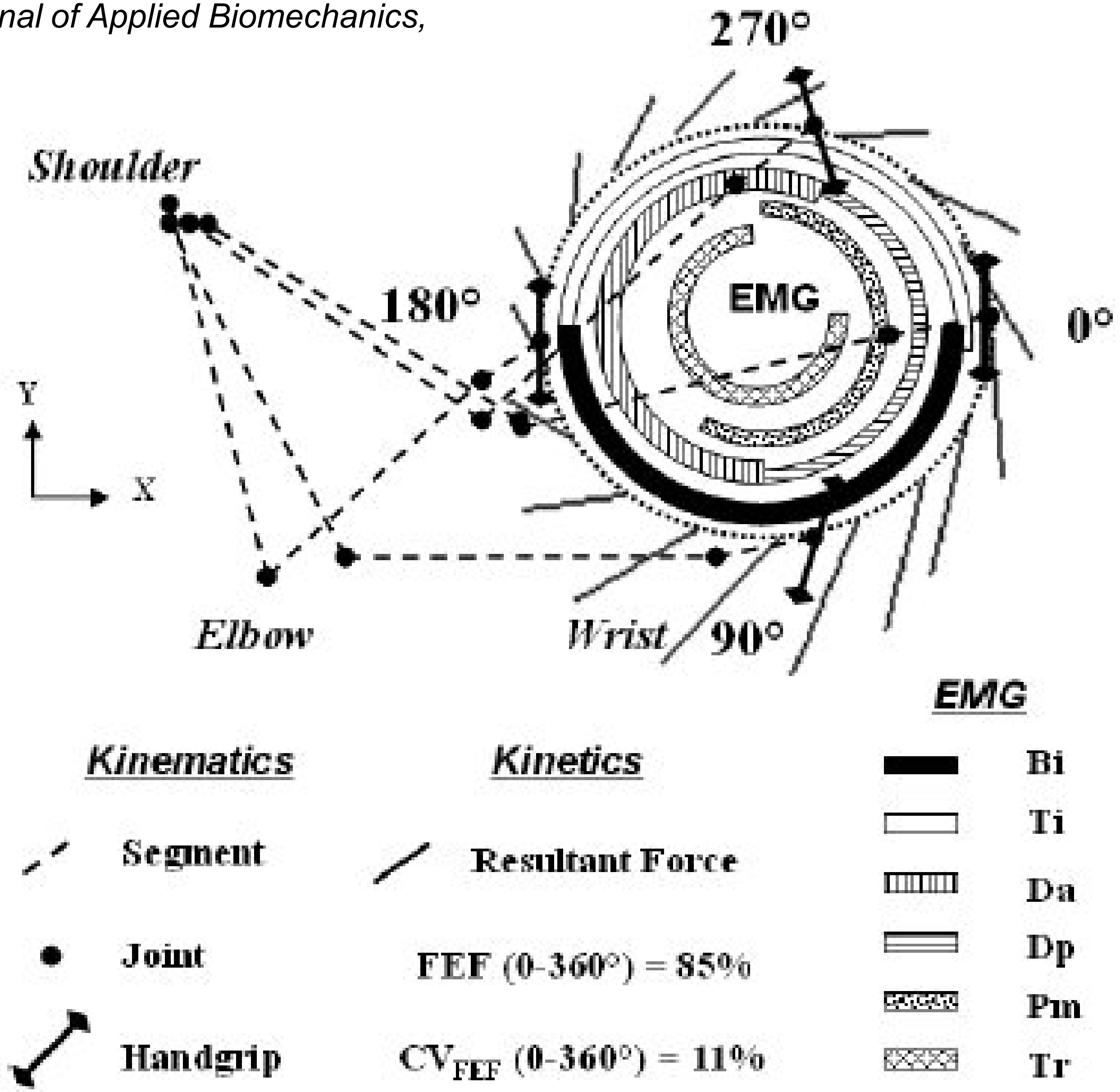


Figure 4 — Muscular activity, segmental displacements, and force applications over five consecutive cycles projected in the sagittal plane for the able-bodied subject. cv_{fef} is the variability coefficient of 2-d Fraction Effective Force (FEF_{2D}). Bi: biceps brachii; Ti: triceps brachii; Pm: pectoralis major; Tr: upper trapezius; Da: anterior deltoid; Dp: posterior deltoid. *x* and *y* are three-dimensional coordinates in the global reference system.

EFD IFES

- Methods used to measure performance
- **What influences performance**
- Limitations
- Possibilities

Crank position

Gear ratio

Mode of propulsion

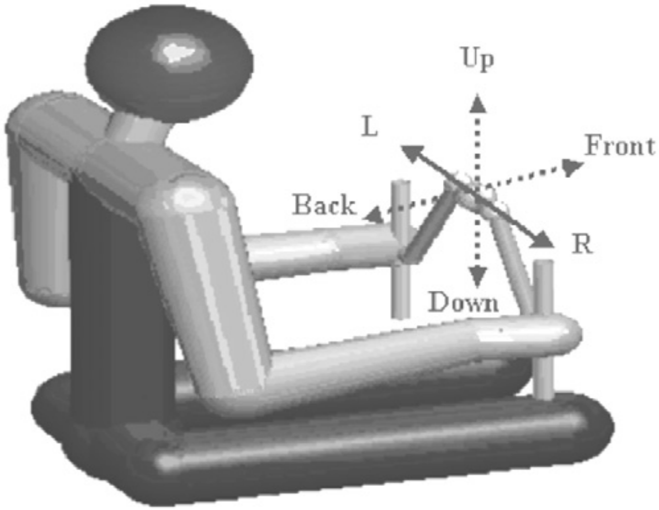
Type of propulsion

Backrest positioning

Handgrip angle

Crank position

- Effects of crank adjustments on ROM upper limb joints (simulated kinematic parameters)
- It is impossible to clearly define an optimal position that could both reduce shoulder and wrist joint range of motion and also avoid joint limit in order to reduce repetitive strain injuries risks
- backrest angle close to 90º



Recommendations:

➢distance between the two cranks should be approximately the same as shoulder width

➢crank axis height should be under the axis of the acromions

➢distance between shoulder and cranks should not allow complete elbow extension.

Faupin & Gorce. International Journal of Industrial Ergonomics. 38, 577–583, 2008

Gear ratio

An increase in gear ratio:

INCREASE	DECREASE
• maximal velocity	• crank frequency
• flexion/extension of the trunk • adduction/abduction of the shoulder	• flexion/extension angular accelerations of the shoulder and the elbow

Higher gear ratios during sprints improve performance

RoM and angular joint accelerations are near or superior to the ergonomic recommendations

Faupin et al. Clinical Biomechanics. 21, 560–566, 2006
Faupin et al. JRRD. 45, 109-116, 2008

Mode of propulsion
Synchronous X Asynchronous

The handcyclist Alessandro Zanardi

http://www.mirror.co.uk/sport/other-sports/alex-zanardi-in-paralympics-hand-cycling-1304707

The handcyclist Alejandro Albor

http://www.nytimes.com/2006/11/02/sports/sportsspecial/02handcycle.html?pagewanted=all

