SRM in Science

Altamirano, Coburn et al. 2012 – Effects of warm-up on peak

Altamirano, Kristianna M.; Coburn, Jared W.; Brown, Lee E.; Judelson, Daniel A. (2012):

Effects of warm-up on peak torque, rate of torque development, and electromyographic and mechanomyographic signals.

In: *Journal of strength and conditioning research / National Strength & Conditioning Association* 26 (5), S. 1296–1301. DOI: 10.1519/JSC.0b013e31822e7a85.

Abstract:

The purpose of this study was to determine if an active warm-up affects peak torque (PT), rate of torque development (RTD), and the electromyographic (EMG) and mechanomyographic (MMG) signals. Twenty-one men (mean age ± SD: 24.0 ± 2.7 years) visited the exercise physiology laboratory on 2 occasions. During the first visit, they either performed an active warm-up (10 minutes of stationary cycling at 70% of predicted maximum heart rate) or sat quietly (no warm-up). Participants were then tested for isometric and isokinetic (60°, 180°, and 300°·s) PT, and RTD (measured as S-gradient) on an isokinetic dynamometer. Electromyographic and MMG sensors were placed over the vastus lateralis muscle to monitor the electrical and mechanical aspects of muscle contractions, respectively. The testing protocol used for the first visit was repeated for the second visit, but the preexercise treatment (warm-up, no warm-up) not given during the first visit was administered. The results indicated that an active warm-up did not affect PT, RTD, or measures of muscle activation as reflected by EMG amplitude, EMG frequency, or MMG frequency ($p > 0.05$). However, MMG amplitude at 180°·s was significantly greater in the warm-up condition compared with the no warm-up condition. The isolated increase in MMG amplitude suggested that warm-up may have affected the mechanical properties of muscle by reducing muscular stiffness or decreasing intramuscular fluid pressure, but that it was not sufficient to influence performance.

Ambrosini, Ferrante et al. 2012 – Cycling induced by electrical stimulation

Ambrosini, Emilia; Ferrante, Simona; Ferrigno, Giancarlo; Molteni, Franco; Pedrocchi, Alessandra (2012):

Cycling induced by electrical stimulation improves muscle activation and symmetry during pedaling in hemiparetic patients.

In: *IEEE transactions on neural systems and rehabilitation engineering : a publication of the IEEE Engineering in Medicine and Biology Society* 20 (3), S. 320–330. DOI: 10.1109/TNSRE.2012.2191574.

Abstract:

A randomized controlled trial, involving 35 post-acute hemiparetic patients, demonstrated that a four-week treatment of cycling induced by functional electrical stimulation (FES-cycling) promotes motor recovery. Analyzing additional data acquired during that study, the present work investigated whether these improvements were associated to changes in muscle strength and motor coordination. Participants were randomized to receive FES-cycling or placebo FES-cycling. Clinical outcome measures were: the Motricity Index (MI), the gait speed, the electromyography activation of the rectus femoris and biceps femoris, and the mechanical work produced by each leg during voluntary pedaling. To provide a comparison with normal values, healthy adults also carried out the pedaling test. Patients were evaluated before, after training, and at follow-up visits. A significant treatment effect in favor of FES-treated patients was found in terms of MI scores and unbalance in mechanical works, while differences in gait speed were not significant (ANCOVA). Significant improvements in the activation of the paretic muscles were highlighted in the FES group, while no significant change was found in the placebo group (Friedman test). Our findings suggested that improvements in motor functions induced by FES-cycling training were associated with a more symmetrical involvement of the two legs and an improved motor coordination.

Andersson, Raastad et al. 2008 – Neuromuscular fatigue and recovery

Andersson, Helena; Raastad, Truls; Nilsson, Johnny; Paulsen, Gøran; Garthe, Ina; Kadi, Fawzi (2008):

Neuromuscular fatigue and recovery in elite female soccer: effects of active recovery.

In: *Medicine and science in sports and exercise* 40 (2), S. 372–380. DOI: 10.1249/mss.0b013e31815b8497.

Abstract:

PURPOSE

To investigate the time course of recovery from neuromuscular fatigue and some biochemical changes between two female soccer matches separated by an active or passive recovery regime.

METHODS

Countermovement jump (CMJ), sprint performance, maximal isokinetic knee flexion and extension, creatine kinase (CK), urea, uric acid, and perceived muscle soreness were measured in 17 elite female soccer players before, immediately after, 5, 21, 45, 51, and 69 h after a first match, and immediately after a second match. Eight players performed active recovery (submaximal cycling at 60% of HRpeak and low-intensity resistance training at < 50% 1RM) 22 and 46 h after the first match.

RESULTS

In response to the first match, a significant decrease in sprint performance (-3.0 +/- 0.5%), CMJ (-4.4 +/- 0.8%), peak torque in knee extension (-7.1 +/- 1.9%) and flexion (-9.4 +/- 1.8%), and an increase in CK (+ 152 +/- 28%), urea (15 +/- 2), uric acid (+ 11 +/- 2%), and muscle soreness occurred. Sprint ability was first to return to baseline (5 h) followed by urea and uric acid (21 h), isokinetic knee extension (27 h) and flexion (51 h), CK, and muscle soreness (69 h), whereas CMJ was still reduced at the beginning of the second match. There were no significant differences in the recovery pattern between the active and passive recovery groups. The magnitude of the neuromuscular and biochemical changes after the second match was similar to that observed after the first match.

CONCLUSION

The present study reveals differences in the recovery pattern of the various neuromuscular and biochemical parameters in response to a female soccer match. The active recovery had no effects on the recovery pattern of the four neuromuscular and three biochemical parameters.

Austin, Nilwik et al. 2010 – In vivo operational fascicle lengths

Austin, Neal; Nilwik, Rachel; Herzog, Walter (2010):

In vivo operational fascicle lengths of vastus lateralis during sub-maximal and maximal cycling.

In: *Journal of biomechanics* 43 (12), S. 2394–2399. DOI: 10.1016/j.jbiomech.2010.04.016.

Abstract:

Instantaneous contractile characteristics of skeletal muscle, during movement tasks, can be determined and related to steady state mechanical properties such as the force-length relationship with the use of ultrasound imaging. A previous investigation into the contractile characteristics of the vastus lateralis (VL) during cycling has shown that fascicles operate on the "weak" descending limb of the force-length relationship, thus not taking advantage of the "strong" plateau region. The purpose of this study was to investigate if VL fascicle lengths change from sub-maximal to maximal cycling conditions, and if maximal cycling results in VL fascicle lengths which operate across the plateau of the force-length relationship. Fifteen healthy male subjects (age 20.9+/-1.8yr, wt. 67.0+/-6.3kg, ht. 176.7+/-7.2cm) were tested to establish the maximal force-length relationship for the VL through ten maximal isometric contractions at various knee angles. Subjects then cycled on an SRM cycle ergometer at cadences of 50 and 80 revolutions per minute at 100W, 250W, and maximal effort. Fascicle lengths were determined at crank angles of 0, 90, and 180 degrees . Fascicles operated at or near the plateau of the maximal force-length relationship for maximal cycling, while operating on the descending limb during sub-maximal conditions for both cadences. However, when comparing the

fascicle operating range for the sub-maximal cycling conditions to the corresponding sub-maximal force-length relationships, the VL now also operated across the plateau region. We concluded from these results that regardless of cycling effort, the VL operated through the ideal plateau region of the corresponding force-length relationship, hence always working optimally. We hypothesize that this phenomenon is due to the coupling of series elastic compliance and length dependent calcium sensitivity in the VL.

Belen, Habrard et al. 2007 – The performance and efficiency

Belen, L.; Habrard, M.; Micallef, J. P.; Le Gallais, D. (2007):

The performance and efficiency of cycling with a carbon fiber eccentric chainring during incremental exercise.

In: *The Journal of sports medicine and physical fitness* 47 (1), S. 40–45.

Abstract:

AIM

The aim of this study was to compare cycling performance and efficiency of a carbon fiber eccentric chainring (EC) versus a metallic standard chainring (SC) during an incremental exercise. The main feature of EC was that crank-arm length changed as a function of the crank angle, being maximal during the pushing phase and minimal during the recovery one. Because of its design, cycling with EC was expected to develop higher torque during the downstroke, and lower torque during the upstroke, thus increasing mechanical efficiency and requiring lower cardioventilatory solicitation at submaximal exercise intensities.

METHODS

Eleven male subjects performed two incremental cycle tests in a randomized order using EC and SC successively. Cardioventilatory data were recorded every minute using an automated breath-by-breath system. Blood samples were taken at rest, exhaustion, 5 and 15 minutes of recovery to access lactate concentrations, [LA], mmol . L(-1) .

RESULTS

The subjects reached significantly lower maximal speed at volitional exhaustion with EC compared with SC (39.4+/-2.5 versus 41.5+/-2.9 km . h(-1), respectively; P<0.05). Analysis of variance revealed significantly higher values for oxygen uptake and carbon dioxide production during incremental exercise with EC (P<0.05). Lastly, [LA] at exhaustion were similar with the two chainrings.

CONCLUSIONS

The carbon fiber EC tested in this study failed to enhance cycling performance and efficiency throughout an incremental exercise. This indicated that carbon fibers did not exhibited its expected mechanical advantage.

Belen, Habrard et al. 2007 – Cycling performance and mechanical variables

Belen, Lucien; Habrard, Mickaël; Micallef, Jean Paul; Perrey, Stéphane; Le Gallais, Daniel (2007):

Cycling performance and mechanical variables using a new prototype chainring.

In: *European journal of applied physiology* 101 (6), S. 721–726. DOI: 10.1007/s00421-007-0547-z.

Abstract:

The primary aim of our study was to examine supra-maximal cycling performance and related mechanical variables in trained cyclists using a new prototype chainring (PC) designed to produce a higher mean net torque (T (N mean)) than a standard chainring (SC). The main feature of the PC is that crank-arm alignment and lever-arm length change as a function of the crank angle during the pedaling cycle. The PC presents two features theorized to effect cycling performance: (1) out of line of pedal cranks resulting in an decrease in the dead points, and (2) a change in crank arm length inducing a torque different from that of

SC during the down- and up-stroke of the pedaling cycle. To investigate this theory, we examined eight male cyclists who performed a 1-km "all-out" cycling test in the following order: SC, PC, and SC. Performance was measured as the time (s) to complete the 1-km test. Mechanical variables included torque (N m(-1)), crank velocity (rad s(-1)), and power output (W). We performed our statistical analysis using a two-way ANOVA for repeated measurements and Newman-Keuls post hoc assessment. Our results showed that performance was similar for SC (69.41 +/- 6.69 s) and PC (73.33 +/- 4.58 s). Torque, crank velocity, and power output were also similar throughout (P > 0.05). We conclude that despite the theoretically benefits proposed by the inventors the new PC investigated in our study failed to improve cycling performance or mechanical variables during a supramaximal test when compared with SC.

Bercier, Halin et al. 2009 – The vastus lateralis neuromuscular activity

Bercier, Stephane; Halin, Renaud; Ravier, Philippe; Kahn, Jean-Francois; Jouanin, Jean-Claude; Lecoq, Anne-Marie; Buttelli, Olivier (2009):

The vastus lateralis neuromuscular activity during all-out cycling exercise.

In: *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 19 (5), S. 922–930. DOI: 10.1016/j.jelekin.2008.03.012.

Abstract:

OBJECTIVE

The objective of this work was to study modifications in motor control through surface electromyographic (sEMG) activity during a very short all-out cycling exercise.

METHODS

Twelve male cyclists (age 23+/-4 years) participated in this study. After a warm-up period, each subject performed three all-out cycling exercises of 6s separated by 2 min of complete rest. This protocol was repeated three times with a minimum of 2 days between each session. The braking torque imposed on cycling motion was 19 Nm. The sEMG of the vastus lateralis was recorded during the first seven contractions of the sprint. Time-frequency analysis of sEMG was performed using continuous wavelet transform. The mean power frequency (MPF, qualitative modifications in the recruitment of motor units) and signal energy (a quantitative indicator of modifications in the motor units recruitment) were computed for the frequency range 10-500 Hz.

RESULTS

sEMG energy increased (P0.05) between contraction number 1 and 2, decreased (P < or =0.05) between contraction number 2 and 3 then stabilized between contraction number 3 and 7 during the all-out test. MPF increased (P < or =0.05) during the all-out test. This increase was more marked during the first two contractions.

CONCLUSIONS

The decrease in energy and the increase in the sEMG MPF suggest a large spatial recruitment of motor units (MUs) at the beginning of the sprint followed by a preferential recruitment of faster MUs at the end of the sprint, respectively.

Bertucci, Grappe et al. 2005 – Effects on the crank torque

Bertucci, William; Grappe, Frederic; Girard, Amaury; Betik, Andrew; Rouillon, Jean Denis (2005):

Effects on the crank torque profile when changing pedalling cadence in level ground and uphill road cycling.

In: *Journal of biomechanics* 38 (5), S. 1003–1010. DOI: 10.1016/j.jbiomech.2004.05.037.

Abstract:

Despite the importance of uphill cycling performance during cycling competitions, there is very little research investigating uphill cycling, particularly concerning field studies. The lack of research is partly due to the difficulties in obtaining data in the field. The aim of this study was to analyse the crank torque in road cycling on level and uphill using different pedalling cadences in the seated position. Seven male cyclists performed four tests in the seated position (1) on level ground at 80 and 100 rpm, and (2) on uphill road cycling (9.25% grade) at 60 and 80 rpm.The cyclists exercised for 1 min at their maximal aerobic power. The bicycle was equipped with the SRM Training System (Schoberer, Germany) for the measurement of power output (W), torque (Nm), pedalling cadence (rpm), and cycling velocity (km h(-1)). The most important finding of this study indicated that at maximal aerobic power the crank torque profile (relationship between torque and crank angle) varied substantially according to the pedalling cadence and with a minor effect according to the terrain. At the same power output and pedalling cadence (80 rpm) the torque at a 45 degrees crank angle tended ($p < 0.06$) to be higher (+26%) during uphill cycling compared to level cycling. During uphill cycling at 60 rpm the peak torque was increased by 42% compared with level ground cycling at 100 rpm. When the pedalling cadence was modified, most of the variations in the crank torque profile were localised in the power output sector (45 degrees to 135 degrees).

Bertucci, Grappe et al. 2007 – Laboratory versus outdoor cycling conditions

Bertucci, William; Grappe, Frederic; Groslambert, Alain (2007):

Laboratory versus outdoor cycling conditions: differences in pedaling biomechanics.

In: *Journal of applied biomechanics* 23 (2), S. 87–92.

Abstract:

The aim of our study was to compare crank torque profile and perceived exertion between the Monark ergometer (818 E) and two outdoor cycling conditions: level ground and uphill road cycling. Seven male cyclists performed seven tests in seated position at different pedaling cadences: (a) in the laboratory at 60, 80, and 100 rpm; (b) on level terrain at 80 and 100 rpm; and (c) on uphill terrain (9.25% grade) at 60 and 80 rpm. The cyclists exercised for 1 min at their maximal aerobic power. The Monark ergometer and the bicycle were equipped with the SRM Training System (Schoberer, Germany) for the measurement of power output (W), torque (Nxm), pedaling cadence (rpm), and cycling velocity (kmxh-1). The most important findings of this study indicate that at maximal aerobic power the crank torque profiles in the Monark ergometer (818 E) were significantly different (especially on dead points of the crank cycle) and generate a higher perceived exertion compared with road cycling conditions.

Bessot, Moussay et al. 2007 – The influence of circadian rhythm

Bessot, N.; Moussay, S.; Clarys, J. P.; Gauthier, A.; Sesboüé, B.; Davenne, D. (2007):

The influence of circadian rhythm on muscle activity and efficient force production during cycling at different pedal rates.

In: *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 17 (2), S. 176–183. DOI: 10.1016/j.jelekin.2006.01.007.

Abstract:

The aim of this study was to examine the pedal rate and chronobiological impacts on muscle activity pattern and propulsive force production during cycling. Ten male competitive cyclists performed at 06:00 and 18:00 h a submaximal exercise on a cycle ergometer at a power output which elicited 50% of their respective W(max). The exercise was divided into 4 periods lasting 5 min each during which subjects were requested to use different pedal rates (free pedal rate, 70, 90 and 120 rev min-1) in random order. The study demonstrated that, under high pedal rate, several muscles exhibited a phase advance of activity. These modifications of temporal organization of muscle activity were not sufficient to keep an identical propulsive torque pattern. Time to peak torque was delayed when pedal rate increased. The effects of circadian fluctuation on electromyographic activity were limited to a later M. rectus femoris burst end and shorter activity duration for M. tibialis anterior at 06:00 h. From the results of

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this study, it seems that the influence of pedal rate in the range of torque fluctuation would depend on time-of-day of testing. The decrease in torque fluctuation due to pedal rate increase is reinforced when testing in the early morning. Taking this specific variable into consideration, the chronobiological effect increases the impact of pedal rate variations.

Bieuzen, Hausswirth et al. 2008 – Prior muscular exercise affects cycling

Bieuzen, F.; Hausswirth, C.; Couturier, A.; Brisswalter, J. (2008):

Prior muscular exercise affects cycling pattern.

In: *International journal of sports medicine* 29 (5), S. 401–407. DOI: 10.1055/s-2007-965568.

Abstract:

The aim of this study was to investigate the effect of concentric or eccentric fatiguing exercise on cycling pattern. Eleven well trained cyclists completed three sessions of cycling (control cycling test [CTRL], cycling following concentric [CC] or eccentric [ECC] knee contractions) at a mean power of 276.8 +/- 26.6 Watts. Concentric and eccentric knee contractions were performed at a load corresponding to 80 % of one repetition maximum with both legs. Before and after CTRL, CC or ECC knee contractions and after cycling, a maximal voluntary contraction (MVC) test was performed. Cardiorespiratory, mechanical and electromyographic activity (EMG) of the rectus femoris, vastus lateralis and biceps femoris muscles were recorded during cycling. A significant decrease in MVC values was observed after CC and ECC exercises and after the cycling. ECC exercise induced a significant decrease in EMG root mean square during MVC and a decrease in pedal rate during cycling. EMG values of the three muscles were significantly higher during cycling exercise following CC exercise when compared to CTRL. The main finding of this study was that a prior ECC exercise induces a greater neuromuscular fatigue than a CC exercise, and changes in cycling pattern.

Bieuzen, Lepers et al. 2007 – Muscle activation during cycling

Bieuzen, François; Lepers, Romuald; Vercruyssen, Fabrice; Hausswirth, Christophe; Brisswalter, Jeanick (2007):

Muscle activation during cycling at different cadences: effect of maximal strength capacity.

In: *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 17 (6), S. 731–738. DOI: 10.1016/j.jelekin.2006.07.007.

Abstract:

The purpose of this study was to examine the influence of maximal strength capacity on muscle activation, during cycling, at three selected cadences: a low cadence (50 rpm), a high cadence (110 rpm) and the freely chosen cadence (FCC). Two groups of trained cyclists were selected on the basis of the different maximal isokinetic voluntary contraction values (MVCi) of their lower extremity muscles as follow: F(min) (lower MVCi group) and F(max) (higher MVCi group). All subjects performed three 4-min cycling exercises at a power output corresponding to 80% of the ventilatory threshold under the three cadences. Neuromuscular activity of vastus lateralis (VL), rectus femoris (RF) and biceps femoris (BF) was studied quantitatively (integrated electromyography, IEMG) and qualitatively (timing of muscle bursts during crank cycle). Cadence effects were observed on the EMG activity of VL muscle and on the burst onset of the BF, VL and RF muscles. A greater normalized EMG activity of VL muscle was observed for the F(min) group than the F(max) group at all cadences (respectively F(min) vs. F(max) at 50 rpm: 17+/-5% vs. 38+/-6%, FCC: 22+/-7% vs. 44+/-5% and 110 rpm: 21+/-6% vs. 45+/-6%). At FCC and 110 rpm, the burst onset of BF and RF muscles of the F(max) group started earlier in the crank cycle than the F(min) group These results indicate that in addition to the cadence, the maximal strength capacity influences the lower extremity muscular activity during cycling.

SRM in Science

Bini, Hume 2014 – Assessment of bilateral asymmetry

Bini, Rodrigo R.; Hume, Patria A. (2014):

Assessment of bilateral asymmetry in cycling using a commercial instrumented crank system and instrumented pedals.

In: *International journal of sports physiology and performance* 9 (5), S. 876–881. DOI: 10.1123/ijspp.2013-0494.

Abstract:

The accuracy of commercial instrumented crank systems for symmetry assessment in cycling has not been fully explored. Therefore, the authors' aims were to compare peak crank torque between a commercial instrumented crank system and instrumented pedals and to assess the effect of power output on bilateral asymmetries during cycling. Ten competitive cyclists performed an incremental cycling test to exhaustion. Forces and pedal angles were recorded using right and left instrumented pedals synchronized with crank-torque measurements using an instrumented crank system. Differences in right (dominant) and left (nondominant) peak torque and asymmetry index were assessed using effect sizes. In the 100- to 250-W power-output range, the instrumented pedal system recorded larger peak torque (dominant 55-122%, nondominant 23-99%) than the instrumented crank system. There was an increase in differences between dominant and nondominant crank torque as power output increased using the instrumented crank system (7% to 33%) and the instrumented pedals (9% to 66%). Lower-limb asymmetries in peak torque increased at higher power-output levels in favor of the dominant leg. Limitations in design of the instrumented crank system may preclude the use of this system to assess peak crank-torque symmetry.

Bini, Jacques et al. 2014 – Joint Torques and Patelofemoral Force

Bini, Rodrigo R.; Jacques, Tiago C.; Vaz, Marco A. (2014):

Joint Torques and Patelofemoral Force During Single-Leg Assisted and Unassisted Cycling.

