Kinematics, kinetics and muscular activity of 15-s all-out handcycling exercise in able-bodied participants

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Abstract The aim of this study was to examine the biomechanics of handcycling during the course of a 15-s all-out sprint test in able-bodied participants. Twelve able-bodied competitive triathletes performed a 15-s all-out sprint test in a recumbent racing handcycle that was attached to an ergometer. During the sprint test, tangential crank kinetics, 3D joint kinematics and muscular activity of ten muscles of the upper extremity and trunk [M. trapezius (TD); M. pectoralis major (PM); M. deltoideus, Pars clavicularis (DA); M. deltoideus, Pars spinalis (DP); M. biceps brachii (BB); M. triceps brachii (TB); forearm flexors (FC); forearm extensors (EC); M. latissimus dorsi (LD) and M. rectus abdominis (RA)] were examined using surface electromyography (sEMG) and motion capturing. Muscular activity was assessed by muscular effort (iEMG), onset, offset and range of activation (RoA). Variables were examined with respect to crank position and used to determine the maximum, minimum and range within crank cycle. Parameters were compared between revolution one (R1), revolution two (R2), the average of revolution three to thirteen (R3) and the average of the remaining revolutions (R4). Whereas the crank torque demonstrated a decrease during the course of the sprint test, cadence rather increased. Shoulder abduction and internal-rotation increased, whereas maximal retroversion was decreased during the course of the sprint. DA, PM, DA, BB and RA demonstrated an increase in iEMG. The onset of muscular activation occurred earlier in crank cycle for PM, DA, BB, TB and RA. RoA increased for PM, DP, BB, TB and LD. The study demonstrates that kinematics, kinetics and muscular activation of all-out handcycling exercise are altered during the course of a 15-s sprint test. The most notable alterations occurred in shoulder kinematics and the activation of DA that is spanned across. There is need to pay particular attention on the condition of the shoulder region.

Keywords biomechanics, sprint test, motion capturing, sEMG, handbike

Introduction

Among rather technical aspects (as e. g. aerodynamics and rolling resistance), the race velocity in handcycling competition is primarily caused by the mechanical power transmitted to the cranks. Mechanical power of handcycling propulsion is equal to the product of the tangential crank torque and crank angular velocity (or cadence). Since the hands remain fixed on the cranks during propulsion, crank kinetics and kinematics are directly depending on the athletes' joint kinematics that are caused by the activation of the surrounding muscles. Most of the previous research examined biomechanical aspects of handcycling at a rather moderate intensity (Faupin et al., 2010; van Drongelen et al., 2011; Faupin et al., 2011; Arnet et al., 2012; Kraaijenbrink et al., 2017). However, for the start, passing manoeuvres or the final sprint, handcycle athletes need to increase their efforts to (almost) maximal intensities (Abel et al, 2006). Hence, the aim of this study was to quantify the biomechanics of all-out handcycling exercise in terms of kinematics, kinetics and muscular activity and examine alterations during the course of a 15-s sprint test.

Methods

Twelve able-bodied male competitive triathletes (26.0 ± 4.4 yrs., 1.83 ± 0.06 m, 74.3 ± 3.6 kg) participated in the study. The tests were performed in a racing handcycle (Shark S, Sopur, Sunrise Medical, Malsch, Germany) that was mounted on a calibrated and validated ergometer (Cyclus 2, TE 2%, 8 Hz, RBM electronic-automation GmbH, Leipzig, Germany).

Crank kinetics were estimated using a power meter (1000 Hz, Schoberer Rad Messtechnik (SRM) GmbH, Jülich, Germany) installed in the crank. Seven high-speed infrared cameras (100 Hz, MX-F40 and MX-3+, Vicon Nexus 2.3, Vicon Motion Systems Ltd., Oxford, UK) were placed around the handcycle. Spherical retro-reflective markers (in all 44) were placed on the crank, ergometer and anatomical landmarks according to the Upper Limb Model (Vicon Motion Systems). Angles and angular velocities of shoulder flexion (SF), shoulder abduction (SA), shoulder rotation (SR), elbow flexion (EF), palmar flexion (PF) and radial abduction (RD) of the dominant (right) arm were considered. Trunk flexion angle (TF) was determined in accordance with ISB recommendations as the angle between the horizontal plane and the line connecting the midpoints between the 7th cervical vertebra (C7) and jugular notch (CLAV) and the 10th thoracic vertebra (T10) and xiphoid process (STRN) (Quittmann et al. 2018).

Muscular activity of ten muscles [M. trapezius, Pars descendens (TD); M. pectoralis major, Pars sternalis (PM); M. deltoideus, Pars clavicularis (DA); M. deltoideus, Pars spinalis (DP); M. biceps brachii, Caput breve (BB); M. triceps brachii, Caput laterale (TB); M. flexor carpi radialis (FC); M. extensor carpi ulnaris (EC); M. latissimus dorsi (LD) and M. rectus abdominis (RA)] was measured unilaterally on the dominant (right) side of the participants using a wireless surface Electromyography (sEMG) system (DTSEMG Sensor®, 1000 Hz, Noraxon Scottsdale, Arizona, USA).

Statistics

Statistical analyses were performed using the Statistical Package for the Social Sciences software (25, SPSS Inc., Chicago, Illinois, USA). Since the first two revolutions are required to overcome the initial resistance and set the cranks in motion, revolutions were compared between revolution one (R1), revolution two (R2), the average of revolution three to thirteen (R3) and the average of the remaining (10 to 14) revolutions (R4). Alterations in kinetics, kinematics and muscular activity during the course the sprint test were examined using a one-way analysis of variance (ANOVA) with repeated measures. Post-hoc comparisons between R1, R2, R3 and R4 were adjusted according to Bonferroni’s correction. The level of significance was set at $\alpha = 0.05$.

Results

Whereas the crank torque demonstrated a decrease during the course of the sprint test, cadence showed an increase. Shoulder abduction and internal-rotation increased, whereas maximal retroversion was decreased during the course of the sprint. The angles and RoM of the elbow and wrist was not significantly altered. The highest values of angular velocity were found for SF. DA, PM, DA, BB and RA demonstrated an increase in muscular effort. The onset of muscular activation for PM, DA, BB, TB and RA occurred earlier in crank cycle at the later phase of the sprint. The onset of DA and DP preceded the onset of TB and BB, respectively. The range of activation increased during the course of the sprint for PM, DP, BB, TB and LD.

Conclusion and discussion

The results of this study demonstrated that kinematics, kinetics and muscular activity are remarkably high and altered during the course of a 15-s all-out sprint test. It seems that the shoulder region is exposed to high stress, reacts rather sensitive to fatigue-based alterations and is probably prone to overuse injuries in handcycling. DA and DP act as important initiators of the push and pull phase and assist larger muscles as PM and BB, respectively. To quantify the joint moments and forces during all-out handcycling exercise, these data can be used in musculoskeletal modelling approaches. However, these findings need to be validated in elite handcycle athletes with a spinal cord injury (SCI). Since the shoulder provides the most degrees of freedom at the expense of reduced stability, athletes and coaches are encouraged to pay particular attention on the conditioning of the shoulder region. However, due to wheelchair athletes' vigorous use of the upper-extremities in daily living and exercise, additional strength training exercises should be applied with caution.

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