Mode of propulsion
Synchronous X Asynchronous

synchronous cycling

- higher flexion/extension of the elbow and shoulder
- higher activity (tendency) of the m. deltoideus pars clavicularis and trapezius
- higher mean 2D force, without speed effect

asynchronous cycling

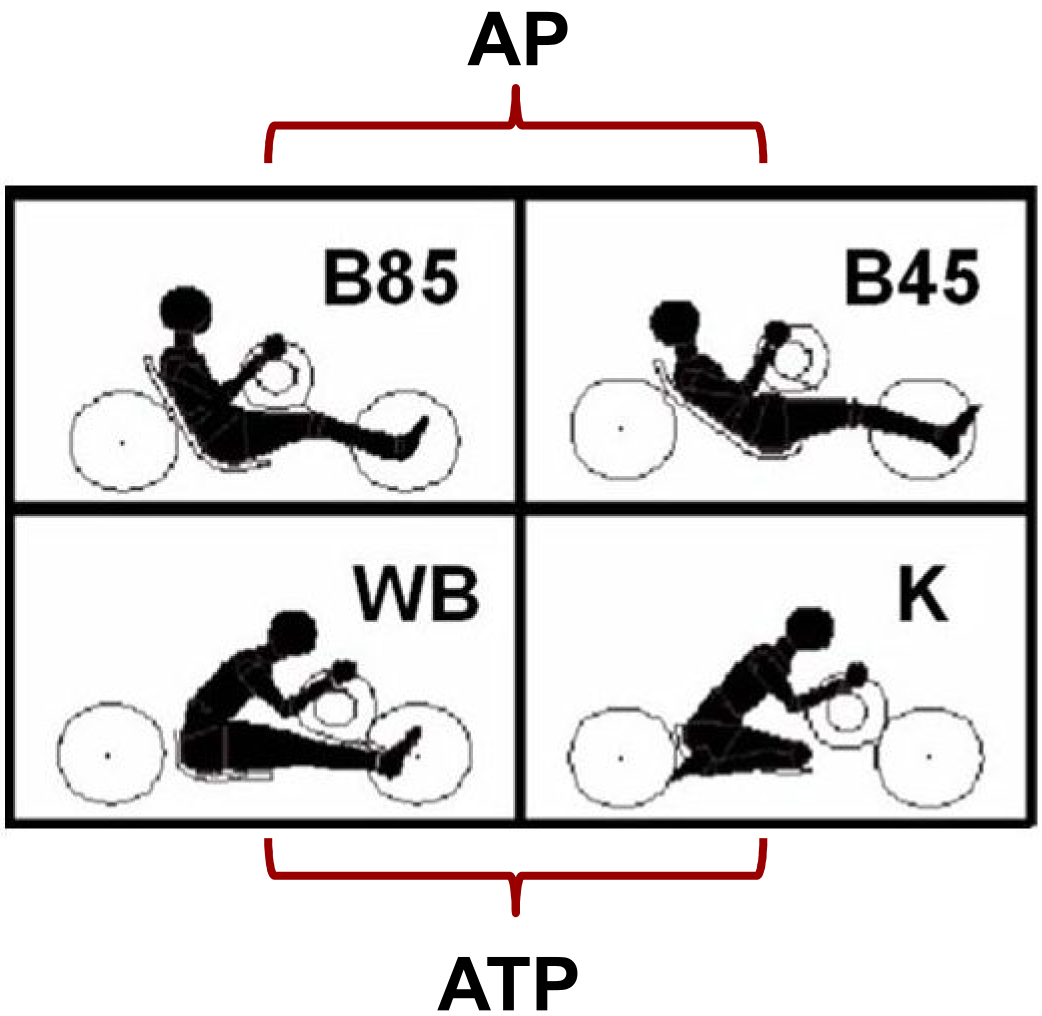
- higher lateral flexion and rotation of the trunk
- higher activity of m. obliquus externus and extensor carpi ulnaris

No significant difference in the mean mediolateral
hand force (Fz), torque values
No consense in fraction effective force

Kinetic results did not establish the most effective mode of propulsion

Bafghi et al. Int J Sports Med. 29, 630-638, 2008
Faupin et al. JRRD. 48, 1049-1060, 2011

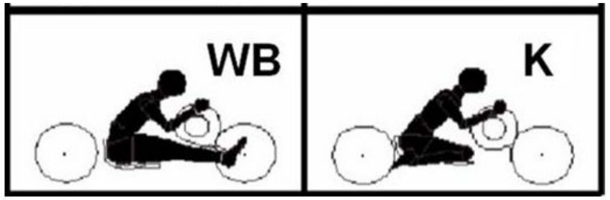
Type of propulsion
arm-power (AP) X arm-trunk-power (ATP)



Faupin et al. JRRD. 48, 1049-1060, 2011

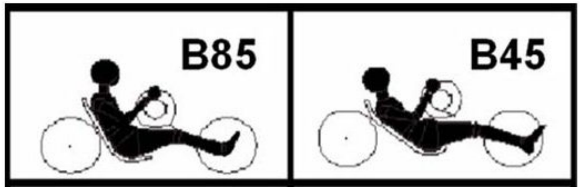
Type of propulsion
arm-power (AP) X arm-trunk-power (ATP)

ATP:



- higher flexion/extension of the trunk, elbow and shoulder
- higher radial peak force
- no differences between WB and K

AP:



- no differences between 45° and 85°

No significant difference in torque values, 2D fraction effective force

→ Kinetic results did not establish the most effective type of propulsion

Faupin et al. JRRD. 48, 1049-1060, 2011

Backrest positioning

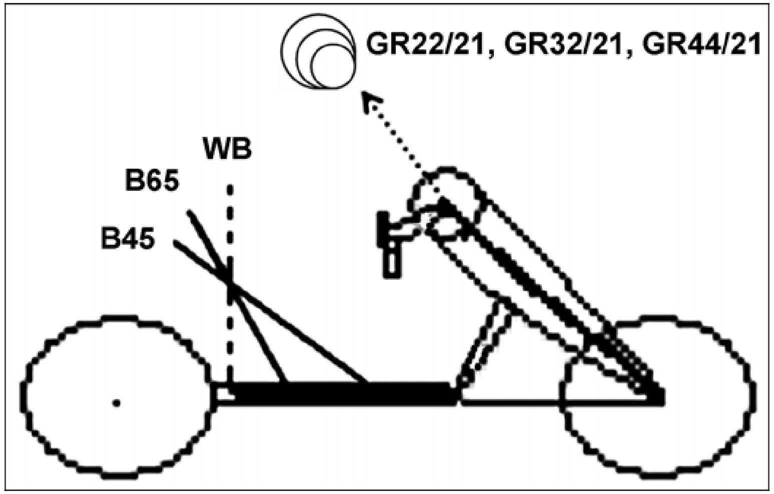
In the absence of a backrest:

- greater velocity
- more trunk movement

} no correlation

- greater amplitude of joint angles in general and elbow flexion/extension and shoulder internal/external rotation

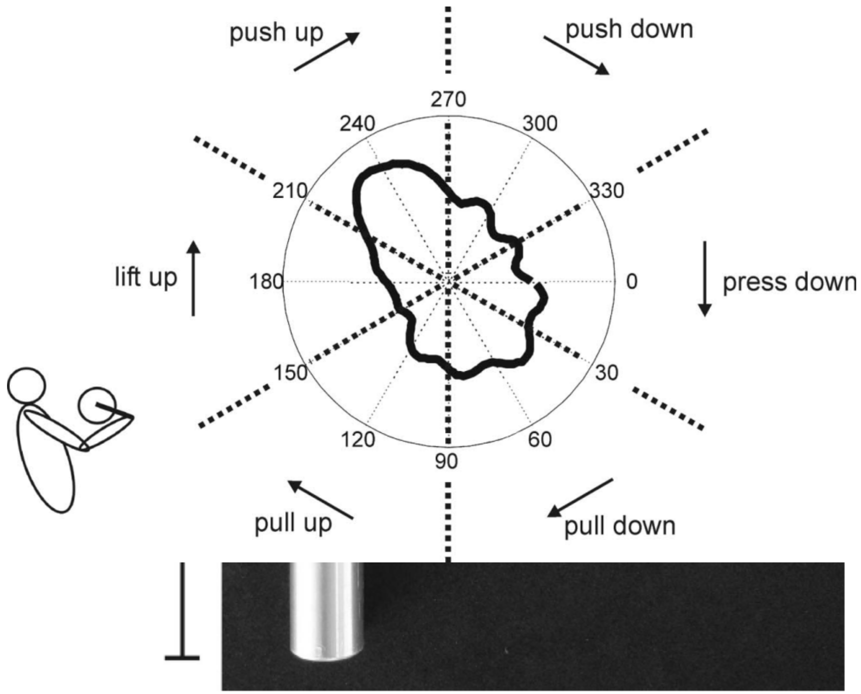
Nondisabled subjects with no handcycling experience