In: *Journal of sport rehabilitation*.

Abstract:

CONTEXT

Unassisted single-leg cycling should be replaced by assisted single-leg cycling, given this last approach has potential to mimic joint kinetics and kinematics from double-leg cycling. However, there is need to test if assisting devices during pedaling effectively replicate joint forces and torque from double-leg cycling.

OBJECTIVES

This study aimed at comparing double-leg, single-leg assisted and unassisted cycling in terms of lower limb kinetics and kinematics.

DESIGN

Cross-sectional crossover.

SETTING

Laboratorial experiment.

PARTICIPANTS

Fourteen healthy non-athletes.

INTERVENTIONS

Two double-leg cycling trials (240 ±23W) and two single-leg trials (120 ±11W) at 90 rpm were performed for 2-min using a bicycle attached to a cycle trainer. Measurements of pedal force and joint kinematics of participants' right lower-limb were

performed during double leg and single leg trials. For the single-leg assisted trial, a custom-made adaptor was used to attach 10kg of weight to the contralateral crank.

MAIN OUTCOME MEASURES

Peak hip, knee and ankle torques (flexors and extensors) along with knee flexion angle and peak patellofemoral compressive force were computed.

RESULTS

Reduced peak hip extensor torque (10%) and increased peak knee flexor torque (157%) were observed at the single-leg assisted cycling compared to the double-leg cycling. No differences were found for peak patellofemoral compressive force or knee flexion angle comparing double-leg to single-leg assisted cycling. However, single-leg unassisted cycling resulted in larger peak patellofemoral compressive force (28%) and reduced knee flexion angle (3%) than double-leg cycling.

CONCLUSIONS

These results suggest that, although single-leg assisted cycling differs for joint torques, it replicates knee loads from double-leg cycling.

Bini, Diefenthaeler et al. 2010 – Fatigue effects on the coordinative

Bini, Rodrigo Rico; Diefenthaeler, Fernando; Mota, Carlos Bolli (2010):

Fatigue effects on the coordinative pattern during cycling: kinetics and kinematics evaluation.

In: *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 20 (1), S. 102–107. DOI: 10.1016/j.jelekin.2008.10.003.

Abstract:

The aim of the present study was to analyze the net joint moment distribution, joint forces and kinematics during cycling to exhaustion. Right pedal forces and lower limb kinematics of ten cyclists were measured throughout a fatigue cycling test at 100% of PO(MAX). The absolute net joint moments, resultant force and kinematics were calculated for the hip, knee and ankle joint through inverse dynamics. The contribution of each joint to the total net joint moments was computed. Decreased pedaling cadence was observed followed by a decreased ankle moment contribution to the total joint moments in the end of the test. The total absolute joint moment, and the hip and knee moments has also increased with fatigue. Resultant force was increased, while kinematics has changed in the end of the test for hip, knee and ankle joints. Reduced ankle contribution to the total absolute joint moment combined with higher ankle force and changes in kinematics has indicated a different mechanical function for this joint. Kinetics and kinematics changes observed at hip and knee joint was expected due to their function as power sources. Kinematics changes would be explained as an attempt to overcome decreased contractile properties of muscles during fatigue.

Bowtell, Avenell et al. 2013 – Effect of hypohydration on peripheral

Bowtell, Joanna L.; Avenell, Gareth; Hunter, Steven P.; Mileva, Katya N. (2013):

Effect of hypohydration on peripheral and corticospinal excitability and voluntary activation.

In: *PloS one* 8 (10), S. e77004. DOI: 10.1371/journal.pone.0077004.

Abstract:

We investigated whether altered peripheral and/or corticospinal excitatory output and voluntary activation are implicated in hypohydration-induced reductions in muscle isometric and isokinetic (90°.s(-1)) strength. Nine male athletes completed two trials (hypohydrated, euhydrated) comprising 90 min cycling at 40°C, with body weight losses replaced in euhydrated trial.

Peripheral nerve and transcranial magnetic stimulations were applied during voluntary contractions pre- and 40 min post-exercise to quantify voluntary activation and peripheral (M-wave) and corticospinal (motor evoked potential) evoked responses in m. vastus medialis. Both maximum isometric (-15.3±3.1 vs -5.4±3.5%) and isokinetic eccentric (-24.8±4.6 vs -7.3±7.2%) torque decreased to a greater extent in hypohydrated than euhydrated trials ($p<0.05$). Half relaxation time of the twitch evoked by peripheral nerve stimulation during maximal contractions increased after exercise in the hypohydrated (21.8±9.3%) but stayed constant in the euhydrated (1.6±10.7%; $p = 0.017$) condition. M-wave amplitude during maximum voluntary contraction increased after exercise in the heat in hypohydrated (10.7±18.0%) but decreased in euhydrated condition (-17.4±16.9%; $p = 0.067$). Neither peripheral nor cortical voluntary activation were significantly different between conditions. Motor evoked potential amplitude increased similarly in both conditions (hypohydrated: 25.7±28.5%; euhydrated: 52.9±33.5%) and was accompanied by lengthening of the cortical silent period in euhydrated but not hypohydrated condition ($p = 0.019$). Different neural strategies seem to be adopted to regulate neural drive in the two conditions, with increases in inhibitory input of either intracortical or corticospinal origin during the euhydrated trial. Such changes were absent in the hypohydrated condition, yet voluntary activation was similar to the euhydrated condition, perhaps due to smaller increases in excitatory drive rather than increased inhibition. Despite this maximal isometric and eccentric strength were impaired in the hypohydrated condition. The increase in peripheral muscle excitability evident in the hypohydrated condition was not sufficient to preserve performance in the face of reduced muscle contractility or impaired excitation-contraction coupling.

Brown, Nicholas A T, Jensen 2006 – The role of segmental mass

Brown, Nicholas A T; Jensen, Jody L. (2006):

The role of segmental mass and moment of inertia in dynamic-contact task construction.

In: *Journal of motor behavior* 38 (4), S. 313–328. DOI: 10.3200/JMBR.38.4.313-326.

Abstract:

The authors examined whether differences between children and adults in the application of muscle forces during a dynamic-contact task (cycling) can be attributed to children's relatively lower segmental mass and moment of inertia. They examined pedal-force construction as adults and younger and older children (n = 7 in each group), with and without mass added to their limbs, pedaled an appropriately scaled bicycle ergometer. When mass was added to their limbs, children adjusted muscular forces on the pedal in a way that began to approach the pattern demonstrated by adults. Because age, neuromotor maturation, and motor experience were held constant, it seems plausible that by 6 to 8 years of age, and perhaps younger, physical size and growth limit children's production of adult-like muscle forces on the pedal.

Brughelli, van Leemputte 2013 – Reliability of power output

Brughelli, Matt; van Leemputte, Marc (2013):

Reliability of power output during eccentric sprint cycling.

In: *Journal of strength and conditioning research / National Strength & Conditioning Association* 27 (1), S. 76–82. DOI: 10.1519/JSC.0b013e31824f2055.

Abstract:

The purpose of this study was to determine the reliability of power outputs during maximal intensity eccentric cycling over short durations (i.e., eccentric sprint cycling) on a "motor-driven" isokinetic ergometer. Fourteen physically active male subjects performed isokinetic eccentric cycling sprints at 40, 60, 80, 100, and 120 revolutions per minute (rpm) on 4 separate occasions (T1-T4). Each sprint lasted for 6 seconds, and absolute measures of mean power (MP) and peak power (PP) per revolution were recorded. Significant increases in MP and PP were observed between T1 and subsequent trials, but no significant differences were identified between T2, T3, and T4. The coefficient of variation (CV) and intraclass correlation coefficient (ICC) were calculated to reflect within-subject and between-session reliability of MP and PP at each cadence. The CV improved to below 10% for cadences of 60, 80, 100, and 120 rpm between T3 and T4, and the majority of ICC values improved to above 0.90. The remaining ICC values remained in the moderate range between T3 and T4 (i.e., 0.82-0.89). Coefficient of variation and ICC values

for the 40 rpm cadence remained at unacceptable levels throughout the 4 trials and thus should be avoided in future investigations. The results of this study indicate that reliable power outputs may be obtained after 2 familiarization sessions during eccentric sprint cycling at cadences ranging from 60 to 120 rpm.

Butcher, Lagerquist et al. 2009 – Relationship between ventilatory constraint

Butcher, S. J.; Lagerquist, O.; Marciniuk, D. D.; Petersen, S. R.; Collins, D. F.; Jones, R. L. (2009):

Relationship between ventilatory constraint and muscle fatigue during exercise in COPD.

In: *The European respiratory journal* 33 (4), S. 763–770. DOI: 10.1183/09031936.00014708.

Abstract:

Dynamic hyperinflation and leg muscle fatigue are independently associated with exercise limitation in patients with chronic obstructive pulmonary disease (COPD). The aims of the present study were to examine 1) the relationship between these limitations and 2) the effect of delaying ventilatory limitation on exercise tolerance and leg muscle fatigue. In total, 11 patients with COPD (with a forced expiratory volume in one second of 52% predicted) completed two cycling bouts breathing either room air or heliox, and one bout breathing heliox but stopping at room air isotime. End-expiratory lung volume (EELV), leg muscle fatigue and exercise time were measured. On room air, end-exercise EELV was negatively correlated with leg fatigue. Heliox increased exercise time (from 346 to 530 s) and leg fatigue (by 15%). At isotime, there was no change in leg fatigue, despite a reduction in EELV compared with end-exercise, in both room air and heliox. The change in exercise time with heliox was best correlated with room air leg fatigue and end-inspiratory lung volume. Patients with chronic obstructive pulmonary disease who had greater levels of dynamic hyperinflation on room air had less muscle fatigue. These patients were more likely to increase exercise tolerance with heliox, which resulted in greater leg muscle fatigue.

Cadová, Vilímek 2009 – The necessity of physiological muscle

Cadová, Michala; Vilímek, Miloslav (2009):

The necessity of physiological muscle parameters for computing the muscle forces: application to lower extremity loading during pedalling.

In: *Acta of bioengineering and biomechanics / Wrocław University of Technology* 11 (3), S. 59–64.

Abstract:

The aim of this study is to determine how the use of physiological parameters of muscles is important. This work is focused on musculoskeletal loading analysis during pedalling adopting two approaches: without (1) and with (2) the use of physiological parameters of muscles. The static-optimization approach together with the inverse dynamics problem makes it possible to obtain forces in individual muscles of the lower extremity. Input kinematics variables were examined in a cycling experiment. The significant difference in the resultant forces in one-joint and two-joint muscles using the two different approaches was observed.

Carpes, Rossato et al. 2007 – Bilateral pedaling asymmetry

Carpes, F. P.; Rossato, M.; Faria, I. E.; Bolli Mota, C. (2007):

Bilateral pedaling asymmetry during a simulated 40-km cycling time-trial.

In: *The Journal of sports medicine and physical fitness* 47 (1), S. 51–57.

Abstract:

AIM

This study investigated the pedaling asymmetry during a 40-km cycling time-trial (TT).

METHODS

Six sub-elite competitive male cyclists pedaled a SRM Training Systems cycle ergometer throughout a simulated 40-km TT. A SRM scientific crank dynamometer was used to measure the bilateral crank torque (N.m) and pedaling cadence (rpm). All data were analyzed into 4 stages with equal length obtained according to total time. Comparisons between each stage of the 40-km TT were made by an analysis of variance (ANOVA). Dominant (DO) and non-dominant (ND) crank peak torque asymmetry was determined by the equation: asymmetry index (AI%)=[(DO-ND)/DO] 100. Pearson correlation analysis was performed to verify the relationship between exercise intensity, mean and crank peak torque.

RESULTS

The crank peak torque was significantly ($P<0.05$) greater in the 4th stage compared with other stages. During the stages 2 and 3, was observed the AI% of 13.51% and 17.28%, respectively. Exercise intensity (%VO(2max)) was greater for stage 4 ($P<0.05$) and was highly correlated with mean and crank peak torque ($r=0.97$ and $r=0.92$, respectively) for each stage.

CONCLUSIONS

The DO limb was always responsible for the larger crank peak torque. It was concluded that pedaling asymmetry is present during a simulated 40-km TT and an increase on crank torque output and exercise intensity elicits a reduction in pedaling asymmetry.

Carpes, Mota et al. 2010 – On the bilateral asymmetry

Carpes, Felipe P.; Mota, Carlos B.; Faria, Irvin E. (2010):

On the bilateral asymmetry during running and cycling - a review considering leg preference.

In: *Physical therapy in sport : official journal of the Association of Chartered Physiotherapists in Sports Medicine* 11 (4), S. 136–142. DOI: 10.1016/j.ptsp.2010.06.005.

Abstract:

BACKGROUND

This review summarizes the effects of bilateral asymmetry on running and cycling performance and risk of injury in healthy subjects and the influence of leg preference. We define the term leg preference derived from lateral preference as representative of the choice for one side of the body to perform a motor action. Useful information is provided for biomechanical and physiological research and coaching with relevance to an understanding regarding the occurrence of lower limb asymmetry.

OBJECTIVES

To provide a synopsis of what is known about bilateral asymmetry in human running and cycling and its relationship to limb preference, especially in the context of competitive sport performance and risk of injury.

DESIGN

Structured narrative review.

METHODS

The relationship between asymmetry and lower limb preference was reviewed using Medline(®), Sciencedirect(®), and Scopus(®) search engines considering studies published in English until June 2009.

SUMMARY

The environment characteristics may influence running asymmetries, which are more frequent in angular parameters. Environment characteristics are related to ground irregularities requiring compensatory movements changing the mechanical workload on joints and bones, which may influence asymmetries in biomechanical parameters between lower limbs. The relationship between asymmetry and injury risk should be assessed with caution since running speed may influence asymmetry

in injured and non-injured subjects who often show similar asymmetry levels. Symmetry can be improved with increasing running speed. In addition to running speed, coaches and athletes interested in minimizing lateral difference should consider a training regime aimed at correcting asymmetry which may negatively affect running technique by influencing the compensatory movements that an athlete usually performs. During cycling, bilateral differences are frequently found and vary with the competitive situation, pedaling cadence, exercise intensity and exercise duration. Regardless of the variability of asymmetry index between subjects, few suggestions are available to overcome lateral differences. Most of the research suggests that bilateral pedaling asymmetries decrease as the workload increases, however the relationship to injury risk was not clearly addressed. For both running and cycling, few investigations examined the central mechanisms of neuromuscular control, and no study addressed the effect of asymmetry on performance.

CONCLUSIONS

Collectively, the volume of studies supporting symmetry is small and to a large extent research considered unilateral assessment. Preferred limb performance can differ from the contralateral limb. In the context of biomechanical and physiological investigations, we believe that further studies should address the role of lower limb symmetry on human motor performance and injury risk focusing on the energetic cost, muscle efficiency and the neuromuscular aspects such as muscle activation and motor units firing rate.

Coffey, Moore et al. 2011 – Nutrient provision increases signalling

Coffey, Vernon G.; Moore, Daniel R.; Burd, Nicholas A.; Rerecich, Tracy; Stellingwerff, Trent; Garnham, Andrew P. et al. (2011):

Nutrient provision increases signalling and protein synthesis in human skeletal muscle after repeated sprints.

In: *European journal of applied physiology* 111 (7), S. 1473–1483. DOI: 10.1007/s00421-010-1768-0.

Abstract:

The effect of nutrient availability on the acute molecular responses following repeated sprint exercise is unknown. The aim of this study was to determine skeletal muscle cellular and protein synthetic responses following repeated sprint exercise with nutrient provision. Eight healthy young male subjects undertook two sprint cycling sessions (10 × 6 s, 0.75 N m torque kg(-1), 54 s recovery) with either pre-exercise nutrient (24 g whey, 4.8 g leucine, 50 g maltodextrin) or non-caloric placebo ingestion. Muscle biopsies were taken from vastus lateralis at rest, and after 15 and 240 min post-exercise recovery to determine muscle cell signalling responses and protein synthesis by primed constant infusion of L: -[ring-(13)C(6)] phenylalanine. Peak and mean power outputs were similar between nutrient and placebo trials. Post-exercise myofibrillar protein synthetic rate was greater with nutrient ingestion compared with placebo (~48%, $P < 0.05$) but the rate of mitochondrial protein synthesis was similar between treatments. The increased myofibrillar protein synthesis following sprints with nutrient ingestion was associated with coordinated increases in Akt-mTOR-S6K-rpS6 phosphorylation 15 min post-exercise (~200-600%, $P < 0.05$), while there was no effect on these signalling molecules when exercise was undertaken in the fasted state. For the first time we report a beneficial effect of nutrient provision on anabolic signalling and muscle myofibrillar protein synthesis following repeated sprint exercise. Ingestion of protein/carbohydrate in close proximity to high-intensity sprint exercise provides an environment that increases cell signalling and protein synthesis.

Cometti, Deley et al. 2011 – Effects of between-set interventions

Cometti, Carole; Deley, Gaelle; Babault, Nicolas (2011):

Effects of between-set interventions on neuromuscular function during isokinetic maximal concentric contractions of the knee extensors.

In: *Journal of sports science & medicine* 10 (4), S. 624–629.

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Abstract:

The presents study investigated the effects of between-set interventions on neuromuscular function of the knee extensors during six sets of 10 isokinetic (120°·s(-1)) maximal concentric contractions separated by three minutes. Twelve healthy men (age: 23.9 ± 2.4 yrs) were tested for four different between-set recovery conditions applied during two minutes: passive recovery, active recovery (cycling), electromyostimulation and stretching, in a randomized, crossover design. Before, during and at the end of the isokinetic session, torque and thigh muscles electromyographic activity were measured during maximal voluntary contractions and electrically-evoked doublets. Activation level was calculated using the twitch interpolation technique. While quadriceps electromyographic activity and activation level were significantly decreased at the end of the isokinetic session (-5.5 ± 14.2 % and -2.7 ± 4.8 %; p < 0.05), significant decreases in maximal voluntary contractions and doublets were observed after the third set (respectively -0.8 ± 12.1% and -5.9 ± 9.9%; p < 0.05). Whatever the recovery modality applied, torque was back to initial values after each recovery period. The present results showed that fatigue appeared progressively during the isokinetic session with peripheral alterations occurring first followed by central ones. Recovery interventions between sets did not modify fatigue time course as compared with passive recovery. It appears that the interval between sets (3 min) was long enough to provide recovery regardless of the interventions. Key pointsAllowing three minutes of recovery between sets of 10 maximal concentric contractions would help the subjects to recover from the peripheral fatigue induced by each set and therefore to start each new set with a high intensity.During this type of session, with three minutes between sets, passive recovery is sufficient; there is no need to apply complicated recovery interventions.

Comolli, Ferrante et al. 2010 – Metrological characterization of a cycle-ergometer

Comolli, Lorenzo; Ferrante, Simona; Pedrocchi, Alessandra; Bocciolone, Marco; Ferrigno, Giancarlo; Molteni, Franco (2010):

Metrological characterization of a cycle-ergometer to optimize the cycling induced by functional electrical stimulation on patients with stroke.

In: *Medical engineering & physics* 32 (4), S. 339–348. DOI: 10.1016/j.medengphy.2010.01.005.

Abstract:

Functional electrical stimulation (FES) is a well established method in the rehabilitation of stroke patients. Indeed, a bilateral movement such as cycling induced by FES would be crucial for these patients who had an unilateral motor impairment and had to recover an equivalent use of limbs. The aim of this study was to develop a low-cost meteorologically qualified cycle-ergometer, optimized for patients with stroke. A commercial ergometer was instrumented with resistive strain gauges and was able to provide the torque produced at the right and left crank, independently. The developed system was integrated with a stimulator, obtaining a novel FES cycling device able to control in real-time the movement unbalance. A dynamic calibration of the sensors was performed and a total torque uncertainty was computed. The system was tested on a healthy subject and on a stroke patient. Results demonstrated that the proposed sensors could be successfully used during FES cycling sessions where the maximum torque produced is about 9Nm, an order of magnitude less than the torque produced during voluntary cycling. This FES cycling system will assist in future investigations on stroke rehabilitation by means of FES and in new exercise regimes designed specifically for patients with unilateral impairments.

Dauty, Huguet et al. 2006 – Réentraînement à l'effort entre

Dauty, M.; Huguet, D.; Tortellier, L.; Potiron-Josse, M.; Dubois, C. (2006):

Réentraînement à l'effort entre le quatrième et le sixième mois après ligamentoplastie de genou au DIDT: comparaison de la pratique de la bicyclette et de la pratique du footing avec un groupe témoin non réentraîné.

In: *Annales de réadaptation et de médecine physique : revue scientifique de la Société française de rééducation fonctionnelle de réadaptation et de médecine physique* 49 (5), S. 218–225. DOI: 10.1016/j.annrmp.2006.03.006.

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Abstract:

OBJECTIVE

To study the effect of cycling or running retraining between 4 and 6 months after patients underwent anterior cruciate ligament reconstruction with hamstring grafting (Semitendinosus-Gracilis) compared with that in patients who had the same surgery but were untrained.

METHOD

Patients who had undergone surgery for an anterior cruciate ligament reconstruction by the same surgeon who used hamstring grafting were included if they were free of knee pain 4 months after the surgery. After giving consent, patients were randomized to receive controlled retraining (cycling or running 3 times a week) or not. The effect of retraining was measured by the evolution of the knee isokinetic peak torque at 60 degrees/s and 180 degrees/s 6 months after surgery.

