Biomechanics contributions to para-cycling performance improvement

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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)
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

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
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)
Figure 4 — Muscular activity, segmental displacements, and force applications over five consecutive cycles projected in the sagittal plane for the able-bodied subject. $cv_{seg}$ 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.
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 90°

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.

**Gear ratio**

An increase in gear ratio:

**INCREASE**

- maximal velocity
- flexion/extension of the trunk
- adduction/abduction of the shoulder

**DECREASE**

- crank frequency
- 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

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

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
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 $+30^\circ$ (more pronated) is optimal for power generation.
- A fixed handle angle of $-15^\circ$ (more supinated) is optimal for work generation during push-up and the pull-up.
- A fixed handle angle of $+30^\circ$ (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
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).
Tracking based on non-dedicated camera images

Inertial sensors

Accelerometers
- Inclination
- Angular Velocity
  - When a is constant: Great inclinometer
  - Measurement of angular rotations
  - Considerable offset and drift over the time

Gyrosopes
- Angular Velocity
- Heading Angle
  - Detection of rotation about the earth’s magnetic field
  - Problems magnetic interference

Magnetometers
- Problems magnetic interference
Inertial Measurement Unit (IMU) + sEMG Wireless Sensors

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

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

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

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1Campinas State University; 2Politecnico di Milano
Kinematical analysis of thoracoabdominal motion and breathing pattern
Ribs motion during breathing

- Nadadores apresentaram maior correlação da 10ª costela com as costelas 5, 6 e 7.
Ribs motion pattern during breathing

• Nadadores apresentaram maior correlação da 10ª costela com as costelas 5, 6 e 7.
Coordination between ribs motion and thoracoabdominal volumes in swimmers during respiratory maneuvers

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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.
A 3D kinematic analysis of breathing patterns in competitive swimmers

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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
INDIVIDUALITY IS THE KEY
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