Faupin et al. JRRD. 45, 109-116, 2008

Handgrip angle

- a fixed handle angle of + 30º (more pronated) is optimal for power generation
- a fixed handle angle of - 15º (more supinated) is optimal for work generation during push-up and the pull-up



- a fixed handle angle of + 30º (more pronated) is optimal for work generation during push-down and pull-down
- free pivotmounted handle does not correlate with the angles showing the best force-production abilities

Kramer et al. Ergonomics. 52, 1276–1286, 2009

- Methods used to measure performance
- What influences performance
- **Limitations**
- Possibilities

Limitations

- **Arm crank ergometry or attached unit differs from handcycling** (seat position, the need to steer, stability, crank type/position, and the possibility of changing gears)
- **Nondisabled subjects**
- **Laboratory environment**

- Methods used to measure performance
- What influences performance
- Limitations
- **Possibilities**

Kinematical analysis in training and competition situations

Optoeletronic devices

- Standard for human movement analysis
- Great precision
- High cost
- Occlusion of markers by the body or external elements
- Low portability

+

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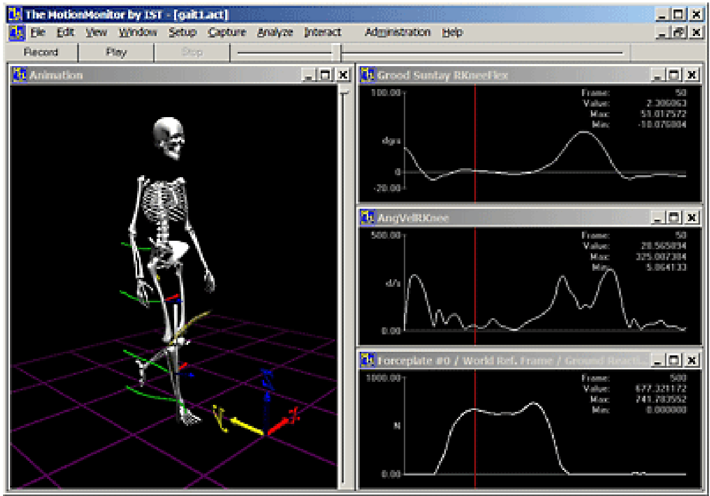
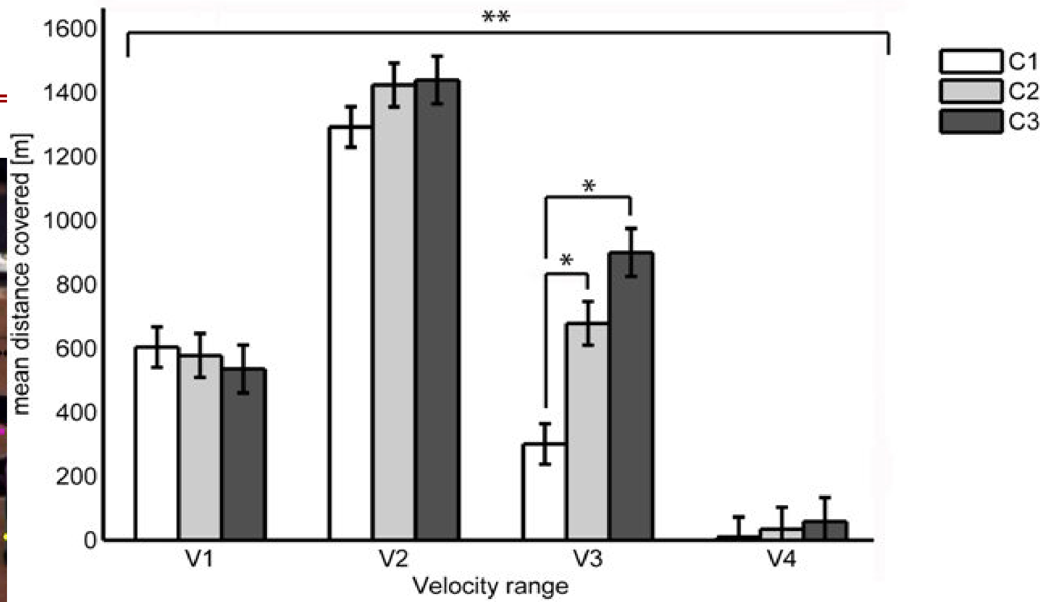


Tracking based on non-dedicated camera images



Mean distance covered in each velocity range by the group C1 (n = 7), C2 (n = 6) and C3 (n = 5). Error bars represent SEM. V1: 0 to 1.36 $m.s^{-1}$, **V2: 1.37 to 2.73 $m.s^{-1}$**, V3: 2.74 to 4.10 $m.s^{-1}$, V4: 4.11 to 5.5 $m.s^{-1}$. * difference between groups; ** difference between velocity ranges (two-way repeated ANOVA and Tukey's post hoc test ($p < 0.05$).

Journal of Sports Sciences, January 15th 2010; 28(2): 193–200

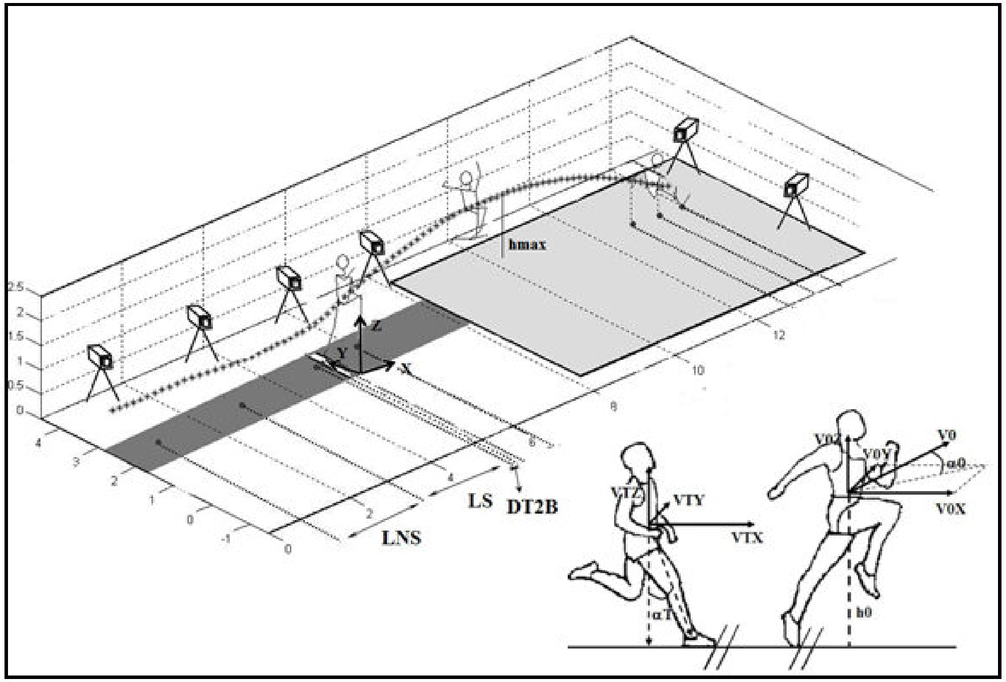
Routledge
Taylor & Francis Group

Tracking of wheelchair rugby players in the 2008 Demolition Derby final

KARINE J. SARRO[1], MILTON S. MISUTA[1], BRENDAN BURKETT[2], LAURIE A. MALONE[3], & RICARDO M. L. BARROS[1]