RESULTS

Fifteen patients were retrained with cycling (GI), 17 with running (GII) and 15 patients did not retrain (GIII). Before retraining, the 3 groups had the same peak torque deficit, measured at an angular speed of 60 degrees/s and 180 degrees/s, for knee extensors (GI: 33+/-11% and 27+/-8%; GII: 30+/-13% and 24+/-10%; GIII: 31+/-15% and 24+/-13%, respectively) and knee flexors (GI: 26+/-11% and 20+/-13%; GII: 20+/-14% and 17+/-13%; GIII: 19+/-15% and 14+/-15%, respectively). After retraining, progress measured at 60 degrees /s of knee extensors and flexors on the operated knees was 18+/-9% and 16+/-10% for GI, 16+/-9% and 11+/-11% for GII and 12+/-15% and 8+/-12 for GIII, respectively. Progress measured at 180 degrees /s followed the same evolution. After comparison of the 3 groups, any significant difference was put in relief according to the type of retraining.

CONCLUSION

Retraining after anterior cruciate ligament reconstruction is necessary for patients to practice their previous sport. In our study, aerobic cycling or running between 4 and 6 months after surgery did not improve peak torque in the operated knee extensors and flexors. However, these 2 types of retraining are well-tolerated.

Diserens, Perret et al. 2007 – The effect of repetitive arm

Diserens, K.; Perret, N.; Chatelain, S.; Bashir, S.; Ruegg, D.; Vuadens, P.; Vingerhoets, F. (2007):

The effect of repetitive arm cycling on post stroke spasticity and motor control: repetitive arm cycling and spasticity.

In: *Journal of the neurological sciences* 253 (1-2), S. 18–24. DOI: 10.1016/j.jns.2006.10.021.

Abstract:

This study's aims were (1) to test whether training on an arm ergometer improves motor performance, and (2) to develop a technique to quantify individual muscle spasticity. Nine patients with a stabilized hemisyndrome (in average 22 months after ischemic stroke in the territory of middle cerebral artery) underwent a 3-week training on an arm ergometer, 5 days/week. The patients were tested one week before training, at training onset, at the end of training and 2 weeks after training. Spasticity was quantified by (1) the Ashworth Scale of the elbow flexors and extensors, (2) the maximum active extension of the biceps, and (3) the minimum torque on the lesioned side during arm cycling. The data were standardized, pooled and a 2-way ANOVA revealed a decrease of the spasticity by the training ($p=0.076$). Similarly muscle force was evaluated by the Rivermead Motorik Assessment, the Motricity Index and the cycling force, and the range of active movement as the sum of the angles at a maximum shoulder flexion, shoulder abduction, elbow flexion and elbow extension. The training increased the force ($p<0.01$) and also the range of motion ($p<0.05$) significantly. The patients confirmed the clinical relevance of the results. The spasticity index - the relation between the muscle activity modulation on the normal and lesioned side - was shown to be a useful tool in quantifying individual muscle spasticity. It was concluded that cycling on an arm ergometer is a useful tool for rehabilitation.

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Ditroilo, Watsford et al. 2011 – Effects of fatigue on muscle

Ditroilo, Massimiliano; Watsford, Mark; Fernández-Peña, Eneko; D'Amen, Giancarlo; Lucertini, Francesco; Vito, Giuseppe de (2011):

Effects of fatigue on muscle stiffness and intermittent sprinting during cycling.

In: *Medicine and science in sports and exercise* 43 (5), S. 837–845. DOI: 10.1249/MSS.0b013e3182012261.

Abstract:

PURPOSE

It was recently demonstrated that musculoarticular (MA) stiffness is related to sprint cycling performance in nonfatigued conditions. This study examined whether relatively stiffer cyclists were more effective at sprinting under fatigued conditions, as occurs during endurance cycling competitions.

METHODS

MA stiffness of the quadriceps was assessed in 21 trained male cyclists (28.7 ± 9.5 yr, 1.74 ± 0.08 m, 67.5 ± 7.2 kg). Participants also performed a maximal 6-s sprint on a cycle ergometer to assess peak power output (POpeak), peak crank torque (CTpeak), and peak rate of crank torque development (RCTDpeak). A cycling fatigue protocol then required cyclists to pedal at 30%, 35%, and 40% of POpeak and sprint at the end of each stage. Surface EMG was recorded from vastus lateralis during each sprint and analyzed in the time domain as integrated EMG (iEMG) and in the frequency domain as instantaneous median frequency (MDF) adopting a continuous wavelet transform. Participants were then retested for MA stiffness.

RESULTS

MA stiffness (-12%) was significantly reduced after the cycling protocol. Further, POpeak, CTpeak, RCTDpeak, and iEMG were reduced by 20%, 15%, 13%, and 20%, respectively, after the fatigue protocol ($P<0.05$). When the cyclists were divided into relatively stiff (SG) and relatively compliant groups (CG), only SG exhibited significant decreases in MA stiffness, CTpeak, RCTDpeak ($P<0.05$), and instantaneous MDF ($R=0.705$).

CONCLUSIONS

Whereas neuromechanical parameters were generally reduced under conditions of fatigue, stiff and compliant cyclists were affected differently, with the sprint abilities of SG decreased to the level of CG. It seems important for endurance cyclists to incorporate training strategies to maintain MA stiffness during competition to offset declines in sprint performance.

Dorel, Hautier et al. 2005 – Torque and power-velocity relationships

Dorel, S.; Hautier, C. A.; Rambaud, O.; Rouffet, D.; van Praagh, E.; Lacour, J-R; Bourdin, M. (2005):

Torque and power-velocity relationships in cycling: relevance to track sprint performance in world-class cyclists.

In: *International journal of sports medicine* 26 (9), S. 739–746. DOI: 10.1055/s-2004-830493.

Abstract:

The aims of the present study were both to describe anthropometrics and cycling power-velocity characteristics in top-level track sprinters, and to test the hypothesis that these variables would represent interesting predictors of the 200 m track sprint cycling performance. Twelve elite cyclists volunteered to perform a torque-velocity test on a calibrated cycle ergometer, after the measurement of their lean leg volume (LLV) and frontal surface area (A(p)), in order to draw torque- and power-velocity relationships, and to evaluate the maximal power (P(max)), and both the optimal pedalling rate (f(opt)) and torque (T(opt)) at which P (max) is reached. The 200 m performances--i.e. velocity (V200) and pedalling rate (f 200)--were measured during international events (REC) and in the 2002 French Track Cycling Championships (NAT). P(max), f(opt), and T(opt) were respectively 1600 +/- 116 W, 129.8 +/- 4.7 rpm and 118.5 +/- 9.8 N . m. P(max) was strongly correlated with T(opt) ($p < 0.001$), which was correlated with LLV ($p < 0.01$). V200 was related to P(max) normalized by A(p) ($p < \text{or} = 0.05$) and also to f(opt) ($p < 0.01$) for REC and NAT. f 200 (155.2 +/- 3, REC; 149 +/- 4.3, NAT) were significantly higher than f(opt) ($p < 0.001$). These findings

demonstrated that, in this population of world-class track cyclists, the optimization of the ratio between P(max) and A(p) represents a key factor of 200 m performance. Concerning the major role also played by f(opt), it is assumed that, considering high values of f 200, sprinters with a high value of optimal pedalling rate (i.e. lower f200-f(opt) difference) could be theoretically in better conditions to maximize their power output during the race and hence performance.

Dorel, Guilhem et al. 2012 – Adjustment of muscle coordination

Dorel, Sylvain; Guilhem, Gael; Couturier, Antoine; Hug, François (2012):

Adjustment of muscle coordination during an all-out sprint cycling task.

In: *Medicine and science in sports and exercise* 44 (11), S. 2154–2164. DOI: 10.1249/MSS.0b013e3182625423.

Abstract:

PURPOSE

This study was designed to assess muscle coordination during a specific all-out sprint cycling task (Sprint). The aim was to estimate the EMG activity level of each muscle group by referring to the submaximal cycling condition (Sub150 W) and to test the hypothesis that a maximal activity is reached for all of the muscles during Sprint.

METHODS

Fifteen well-trained cyclists were tested during submaximal and sprint cycling exercises and a series of maximal voluntary contractions (MVCs) in isometric and isokinetic modes (MVC at the three lower limb joints). Crank torque and surface EMG signals for 11 lower limb muscles were continuously measured.

RESULTS

Results showed that Sprint induced a very large increase of EMG activity level for the hip flexors (multiplied by 7-9 from 150 W to Sprint) and the knee flexors and hip extensors (multiplied by 5-7), whereas plantar flexors and knee extensors demonstrated a lower increase (multiplied by 2-3). During Sprint, EMG activity level failed to reach a maximal value for hamstrings, tibialis anterior, tensor fasciae latae, and gluteus maximus (i.e., <70% to 80% of peak EMG activity during MVC, $P < 0.05$ to $P < 0.001$), and individual EMG patterns demonstrated a significant earlier onset and/or later offset for the majority of the muscles ($P < 0.01$ to $P < 0.001$).

CONCLUSIONS

Results clearly suggest a change in the relative contribution of the different muscles to the power production between Sub150 W and Sprint, and provide evidence that EMG activity level is not systematically maximal for all muscles involved in the all-out sprint cycling task. The longer period of activity induced during Sprint is likely to represent an interesting coordination strategy to enhance the work generated by all of the muscle groups.

Dounskaia, Nogueira et al. 2010 – Limitations on coupling of bimanual

Dounskaia, Natalia; Nogueira, Keith G.; Swinnen, Stephan P.; Drummond, Elizabeth (2010):

Limitations on coupling of bimanual movements caused by arm dominance: when the muscle homology principle fails.

In: *Journal of neurophysiology* 103 (4), S. 2027–2038. DOI: 10.1152/jn.00778.2009.

Abstract:

Studies of bimanual movements typically report interference between motions of the two arms and preference to perform mirror-symmetrical patterns. However, recent studies have demonstrated that the two arms differ in the ability to control interaction torque (INT). This predicts limitations in the capability to perform mirror-symmetrical movements. Here, two experiments were performed to test this prediction. The first experiment included bimanual symmetrical and asymmetrical circle

drawing at two frequency levels. Unimanual circle drawing was also recorded. The increases in cycling frequency caused differences between the two arms in movement trajectories in both bimanual modes, although the differences were more pronounced in the asymmetrical compared with the symmetrical mode. Based on torque analysis, the differences were attributed to the nondominant arm's decreased capability to control INT. The intraarm differences during the symmetrical pattern of bimanual movements were similar (although more pronounced) to those during unimanual movements. This finding was verified in the second experiment for symmetrical bimanual oval drawing. Four oval orientations were used to provide variations in INT. Similar to the first experiment, increases in cycling frequency caused spontaneous deviations from perfect bimanual symmetry associated with inefficient INT control in the nondominant arm. This finding supports the limitations in performing mirror-symmetrical bimanual movements due to differences in joint control between the arms. Based on our results and previous research, we argue that bimanual interference occurs during specification of characteristics of required motion, whereas lower-level generation of muscle forces is independent between the arms. A hierarchical model of bimanual control is proposed.

Driss, Lambertz et al. 2012 – Influence of musculo-tendinous stiffness

Driss, Tarak; Lambertz, Daniel; Rouis, Majdi; Vandewalle, Henry (2012):

Influence of musculo-tendinous stiffness of the plantar ankle flexor muscles upon maximal power output on a cycle ergometre.

In: *European journal of applied physiology* 112 (11), S. 3721–3728. DOI: 10.1007/s00421-012-2353-5.

Abstract:

The importance of maximal voluntary torque (T (MVC)), maximal rate of torque development (MRTD) and musculo-tendinous stiffness of the triceps surae for maximal power output on a cycle ergometre (Pmax) was studied in 21 healthy subjects by studying the relationships between maximal cycling power related to body mass (Pmax BM(-1)) with T (MVC), MRTD and different indices of musculo-tendinous stiffness of the ankle flexor. Pmax BM(-1) was calculated from the data of an all-out force-velocity test on a Monark cycle ergometre. T (MVC) and MRTD were measured on a specific ankle ergometre. Musculo-tendinous stiffness was estimated by means of quick releases at 20, 40, 60 and 80% T (MVC) on the same ankle ergometre. Pmax BM(-1) was significantly and positively correlated with MRTD related to body mass but the positive correlation between Pmax BM(-1) and T (MVC) did not reach the significance level (0.05). Pmax BM(-1) was significantly and positively correlated with the estimation of stiffness at 40% T (MVC) (S(0.4)), but not with stiffness at 20, 60 and 80% T (MVC). The results of the present study suggest that maximal power output during cycling is significantly correlated with the level of musculo-tendinous stiffness which corresponds to torque range around peak torque at optimal pedal rate. However, the low coefficient of determination (r2 = 0.203) between Pmax BM(-1) and S (0.4) BM(-1) suggested that Pmax BM(-1) largely depended on other factors than the musculo-tendinous stiffness of the only plantar flexors.

Driss, Vandewalle 2013 – The measurement of maximal anaerobic

Driss, Tarak; Vandewalle, Henry (2013):

The measurement of maximal (anaerobic) power output on a cycle ergometer: a critical review.

In: *BioMed research international* 2013, S. 589361. DOI: 10.1155/2013/589361.

Abstract:

The interests and limits of the different methods and protocols of maximal (anaerobic) power (Pmax) assessment are reviewed: single all-out tests versus force-velocity tests, isokinetic ergometers versus friction-loaded ergometers, measure of Pmax during the acceleration phase or at peak velocity. The effects of training, athletic practice, diet and pharmacological substances upon the production of maximal mechanical power are not discussed in this review mainly focused on the technical (ergometer, crank length, toe clips), methodological (protocols) and biological factors (muscle volume, muscle fiber type, age, gender, growth,

temperature, chronobiology and fatigue) limiting Pmax in cycling. Although the validity of the Wingate test is questionable, a large part of the review is dedicated to this test which is currently the all-out cycling test the most often used. The biomechanical characteristics specific of maximal and high speed cycling, the bioenergetics of the all-out cycling exercises and the influence of biochemical factors (acidosis and alkalosis, phosphate ions…) are recalled at the beginning of the paper. The basic knowledge concerning the consequences of the force-velocity relationship upon power output, the biomechanics of sub-maximal cycling exercises and the study on the force-velocity relationship in cycling by Dickinson in 1928 are presented in Appendices.

Duc, Betik et al. 2005 – EMG activity does not change

Duc, S.; Betik, A-C; Grappe, F. (2005):

EMG activity does not change during a time trial in competitive cyclists.

In: *International journal of sports medicine* 26 (2), S. 145–150. DOI: 10.1055/s-2004-817922.

Abstract:

The purpose of the present study was to measure the electromyographic (EMG) activity of four lower limb muscles and the propulsive torque during a cycling time-trial (TT). Nine competitive cyclists (V.O (2max): 73.8 +/- 5.3 ml . min (-1) . kg (-1)) performed two tests separated over a one-week period on a friction-load cycle ergometer equipped with a SRM crankset scientific system: 1) a continuous incremental test for the determination of the peak power output (PPO); and 2) a 30-min TT test at a self-selected work intensity. The EMG activity of the vastus medialis (VM), the rectus femoris (RF), the biceps femoris (BF), and the gastrocnemius medialis (GAS), and the propulsive torque were recorded every 5 min for 10 s. There was no time effect on the power output, the pedalling cadence, and the mean propulsive torque. The EMG activity of the VM and the RF muscles was unchanged during the TT ($p > 0.05$). The EMG activity of the two knee flexor muscles (BF and GAS) tended to increase with time but it was not significant ($p > 0.05$). The EMG/torque of the VM and the RF muscles tended to decrease with time but it was not significant ($p > 0.05$). The lack of increase in the EMG activity of the four investigated muscles seems to indicate that the subjects performed the TT test at a muscular work steady-state.

Edwards, Jobson et al. 2007 – The effect of crank inertial

Edwards, Lindsay M.; Jobson, Simon A.; George, Simon R.; Day, Stephen H.; Nevill, Alan M. (2007):

The effect of crank inertial load on the physiological and biomechanical responses of trained cyclists.

In: *Journal of sports sciences* 25 (11), S. 1195–1201. DOI: 10.1080/02640410601034724.

Abstract:

The existing literature suggests that crank inertial load has little effect on the responses of untrained cyclists. However, it would be useful to be aware of any possible effect in the trained population, particularly considering the many laboratory-based studies that are conducted using relatively low-inertia ergometers. Ten competitive cyclists (mean VO(2max) = 62.7 ml x kg(-1) x min(-1), s = 6.1) attended the human performance laboratories at the University of Wolverhampton. Each cyclist completed two 7-min trials, at two separate inertial loads, in a counterbalanced order. The inertial loads used were 94.2 kg x m(2) (high-inertia trial) and 2.4 kg x m(2) (low-inertia trial). Several physiological and biomechanical measures were undertaken. There were no differences between inertial loads for mean peak torque, mean minimum torque, oxygen uptake, blood lactate concentration or perceived exertion. Several measures showed intra-individual variability with blood lactate concentration and mean minimum torque, demonstrating coefficients of variation > 10%. However, the results presented here are mostly consistent with previous work in suggesting that crank inertial load has little direct effect on either physiology or propulsion biomechanics during steady-state cycling, at least when cadence is controlled.

SRM in Science

Edwards, Jobson et al. 2009 – Whole-body efficiency is negatively correlated

Edwards, Lindsay M.; Jobson, Simon A.; George, Simon R.; Day, Stephen H.; Nevill, Alan M. (2009):

Whole-body efficiency is negatively correlated with minimum torque per duty cycle in trained cyclists.

In: *Journal of sports sciences* 27 (4), S. 319–325. DOI: 10.1080/02640410802526916.

Abstract:

The purpose of this study was to determine whether there is a causal relationship between pedalling "circularity" and cycling efficiency. Eleven trained cyclists were studied during submaximal cycling. Variables recorded included gross and delta efficiency and the ratio of minimum to peak torque during a duty cycle. Participants also completed a questionnaire about their training history. The most notable results were as follows: gross efficiency ($r = -0.72$, $P < 0.05$ at 250 W) was inversely correlated with the ratio of minimum to peak torque, particularly at higher work rates. There was a highly significant inverse correlation between delta efficiency and average minimum torque at 200 W ($r = -0.76$, $P < 0.01$). Cycling experience was positively correlated with delta efficiency and gross efficiency, although experience and the ratio of minimum to peak torque were not related. These results show that variations in pedalling technique may account for a large proportion of the variation in efficiency in trained cyclists. However, it is also possible that some underlying physiological factor influences both. Finally, it appears that experience positively influences efficiency, although the mechanism by which this occurs remains unclear.

Estigoni, Fornusek et al. 2011 – Evoked EMG and muscle fatigue

Estigoni, Eduardo H.; Fornusek, Ché; Smith, Richard M.; Davis, Glen M. (2011):

Evoked EMG and muscle fatigue during isokinetic FES-cycling in individuals with SCI.

In: *Neuromodulation : journal of the International Neuromodulation Society* 14 (4), S. 349-55; discussion 355. DOI: 10.1111/j.1525-1403.2011.00354.x.

Abstract:

PURPOSE

This study investigated whether muscle fatigue during functional electrical stimulation (FES)-induced cycling was associated with changes occurring in evoked electromyographic signals (eEMG, M-waves) in individuals with spinal cord injury. We also explored the effects of recovery intervals between exercise sessions on the relationship between eEMG and muscle torque.

METHODS

Eight individuals with spinal cord injury performed three FES-cycling sessions of 15-min duration, with 5 min of recovery between them. The quadriceps muscles were electrically stimulated as the prime agonist to produce cycling. Pedal torques and surface eEMG signals were synchronously processed and recorded for offline analysis.

RESULTS

Large Torque decreases (20-44%) were observed in the first 5 min of cycling during the three exercise bouts, while changes of similar magnitude did not occur on any of the M-wave time-series (less than 19%). Between 5 and 15 min of cycling, muscle fatigue lowered the plateau baselines of Torque (ranging from 41% to 62%), M-wave peak-to-peak amplitude (PtpA) and Area (ranging from 60% to 98%) time-series, yet the magnitudes of these reductions were not consistent between them.

CONCLUSION

We concluded that muscle fatigue during FES-cycling was not associated with, nor could be predicted by, eEMG signals. Nonetheless, the consistency between M-waves and Torque time-curves in their direction of change clearly warrants further investigation.

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Ettema, Lorås et al. 2009 – The effects of cycling cadence

Ettema, Gertjan; Lorås, Håvard; Leirdal, Stig (2009):

The effects of cycling cadence on the phases of joint power, crank power, force and force effectiveness.

In: *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 19 (2), S. e94-101. DOI: 10.1016/j.jelekin.2007.11.009.

Abstract:

We examined the influence of cadence in cycling technique by quantifying phase relationships for a number of important variables at the crank and lower extremity joints. Any difference in the effect of cadence on force, effectiveness, and power phases would indicate an essential change in coordination pattern. Cycle kinetics was recorded for 10 male competitive cyclists at five cadences (60-100 rpm) at submaximal load (260 W). Joint powers were calculated using inverse dynamics methods. All data were expressed as a function of crank position. The phase of the crank mechanical profiles (total force, crank and joint power, and effectiveness) was calculated using four methods: crank angle of maximum (MA) and minimum (MI), fitting a sine wave (SI) and by cross-correlation (XC). These methods, apart from the MA method, showed the same relative phase. The variables, however, showed different phases being expressed as time lag: force effectiveness: 0.131 (+/-0.034)s; total force: 0.149 (+/-0.021)s; power: 0.098 (+/-0.027)s. The phases in joint powers hip 0.071 (+/-0.008), knee 0.082 (+/-0.009), and hip 0.077 (+/-0.012) were only well described by XC, and were somewhat lower than the crank power phase. These differences indicate the potential effect of inertia of the lower limb in phase shifts from joints to crank. Furthermore, the differences between the various crank variables indicate a change of technique with cadence.

Farina, Spazzin et al. 2012 – An in vitro comparison

Farina, Ana Paula; Spazzin, Aloísio Oro; Pantoja, Juliana Maria Costa Nuñez; Consani, Rafael Leonardo Xediek; Mesquita, Marcelo Ferraz (2012):

An in vitro comparison of joint stability of implant-supported fixed prosthetic suprastructures retained with different prosthetic screws and levels of fit under masticatory simulation conditions.

In: *The International journal of oral & maxillofacial implants* 27 (4), S. 833–838.

Abstract:

PURPOSE

This study sought to determine an optimal postinsertion retorque protocol to maintain implantsuprastructure joint stability after being subjected to a 1-year in vitro masticatory simulation.

MATERIALS AND METHODS

Ten mandibular implant-supported dentures were manufactured and 20 epoxy resin models were obtained for two fit levels: passive fit and misfit. Eight groups (n = 20) were created on the basis of vertical fit (passive or misfit) and prosthetic screw material (titanium or gold). The single-screw test was performed and the vertical misfit was quantified using an optical microscope. Loosening torque was measured after simulations of two types of clinical use: (1) 6 months of use, torque loosening, retightening, another 6 months of use, and loosening torque; and (2) 1 year of use followed by loosening torque. Data were analyzed by means of two-way analysis of variance and the Tukey test.

RESULTS

The factors of cycling time and condition use (fit level and screw type), as well the interaction between these factors, significantly influenced the loosening torque ($P < .05$). After 6 months and another 6 months of clinical use simulation, titanium screws showed higher loosening torque values than did gold screws for the same fit level ($P < .05$). After 1 year of clinical use

simulation, titanium and gold screws in passively fit dentures showed higher loosening torque values than they did in misfit dentures (P < .05). The titanium screws presented a decrease in the loosening torque after 1 year in misfit dentures.

CONCLUSIONS

The stability of titanium screws was higher than that of gold screws after 6 months of simulation because of their lower plastic deformation. When the cycling time was analyzed, titanium screws were less stable after 1 year of simulation because of loss of torque in the presence of misfit.

Faupin, Gorce et al. 2011 – Effects of type and mode

Faupin, Arnaud; Gorce, Philippe; Meyer, Christophe (2011):

Effects of type and mode of propulsion on hand-cycling biomechanics in nondisabled subjects.

In: *Journal of rehabilitation research and development* 48 (9), S. 1049–1060.

Abstract:

This study investigated the range of motion (ROM) (in degrees) of the upper limb and trunk, forces (Newtons), two-dimensional fraction effective force (FEF(2D)) (in percent), and torque (Newton meters) during hand cycling. Seven nondisabled participants performed a 1 min exercise test at 70 rpm on a hand cycle (HC) fixed to an ergometer in synchronous (SC) mode versus asynchronous (AC) mode and in arm-power (AP) versus arm-trunk-power (ATP) type of propulsion. Higher ($p < 0.001$) flexion/extension of the trunk was found during ATP versus AP type and higher ($p < 0.001$) lateral flexion and rotation of the trunk in AC versus SC mode. The trunk ROM should explain the different force generation patterns observed in this investigation between AC and SC modes and AP and ATP types. However, kinetic results do not allow the most effective type or mode of propulsion (FEF(2D): from 72.9% to 89.3%) to be established. We conclude that trunk movement is an important parameter to consider in ergonomically optimizing hand cycling. Nevertheless, future studies in experienced HC users, especially with limited trunk function, should be performed.

Fontes, Okano et al. 2013 – Brain activity and perceived exertion

Fontes, Eduardo B.; Okano, Alexandre H.; Guio, François de; Schabort, Elske J.; Min, Li Li; Basset, Fabien A. et al. (2013):

Brain activity and perceived exertion during cycling exercise: an fMRI study.

In: *British journal of sports medicine. DOI:* 10.1136/bjsports-2012-091924.

Abstract:

BACKGROUND/AIM: Currently, the equipment and techniques available to assess brain function during dynamic exercise are limited, which has restricted our knowledge of how the brain regulates exercise. This study assessed the brain areas activated during cycling by making use of a novel cycle ergometer, constructed to measure functional MRI (fMRI) brain images during dynamic exercise. Furthermore, we compared brain activation at different levels of ratings of perceived exertion (RPE) generated during the exercise. METHODS: Seven healthy adults performed cycling exercise in a novel MRI compatible cycle ergometer while undergoing brain fMRI. Participants completed a cycling block protocol comprising six trials of 2 min cycling with 16-s intervals between trials. Participants reported their RPE every minute through an audio link. The MRI cycling ergometer transferred the torque generated on the ergometer through a cardan system to a cycling ergometer positioned outside the MRI room. For data analysis, the effects of cycling as opposed to rest periods were examined after motion correction. RESULTS: The multiparticipant analysis revealed in particular the activation of the cerebellar vermis and precentral and postcentral gyrus when periods of cycling versus rest were compared. Single participant analysis in four participants revealed that activation of the posterior cingulate gyrus and precuneus occurred in cycling blocks perceived as 'hard' compared with exercise blocks that were less demanding. CONCLUSIONS: The present study offers a new approach to assess brain activation during dynamic cycling exercise, and suggests that specific brain areas could be involved in the sensations generating the rating of perceived exertion.

Fornusek, Davis 2008 – Cardiovascular and metabolic responses

Fornusek, Ché; Davis, Glen M. (2008):

Cardiovascular and metabolic responses during functional electric stimulation cycling at different cadences.

In: *Archives of physical medicine and rehabilitation* 89 (4), S. 719–725. DOI: 10.1016/j.apmr.2007.09.035.

Abstract:

OBJECTIVE

To determine the influence of pedaling cadence on cardiorespiratory responses and muscle oxygenation during functional electric stimulation (FES) leg cycling.

DESIGN

Repeated measures.

SETTING

Laboratory.

PARTICIPANTS

Nine subjects with T4 through T10 spinal cord injury (SCI) (American Spinal Injury Association grade A).

INTERVENTIONS

FES cycling was performed at pedaling cadences of 15, 30, and 50 revolutions per minute (rpm).

MAIN OUTCOME MEASURES

At each cadence, heart rate, oxygen uptake, and cardiac output were recorded during 35 minutes of cycling. Near infrared spectroscopy was used to quantify quadriceps muscle oxygenation.

RESULTS

All pedaling cadences induced similar elevations in cardiorespiratory metabolism, compared with resting values. Higher average power output was produced at 30rpm (8.2+/-0.7W, P<.05) and 50rpm (7.9+/-0.5W, P<.05) compared with 15rpm (6.3+/-0.6W). Gross mechanical efficiency was significantly higher (P<.05) at 30 and 50rpm than at 15rpm. Quadriceps muscle oxygenation did not differ with pedaling cadences.

CONCLUSIONS

Cardiorespiratory responses and muscle metabolism adjustments during FES leg cycling were independent of pedal cadence. FES cycling at a cadence of 50rpm may not confer any advantages over 30 or 15rpm for cardiovascular fitness promotion in persons with SCI.

Fornusek, Davis et al. 2013 – Pilot study of the effect

Fornusek, Ché; Davis, Glen Macartney; Russold, Michael Friedrich (2013):

Pilot study of the effect of low-cadence functional electrical stimulation cycling after spinal cord injury on thigh girth and strength.

In: *Archives of physical medicine and rehabilitation* 94 (5), S. 990–993. DOI: 10.1016/j.apmr.2012.10.010.

Abstract:

OBJECTIVE

To investigate the long-term effects of functional electrical stimulation (FES)-evoked cycle training cadence on leg muscle hypertrophy and electrically evoked strength.

DESIGN

Open intervention study.

SETTING

Laboratory setting.

PARTICIPANTS

Untrained individuals with chronic spinal cord injury (N=8).

INTERVENTIONS

Six weeks (3d/wk) of training on an isokinetic FES cycle ergometer. For each subject, 1 leg was randomly allocated to cycling at 10 revolutions per minute (rpm) (LOW) for 30min/d, and the other cycling at 50rpm (HIGH) for 30min/d.

MAIN OUTCOME MEASURES

Pre- and posttraining measurements of lower limb circumference were performed at the distal and middle position of each thigh. Electrically evoked quadriceps muscle torque during an isometric contraction was also assessed.

RESULTS

Six weeks of FES cycle training significantly increased thigh girth in both LOW and HIGH groups. At midthigh, girth increases induced by LOW (6.6%±1.2%) were significantly greater than those by HIGH (3.6%±0.8%). LOW also produced greater gains in electrically evoked isometric torque than HIGH after training.

CONCLUSIONS

These results suggest that lower pedaling cadences evoke greater muscle hypertrophy and electrically stimulated muscle strength compared with higher cadences.

Fornusek, Sinclair et al. 2007 – The force-velocity relationship of paralyzed

Fornusek, Ché; Sinclair, Peter J.; Davis, Glen M. (2007):

The force-velocity relationship of paralyzed quadriceps muscles during functional electrical stimulation cycling.

In: *Neuromodulation : journal of the International Neuromodulation Society* 10 (1), S. 68–75. DOI: 10.1111/j.1525-1403.2007.00089.x.

Abstract:

Objectives. To investigate the nature of the force-velocity relationship on muscle forces and power outputs during functional electrical stimulation (FES)-evoked cycling at different pedaling cadences. Materials and Methods. Ten patients with T4-T9 spinal cord injuries (ASIA A) performed FES-evoked cycling at 50 rev/min using a motorized isokinetic ergometer for 20 min, after which quadriceps crank torque and power were measured at 10, 30, and 50 rev/min. Results. Pedal cadence affected both the shape and the magnitudes of the quadriceps torque and power curves. Significantly greater average torque (T) and peak crank torques (PTi) were elicited at lower pedal cadences ($T(10) > T(50)$, $p < 0.001$; $PTi(10) > PTi(50)$, $p = 0.007$). Instantaneous peak power (PPi) and average power output (PO) increased significantly with pedal cadence, such that $PPi(50)$ and $PPi(30) > PPi(10)$ ($p < 0.001$) and $PO(50)$ or $PO(30) > PO(10)$ ($p < 0.001$). At the higher cadences, peak torque and peak power were developed at significantly later angles ($p < 0.001$). Conclusions. The force-velocity relationship of muscle has a significant effect upon the muscle forces produced during FES-evoked cycling. However, muscle force rise times and fatigue within FES-evoked contractions, especially at a low cadence, should be considered when making comparisons between different FES-cycling cadences.

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SRM in Science

Gardner, Martin et al. 2007 – Maximal torque- and power-pedaling rate

Gardner, A. Scott; Martin, James C.; Martin, David T.; Barras, Martin; Jenkins, David G. (2007):

Maximal torque- and power-pedaling rate relationships for elite sprint cyclists in laboratory and field tests.

In: *European journal of applied physiology* 101 (3), S. 287–292. DOI: 10.1007/s00421-007-0498-4.

Abstract:

Performance models provide an opportunity to examine cycling in a broad parameter space. Variables used to drive such models have traditionally been measured in the laboratory. The assumption, however, that maximal laboratory power is similar to field power has received limited attention. The purpose of the study was to compare the maximal torque- and power-pedaling rate relationships during "all-out" sprints performed on laboratory ergometers and on moving bicycles with elite cyclists. Over a 3-day period, seven male (mean +/- SD; 180.0 +/- 3.0 cm; 86.2 +/- 6.1 kg) elite track cyclists completed two maximal 6 s cycle ergometer trials and two 65 m sprints on a moving bicycle; calibrated SRM powermeters were used and data were analyzed per revolution to establish torque- and power-pedaling rate relationships, maximum power, maximum torque and maximum pedaling rate. The inertial load of our laboratory test was (37.16 +/- 0.37 kg m(2)), approximately half as large as the field trials (69.7 +/- 3.8 kg m(2)). There were no statistically significant differences between laboratory and field maximum power (1791 +/- 169; 1792 +/- 156 W; P = 0.863), optimal pedaling rate (128 +/- 7; 129 +/- 9 rpm; P = 0.863), torque-pedaling rate linear regression slope (-1.040 +/- 0.09; -1.035 +/- 0.10; P = 0.891) and maximum torque (266 +/- 20; 266 +/- 13 Nm; P = 0.840), respectively. Similar torque- and power-pedaling rate relationships were demonstrated in laboratory and field settings. The findings suggest that maximal laboratory data may provide an accurate means of modeling cycling performance.

Gardner, Nork et al. 2009 – Stiffness modulation of locking plate

Gardner, Michael J.; Nork, Sean E.; Huber, Phillipe; Krieg, James C. (2009):

Stiffness modulation of locking plate constructs using near cortical slotted holes: a preliminary study.

In: *Journal of orthopaedic trauma* 23 (4), S. 281–287. DOI: 10.1097/BOT.0b013e31819df775.

Abstract:

OBJECTIVES

Axial stiffness is a critical mechanical parameter in fracture plating. Standard locked plates allow minimal opportunities for stiffness alteration, and current methods are arbitrary and may lead to stiffness mismatch between the implant and bone. Milling the near cortex into a slot allows for an increase in translation of the screw shaft at the near cortex. The purpose of this proof of concept study was to determine the effects of slots on stiffness and their ability to maintain fixation of locking plates under cyclic loading.

METHODS

Using segments of fourth-generation synthetic diaphyseal bone, a simulated fracture with a gap was created and locked plates were applied with 4 bicortical locked screws in each fragment. On one fragment, the 4 near cortex holes were sequentially milled to 5 x 6-mm slots. Axial and torsional stiffnesses were determined for constructs with 0 through 4 slots. Specimens with 4 slots then underwent axial cyclic loading to determine the change in stiffness and loss of fixation. Extraction torque was measured for all screws to assess for screw loosening with cycling.

RESULTS

In constructs with 4 slots, axial stiffness decreased by 73% (P < 0.05) relative to the 0-slot constructs. Torsional stiffness of the 3- and 4-slot specimens decreased by 20% (SD, 13%; P < 0.05) and 17% (SD, 13%; P < 0.05), respectively, compared with the 0-slot specimens. With cyclic loading, no failures occurred in any specimen. No change in stiffness had occurred by the end of cycling (106% of initial stiffness; SD, 4%; P = 0.96). No screw loosening occurred during cyclic loading.

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CONCLUSIONS

Purposeful stiffness modulation in fracture fixation is critical to facilitate uneventful fracture healing. Converting near cortical holes to slots allowed selective axial stiffness adjustment without sacrificing fixation stability under cyclic loading. With further refinement, this simple modification of standard implant application may allow the surgeon to decrease the modulus mismatch between plating constructs and bone to decrease the risk of fixation failure.

Girard, Racinais 2014 – Combining heat stress and moderate

Girard, Olivier; Racinais, Sébastien (2014):

Combining heat stress and moderate hypoxia reduces cycling time to exhaustion without modifying neuromuscular fatigue characteristics.

In: *European journal of applied physiology* 114 (7), S. 1521–1532. DOI: 10.1007/s00421-014-2883-0.

Abstract:

PURPOSE

This study investigated the isolated and combined effects of heat [temperate (22 °C/30 % rH) vs. hot (35 °C/40 % rH)] and hypoxia [sea level (FiO2 0.21) vs. moderate altitude (FiO2 0.15)] on exercise capacity and neuromuscular fatigue characteristics.

METHODS

Eleven physically active subjects cycled to exhaustion at constant workload (66 % of the power output associated with their maximal oxygen uptake in temperate conditions) in four different environmental conditions [temperate/sea level (control), hot/sea level (hot), temperate/moderate altitude (hypoxia) and hot/moderate altitude (hot + hypoxia)]. Torque and electromyography (EMG) responses following electrical stimulation of the tibial nerve (plantar-flexion; soleus) were recorded before and 5 min after exercise.

RESULTS

Time to exhaustion was reduced ($P < 0.05$) in hot (-35 ± 15 %) or hypoxia (-36 ± 14 %) compared to control (61 ± 28 min), while hot + hypoxia (-51 ± 20 %) further compromised exercise capacity ($P < 0.05$). However, the effect of temperature or altitude on end-exercise core temperature ($P = 0.089$ and $P = 0.070$, respectively) and rating of perceived exertion ($P > 0.05$) did not reach significance. Maximal voluntary contraction torque, voluntary activation (twitch interpolation) and peak twitch torque decreased from pre- to post-exercise (-9 ± 1, -4 ± 1 and -6 ± 1 % all trials compounded, respectively; $P < 0.05$), with no effect of the temperature or altitude. M-wave amplitude and root mean square activity were reduced ($P < 0.05$) in hot compared to temperate conditions, while normalized maximal EMG activity did not change. Altitude had no effect on any measured parameters.

CONCLUSION

Moderate hypoxia in combination with heat stress reduces cycling time to exhaustion without modifying neuromuscular fatigue characteristics. Impaired oxygen delivery or increased cardiovascular strain, increasing relative exercise intensity, may have also contributed to earlier exercise cessation.

Gordon, Franklin et al. 2007 – Further mechanical considerations between polar

Gordon, R. S.; Franklin, K. L.; Davies, B.; Baker, J. S. (2007):

Further mechanical considerations between polar and SRM mobile ergometer systems during laboratory-based high-intensity, intermittent cycling activity.

In: *Research in sports medicine (Print)* 15 (4), S. 241–247. DOI: 10.1080/15438620701525540.

Abstract:

The purpose of this article is to outline mechanical issues related to the use of the Polar S710 heart monitor with Power Unit when compared with the SRM Powercrank system. There are issues outlined in this article that refer to the suitability of the Polar S710 for the quantification of performance during downhill cycling that relate to chain vibration, chain tension, and time interval sampling rates.

Gregersen, Hull et al. 2006 – How changing the inversion/eversion foot

Gregersen, Colin S.; Hull, M. L.; Hakansson, Nils A. (2006):

How changing the inversion/eversion foot angle affects the nondriving intersegmental knee moments and the relative activation of the vastii muscles in cycling.

In: *Journal of biomechanical engineering* 128 (3), S. 391–398. DOI: 10.1115/1.2193543.

Abstract:

Nondriving intersegmental knee moment components (i.e., varus/valgus and internal/external axial moments) are thought to be primarily responsible for the etiology of overuse knee injuries such as patellofermoral pain syndrome in cycling because of their relationship to muscular imbalances. However the relationship between these moments and muscle activity has not been studied. Thus the four primary objectives of this study were to test whether manipulating the inversion/eversion foot angle alters the varus/valgus knee moment (Objective 1) and axial knee moment (Objective 2) and to determine whether activation patterns of the vastus medialis oblique (VMO), vastus lateralis (VL), and tensor fascia latae (TFL) were affected by changes in the varus/valgus (Objective 3) and axial knee moments (Objective 4). To fulfill these objectives, pedal loads and lower limb kinematic data were collected from 15 subjects who pedaled with five randomly assigned inversion/eversion angles: 10 deg and 5 deg everted and inverted and 0 deg (neutral). A previously described mathematical model was used to compute the nondriving intersegmental knee moments throughout the crank cycle. The excitations of the VMO, VL, and TFL muscles were measured with surface electromyography and the muscle activations were computed. On average, the 10-deg everted position decreased the peak varus moment by 55% and decreased the peak internal axial moment by 53% during the power stroke (crank cycle region where the knee moment is extensor). A correlation analysis revealed that the VMO/VL activation ratio increased significantly and the TFL activation decreased significantly as the varus moment decreased. For both the VMO/VL activation ratio and the TFL activation, a path analysis indicated that the varus/valgus moment was highly correlated to the axial moment but that the correlation between muscle activation and the varus moment was due primarily to the varus/valgus knee moment rather than the axial knee moment. The conclusion from these results is that everting the foot may be beneficial towards either preventing or ameliorating patellofemoral pain syndrome in cycling.

Hansen, Rønnestad et al. 2012 – Cyclists' improvement of pedaling efficacy

Hansen, Ernst A.; Rønnestad, Bent R.; Vegge, Geir; Raastad, Truls (2012):

Cyclists' improvement of pedaling efficacy and performance after heavy strength training.

In: *International journal of sports physiology and performance* 7 (4), S. 313–321.

Abstract:

The authors tested whether heavy strength training, including hip-flexion exercise, would reduce the extent of the phase in the crank revolution where negative or retarding crank torque occurs. Negative torque normally occurs in the upstroke phase when the leg is lifted by flexing the hip. Eighteen well-trained cyclists either performed 12 wk of heavy strength training in addition to their usual endurance training (E+S; n = 10) or merely continued their usual endurance training during the intervention period (E; n = 8). The strength training consisted of 4 lower body exercises (3 × 4-10 repetition maximum) performed twice a week. E+S enhanced cycling performance by 7%, which was more than in E (P = .02). Performance was determined as average power

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output in a 5-min all-out trial performed subsequent to 185 min of submaximal cycling. The performance enhancement, which has been reported previously, was here shown to be accompanied by improved pedaling efficacy during the all-out cycling. Thus, E+S shortened the phase where negative crank torque occurs by ~16°, corresponding to ~14%, which was more than in E (P = .002). In conclusion, adding heavy strength training to usual endurance training in well-trained cyclists improves pedaling efficacy during 5-min all-out cycling performed after 185 min of cycling.

Hansen, Jensen et al. 2009 – Effect of chain wheel shape

Hansen, Ernst Albin; Jensen, Kurt; Hallén, Jostein; Rasmussen, John; Pedersen, Preben K. (2009):

Effect of chain wheel shape on crank torque, freely chosen pedal rate, and physiological responses during submaximal cycling.

In: *Journal of physiological anthropology* 28 (6), S. 261–267.