[1]*College of Physical Education, Campinas State University, Campinas, Brazil,* [2]*School of Health and Sport Sciences, University of the Sunshine Coast, Maroochydore, Queensland, Australia, and* [3]*Research and Education, Lakeshore Foundation, Birmingham, Alabama, USA*

Tracking based on non-dedicated camera images



Lara, Jerusa Petróvna Resende. Three-dimensional kinematic analysis of the long jump in high level in competition. Masters Thesis. Campinas-Brazil, 2011

Inertial sensors

Accelerometers

Inclination

When a=constant: Great inclinometer

Not possible to detect rotations about the gravity vector

Gyroscopes

Angular Velocity

Measurement of angular rotations

Considerable offset and drift over the time

Magnetometers

Heading Angle

Detection of rotation about the earth's magnetic field

Problems magnetic interference

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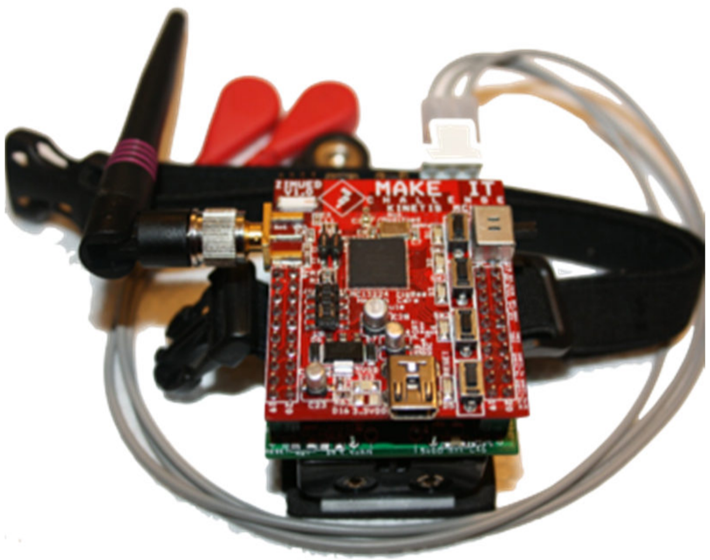
Inertial Measurement Unit (IMU) + sEMG Wireless Sensors



- Smaller size
- Lower costs
- Multiple sEMG channels
- Single board design

lai
Intelligent Automation Laboratory
Electrical Engineering Department
Federal University of Espirito Santo

Dutch Research Center Uses iMEMS Inertial Sensors to Study Rowing Kinematics

Published on October 24, 2011 at 12:48 AM

http://www.azonano.com/news.aspx?newsID=23623

By Cameron Chai

Netherlands-based research center, Roessingh Research & Development, a specialist in ambulatory three-dimensional human movement analysis, is utilizing Analog Devices' iMEMS inertial sensors to enhance the performance and decrease risk of getting injured of competitive rowers.

Analog Devices' iMEMS inertial sensing technology enables motion capture suit to record physical movement and study rowing kinematics. Credit: Xsens Technologies

rowing coaches can correct and improve movements and thus decrease the injury risk to the rowers

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Kinematical analysis of thoracoabdominal motion and breathing pattern

- Pulmonary function + Thoracoabdominal motion pattern during breathing + thoracoabdominal partial volume
- Effects of handcycling practice
- Effects of breathing motion pattern in performance

Journal of Applied Biomechanics, 2009, 25, 247-252

Proposition and Evaluation of a Novel Method Based on Videogrammetry to Measure Three-Dimensional Rib Motion During Breathing

Karine Jacon Sarro,[1] Amanda Piaia Silvatti,[1] Andrea Aliverti,[2] and Ricardo M. L. Barros[1]
[1]Campinas State University; [2]Politecnico di Milano