Abstract:

The development of noncircular chain wheels for the enhancement of cycling performance has been in progress for a long time and continues apace. In this study we tested whether submaximal cycling using a non-circular (Biopace) versus a circular chain wheel resulted in lower peak crank torque at preset pedal rates as well as resulting in lower pedal rate and metabolic response at freely chosen pedal rate. Ten trained cyclists (mean+/-SD: 27+/-3 years of age, 182+/-4 cm tall, 77.5+/-7.0 kg of body mass, and peak oxygen uptake of 61.7+/-4.4 ml kg(-1) min(-1)) cycled with a Biopace and a circular chain wheel at 180 W at 65 and 90 rpm for recording of crank torque profiles, and at their freely chosen pedal rate for recording of pedal rate and metabolic response, including oxygen uptake and blood lactate concentration. Crank torque profiles were similar between the two chain wheels during cycling at preset pedal rates. During cycling at the freely chosen pedal rate (being 93+/-6 and 93+/-4 rpm for the Biopace and circular chain wheel, respectively), blood lactate concentration was significantly different between the two chain wheels, being on average 0.2 mmol l(-1) lower with the Biopace chain wheel. A musculoskeletal simulation model supported the idea that a contributing factor to the observed difference in blood lactate concentration may be slightly reduced muscle activity around the phase where peak crank torque occurs during cycling with the Biopace chain wheel. In that particular phase of the crank revolution, the observed slightly lower muscle activity may result from larger transfer of energy from the legs to the crank.

Hasson, Caldwell et al. 2008 – Changes in muscle and joint

Hasson, Christopher J.; Caldwell, Graham E.; van Emmerik, Richard E A (2008):

Changes in muscle and joint coordination in learning to direct forces.

In: *Human movement science* 27 (4), S. 590–609. DOI: 10.1016/j.humov.2008.02.015.

Abstract:

While it has been suggested that bi-articular muscles have a specialized role in directing external reaction forces, it is unclear how humans learn to coordinate mono- and bi-articular muscles to perform force-directing tasks. Participants were asked to direct pedal forces in a specified target direction during one-legged cycling. We expected that with practice, performance improvement would be associated with specific changes in joint torque patterns and mono- and bi-articular muscular coordination. Nine male participants practiced pedaling an ergometer with only their left leg, and were instructed to always direct their applied pedal force perpendicular to the crank arm (target direction) and to maintain a constant pedaling speed. After a single practice session, the mean error between the applied and target pedal force directions decreased significantly. This improved performance was accompanied by a significant decrease in the amount of ankle angular motion and a smaller increase in knee and hip angular motion. This coincided with a re-organization of lower extremity joint torques, with a decrease in ankle plantarflexor torque and an increase in knee and hip flexor torques. Changes were seen in both mono- and bi-articular muscle activity patterns. The mono-articular muscles exhibited greater alterations, and appeared to contribute to both mechanical work and force-directing. With practice, a loosening of the coupling between bi-articular thigh muscle activation and joint torque co-regulation was observed. The results demonstrated that participants were able to learn a complex and dynamic force-directing

task by changing the direction of their applied pedal forces through re-organization of joint torque patterns and mono- and bi-articular muscle coordination.

Hotta, Ishida et al. 2011 – The effect of intense interval

Hotta, Norio; Ishida, Koji; Sato, Kohei; Koike, Teruhiko; Katayama, Keisho; Akima, Hiroshi (2011):

The effect of intense interval cycle-training on unloading-induced dysfunction and atrophy in the human calf muscle.

In: *Journal of physiological anthropology* 30 (1), S. 29–35.

Abstract:

We investigated whether intense interval training on a cycle ergometer would prevent loss of muscle strength and atrophy in the human calf during unilateral lower limb suspension (ULLS). The present study involved 11 healthy men. We defined unloading leg and contralateral leg as ULLS-leg and CONT-leg, respectively. The subjects were divided into 2 groups: one with single-leg cycling training (Tr-UL, n=6); the other as a control (UL, n=5). The Tr-UL group performed an intense 25-min interval cycling training up to 80% of peak oxygen uptake on alternate days during 20-d ULLS. It was found that: 1) in maximal voluntary contraction (MVC) and the cross-sectional area of the planter flexor, there was a significant time- (pre-ULLS and post-ULLS) by-leg (ULLS-leg and CONT-leg) interaction; 2) in voluntary activation during MVC evaluated by the twitch interpolation technique, no significant time-by-leg interaction was detected but the trend of change from before to after ULLS tended to be different between ULLS-leg and CONT-leg; and 3) regarding ULLS-leg, the change in any parameters was not significantly different between the Tr-UL and UL groups. These results suggest that unloading induces dysfunction and atrophy in the human calf and that high-intensity interval training on a cycle ergometer cannot significantly prevent unloading-induced deconditioning in the human calf.

Hue, Racinais et al. 2008 – Does an eccentric chainring improve

Hue, Olivier; Racinais, Sébastien; Chamari, Karim; Damiani, Michael; Hertogh, Claude; Blonc, Stephen (2008):

Does an eccentric chainring improve conventional parameters of neuromuscular power?

In: *Journal of science and medicine in sport / Sports Medicine Australia* 11 (3), S. 264–270. DOI: 10.1016/j.jsams.2007.06.004.

Abstract:

This study compared the conventional parameters of anaerobic cycling power in physically active non-cyclists using the Pro-Race system and a traditional chainring. The force-velocity test was chosen for this purpose because it is the shortest validated cycling laboratory test in which each parameter of maximal anaerobic power can be estimated. The power output (W(max)) and the force at which W(max) is produced (F(opt)) were significantly improved with the eccentric chainring (1100+/-227W versus 1006+/-197W and 1.39+/-0.15N/kg body mass versus 1.13+/-0.16N/kg body mass with the eccentric and round designs, respectively; P<0.006 and P<0.0004, respectively). The power gained (delta power) was significantly correlated with the eccentric chainring F(opt) (r=0.649; P<0.05), the mid-thigh circumference (r=0.685; P<0.05), the estimated lean thigh volume (r=0.765; P<0.01) and the estimated lean lower limb volume (r=0.665; P<0.05). We concluded that the eccentric chainring significantly improved the estimated anaerobic power output during a force-velocity test by increasing the force component, F(opt). Cautious interpretation of our results suggests that the subjects with physical attributes that contribute to developing high forces may have a significant advantage in performing with the eccentric chainring.

SRM in Science

Hughes, Chapman et al. 2013 – Indirect measures of substrate utilisation

Hughes, Jonathan; Chapman, Phillip; Brown, Stephen; Johnson, Nathan; Stannard, Stephen (2013):

Indirect measures of substrate utilisation following exercise-induced muscle damage.

In: *European journal of sport science* 13 (5), S. 509–517. DOI: 10.1080/17461391.2012.755570.

Abstract:

This study investigated whether exercise-induced muscle damage (EIMD) resulted in changes to whole-body substrate utilisation during exercise performed during the subsequent 48 hours. Eight males (31 ± 6 years) performed 30 minutes of bench-stepping exercise. One leg performed eccentric contractions (Ecc) by lowering the body whilst the control leg performed concentric contractions (Con) by raising the body. On the two days following bench-stepping exercise participants performed measures of muscle function on an isokinetic dynamometer and undertook a bout of one leg cycling exercise, at two differing workloads, with the first workload (WL1) at 1.5 ± 0.25 W/kg and the second workload (WL2) at 1.8 ± 0.25 W/kg with each leg. Expired respiratory gases were collected during cycling to estimate whole body substrate utilisation. There were significant decrements in measures of muscular performance (isometric force, concentric and eccentric torque) and increased perception of soreness in Ecc compared with Con ($P < 0.05$). The effect of the Ecc treatment on substrate utilisation during one-legged cycling revealed a significant trial × time interaction with higher rates of CHO oxidation in the Ecc condition compared with Con that were further increased 48 hours later ($P = 0.02$). A significant treatment × time × effort interaction ($P < 0.01$) indicated the effect of the treatment altered as workload increased with higher rates of CHO oxidation occurring in WL2. This is consistent with greater reliance upon muscle glycogen. Suggesting that in EIMD, reductions in strength and increased feelings of soreness can be associated with greater reliance upon intramuscular CHO oxidation, than lipid, during subsequent concentric work.

Hurst, Atkins 2006 – Agreement between polar and SRM

Hurst, Howard T.; Atkins, Stephen (2006):

Agreement between polar and SRM mobile ergometer systems during laboratory-based high-intensity, intermittent cycling activity.

In: *Journal of sports sciences* 24 (8), S. 863–868. DOI: 10.1080/02640410500245678.

Abstract:

The purpose of this study was to assess the agreement between two mobile cycle ergometer systems for recording high-intensity, intermittent power output. Twelve trained male cyclists (age 31.4 +/- 9.8 years) performed a single 3 min intermittent cycle test consisting of 12 all-out efforts, separated by periods of passive recovery ranging from 5 to 15 s. Power output was recorded using a Polar S710 heart rate monitor and power sensor kit and an SRM Powercrank system for each test. The SRM used torque and angular velocity to calculate power, while the S710 used chain speed and vibration to calculate power. Significant differences ($P < 0.05$) in power were found at 8 of the 12 efforts. A significant difference ($P = 0.001$) was also found when power was averaged over all 12 intervals. Mean power was 556 +/- 102 W and 446 +/- 61 W for the SRM and S710 respectively. The S710 underestimated power by an average of 23% with random errors of */[division sign] 24% when compared with the SRM. Random errors ranged from 36% to 141% with a median of 51%. The results indicate there was little agreement between the two systems and that the Polar S710 did not provide a valid measure of power during intermittent cycling activity when compared with the SRM. Power recorded by the S710 system was influenced greatly by chain vibration and sampling rates.

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SRM in Science

Item, Denkinger et al. 2011 – Combined effects of whole-body vibration

Item, F.; Denkinger, J.; Fontana, P.; Weber, M.; Boutellier, U.; Toigo, M. (2011):

Combined effects of whole-body vibration, resistance exercise, and vascular occlusion on skeletal muscle and performance.

In: *International journal of sports medicine* 32 (10), S. 781–787. DOI: 10.1055/s-0031-1277215.

Abstract:

The purpose of this study was to evaluate the effects of a new high-intensity training modality comprised of vibration exercise with superimposed resistance exercise and vascular occlusion (vibroX) on skeletal muscle and performance. Young untrained women were randomized to either train in a progressive mode on 3 days per week for 5 weeks (N=12) or to maintain a sedentary lifestyle (N=9). VibroX increased peak cycling power (+9%, P=0.001), endurance capacity (+57%, P=0.002), ventilatory threshold (+12%, P<0.001), and end-test torque (+15%, P=0.002) relative to the sedentary group. Training load increased by 84.5% (P<0.001) after vibroX. The increases were paralleled by increases in myosin heavy chain type 1 vastus lateralis muscle fiber cross-sectional area (+14%, P=0.031) and proportion (+17%, P=0.015), thigh lean mass (+4%, P=0.001), capillary-to-fiber ratio (+14%, P=0.003), and cytochrome c oxidase activity. Conversely, maximal values for oxygen consumption, cardiac output, isokinetic leg extension power and jumping power remained unaffected. Notably, vastus lateralis muscle adaptations were achieved with a very low weekly training volume. We conclude that vibroX quickly increases muscle (fiber) size, capillarization, and oxidative potential, and markedly augments endurance capacity in young women.

Jacobs, Burns 2009 – Acute enhancement of lower-extremity dynamic

Jacobs, Patrick L.; Burns, Patricia (2009):

Acute enhancement of lower-extremity dynamic strength and flexibility with whole-body vibration.

In: *Journal of strength and conditioning research / National Strength & Conditioning Association* 23 (1), S. 51–57. DOI: 10.1519/JSC.0b013e3181839f19.

Abstract:

The purpose of this investigation was to examine the acute effects of whole-body vibration (WBV) on muscular strength, flexibility, and heart rate (HR). Twenty adults (10 men, 10 women) untrained to WBV participated in the study. All subjects completed assessment of lower-extremity isokinetic torque, flexibility, and HR immediately before and after 6 minutes of WBV and 6 minutes of leg cycling ergometry (CYL), in randomized order. During WBV, subjects stood upright on a vibration platform for a total of 6 minutes. Vibration frequency was gradually increased during the first minute to a frequency of 26 Hz, which was maintained for the remaining 5 minutes. During CYL, power output was gradually increased to 50 W during the first minute and maintained at that power output for the remaining 5 minutes. Lower-extremity flexibility was determined using the sit-and-reach box test. Peak and average isokinetic torque of knee extension and flexion were measured by means of a motor-driven dynamometer with velocity fixed at 120 degrees .s. Change scores for the outcome measures were compared between treatments using Student's paired t-tests. Analysis revealed significantly greater HR acceleration with CYL (24.7 bpm) than after WBV (15.8 bpm). The increase of sit-and-reach scores after WBV (4.7 cm) was statistically greater ($p < 0.05$) than after CYL (0.8 cm). After WBV, increases in peak and average isokinetic torque of knee extension, 7.7% and 9.6%, were statistically greater than after CYL ($p < 0.05$). Average torque of knee flexion also increased more with WBV (+7.8%) than with CYL (-1.5%) ($p < 0.05$). The findings of this study indicate that short-term WBV standing elicits acute enhancements of lower-extremity muscular torque and flexibility, suggesting the application of this technology as a preparatory activity before more intense exercise.

SRM in Science

Jorge, Juliana Ribeiro Pala, Barao, Valentim Adelino Ricardo et al. 2013 – The role of implant/abutment system

Jorge, Juliana Ribeiro Pala; Barao, Valentim Adelino Ricardo; Delben, Juliana Aparecida; Assuncao, Wirley Goncalves (2013):

The role of implant/abutment system on torque maintenance of retention screws and vertical misfit of implant-supported crowns before and after mechanical cycling.

In: *The International journal of oral & maxillofacial implants* 28 (2), S. 415–422.

Abstract:

PURPOSE

This study aimed to evaluate the role of the implant/abutment system on torque maintenance of titanium retention screws and the vertical misfit of screw-retained implant-supported crowns before and after mechanical cycling.

MATERIALS AND METHODS

Three groups were studied: morse taper implants with conical abutments (MTC group), external-hexagon implants with conical abutments (EHC group), and external-hexagon implants with UCLA abutments (EHU group). Metallic crowns casted in cobalt-chromium alloy were used (n = 10). Retention screws received insertion torque and, after 3 minutes, initial detorque was measured. Crowns were retightened and submitted to cyclic loading testing under oblique loading (30 degrees) of 130 ± 10 N at 2 Hz of frequency, totaling 1 × 106 cycles. After cycling, final detorque was measured. Vertical misfit was measured using a stereomicroscope. Data were analyzed by analysis of variance, Tukey test, and Pearson correlation test (P < .05).

RESULTS

All detorque values were lower than the insertion torque both before and after mechanical cycling. No statistically significant difference was observed among groups before mechanical cycling. After mechanical cycling, a statistically significantly lower loss of detorque was verified in the MTC group in comparison to the EHC group. Significantly lower vertical misfit values were noted after mechanical cycling but there was no difference among groups. There was no significant correlation between detorque values and vertical misfit.

CONCLUSIONS

All groups presented a significant decrease of torque before and after mechanical cycling. The morse taper connection promoted the highest torque maintenance. Mechanical cycling reduced the vertical misfit of all groups, although no significant correlation between vertical misfit and torque loss was found.

Kakebeeke, Lechner et al. 2005 – The effect of passive cycling

Kakebeeke, T. H.; Lechner, H. E.; Knapp, P. A. (2005):

The effect of passive cycling movements on spasticity after spinal cord injury: preliminary results.

In: *Spinal cord* 43 (8), S. 483–488. DOI: 10.1038/sj.sc.3101747.

Abstract:

OBJECTIVE

To investigate the influence of rhythmic passive movements of the legs on the reduction of spasticity after spinal cord injury (SCI).

SETTING

Swiss Paraplegic Centre Nottwil, Switzerland.

METHODS

A total of 10 subjects with motor complete SCI were treated with a cycling device for half an hour. Before and after cycling their spasticity was tested with an isokinetic dynamometer. The subjects were tested one week later by exactly the same procedure with a half an hour break instead of the cycling. Subjects were asked about their spasticity before and after the cycling and break.

RESULTS

There was no significant difference in elicited peak torque either before and after the cycling, or before and after the break (MANOVA, $P<0.05$). Six out of 10 subjects estimated their spasticity as less after the cycling.

CONCLUSION

With the isokinetic dynamometer, it was not possible to show an effect of passive cycling on spasticity reduction. However, six out of 10 of the subjects estimated their spasticity to be less after cycling. This positive effect might be attributed to a reduced spasticity in the trunk and/or to the attention the subjects perceived during the intervention.

Kiryu, Yamagata 2006 – Relationships between muscle activity

Kiryu, Tohru; Yamagata, Jun (2006):

Relationships between muscle activity and autonomic regulation during cycling with a torque-assisted bicycle.

In: *Conference proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference* 1, S. 2702–2705. DOI: 10.1109/IEMBS.2006.260662.

Abstract:

For customizing the assistance scheme of a torque-assisted bicycle, we estimated physical activity during cycling with ECG and surface EMG for the circuit including a steep uphill section near the middle and compared it with the vehicle data. Using the respiratory-sinus-arrhythmia-related power ratio in the fluctuation of the R-R interval, prRSA and a muscular fatigue index, we classified physical activity into four groups for each trial. Results showed that the assist enlarged prRSA but did not sufficiently support muscular fatigue.

Kiryu, Yamashita 2007 – A ubiquitous wearable unit

Kiryu, Tohru; Yamashita, Kazuki (2007):

A ubiquitous wearable unit for controlling muscular fatigue during cycling exercise sessions.

In: *Conference proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference* 2007, S. 4814–4817. DOI: 10.1109/IEMBS.2007.4353417.

Abstract:

For health promotion and motor rehabilitation, controlling muscular fatigue on-site is important during exercise sessions. We have developed a ubiquitous wearable unit with a Linux board and tried to apply it to the control of a torque-assisted bicycle with a biosignal-based fuzzy system designed for a cycle ergometer. The results showed that an appropriate design for the cycle ergometor (indoor exercise) would be sufficiently applicable for the torque-assisted bicycle (outdoor exercise) in terms of heart rate, but was not sufficient in terms of muscular fatigue. It needs more detailed control for muscular activity.

SRM in Science

Koninckx, van Leemputte et al. 2010 – Effect of isokinetic cycling

Koninckx, Erwin; van Leemputte, Marc; Hespel, Peter (2010):

Effect of isokinetic cycling versus weight training on maximal power output and endurance performance in cycling.

In: *European journal of applied physiology* 109 (4), S. 699–708. DOI: 10.1007/s00421-010-1407-9.

Abstract:

The aim of this study was to compare the effects of a weight training program for the leg extensors with isokinetic cycling training (80 rpm) on maximal power output and endurance performance. Both strength training interventions were incorporated twice a week in a similar endurance training program of 12 weeks. Eighteen trained male cyclists (VO(2peak) 60 +/- 1 ml kg(-1) min(-1)) were grouped into the weight training (WT n = 9) or the isokinetic training group (IT n = 9) matched for training background and sprint power (P (max)), assessed from five maximal sprints (5 s) on an isokinetic bicycle ergometer at cadences between 40 and 120 rpm. Crank torque was measured (1 kHz) to determine the torque distribution during pedaling. Endurance performance was evaluated by measuring power, heart rate and lactate during a graded exercise test to exhaustion and a 30-min performance test. All tests were performed on subjects' individual race bicycle. Knee extension torque was evaluated isometrically at 115 degrees knee angle and dynamically at 200 degrees s(-1) using an isokinetic dynamometer. P (max) at 40 rpm increased in both the groups (~15%; P < 0.05). At 120 rpm, no improvement of P (max) was found in the IT training group, which was possibly related to an observed change in crank torque at high cadences (P < 0.05). Both groups improved their power output in the 30-min performance test (P < 0.05). Isometric knee extension torque increased only in WT (P < 0.05). In conclusion, at low cadences, P (max) improved in both training groups. However, in the IT training group, a disturbed pedaling technique compromises an improvement of P (max) at high cadences.

Lawson, Shultz et al. 2014 – Estimation of crank angle

Lawson, B. E.; Shultz, A.; Ledoux, E.; Goldfarb, M. (2014):

Estimation of crank angle for cycling with a powered prosthesis.

In: *Conference proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference* 2014, S. 6207–6210. DOI: 10.1109/EMBC.2014.6945047.

Abstract:

In order for a prosthesis to restore power generation during cycling, it must supply torque in a manner that is coordinated with the motion of the bicycle crank. This paper outlines an algorithm for the real time estimation of the angular position of a bicycle crankshaft using only measurements internal to an intelligent knee and ankle prosthesis. The algorithm assumes that the rider/prosthesis/bicycle system can be modeled as a four-bar mechanism. Assuming that a prosthesis can generate two independent angular measurements of the mechanism (in this case the knee angle and the absolute orientation of the shank), Freudenstein's equation can be used to synthesize the mechanism continuously. A recursive least-squares algorithm is implemented to estimate the Freudenstein coefficients, and the resulting link lengths are used to reformulate the equation in terms of input-output relationships mapping both measured angles to the crank angle. Using two independent measurements allows the algorithm to uniquely determine the crank angle from multi-valued functions. In order to validate the algorithm, a bicycle was mounted on a trainer and configured with the prosthesis using an artificial hip joint attached to the seat post. Motion capture was used to monitor the mechanism for forward and backward pedaling and the results are compared to the output of the presented algorithm. Once the parameters have converged, the algorithm is shown to predict the crank angle within 15° of the externally measured value throughout the entire crank cycle during forward rotation.

Lepers, Theurel et al. 2008 – Neuromuscular fatigue following constant

Lepers, R.; Theurel, J.; Hausswirth, C.; Bernard, T. (2008):

Neuromuscular fatigue following constant versus variable-intensity endurance cycling in triathletes.

In: *Journal of science and medicine in sport / Sports Medicine Australia* 11 (4), S. 381–389. DOI: 10.1016/j.jsams.2007.03.001.

Abstract:

The aim of this study was to determine whether or not variable power cycling produced greater neuromuscular fatigue of knee extensor muscles than constant power cycling at the same mean power output. Eight male triathletes (age: 33+/-5 years, mass: 74+/-4 kg, VO2max: 62+/-5 mL kg(-1) min(-1), maximal aerobic power: 392+/-17 W) performed two 30 min trials on a cycle ergometer in a random order. Cycling exercise was performed either at a constant power output (CP) corresponding to 75% of the maximal aerobic power (MAP) or a variable power output (VP) with alternating +/-15%, +/-5%, and +/-10% of 75% MAP approximately every 5 min. Maximal voluntary contraction (MVC) torque, maximal voluntary activation level and excitation-contraction coupling process of knee extensor muscles were evaluated before and immediately after the exercise using the technique of electrically evoked contractions (single and paired stimulations). Oxygen uptake, ventilation and heart rate were also measured at regular intervals during the exercise. Averaged metabolic variables were not significantly different between the two conditions. Similarly, reductions in MVC torque (approximately -11%, $P<0.05$) after cycling were not different ($P>0.05$) between CP and VP trials. The magnitude of central and peripheral fatigue was also similar at the end of the two cycling exercises. It is concluded that, following 30 min of endurance cycling, semi-elite triathletes experienced no additional neuromuscular fatigue by varying power (from +/-5% to 15%) compared with a protocol that involved a constant power.

Li, Hou et al. 2009 – An FES cycling control system

Li, Peng-Feng; Hou, Zeng-Guang; Zhang, Feng; Tan, Min; Wang, Hong-Bo; Hong, Yi; Zhang, Jun-Wei (2009):

An FES cycling control system based on CPG.

In: *Conference proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference* 2009, S. 1569–1572. DOI: 10.1109/IEMBS.2009.5332393.

Abstract:

This paper presents a scientific strategy for cycling induced by the functional electrical stimulation. In order to simulate the FES-cycling movement produced by human body, a neuro-musculo-skeletal model containing 16 segments and 186 muscles is developed, which can simulate human movements precisely. This model contains mathematical model of electrically stimulated skeletal muscles. Having known the kinematics and dynamics of the model, we design an FES-cycling control system based on the central pattern generator (CPG), which can produce rhythm stimulus to produce desired torque and generate rhythm cycling movements. And an approach to control multiple muscles is proposed. In the end of this paper, the simulation results are provided.

Lin, Lo et al. 2012 – Biomechanical assessments of the effect

Lin, Sang-I; Lo, Chao-Chen; Lin, Pei-Yi; Chen, Jia-Jin J. (2012):

Biomechanical assessments of the effect of visual feedback on cycling for patients with stroke.

In: *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 22 (4), S. 582–588. DOI: 10.1016/j.jelekin.2012.03.009.

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Abstract:

Stroke patients exhibit abnormal pattern in leg cycling exercise. The aim of this study was to investigate the effects of visual feedback on the control of cycling motion in stroke patients from kinesiological, kinematic and kinetic aspects. The cycling performance derived from cycling electromyography (EMG), cycling cadence, and torque of forty stroke subjects was evaluated under conditions with and without visual feedback of cycling cadence. Kinesiological indices, shape symmetry index (SSI) and area symmetry index (ASI) were extracted from EMG linear envelopes to evaluate the symmetry of muscle firing patterns during cycling. Roughness index (RI) was calculated from cycling cadence to represent cycling smoothness from kinematic aspects. Averaged cycling power (Pav), the product of cadence and torque, was used to represent force output. The rectus femoris EMG showed significantly greater ASI with visual feedback, however, the difference in SSI between the two conditions was not significant. For the biceps femoris, there was a significant decrease in SSI with visual feedback, while the ASI was not affected significantly by the task conditions. The cycling smoothness was better and the average power generated was larger when visual feedback was provided. This study found that the addition of visual feedback improved both neuromuscular control and overall performance. Such improvement is likely to be the result of better control of the rectus femoris muscle activation and coordination of both legs.

Louis, Hausswirth et al. 2012 – Strength training improves cycling efficiency

Louis, Julien; Hausswirth, Christophe; Easthope, Christopher; Brisswalter, Jeanick (2012):

Strength training improves cycling efficiency in master endurance athletes.

In: *European journal of applied physiology* 112 (2), S. 631–640. DOI: 10.1007/s00421-011-2013-1.

Abstract:

The purpose of this study was to test the effect of a 3-week strength training program of knee extensor muscles on cycling delta efficiency in master endurance athletes. Nine master (age 51.5 ± 5.5 years) and 8 young (age 25.6 ± 5.9 years) endurance athletes with similar training levels participated in this study. During three consecutive weeks, all the subjects were engaged in a strength training program of the knee extensor muscles. Every week, they performed three training sessions consist of 10 × 10 knee extensions at 70% of maximal repetition with 3 min rest between in a leg extension apparatus. Maximal voluntary contraction torque (MVC torque) and force endurance (End) were assessed before, after every completed week of training, and after the program. Delta efficiency (DE) in cycling was evaluated before and after the training period. Before the training period, MVC torque, End, and DE in cycling were significantly lower in masters than in young. The strength training induced a significant improvement in MVC torque in all the subjects, more pronounced in masters (+17.8% in masters vs. +5.9% in young, $P < 0.05$). DE in cycling also significantly increased after training in masters, whereas it was only a trend in young. A significant correlation ($r = 0.79$, $P < 0.01$) was observed between MVC torque and DE in cycling in masters. The addition of a strength training program for the knee extensor muscles to endurance-only training induced a significant improvement in strength and cycling efficiency in master athletes. This enhancement in muscle performance alleviated all the age-related differences in strength and efficiency.

Mateo, Blasco-Lafarga et al. 2011 – Pedaling power and speed production

Mateo, Manuel; Blasco-Lafarga, Cristina; Zabala, Mikel (2011):

Pedaling power and speed production vs. technical factors and track difficulty in bicycle motocross cycling.

In: *Journal of strength and conditioning research / National Strength & Conditioning Association* 25 (12), S. 3248–3256. DOI: 10.1519/JSC.0b013e3181f90847.

Abstract:

Mateo, M, Blasco-Lafarga, C, and Zabala, M. Pedaling power and speed production vs. technical factors and track difficulty in BMX cycling. J Strength Cond Res 25(12): 3248-3256, 2011-This article analyzes whether there is a determined profile in the production of cyclic and acyclic periods in relation to the phases of a bicycle motocross (BMX) race and whether this profile is

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related to the variables, Difficulty of track and Techniques used. After an initial test for determining maximum pedaling power (Pmax), 9 athletes belonging to the Spanish national team completed 3 series of 3 different types of races: (a) Complete track without pedaling; (b) Track, pedaling only at the gate start; and (c) track with free pedaling. The triple test was carried out over 3 days and on different level tracks: (a) high difficulty (HD), (b) medium difficulty (MD), and (c) low difficulty (LD). Our results show that average peak power applied in the BMX race was 85.21 ± 2.15% Pmax, coming down to 73.02 ± 18.38% at the gate start and to 51.37 ± 15.84% on the first straight. On the other hand, mean power (MP) in the BMX race is 33.79 ± 8.60% MPmax, with statistically significant differences in relation to the difficulty of the track ($p < 0.000$; 0.009; higher in the easiest). The mean velocity developed is 34.21 ± 1.0 km·h with significant differences ($p < 0.000$) in relation to the difficulty of the track. Acyclic efforts accounted for 86.3%, and cyclic efforts accounted for the remaining 16.7% of the overall performance in the race, with differences in relation to the difficulty of the track ($p \leq 0.003$). Both power profile and performance (measured as velocity) are dependent on the phases and techniques of the race and are significantly affected by the level of difficulty of the track. The greater the technical level of the track, the lesser the possibility of developing cyclic power and vice versa.

McIntyre J, P R, Mawston et al. 2012 – Changes of whole-body power

McIntyre J, P R; Mawston, Grant A.; Cairns, Simeon P. (2012):

Changes of whole-body power, muscle function, and jump performance with prolonged cycling to exhaustion.

In: *International journal of sports physiology and performance* 7 (4), S. 332–339.

Abstract:

PURPOSE

To quantify how whole-body power, muscle-function, and jump-performance measures change during prolonged cycling and recovery and determine whether there are relationships between the different fatigue measures.

METHODS

Ten competitive or recreationally active male cyclists underwent repeated 20-min stages of prolonged cycling at 70% VO2peak until exhaustion. Whole-body peak power output (PPO) was assessed using an all-out 30-s sprint 17 min into each cycle stage. Ratings of perceived exertion (RPE) were recorded throughout. Isometric and isokinetic muscle-function tests were made between cycle stages, over ~6 min, and during 30-min recovery. Drop-jump measures were tested at exhaustion and during recovery.

RESULTS

PPO initially increased or was maintained in some subjects but fell to 81% of maximum at exhaustion. RPE was near maximal (18.7) at exhaustion, with the time to exhaustion related to the rate of rise of RPE. PPO first started to decline only when RPE exceeded 16 (ie, hard). Peak isometric and concentric isokinetic torque (180°/s) for the quadriceps fell to 86% and 83% of pretest at exhaustion, respectively. In contrast, the peak concentric isokinetic torque (180°/s) of the hamstrings increased by 10% before declining to 93% of maximum. Jump height fell to 92% of pretest at exhaustion and was correlated with the decline in PPO ($r = .79$). Muscle-function and jump-performance measures did not recover over the 30-min postexercise rest period.

CONCLUSIONS

At exhaustion, whole-body power, muscle-function, and jump-performance measures had all fallen by 7-19%. PPO and drop-jump decrements were linearly correlated and are appropriate measures of maximal performance.

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SRM in Science

Morin, Samozino et al. 2010 – Direct measurement of power

Morin, J. B.; Samozino, P.; Bonnefoy, R.; Edouard, P.; Belli, A. (2010):

Direct measurement of power during one single sprint on treadmill.

In: *Journal of biomechanics* 43 (10), S. 1970–1975. DOI: 10.1016/j.jbiomech.2010.03.012.

Abstract:

We tested the validity of an instrumented treadmill dynamometer for measuring maximal propulsive power during sprint running, and sought to verify whether this could be done over one single sprint, as shown during sprint cycling. The treadmill dynamometer modified towards sprint use (constant motor torque) allows vertical and horizontal forces to be measured at the same location as velocity, i.e. at the foot, which is novel compared to existing methods in which power is computed as the product of belt velocity and horizontal force measured by transducers placed in the tethering system. Twelve males performed 6s sprints against default, high and low loads set from the motor torque necessary to overcome the friction due to subjects' weight on the belt (default load), and 20% higher and lower motor torque values. Horizontal ground reaction force, belt velocity, propulsive power and linear force-velocity relationships were compared between the default load condition and when taking all conditions together. Force and velocity traces and values were reproducible and consistent with the literature, and no significant difference was found between maximal power and force-velocity relationships obtained in the default load condition only vs. adding data from all conditions. The presented method allows one to measure maximal propulsive power and calculate linear force-velocity relationships from one single sprint data. The main novelties are that both force and velocity are measured at the same location, and that instantaneous values are averaged over one contact period, and not over a constant arbitrary time-window.

Mornieux, Guenette et al. 2007 – Influence of cadence

Mornieux, Guillaume; Guenette, Jordan A.; Sheel, A. William; Sanderson, David J. (2007):

Influence of cadence, power output and hypoxia on the joint moment distribution during cycling.

In: *European journal of applied physiology* 102 (1), S. 11–18. DOI: 10.1007/s00421-007-0555-z.

Abstract:

The purpose of this study was to use a hypoxic stress as a mean to disrupt the normal coordinative pattern during cycling. Seven male cyclists pedalled at three cadence (60, 80, 100 rpm) and three power output (150, 250, 350 W) conditions in normoxia and hypoxia (15% O2). Simultaneous measurements of pedal force, joint kinematics, % oxyhaemoglobin saturation, and minute ventilation were made for each riding condition. A conventional inverse dynamics approach was used to compute the joint moments of force at the hip, knee, and ankle. The relative contribution of the joint moments of force with respect to the total moment was computed for each subject and trial condition. Overall, the ankle contributed on average 21%, the knee 29% and the hip 50% of the total moment. This was not affected by the relative inspired oxygen concentration. Results showed that the relative ankle moment of force remained at 21% regardless of manipulation. The relative hip moment was reduced on average by 4% with increased cadence and increased on average by 4% with increased power output whereas the knee moment responded in the opposite direction. These results suggest that the coordinative pattern in cycling is a dominant characteristic of cycling biomechanics and remains robust even in the face of arterial hypoxemia.

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SRM in Science

Peiffer, Abbiss et al. 2009 – Effect of cold water immersion

Peiffer, Jeremiah J.; Abbiss, Chris R.; Nosaka, Kazunori; Peake, Jonathan M.; Laursen, Paul B. (2009):

Effect of cold water immersion after exercise in the heat on muscle function, body temperatures, and vessel diameter.

In: *Journal of science and medicine in sport / Sports Medicine Australia* 12 (1), S. 91–96. DOI: 10.1016/j.jsams.2007.10.011.

Abstract:

Cold water immersion (CWI) is a popular recovery modality, but actual physiological responses to CWI after exercise in the heat have not been well documented. The purpose of this study was to examine effects of 20-min CWI (14 degrees C) on neuromuscular function, rectal (T(re)) and skin temperature (T(sk)), and femoral venous diameter after exercise in the heat. Ten well-trained male cyclists completed two bouts of exercise consisting of 90-min cycling at a constant power output (216+/-12W) followed by a 16.1km time trial (TT) in the heat (32 degrees C). Twenty-five minutes post-TT, participants were assigned to either CWI or control (CON) recovery conditions in a counterbalanced order. T(re) and T(sk) were recorded continuously, and maximal voluntary isometric contraction torque of the knee extensors (MVIC), MVIC with superimposed electrical stimulation (SMVIC), and femoral venous diameters were measured prior to exercise, 0, 45, and 90min post-TT. T(re) was significantly lower in CWI beginning 50min post-TT compared with CON, and T(sk) was significantly lower in CWI beginning 25min post-TT compared with CON. Decreases in MVIC, and SMVIC torque after the TT were significantly greater for CWI compared with CON; differences persisted 90min post-TT. Femoral vein diameter was approximately 9% smaller for CWI compared with CON at 45min post-TT. These results suggest that CWI decreases T(re), but has a negative effect on neuromuscular function.

Peiffer, Abbiss et al. 2010 – Effect of cold water immersion

Peiffer, Jeremiah J.; Abbiss, Chris R.; Watson, Greig; Nosaka, Kazunori; Laursen, Paul B. (2010):

Effect of cold water immersion on repeated 1-km cycling performance in the heat.

In: *Journal of science and medicine in sport / Sports Medicine Australia* 13 (1), S. 112–116. DOI: 10.1016/j.jsams.2008.08.003.

Abstract:

This study examined the effect of a short cold water immersion (CWI) intervention on rectal and muscle temperature, isokinetic strength and 1-km cycling time trial performance in the heat. Ten male cyclists performed a 1-km time trial at 35.0+/-0.3 degrees C and 40.0+/-3.0% relative humidity, followed by 20 min recovery sitting in either cold water (14 degrees C) for 5 min or in 35 degrees C air (control); a second 1-km time trial immediately followed. Peak and mean cycling power output were recorded for both time trials. Rectal and muscle temperature, and maximal isokinetic concentric torque of the knee extensors were measured before and immediately after the first and second time trials. Rectal temperature was not different between cold water immersion and control conditions at any time points. After the second time trial, however, muscle temperature was significantly lower (-1.3+/-0.7 degrees C) in cold water immersion compared with the control trial. While peak and mean power decreased from the first to second time trial in both conditions (-86+/-54 W and -24+/-16 W, respectively), maximal isokinetic concentric torque was similar between conditions at all time points. The 5 min cold water immersion intervention lowered muscle temperature but did not affect isokinetic strength or 1-km cycling performance.

Peiffer, Abbiss et al. 2009 – Effect of cold-water immersion duration

Peiffer, Jeremiah J.; Abbiss, Chris R.; Watson, Greig; Nosaka, Ken; Laursen, Paul B. (2009):

Effect of cold-water immersion duration on body temperature and muscle function.

In: *Journal of sports sciences* 27 (10), S. 987–993. DOI: 10.1080/02640410903207424.

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Abstract:

This study compared the effect of 5, 10 and 20 min of cold-water (14 degrees C) immersion on rectal and muscle temperature and neuromuscular function. Twelve cyclists performed four cycling time-to-exhaustion trials in hot conditions (40 degrees C and 40%rh), followed 25 min later by cold-water immersion for 5, 10 or 20 min or 20 min in room temperature (24 degrees C; control). Rectal temperature was measured continuously, and muscle temperature was measured before, immediately after and 45 min after the time-to-exhaustion-test, as well as before and after water immersion. Sixty-second maximal voluntary isometric torque and isokinetic torque of the knee extensors were measured before, immediately after and 55 min after time-to-exhaustion-test. A greater rate of decrease in rectal temperature was observed in all water immersion conditions 45-80 min after time-to-exhaustion-test compared with control. Compared with control, muscle temperature 45 min after time-to-exhaustion-test was lower for all water immersion conditions; however, muscle temperature was lower for the 10- and 20-min conditions compared with 5 min. Isometric torque measured 55 min after time-to-exhaustion-test was lower for all conditions. Isokinetic torque was lower for all conditions immediately and 55-min post-time-to-exhaustion-test. Of the durations measured, 5 min of cold-water immersion appeared as the most appropriate duration for reducing rectal temperature but limiting decreases in muscle temperature.

Peñailillo, Blazevich et al. 2014 – Muscle Fascicle Behavior during Eccentric

Peñailillo, Luis; Blazevich, Anthony; Nosaka, Kazunori (2014):

Muscle Fascicle Behavior during Eccentric Cycling and Its Relation to Muscle Soreness.

In: *Medicine and science in sports and exercise. DOI:* 10.1249/MSS.0000000000000473.

Abstract:

A single bout of eccentric exercise confers a protective effect against muscle damage and soreness in subsequent eccentric exercise bouts, but the mechanisms underpinning this effect are unclear.

PURPOSE

This study compared vastus lateralis (VL) muscle-tendon behavior between two eccentric cycling bouts to test the hypothesis that muscle-tendon behavior would be different between bouts, and would be associated with the protective effect.

METHODS

Eleven untrained men (27.1 ± 7.0 y) performed two bouts of eccentric cycling (ECC1, ECC2) separated by 2 weeks for 10 min at 65% of maximal concentric workload (191.9 ± 44.2 W) each. Muscle soreness (by visual analog scale) and maximal voluntary isometric knee extensor torque (MVC) were assessed before and 1-2 days after exercise. Using ultrasonography, VL fascicle length and angle changes during cycling were assessed, and tendinous tissue (TT) length changes were estimated. VL electromyogram (EMG) amplitude, crank torque and knee joint angles were measured during cycling.

RESULTS

Soreness was greater ($P<0.0001$) after ECC1 than ECC2, although MVC changes were not different between bouts ($P=0.47$). No significant differences in peak electromyogram amplitude (normalized to EMG during MVC), crank peak torque or knee angles were evident between bouts. However, fascicle elongation was 16% less during ECC2 than ECC1 ($P<0.01$), indicating less fascicle strain in ECC2. Maximum TT length occurred at a smaller knee joint angle during ECC2 than ECC1 ($P=0.055$).

CONCLUSION

These results suggest that a lesser fascicle elongation and earlier TT elongation were associated with reduced muscle soreness after ECC2 than ECC1, thus changes in muscle-tendon behavior may be an important mechanism underpinning the protective effect.

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Peñailillo, Silvestre et al. 2013 – Changes in surface EMG assessed

Peñailillo, Luis; Silvestre, Rony; Nosaka, Kazunori (2013):

Changes in surface EMG assessed by discrete wavelet transform during maximal isometric voluntary contractions following supramaximal cycling.

In: *European journal of applied physiology* 113 (4), S. 895–904. DOI: 10.1007/s00421-012-2499-1.

Abstract:

To better understand characteristics of neuromuscular fatigue in supramaximal cycling exercise, this study examined changes in surface electromyography (sEMG) frequency during maximal voluntary isometric contractions (MVC) following a 30-s Wingate anaerobic test (WAnT) using discrete wavelet transform (DWT). The changes in sEMG were also compared between DWT and mean frequency (MNF) obtained by fast Fourier transform (FFT). 17 healthy men performed a WAnT with a 7.5 % of body mass load. Knee extensor MVC torque was measured before and 1, 3, 6, 9, 12 and 15 min following WAnT, and sEMG was recorded from vastus lateralis muscle during the torque measures. sEMG was analysed for (RMS), MNF by FFT and frequency domains of DWT (divided into six domains). MVC torque decreased 21-23 % at 3-15 min, RMS increased 26-34 % at 1-15 min, and MNF decreased 8-10 % from baseline (76.3 ± 3.2 Hz) at 1-3 min post-cycling ($P < 0.05$). The DWT frequency domains showed that the changes lasted longer than MNF such that the intensity increased at 12 and 15 min for domain 2 (125-250 Hz), all time points for domain 3 (62.5-125 Hz), and 1-6 min for domains 4 (31.2-62.5 Hz) and 5 (15.6-31.2 Hz). The magnitude of increase in the intensity at 1 min post-exercise (45-60 %) was largest for domains 3 and 5 ($P < 0.05$). A significant correlation was evident only between the magnitude of changes in the domain 5 and MNF ($r = -0.56$). It is concluded that DWT provides information on neuromuscular fatigue that is not detected by MNF derived from FFT.