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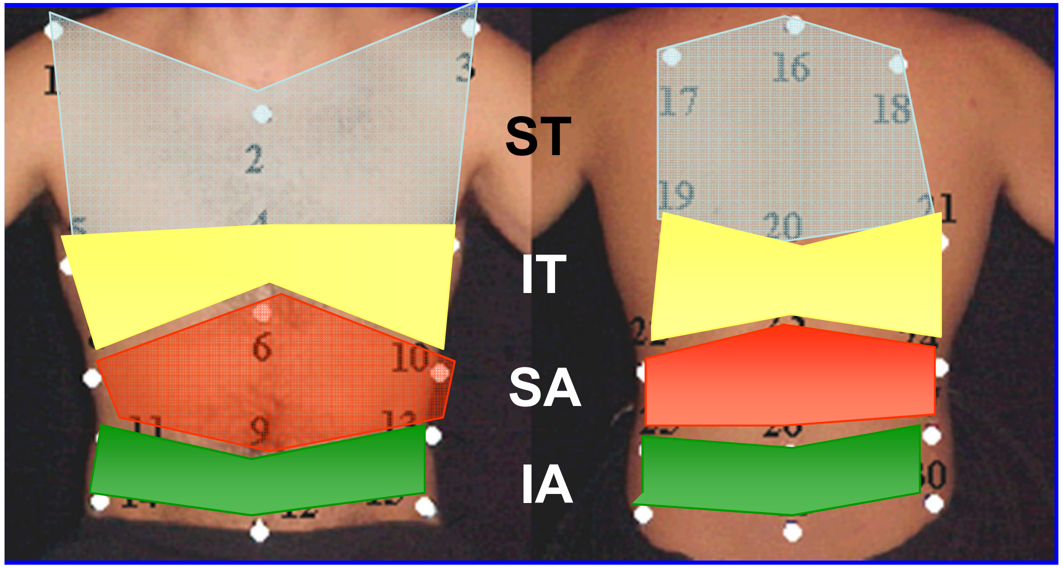
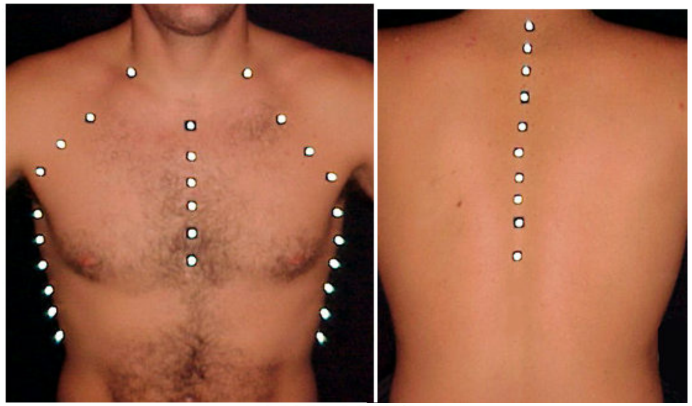
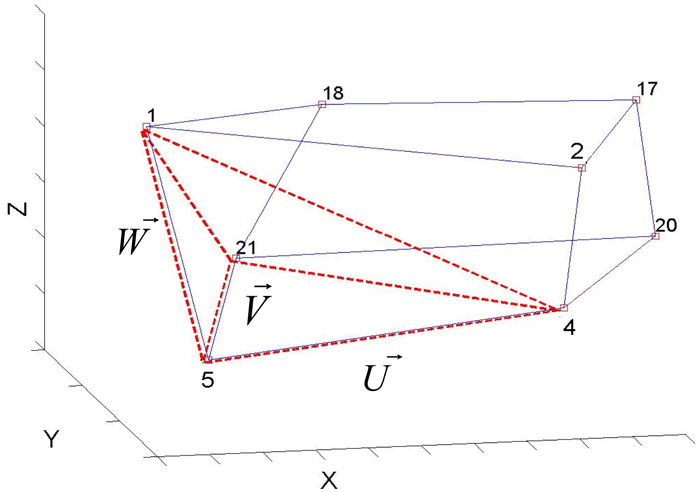
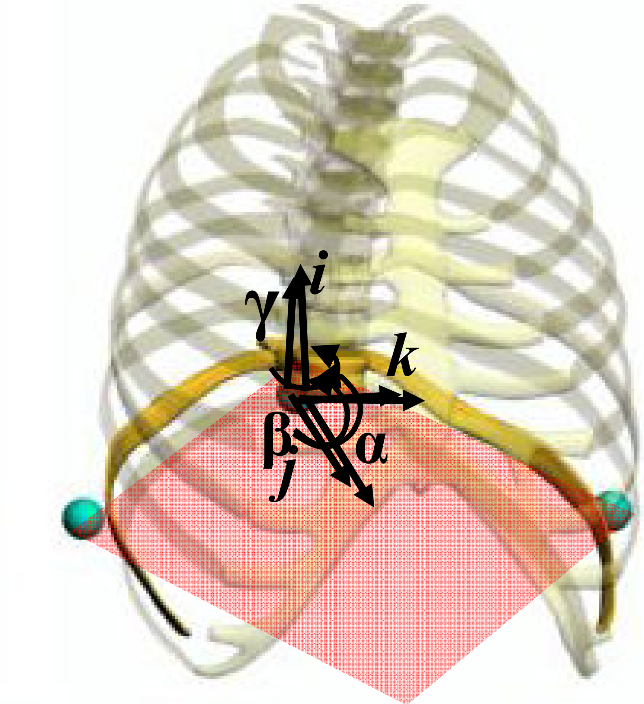
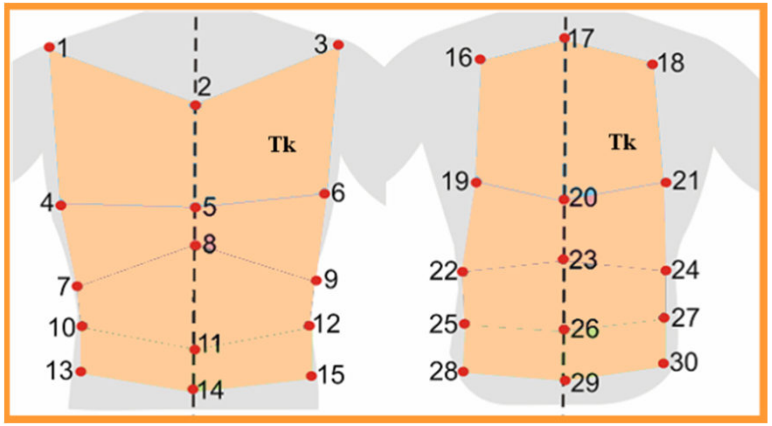
Kinematical analysis of thoracoabdominal motion and breathing pattern