Peveler, Shew et al. 2012 – A kinematic comparison of alterations

Peveler, Willard W.; Shew, Brandy; Johnson, Samantha; Palmer, Thomas G. (2012):

A kinematic comparison of alterations to knee and ankle angles from resting measures to active pedaling during a graded exercise protocol.

In: *Journal of strength and conditioning research / National Strength & Conditioning Association* 26 (11), S. 3004–3009. DOI: 10.1519/JSC.0b013e318243fdcb.

Abstract:

Saddle height is one of the most researched areas of bike fit. The current accepted method for adjusting saddle height involves the use of a goniometer to adjust saddle height so that a knee angle between 25° and 35° is obtained. This measurement is taken while the cyclist maintains a static position with the pedal at the 6-o'-clock position. However, the act of pedaling is dynamic, and angles may alter during movement. The purpose of this study was to examine the alterations to knee and ankle angle occurring from static measures to active pedaling across intensities experienced by cyclists during a graded exercise protocol. Thirty-four recreational to highly trained cyclists were evaluated using 2D analysis of stationary position and 3 active levels (level 1, respiratory exchange ratio of 1.00, and max). Dependent measures were compared using repeated measures analysis of variance ($p = 0.05$). When examining the results, it is evident that significant alterations to pedal stroke occur from stationary measures to active pedaling and as intensity increases toward maximal. Plantar flexion increased when moving from stationary measures to active pedaling, which resulted in an increase in knee angle. Although still greater than stationary measures, less plantar flexion occurred at higher intensities when compared with lower intensity cycling. Less plantar flexion at higher intensities is most likely a result of application of a larger downward torque occurring because of greater power requirements at higher intensities. There appeared to be greater variability in angle when examining novice cyclists in relation to more experienced cyclists. Although stationary measures are where a bike fit session will begin, observation during the pedal cycle may be needed to fine-tune the riders' fit.

Racinais, Chamari et al. 2006 – Effect of an acute hot

Racinais, S.; Chamari, K.; Hachana, Y.; Bartagi, Z.; Blonc, S.; Hue, O. (2006):

Effect of an acute hot and dry exposure in moderately warm and humid environment on muscle performance at different times of day.

In: *International journal of sports medicine* 27 (1), S. 49–54. DOI: 10.1055/s-2005-837503.

Abstract:

This study investigated whether 30 min of acute hot exposure has an additional passive warm-up effect for the improvement in muscle performance in a moderately warm and humid environment. We also sought to determine whether this effect is dependent on the diurnal variation in body temperature. Nine male subjects (age: 31.9 [+/- 5] years, height: 177 [+/- 6] cm, body mass: 69.3 [+/- 10] kg) were tested (CMJ, cycling sprints, and isokinetic contractions of the knee flexors and extensors) in a moderately warm and humid environment (24 [+/- 1] degrees C and 70 [+/- 4] % rh) with and without acute heat exposure (30 min of rest in a sauna at 76 [+/- 2] degrees C and 27 [+/- 1] % rh), both in the morning (07:00 - 09:00 h) and in the evening (17:00 - 19:00 h). Our results indicated a significant effect of both time-of-day and acute heat exposure on leg skin temperature ($p < 0.01$) but failed to show any effect of time-of-day or acute heat exposure on the various evaluated parameters (CMJ: speed, force, power and height; cycling power: over a half pedal revolution and a total pedal revolution; isokinetic torque: knee extensor and flexor muscles at 4.19 rad x s (-1), 3.14 rad x s (-1), 2.09 rad x s (-1), and 1.05 rad x s (-1)). In conclusion, our data suggest that 30 min of acute hot exposure does not have any passive warm-up effect in a moderately warm and humid environment. Furthermore, the diurnal variation in body temperature has no passive warm-up effect in a moderately warm and humid or in an extremely hot environment.

Rampinini, Connolly et al. 2014 – Peripheral neuromuscular fatigue induced

Rampinini, E.; Connolly, D. R.; Ferioli, D.; La Torre, A.; Alberti, G.; Bosio, A. (2014):

Peripheral neuromuscular fatigue induced by repeated-sprint exercise: cycling vs running.

In: *The Journal of sports medicine and physical fitness*.

Abstract:

AIM

Peripheral fatigue in Knee Extensor (KE) and Plantar Flexor (PF) muscles were investigated following Repeated--Sprint ability (RSA) cycling and running tests.

METHODS

Both RSA tests involved 5x6 s sprints and peripheral fatigue was quantified using diverse electrical stimulations (1Hz, 10Hz, 20Hz, 50Hz and 100Hz).

RESULTS

RSA cycling induced higher KE decrements in peak torque (PT), maximal rate of torque development and relaxation (PT decrements at different stimulation frequencies: from --39% to --53% cycling vs --16% to --39% running, $p < 0.049$). The PT ratios of the KE did not highlight differences in low--frequency fatigue. No major differences were noted in PT decrements of PF ($p > 0.231$); however, greater reductions in some PT ratios (10/100 Hz, 20/50 Hz and 20/100 Hz) confirmed the presence of low--frequency fatigue in PF following RSA cycling. Subjects reported significantly higher RPE leg values following RSA cycling (8.2 vs 7.3 respectively, $p = 0.018$) despite no differences in blood lactate, hydrogen ions and bicarbonates ($p > 0.467$).

CONCLUSION

Higher levels of peripheral fatigue induced by RSA cycling may be partially related to longer fractional duration of muscle contraction phases that can limit local blood flow. The discrepancies in neuromuscular fatigue between KE and PF can be explained by differences in muscle fibre composition or muscle contributions during RSA tests.

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SRM in Science

Rønnestad, Hansen et al. 2014 – Strength training improves performance

Rønnestad, B. R.; Hansen, J.; Hollan, I.; Ellefsen, S. (2014):

Strength training improves performance and pedaling characteristics in elite cyclists.

In: *Scandinavian journal of medicine & science in sports. DOI:* 10.1111/sms.12257.

Abstract:

The purpose was to investigate the effect of 25 weeks heavy strength training in young elite cyclists. Nine cyclists performed endurance training and heavy strength training (ES) while seven cyclists performed endurance training only (E). ES, but not E, resulted in increases in isometric half squat performance, lean lower body mass, peak power output during Wingate test, peak aerobic power output (Wmax), power output at 4 mmol L(-1) [la(-)], mean power output during 40-min all-out trial, and earlier occurrence of peak torque during the pedal stroke (P < 0.05). ES achieved superior improvements in Wmax and mean power output during 40-min all-out trial compared with E (P < 0.05). The improvement in 40-min all-out performance was associated with the change toward achieving peak torque earlier in the pedal stroke (r = 0.66, P < 0.01). Neither of the groups displayed alterations in VO2max or cycling economy. In conclusion, heavy strength training leads to improved cycling performance in elite cyclists as evidenced by a superior effect size of ES training vs E training on relative improvements in power output at 4 mmol L(-1) [la(-)], peak power output during 30-s Wingate test, Wmax , and mean power output during 40-min all-out trial.

Ross, Gregson et al. 2010 – Muscle contractile function and neural

Ross, Emma Z.; Gregson, Warren; Williams, Karen; Robertson, Colin; George, Keith (2010):

Muscle contractile function and neural control after repetitive endurance cycling.

In: *Medicine and science in sports and exercise* 42 (1), S. 206–212. DOI: 10.1249/MSS.0b013e3181b07a18.

Abstract:

PURPOSE

To examine alterations in muscle contractile properties, cortical excitability, and voluntary activation as a consequence of 20 d of repetitive endurance cycling within a 22-d period.

METHODS

Eight well-trained male cyclists completed 20 prolonged cycling stages interspersed by two rest days (days 9 and 17), which replicated the 2007 Tour de France route and schedule. Isometric knee extensor torque and EMG responses of the vastus lateralis in response to percutaneous electrical stimulation and transcranial magnetic stimulation were measured before, on days 9 and 17, and 2 d after completion of Tour de France. Postexercise measurements on days 9 and 17 were taken >18 h after cessation of the previous exercise bout.

RESULTS

Maximal voluntary contraction of the knee extensors decreased by 20 +/- 10% (P < 0.01) during Tour de France but recovered after 2 d of rest. Peripherally evoked M-wave and potentiated twitch responses were also significantly decreased during Tour de France, up to 31 +/- 21% and 22 +/- 18%, respectively (P < 0.05), but returned to baseline values after 2 d of recovery. Voluntary activation was reduced to 75 +/- 8% (P < 0.05) during Tour de France and remained significantly depressed (79 +/- 7%, P < 0.05) after completion. The amplitude of motor evoked potentials was decreased by 44 +/- 28% (P < 0.01) on day 9 and remained significantly depressed during the remainder of, and after, Tour de France.

CONCLUSIONS

A reduction in knee extensor strength, which occurs after repetitive prolonged cycling exercise, is a result of both central and peripheral processes. Reduced sarcolemmal excitability and impairment of contractile mechanisms exists even after 18 h of recovery. An enduring reduction in corticomotor output persists even after 2 d of rest.

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Rouffet, Hautier 2008 – EMG normalization to study muscle

Rouffet, David M.; Hautier, Christophe A. (2008):

EMG normalization to study muscle activation in cycling.

In: *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 18 (5), S. 866–878. DOI: 10.1016/j.jelekin.2007.03.008.

Abstract:

The value of electromyography (EMG) is sensitive to many physiological and non-physiological factors. The purpose of the present study was to determine if the torque-velocity test (T-V) can be used to normalize EMG signals into a framework of biological significance. Peak EMG amplitude of gluteus maximus (GMAX), vastus lateralis (VL), rectus femoris (RF), biceps femoris long head (BF), gastrocnemius medialis (GAS) and soleus (SOL) was calculated for nine subjects during isometric maximal voluntary contractions (IMVC) and torque-velocity bicycling tests (T-V). Then, the reference EMG signals obtained from IMVC and T-V bicycling tests were used to normalize the amplitude of the EMG signals collected for 15 different submaximal pedaling conditions. The results of this study showed that the repeatability of the measurements between IMVC (from 10% to 23%) and T-V (from 8% to 20%) was comparable. The amplitude of the peak EMG of VL was 99+/-43% higher ($p<0.001$) when measured during T-V. Moreover, the inter-individual variability of the EMG patterns calculated for submaximal cycling exercises differed significantly when using T-V bicycling normalization method (GMAX: 0.33+/-0.16 vs. 1.09+/-0.04, VL: 0.07+/-0.02 vs. 0.64+/-0.14, SOL: 0.07+/-0.03 vs. 1.00+/-0.07, RF: 1.21+/-0.20 vs. 0.92+/-0.13, BF: 1.47+/-0.47 vs. 0.84+/-0.11). It was concluded that T-V bicycling test offers the advantage to be less time and energy-consuming and to be as repeatable as IMVC tests to measure peak EMG amplitude. Furthermore, this normalization method avoids the impact of non-physiological factors on the amplitude of the EMG signals so that it allows quantifying better the activation level of lower limb muscles and the variability of the EMG patterns during submaximal bicycling exercises.

Sarre, Lepers 2007 – Cycling exercise and the determination

Sarre, G.; Lepers, R. (2007):

Cycling exercise and the determination of electromechanical delay.

In: *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 17 (5), S. 617–621. DOI: 10.1016/j.jelekin.2006.07.005.

Abstract:

The main aim of the present paper was to address the validity of a methodology proposed in a previous paper [Li L, Baum BS. Electromechanical delay estimated by using electromyography during cycling at different pedaling frequencies. J Electromyogr Kinesiol 2004;14(6):647-52], aimed at determining the electromechanical delay from pedaling exercise performed at various cadences. Twelve trained subjects undertook pedaling bouts corresponding to combinations of cadences ranging from 50 to 100 RPM and power output from 37.5% to 75% of Pmax. As cadence increased, peak torque angle was found to shift forward in crank cycle (from 60-65 degrees at 50 RPM to 75-80 degrees at 100 RPM, depending on the power output level), while muscle bursts shifted backward in accordance with previous works. It is therefore suggested to take into account this peak torque angle lag to improve the methodology proposed by Li and Baum. The present results also evidenced that the central strategy, consisting in earlier muscle activation in crank cycle as cadence increases, is only partial. Neural strategy seems to be a trade-off between mechanical efficiency of muscular force output and coactivation.

SRM in Science

Sarre, Lepers et al. 2005 – Stability of pedalling mechanics

Sarre, G.; Lepers, R.; van Hoecke, J. (2005):

Stability of pedalling mechanics during a prolonged cycling exercise performed at different cadences.

In: *Journal of sports sciences* 23 (7), S. 693–701. DOI: 10.1080/02640410400021997.

Abstract:

The aim of this study was to analyse the effect of pedalling rate on the pattern of mechanical torque application and on neuromuscular fatigue during prolonged cycling exercise. Eleven well-trained individuals performed three 1-h pedalling sessions, at 50 rev.min-1, 110 rev.min-1 and a freely chosen cadence, at an intensity corresponding to 65% of their maximal aerobic power. The mechanical torque applied on the right pedal was recorded for 30 s every 5 min while pedalling. Contractile and neural properties of the quadriceps and hamstring muscles were analysed before and immediately after each of the three pedalling sessions. The post-exercise reduction in knee extensors maximal voluntary contraction was significant ($P<0.01$) irrespective of the cadence, but no difference was found between cadences. The use of a particular cadence did not lead to preferentially central or peripheral fatigue. An increase in cadence resulted in greater positive and negative work generated during pedalling. The mechanical pattern was not altered during the exercise, whatever the selected cadence. The present study demonstrates that despite the occurrence of neuromuscular fatigue, trained individuals maintained a stable pedalling pattern throughout an endurance cycling exercise for cadences ranging from 50 to 110 rev.min-1.

Shen, Riyahi et al. 2014 – Effect of a Combination

Shen, Ya; Riyahi, Abdullah Mahmoud; Campbell, Les; Zhou, Huimin; Du, Tianfeng; Wang, Zhejun et al. (2014):

Effect of a Combination of Torsional and Cyclic Fatigue Preloading on the Fracture Behavior of K3 and K3XF Instruments.

In: *Journal of endodontics. DOI:* 10.1016/j.joen.2014.10.008.

Abstract:

INTRODUCTION

The purpose of this study was to evaluate the effect of various degrees of cyclic fatigue on torsional failure and torsional preloading on the cyclic fatigue life of heat-treated K3XF nickel-titanium (NiTi) instruments (SybronEndo, Orange, CA).

METHODS

The mean number of cycles until failure (Nf) of K3XF and K3 NiTi instruments was examined in a 3-point bending apparatus with a 7-mm radius and 45° curve. Torque and distortion angles at failure of new instruments and instruments stressed to 25%, 50%, and 75% of the Nf were measured according to ISO 3630-1. Other new files were preloaded at 25%, 50%, and 75% of the mean distortion angles before the fatigue test. After torsional preloading, the Nf was examined. The fracture surface of each fragment was examined with a scanning electron microscope.

RESULTS

The fatigue resistance of K3XF instruments was 2 times higher than that of K3 instruments ($P < .05$). The torque and angle of rotation at fracture of K3XF instruments were similar to those of K3 instruments. The 25%, 50%, and 75% torsional preloading significantly lowered the Nf of both K3 and K3XF instruments ($P < .05$). In the fatigue prestressed groups, K3 instruments with 75% preloading had significantly lower torque and distortion angles than unused K3 instruments ($P < .05$). The fractographic patterns corresponded to the pattern defined by the last stage test.

CONCLUSIONS

A low amount of torsional preloading reduced the fatigue resistance of K3 and K3XF instruments. A high amount of precycling fatigue significantly reduced the torsional resistance of K3 instruments. The torsional resistance of K3XF instruments was less affected by previous load cycling even after extensive precycling.

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SRM in Science

Stewart, Whyte et al. 2014 – Exercise-induced dehydration does not alter

Stewart, C. J.; Whyte, D. G.; Cannon, J.; Wickham, J.; Marino, F. E. (2014):

Exercise-induced dehydration does not alter time trial or neuromuscular performance.

In: *International journal of sports medicine* 35 (9), S. 725–730. DOI: 10.1055/s-0033-1364022.

Abstract:

This study examined the effect of exercise-induced dehydration by ~4% body mass loss on 5-km cycling time trial (TT) performance and neuromuscular drive, independent of hyperthermia. 7 active males were dehydrated on 2 occasions, separated by 7 d. Participants remained dehydrated (DEH, -3.8±0.5%) or were rehydrated (REH, 0.2±0.6%) over 2 h before completing the TT at 18-25 °C, 20-30% relative humidity. Neuromuscular function was determined before dehydration and immediately prior the TT. The TT started at the same core temperature (DEH, 37.3±0.3°C; REH, 37.0±0.2 °C (P>0.05). Neither TT performance (DEH, 7.31±1.5 min; REH, 7.10±1.3 min (P>0.05)) or % voluntary activation were affected by dehydration (DEH, 88.7±6.4%; REH, 90.6±6.1% (P>0.05)). Quadriceps peak torque was significantly elevated in both trials prior to the TT (P<0.05), while a 19% increase in the rate of potentiated peak twitch torque development (P<0.05) was observed in the DEH trial only. All other neuromuscular measures were similar between trials. Short duration TT performance and neuromuscular function are not reduced by dehydration, independent of hyperthermia.

Szecsi, Krewer et al. 2008 – Functional electrical stimulation assisted cycling

Szecsi, J.; Krewer, C.; Müller, F.; Straube, A. (2008):

Functional electrical stimulation assisted cycling of patients with subacute stroke: kinetic and kinematic analysis.

In: *Clinical biomechanics (Bristol, Avon)* 23 (8), S. 1086–1094. DOI: 10.1016/j.clinbiomech.2008.05.001.

Abstract:

BACKGROUND

Cycling is a safe and functionally effective exercise for patients with early post-stroke and poor balance. Such exercise is considered even more effective when functional electrical stimulation is added. Our principal aim was to determine the biomechanically quantifiable parameters of cycling that can be improved in patients with subacute hemiparesis by incorporating functional electrical stimulation. These parameters were defined as objective goals that can be achieved in clinical applications. A secondary aim was to determine whether they could be used to identify subjects who would benefit from such therapy.

METHODS

Using a tricycle testbed, we tested 39 subacute (mean 10.9 weeks post-stroke (SD 5.9)), hemiplegic subjects. During isometric measurements we recorded volitional and electrically evoked crank torques, the latter at maximal tolerable intensity. During ergometric measurements, volitional pedaling was alternated with combined pedaling (volitional supported by stimulation), performed at 30-s intervals. Power, smoothness, and symmetry of cycling were evaluated.

FINDINGS

Twenty-six percent of the subjects significantly improved the smoothness of their cycling with functional electrical stimulation. Only 8% and 10% significantly increased their power and symmetry, respectively. The improvement in smoothness significantly correlated with the capability of the individual to generate electrical torque (Spearman's rank correlation coefficient=0.66 at P=0.001).

INTERPRETATION

The smoothness of cycling was the most sensitive parameter improved by functional electrical stimulation. This improvement depended on the amount of torque evoked, and the torque achieved, in turn, correlated with the tolerated intensity of stimulation.

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Szecsi, Schiller et al. 2009 – A comparison of functional electrical

Szecsi, Johann; Schiller, Martin; Straube, Andreas; Gerling, Dieter (2009):

A comparison of functional electrical and magnetic stimulation for propelled cycling of paretic patients.

In: *Archives of physical medicine and rehabilitation* 90 (4), S. 564–570. DOI: 10.1016/j.apmr.2008.09.572.

Abstract:

OBJECTIVE

To compare isometric torque and cycling power, smoothness and symmetry using repetitive functional magnetic stimulation (FMS) and functional electrical stimulation (FES) in patients with paretic legs with preserved sensibility and in patients without sensibility.

DESIGN

Repeated-measures design.

SETTING

Laboratory setting.

PARTICIPANTS

Eleven subjects with complete spinal cord injury (SCI) and 29 subjects with chronic hemiparesis (16.6+/-5.5mo poststroke) volunteered.

INTERVENTIONS

Using a tricycle testbed, participants were exposed to isometric measurements and ergometric cycling experiments, performed during both 20Hz FMS and FES stimulation. Subjects with hemiparesis and with complete SCI were stimulated at maximally tolerable level and maximal intensity, respectively.

MAIN OUTCOME MEASURES

Maximal isometric pedaling torque and mean ergometric power, smoothness, and symmetry were recorded for voluntary, FES, and FMS conditions.

RESULTS

Two different patterns of the efficacy of FMS were identified. (1) Patients with complete SCI did not benefit (less torque and power was evoked with FMS than with FES, P<.003 and 10(-4) respectively). (2) Patients with hemiplegia and preserved sensibility could improve their torque output (P<.05), smoothness, and symmetry of pedaling (P<.05) with FMS more than with FES.

CONCLUSIONS

FMS is a potential alternative to surface FES of the large thigh musculature in stimulation-supported cycling of patients with partially or completely preserved sensibility.

Szecsi, Schlick et al. 2009 – Functional electrical stimulation-assisted cycling

Szecsi, Johann; Schlick, Cornelia; Schiller, Martin; Pöllmann, Walter; Koenig, Nikolaus; Straube, Andreas (2009):

Functional electrical stimulation-assisted cycling of patients with multiple sclerosis: biomechanical and functional outcome--a pilot study.