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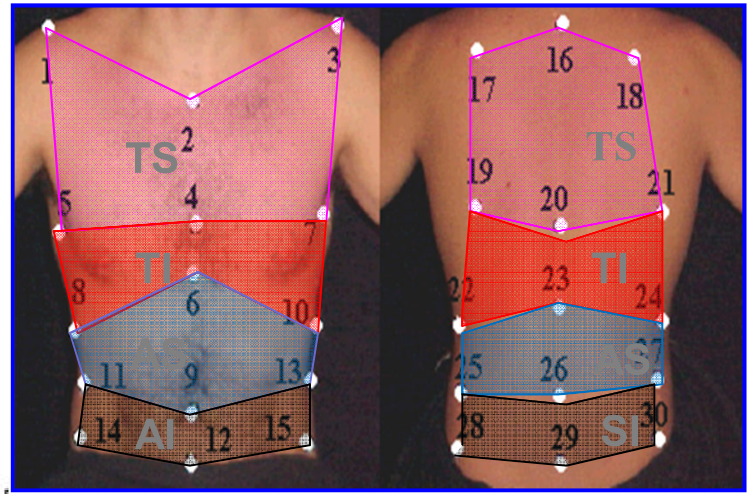
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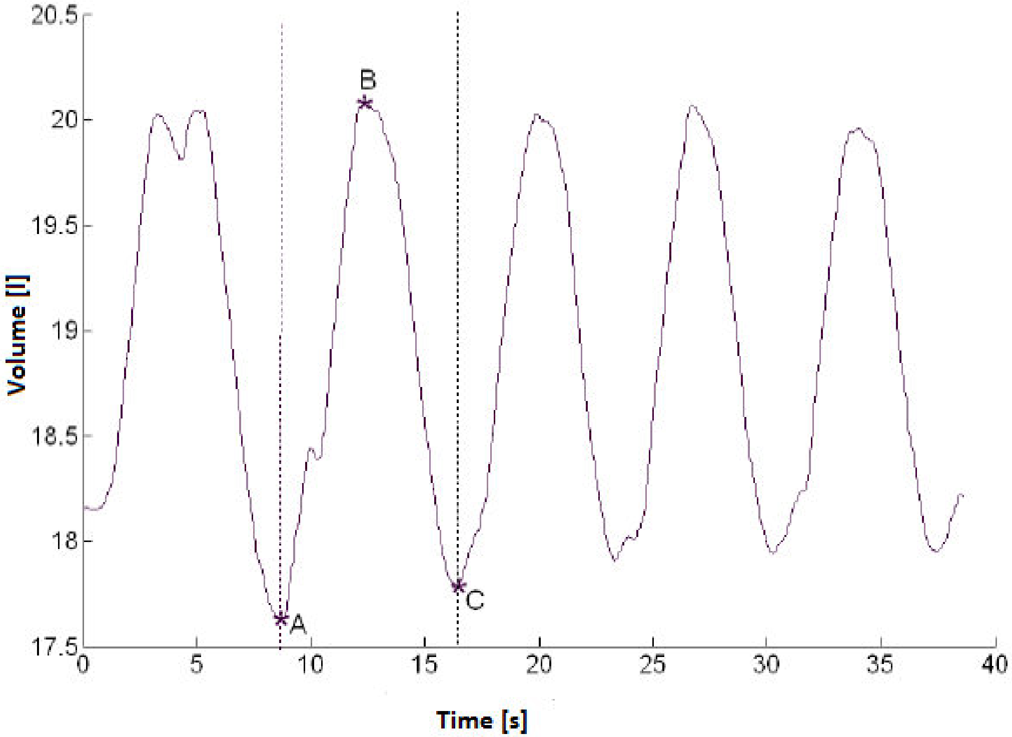
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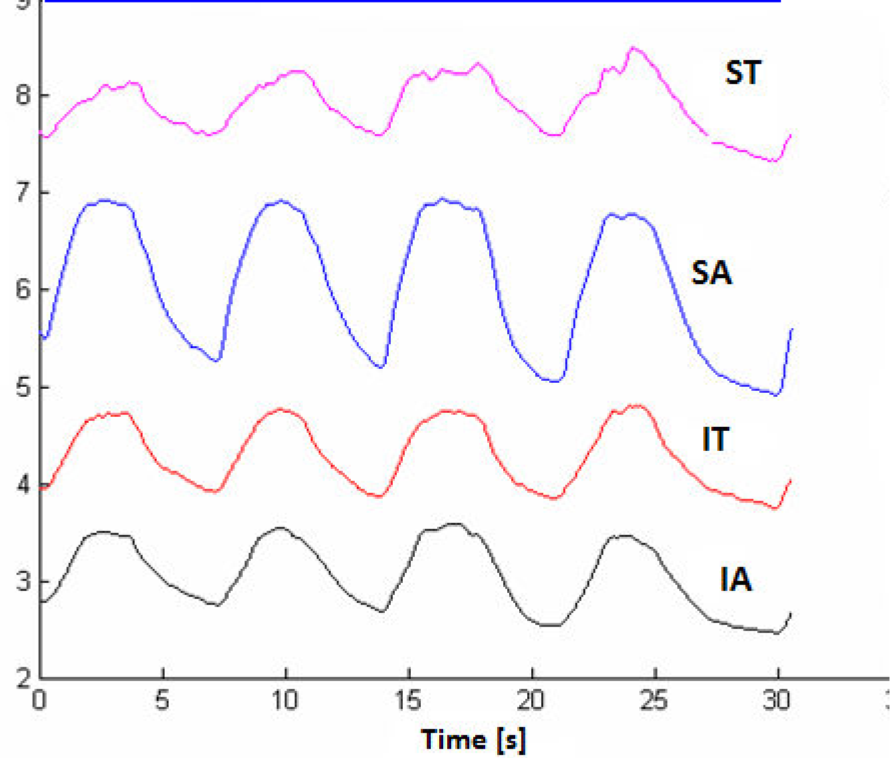
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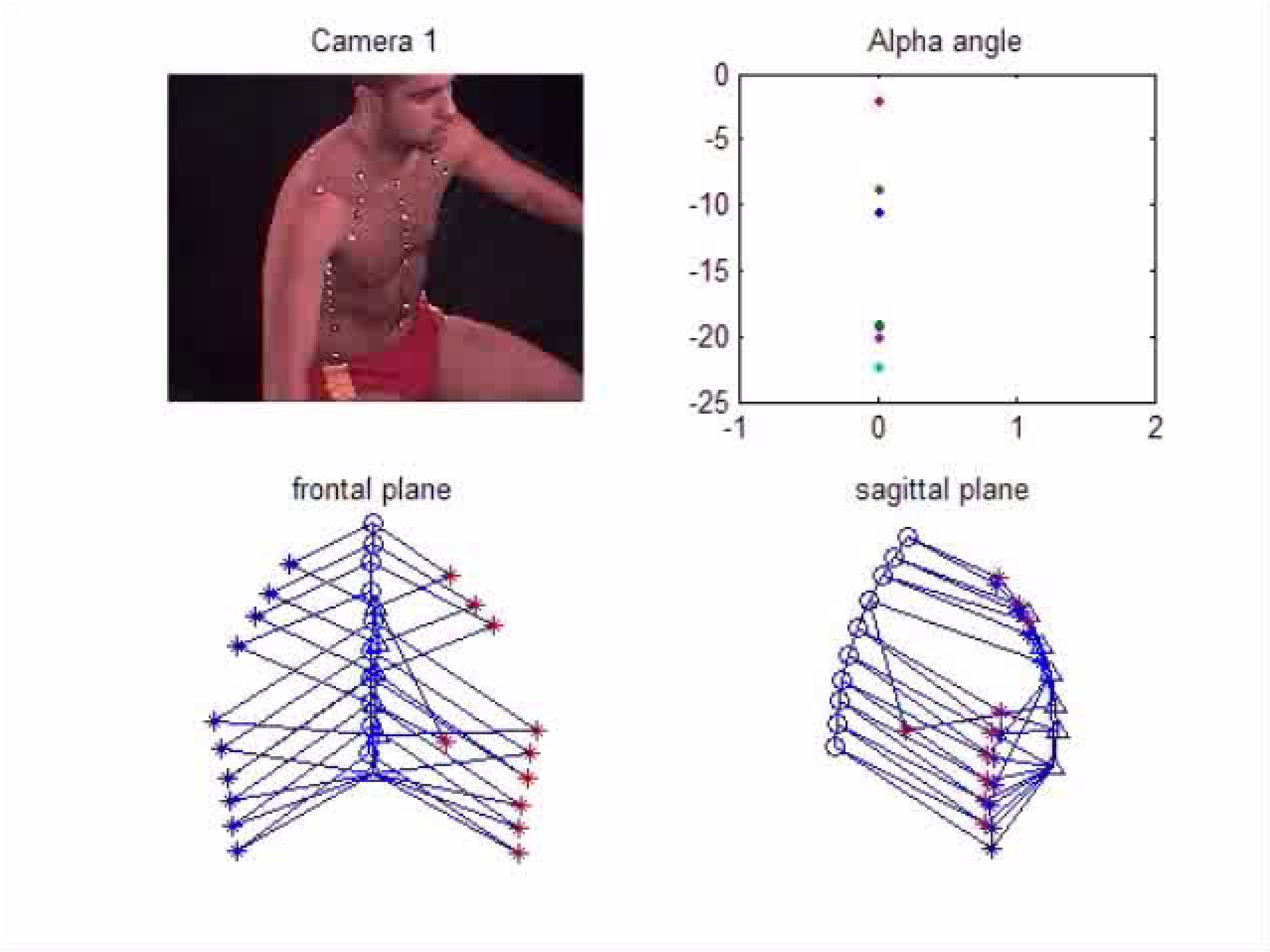
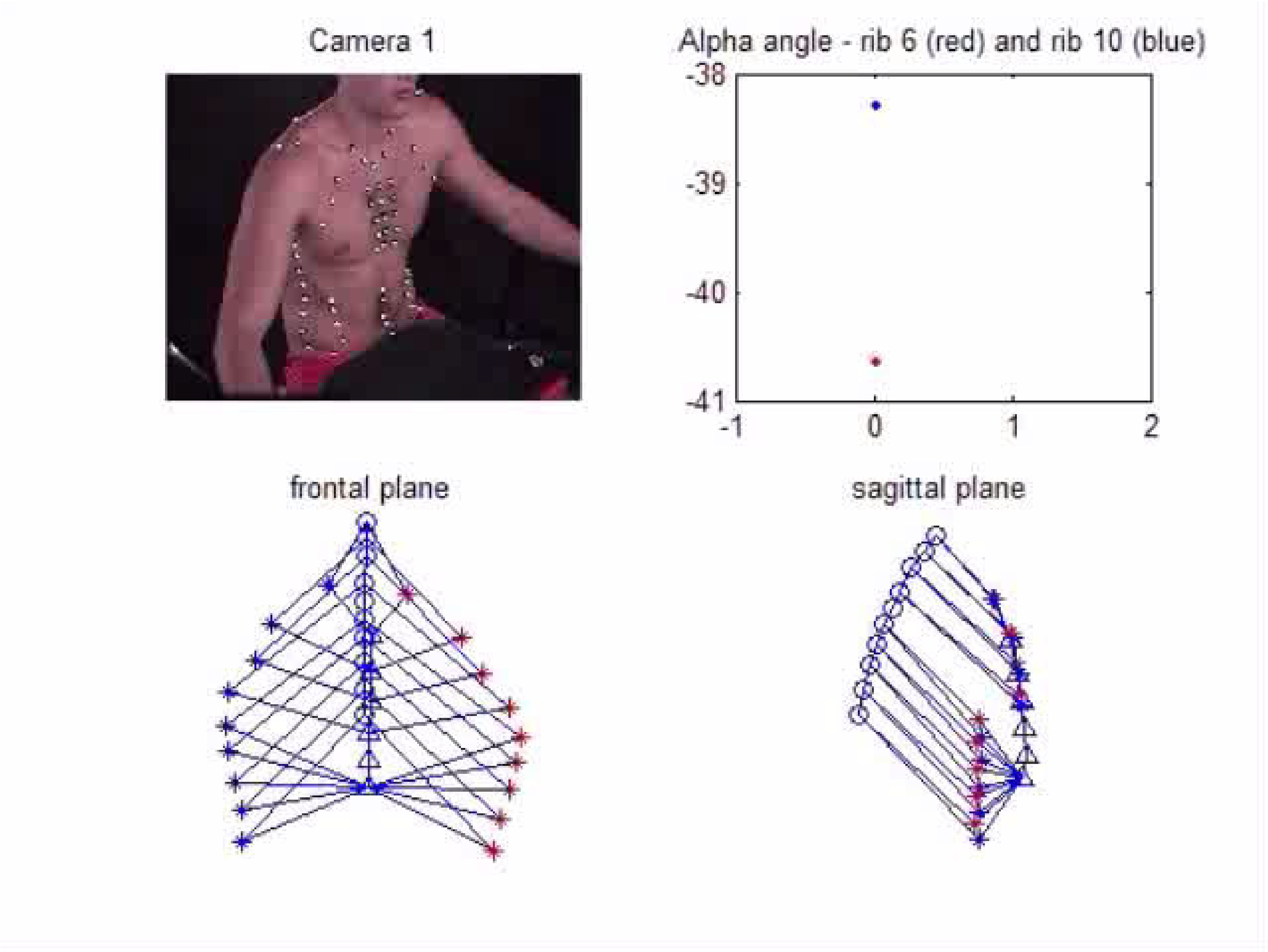
Ribs motion during breathing



Ribs motion pattern during breathing



©Journal of Sports Science and Medicine (2008) 7, 195-200
http://www.jssm.org

Research article

Coordination between ribs motion and thoracoabdominal volumes in swimmers during respiratory maneuvers

Karine J. Sarro ✉, Amanda P. Silvatti and Ricardo M. L. Barros
Laboratory of Instrumentation for Biomechanics, College of Physical Education, Campinas State University, Campinas (SP), Brazil

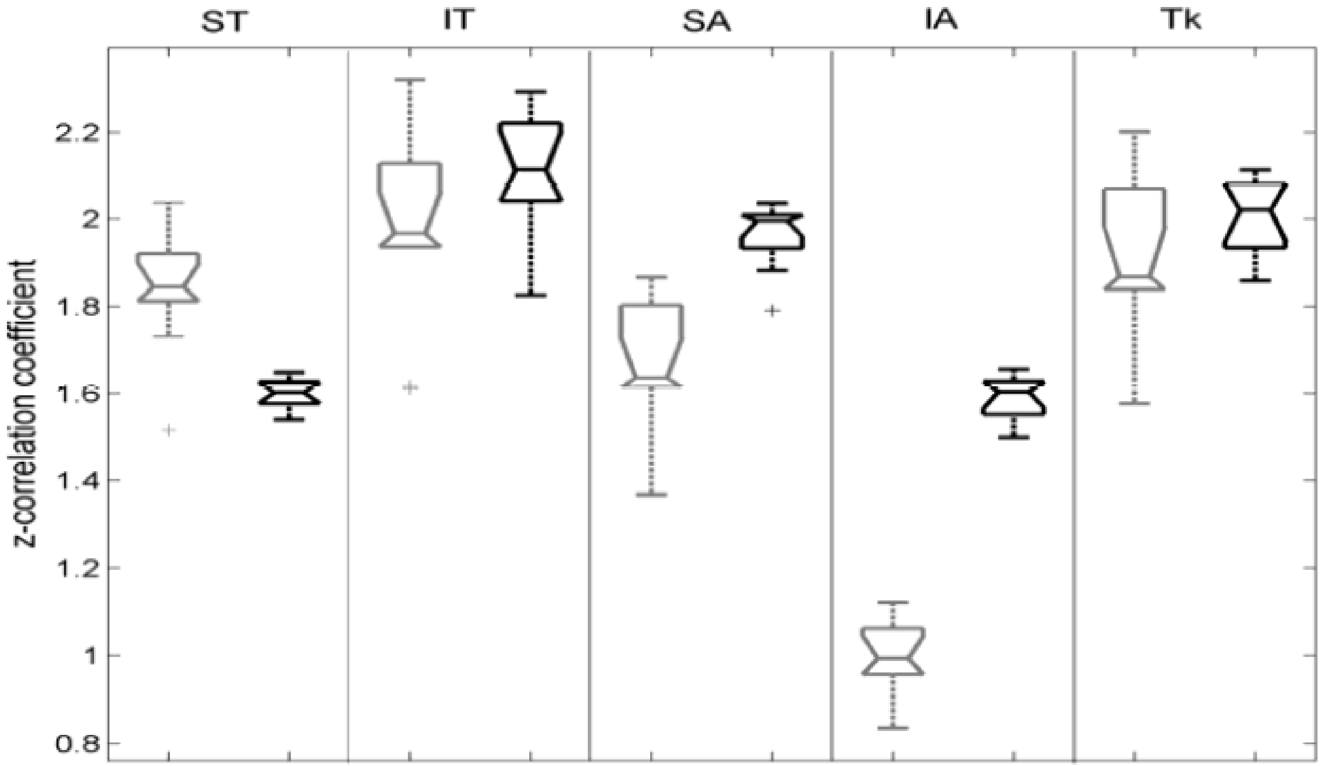


Figure 3. Distribution of the mean values of the z-correlation coefficient between the ribs angles and the volumes of each compartment of the chest wall presented by the control group (grey) and swimmer group (black) during vital capacity maneuvers. ST = superior thorax, IT = inferior thorax, SA = superior abdomen, IA = inferior abdomen, Tk = total trunk.

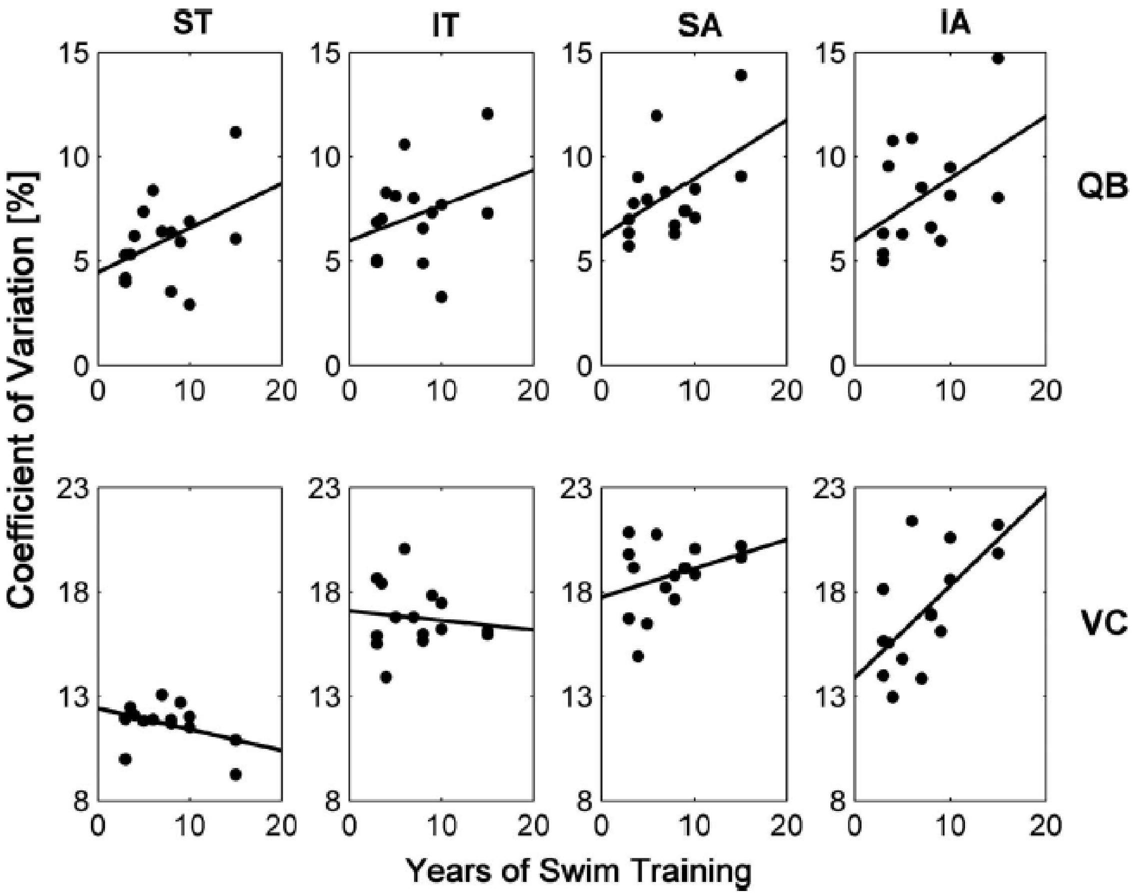
Journal of Sports Sciences, 2012;30(14):1551-60