In: *Journal of rehabilitation medicine* 41 (8), S. 674–680. DOI: 10.2340/16501977-0397.

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Abstract:

OBJECTIVE

To determine whether functional electrical stimulation-supported ergometric training of patients with multiple sclerosis has a prosthetic or therapeutic effect on biomechanical (power, smoothness of cycling) and functional outcomes (walking capability, strength of muscle, spasticity).

DESIGN

Twelve subjects with multiple sclerosis participated in an electrical stimulation-supported ergometric training (3 sessions/week for 2 weeks). Measurements were made in a cross-over design to study prosthetic (with and without stimulation) and therapeutic effects (before and after training).

METHODS

Power and smoothness were calculated by cadence and torque recordings of cycling and spasticity; strength and walking capability were measured by the Modified Ashworth Scale, Manual Muscle Test, and 10-Metre Walk Test.

RESULTS

The power and smoothness of pedalling significantly improved prosthetically with electrical stimulation ($p=0.02$), but did not show significant improvement over the 2 weeks of training. Significant short-term reductions in spasticity (before vs after training session; $p<0.05$) were found. Isometric strength did not increase significantly during the 2-week training period and there was no improvement in walking ability.

CONCLUSION

Patients with multiple sclerosis are able to improve their cycling power and smoothness by pedalling with stimulation. We suggest that severely affected patients benefit more from functional electric stimulation-cycling therapy than do slightly affected patients.

Theurel, Lepers 2008 – Neuromuscular fatigue is greater

Theurel, Jean; Lepers, Romuald (2008):

Neuromuscular fatigue is greater following highly variable versus constant intensity endurance cycling.

In: *European journal of applied physiology* 103 (4), S. 461–468. DOI: 10.1007/s00421-008-0738-2.

Abstract:

The present study compared neuromuscular fatigue of the knee extensor muscles following highly variable versus constant power output cycling. Ten subjects performed two 33-min cycling trials of the same average power output, in a random order. Cycling exercise was performed either at constant (CST) power output, corresponding to 70% of the maximal aerobic power (MAP), or at variable (VAR) power output with alternating high (200, 150 and 100% of MAP during 10, 15 and 20 s, respectively) and moderate (50% of MAP) power output periods. Neuromuscular tests were performed before and immediately after the two trials. Heart rate (HR) was measured during exercise and blood lactate concentration ([La]) at the end of both trials. Reductions in maximal voluntary contraction torque, voluntary activation level and peak doublet were significantly greater after VAR than after CST. HR and [La] were significantly higher during VAR than during CST. Cycling at a varying power output in comparison to constant power resulted in additional muscular fatigue that may be explained by greater anaerobic contribution and muscle solicitation during the highly variable power output protocol.

SRM in Science

Tomaras, MacIntosh 2011 – Less is more

Tomaras, Elias K.; MacIntosh, Brian R. (2011):

Less is more: standard warm-up causes fatigue and less warm-up permits greater cycling power output.

In: *Journal of applied physiology (Bethesda, Md. : 1985)* 111 (1), S. 228–235. DOI: 10.1152/japplphysiol.00253.2011.

Abstract:

The traditional warm-up (WU) used by athletes to prepare for a sprint track cycling event involves a general WU followed by a series of brief sprints lasting ≥ 50 min in total. A WU of this duration and intensity could cause significant fatigue and impair subsequent performance. The purpose of this research was to compare a traditional WU with an experimental WU and examine the consequences of traditional and experimental WU on the 30-s Wingate test and electrically elicited twitch contractions. The traditional WU began with 20 min of cycling with a gradual intensity increase from 60% to 95% of maximal heart rate; then four sprints were performed at 8-min intervals. The experimental WU was shorter with less high-intensity exercise: intensity increased from 60% to 70% of maximal heart rate over 15 min; then just one sprint was performed. The Wingate test was conducted with a 1-min lead-in at 80% of optimal cadence followed by a Wingate test at optimal cadence. Peak active twitch torque was significantly lower after the traditional than experimental WU (86.5 ± 3.3% vs. 94.6 ± 2.4%, $P < 0.05$) when expressed as percentage of pre-WU amplitude. Wingate test performance was significantly better ($P < 0.01$) after experimental WU (peak power output = 1,390 ± 80 W, work = 29.1 ± 1.2 kJ) than traditional WU (peak power output = 1,303 ± 89 W, work = 27.7 ± 1.2 kJ). The traditional track cyclist's WU results in significant fatigue, which corresponds with impaired peak power output. A shorter and lower-intensity WU permits a better performance.

Twist, Eston 2005 – The effects of exercise-induced muscle

Twist, Craig; Eston, Roger (2005):

The effects of exercise-induced muscle damage on maximal intensity intermittent exercise performance.

In: *European journal of applied physiology* 94 (5-6), S. 652–658. DOI: 10.1007/s00421-005-1357-9.

Abstract:

Exercise-induced muscle damage (EIMD) is a common occurrence following activities with a high eccentric component. Alterations to the torque-velocity relationship following EIMD would appear to have serious implications for athletic performance, particularly as they relate to impairment of maximal intensity exercise. However, this has been studied infrequently. The purpose of this study was to assess the effects of EIMD on maximal intermittent sprint performance. Ten male participants (age 22.4 +/- 3.2 years, height 178.6 +/- 5.2 cm, mass 80.6 +/- 10.7 kg) performed 10 x 6 s cycle ergometer sprints, interspersed with 24 s recovery against a load corresponding to 0.10 kp/kg and 10 x 10 m sprints from a standing start, each with 12 s active (walking) recovery. All variables were measured immediately before and at 30 min, 24, 48 and 72 h following a plyometric exercise protocol comprising of 10 x 10 maximal counter movement jumps. Repeated measures ANOVA showed significant changes over time (all $P<0.05$) for perceived soreness, plasma creatine kinase activity (CK), peak power output (PPO), sprint time and rate of fatigue. Soreness was significantly higher ($P<0.01$) than baseline values at all time intervals (3.1, 4.9, 5.5 and 3.2 at 30 min, 24, 48 and 72 h, respectively). CK was significantly elevated ($P<0.05$) at 24 h (239 IU/l) and 48 h (245 IU/l) compared to baseline (151 IU/l). PPO was significantly lower ($P<0.05$) than baseline (1,054 W) at all time intervals (888, 946, 852 and 895 W, at 30 min, 24, 48 and 72 h, respectively). The rate of fatigue over the ten cycling sprints was reduced compared to baseline, with the greatest reduction of 48% occurring at 48 h ($P<0.01$). This was largely attributed to the lower PPO in the initial repetitions, resulting in a lower starting point for the rate of fatigue. Values returned to normal at 72 h. Sprint times over 10 m were higher ($P<0.05$) at 30 min, 24 h and 48 h compared to baseline (1.96 s) with values corresponding to 2.01, 2.02 and 2.01 at 30 min, 24 h and 48 h, respectively. Values returned to baseline by 72 h. The results provide further evidence that, following a plyometric, muscle-damaging exercise protocol, the ability of the muscle to generate power is reduced for at least 3 days. This is also manifested by a small, but statistically significant reduction in very short-term (approximately 2 s) intermittent sprint running performance. These findings have implications for appropriate training strategies in multiple sprint sports.

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van Soest, A J, Gföhler et al. 2005 – Consequences of ankle joint fixation

van Soest, A J; Gföhler, Margit; Casius, L J Richard (2005):

Consequences of ankle joint fixation on FES cycling power output: a simulation study.

In: *Medicine and science in sports and exercise* 37 (5), S. 797–806.

Abstract:

INTRODUCTION

During fixed-ankle FES cycling in paraplegics, in which the leg position is completely determined by the crank angle, mechanical power output is low. This low power output limits the cardiovascular load that could be realized during FES ergometer cycling, and limits possibilities for FES cycling as a means of locomotion. Stimulation of ankle musculature in a released-ankle setup might increase power output. However, releasing the ankle joint introduces a degree of freedom in the leg that has to be controlled, which imposes constraints on the stimulation pattern.

METHODS

In this study, a forward dynamics modeling/simulation approach was used to assess the potential effect of releasing the ankle on the maximal mechanical power output.

RESULTS

For the released-ankle setup, the optimal stimulation pattern was found to be less tightly related to muscle shortening/lengthening than for the fixed-ankle setup, which indicates the importance of the constraints introduced by releasing the ankle. As a result, the maximal power output for 45-RPM cycling in the released-ankle setup was found to be about 10% lower than with a fixed ankle, despite the additional muscle mass available for stimulation. Power output for the released-ankle setup can be improved by tuning the point of contact between the foot and pedal to the relative strength of the ankle plantar flexors. For the model used, power output was 14% higher than for the fixed-ankle setup when this point of contact was moved posteriorly by 0.075 m.

CONCLUSION

Releasing the ankle joint and stimulating the triceps surae and tibialis anterior is expected to result in a modest increase in power output at best.

Verellen, Meyer et al. 2008 – Consistency of within-cycle torque distribution

Verellen, Joeri; Meyer, Christophe; Reynders, Sofie; van Biesen, Debbie; Vanlandewijck, Yves (2008):

Consistency of within-cycle torque distribution pattern in hand cycling.

In: *Journal of rehabilitation research and development* 45 (9), S. 1295–1302.

Abstract:

This investigation studied the consistency of the within-cycle torque pattern in hand cycling (1) in subsequent cycles, (2) between different individuals, (3) between different power output levels, and (4) with respect to fatigue. Ten nondisabled male participants performed a progressive peak arm crank ergometry test; a number of 5-minute submaximal tests at 10, 20, 30, and 40 W; and one 15-minute submaximal test at 80% to 90% of their peak heart rate. A hand cycle unit attached to a computerized motor allowed for power output adjustments and registered position and torque. Variation coefficients were calculated and averaged for evaluation of the pattern consistency. Values were 2.7% to 3.9% for subsequent cycles, 3.2% to 5.3% between participants, 2.8% between different power output levels, and 3.1% with respect to fatigue. These results indicate a consistent within-cycle torque distribution pattern for subsequent cycles that is minimally influenced by factors such as power output and fatigue.

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SRM in Science

Verney, Kadi et al. 2006 – Combined lower body endurance

Verney, Julien; Kadi, Fawzi; Saafi, Mohamed A.; Piehl-Aulin, Karin; Denis, Christian (2006):

Combined lower body endurance and upper body resistance training improves performance and health parameters in healthy active elderly.

In: *European journal of applied physiology* 97 (3), S. 288–297. DOI: 10.1007/s00421-006-0175-z.

Abstract:

We investigated the effects of combined lower body (LB) endurance and upper body (UB) resistance training on endurance, strength, blood lipid profile and body composition in active older men. Ten healthy still active men (73+/-4 years, V(O2) peak: 36 (31-41) ml min-1 kg-1) were tested before and after 14 weeks of combined training (3 times week-1). Training consisted of 3x12 min of high intensity interval training on a bicycle for endurance interspersed by 3x12 min of UB resistance exercises. V(O2) peak during leg cycling and arm cranking, isokinetic torque of knee extensor and shoulder abductor and the cross-sectional area (CSA) of several muscles from UB and LB were measured. Sagittal abdominal diameter (SAD) and abdominal fat area were measured on MRI scans. Total body composition was assessed by hydrostatic weighing (HW) and dual-energy X-ray absorptiometry (DEXA). Blood lipid profile was assessed before and after training. By the end of the training period, V(O2) peak (l min-1) increased significantly by 9 and 16% in leg cycling and arm cranking tests, respectively. Maximal isokinetic torque increased both for the knee extensor and shoulder abductor muscle groups. CSA increased significantly in deltoid muscle. Percentage of body fat decreased by 1.3% (P<0.05) and abdominal fat and SAD decreased by 12 and 6%, respectively (P<0.01). There was also a significant decrease in total cholesterol and low-density lipoprotein. Thus, combined LB endurance and UB resistance training can improve endurance, strength, body composition and blood lipid profile even in healthy active elderly.

Vrints, Koninckx et al. 2011 – The effect of saddle position

Vrints, Jeroen; Koninckx, Erwin; van Leemputte, Marc; Jonkers, Ilse (2011):

The effect of saddle position on maximal power output and moment generating capacity of lower limb muscles during isokinetic cycling.

In: *Journal of applied biomechanics* 27 (1), S. 1–7.

Abstract:

Saddle position affects mechanical variables during submaximal cycling, but little is known about its effect on mechanical performance during maximal cycling. Therefore, this study relates saddle position to experimentally obtained maximal power output and theoretically calculated moment generating capacity of hip, knee and ankle muscles during isokinetic cycling. Ten subjects performed maximal cycling efforts (5 s at 100 rpm) at different saddle positions varying ± 2 cm around the in literature suggested optimal saddle position (109% of inner leg length), during which crank torque and maximal power output were determined. In a subgroup of 5 subjects, lower limb kinematics were additionally recorded during submaximal cycling at the different saddle positions. A decrease in maximal power output was found for lower saddle positions. Recorded changes in knee kinematics resulted in a decrease in moment generating capacity of biceps femoris, rectus femoris and vastus intermedius at the knee. No differences in muscle moment generating capacity were found at hip and ankle. Based on these results we conclude that lower saddle positions are less optimal to generate maximal power output, as it mainly affects knee joint kinematics, compromising mechanical performance of major muscle groups acting at the knee.

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SRM in Science

Wakeling, Blake et al. 2010 – Muscle coordination is key

Wakeling, J. M.; Blake, O. M.; Chan, H. K. (2010):

Muscle coordination is key to the power output and mechanical efficiency of limb movements.

In: *The Journal of experimental biology* 213 (3), S. 487–492. DOI: 10.1242/jeb.036236.

Abstract:

The purpose of this study was to determine which features of muscle mechanics and muscle coordination affect the power output from a limb during locomotion. Eight subjects were tested while cycling at maximum exertion for 25 min on a stationary dynamometer. Cadence and load were varied to span a range of power outputs and myoelectric activity was measured from 10 muscles in the leg. Cycle-by-cycle variations in muscle coordination, cadence and power output were observed and the EMG intensity across all muscles was used as an estimate of the metabolic cost for each cycle. Data for the cycles at greatest power output were separated into three groups: maximum power, 80% power but lower EMG intensity and 80% power and higher EMG intensity. Torque-angular velocity relations were determined for the ankle and knee joints. During cycling at maximum power output the ankle joint was not extending at the velocity necessary for maximum power output; thus, maximum limb power occurs when some of the individual muscles cannot be generating maximum power output. Increases in EMG intensity occurred with no increase in power output from the limb: these corresponded to decreases in the efficiency and changes in coordination. Increases in power were achieved that were not matched by equivalent increases in EMG intensity, but did occur with changes in coordination. It is proposed that the power output from the limb is limited by the coordination pattern of the muscles rather than the maximum power output from any one muscle itself.

Wakeling, Horn 2009 – Neuromechanics of muscle synergies

Wakeling, James M.; Horn, Tamara (2009):

Neuromechanics of muscle synergies during cycling.

In: *Journal of neurophysiology* 101 (2), S. 843–854. DOI: 10.1152/jn.90679.2008.

Abstract:

Muscle synergies have been proposed as building blocks that could simplify the construction of motor behaviors. However, the muscles within synergistic groups may have different architectures, mechanical linkages to the skeleton, and biochemical properties, and these put competing demands on the most appropriate way to activate them for different mechanical tasks. This study identifies the extent to which synergistic patterns of muscle activity vary when the mechanical demands on a limb were altered, and additionally identifies how consistent the spectral profiles of the electromyographic (EMG) intensities were across the different movement tasks. The muscle activities were measured with surface EMG across 10 muscles in the leg during cycling at a range of loads and velocities. The EMGs were quantified by their intensities in time-frequency space using wavelet analysis; the instantaneous patterns of activity identified using principal component analysis, statistically compared and further visualized using the varimax rotation. Variability (35.7%) in the patterns of activity between the muscles were correlated with the torque and velocity of the pedal crank. Anatomic groups of muscles share a common mechanical action across a joint; uncoupling between such muscles was identified in 68.8% of the varimax patterns that encompassed all 10 muscles and 20.8-29.5% of the activity patterns when the anatomic groups were analyzed separately. The EMG spectra showed greatest heterogeneity for the gastrocnemii. These results show that the activity of muscles within anatomic groups is partially uncoupled in response to altered mechanical demands on the limb.

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Watsford, Ditroilo et al. 2010 – Muscle stiffness and rate

Watsford, Mark; Ditroilo, Massimiliano; Fernández-Peña, Eneko; D'Amen, Giancarlo; Lucertini, Francesco (2010):

Muscle stiffness and rate of torque development during sprint cycling.

In: *Medicine and science in sports and exercise* 42 (7), S. 1324–1332. DOI: 10.1249/MSS.0b013e3181ce509d.

Abstract:

PURPOSE

Crank torque (CT) application and rate of CT development (RCTD) are important considerations in sprint cycling. The stiffness of the musculotendinous unit is related to the isometric rate of torque development (RTD); however, this relationship has yet to be examined in sprint cycling.

METHODS

Maximal isometric torque (MIT) and isometric RTD of the quadriceps were assessed in 21 trained male cyclists (28.7 +/- 9.5 yr, 1.74 +/- 0.08 m, and 67.5 +/- 7.2 kg). Unilateral musculoarticular (MA) stiffness of the quadriceps was quantified using an oscillation test. Further, the participants performed a maximal 6-s sprint to assess peak power output (POpeak), peak CT (CTpeak), peak RCTD (RCTDpeak), and the crank angles associated with CTpeak and RCTDpeak. Participants were ranked on MA stiffness properties and were divided into a relatively stiff group (SG) and a relatively compliant group (CG).

RESULTS

The SG displayed a significantly higher MA stiffness than the CG ($P < 0.05$). Furthermore, the SG reported significantly elevated MIT (27%), RTD (26%), and RCTDpeak (16%) when compared with the CG ($P < 0.05$), along with trends for increased POpeak (7%) and CTpeak (8%). The angles at CTpeak and RCTDpeak were 7% and 12% lower for the SG, respectively ($P < 0.05$). MA stiffness was significantly correlated with RCTDpeak, MIT, RTD, and POpeak.

CONCLUSIONS

Higher stiffness is related to superior RCTDpeak in trained cyclists during a single sprint. A significant proportion of the variance in RCTDpeak was attributed to MA stiffness (37%), which was of greater magnitude than the relationship between RCTDpeak and MIT. Furthermore, the lower CTpeak angle and RCTDpeak angle may contribute to a more rapid development of CT. Accordingly, MA stiffness seems to be an important consideration for sprint cycling.

Whitty, Murphy et al. 2009 – Factors associated with the selection

Whitty, Anthony G.; Murphy, Aron J.; Coutts, Aaron J.; Watsford, Mark L. (2009):

Factors associated with the selection of the freely chosen cadence in non-cyclists.

In: *European journal of applied physiology* 106 (5), S. 705–712. DOI: 10.1007/s00421-009-1071-0.

Abstract:

The purpose of this study was to examine both the freely chosen cadence (FCC) and the physical variables associated with cadence selection in non-cyclists. Eighteen participants pedalled at 40, 50, and 60% of their maximal power output (determined by a maximal oxygen uptake test, W (max)), whilst cadence (50, 65, 80, 95, 110 rpm, and FCC) was manipulated. Gross efficiency, was used to analyse the most economical cadence whilst central and peripheral ratings of perceived exertion (RPE) were used to measure the most comfortable cadence and the cadence whereby muscle strain was minimised. Peak (T (peak)), mean crank torque (T (mean)) and the crank torque profile were analysed at 150 and 200 W at cadences of 50, 65, 80, 95, and 110 rpm in order to determine the mechanical load. FCC was found to be approximately 80 rpm at all workloads and was significantly higher than the most economical cadence (50 rpm). At 60% W (max), RPE peripheral was minimised at 80 rpm which coincided with the FCC. Both T (peak) and T (mean) decreased as cadence increased and, conversely, increased as power output increased. An analysis of the crank torque profile showed that the crank angle at both the top (DP(top)) and the bottom (DP(bot)) dead point of the crank cycle at 80 rpm occurred later in the cycling revolution when compared to 50 rpm. The findings suggested that the FCC in non-cyclists was more closely related to variables that minimise muscle strain and mechanical load than those associated with minimising metabolic economy.

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SRM in Science

Wiedemann, M S F, Bosquet 2010 – Anaerobic Work Capacity derived

Wiedemann, M S F; Bosquet, L. (2010):

Anaerobic Work Capacity derived from isokinetic and isoinertial cycling.

In: *International journal of sports medicine* 31 (2), S. 89–94. DOI: 10.1055/s-0029-1233466.

Abstract:

The purpose of this study was to compare Anaerobic Work Capacity (AWC) measured on an isoinertial or an isokinetic bicycle ergometer. Twelve male participants completed two randomly ordered exercise testing sessions including a torque-velocity test followed by a 30-s all-out test on an isokinetic ergometer, or a force-velocity test followed by a Wingate Anaerobic Test on an isoinertial ergometer. Optimal load measured during the force-velocity test on the isoinertial ergometer was 1.13+/-0.11 N.kg(-1). Optimal cadence measured during the torque-velocity test on the isokinetic ergometer was 107+/-13 rpm. Although P(peak) measures were significantly correlated (r=0.77), we found a large difference between them (effect size=2.85) together with wide limits of agreement (bias+/-95%LOA=24+/-12%). The same observation was made with P(mean), but with a smaller magnitude of difference (bias+/-95%LOA=4.2+/-12%; effect size=0.51; r=0.73). This lack of agreement led us to the conclusion that AWC measures obtained during 30-s all-out tests performed on an isoinertial or an isokinetic bicycle ergometer are not necessarily similar and cannot be used interchangeably.

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