Routledge
Taylor & Francis Group

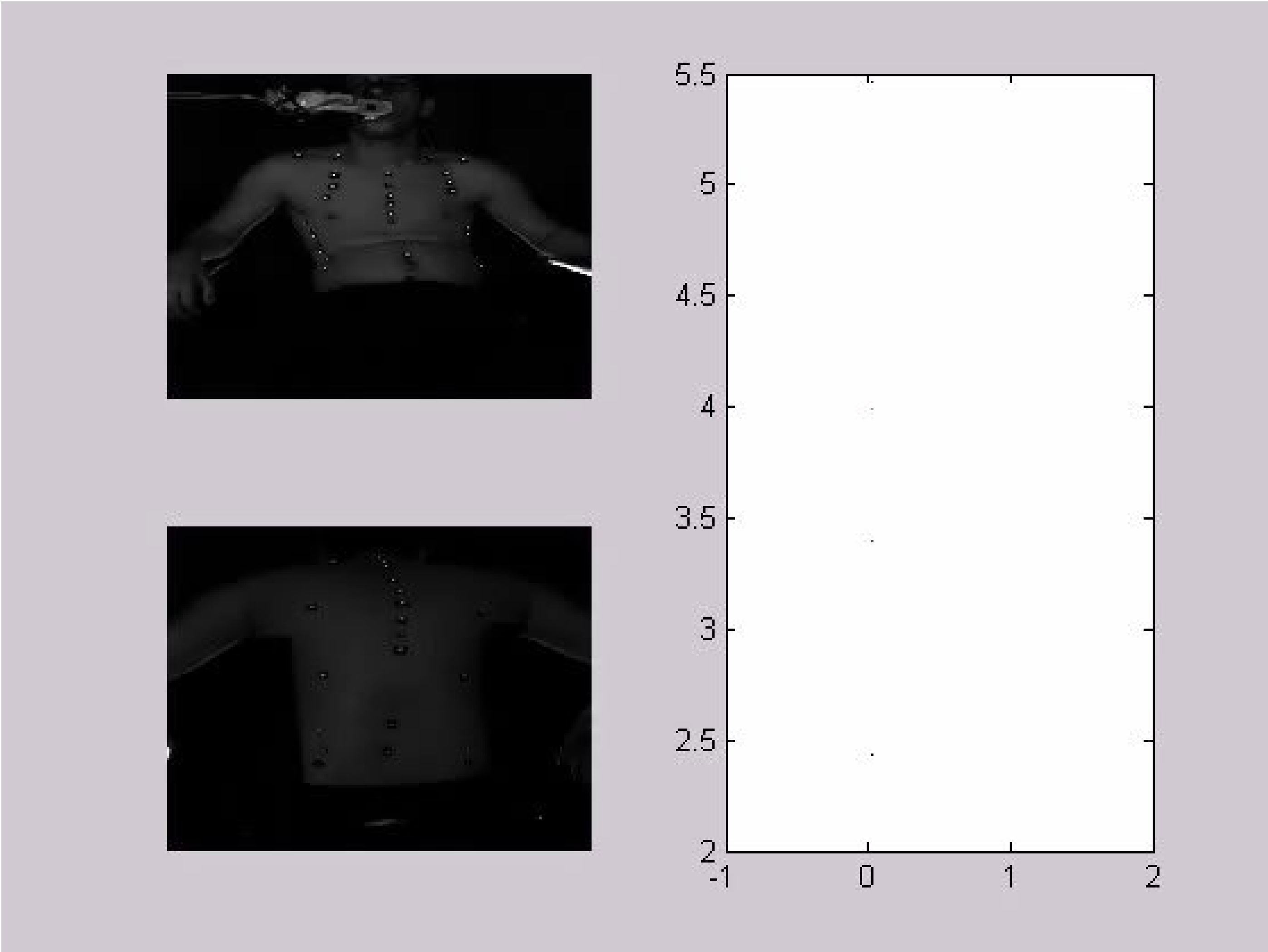
A 3D kinematic analysis of breathing patterns in competitive swimmers

AMANDA P. SILVATTI[1], KARINE J. SARRO[2], PIETRO CERVERI[3], GUIDO BARONI[3] & RICARDO M. L. BARROS[1]

[1]*University of Campinas, College of Physical Education, Campinas, Brazil,* [2]*Federal University of Espírito Santo, Vitoria, Brazil, and* [3]*Politecnico di Milano, Biomedical Engineering Department, Milano, Italy*



Thoracoabdominal volumes of a wheelchair rugby athletes



higher volume variation of the inferior abdomen than the superior thorax.

After 1 year of wheelchair rugby training:

✓ significant increase in forced vital capacity, forced expired volume after 1 second, and maximal voluntary ventilation

✓ players with longer training time had higher pulmonary function values

✓ modified breathing pattern with an increased contribution of the Superior Thorax (31.4%) to the total volume during respiration

Journal of Strength & Conditioning Research:
January 2013 - Volume 27 - Issue 1 - p 50–56

Wheelchair Rugby Improves Pulmonary Function in People With Tetraplegia After 1 Year of Training

Moreno, Marlene A.[1,2]; Paris, Juliana V.[2]; Sarro, Karine J.[3]; Lodovico, Angélica[2]; Silvatti, Amanda P.[2]; Barros, Ricardo M. L.[2]

ISB 2013 BRAZIL

WHEELCHAIR RUGBY IMPROVES THORACOABDOMINAL MOBILITY IN PEOPLE WITH TETRAPLEGIA AFTER ONE YEAR OF TRAINING

[1]Juliana Viana Paris, [2] Marlene Aparecida. Moreno, [3]Karine Jacon Sarro, and [1] Ricardo M. L. Barros
[1]Faculty of Physical Education, University of Campinas, Campinas, Brazil. [2] College of Health Science. Methodist University of Piracicaba, Piracicaba, São Paulo, Brazil, Brazil. [3]Federal University of Espírito Santo, UFES Vitória, Brazil . email:

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INDIVIDUALITY IS THE KEY

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