A2-3 ID238

PEDAL FORCES DURING CYCLING IN PATIENTS WITH ACUTE UNILATERAL ACL RUPTURE

Hermann Schwameder, Nathalie Alexander, Roman Hailing, Gerda Strutzenberger

Department of Sport Science and Kinesiology, University of Salzburg, Austria

The aim of this study was to measure the pedal forces during cycling on the injured and non-injured limb in patients with acute unilateral ACL rupture. 5 male patients cycled at intensities of 60, 100, 140, 180, 220 and 260 W. Three-dimensional pedal forces were collected and peak values for vertical and anterior-posterior pedal force were identified for each leg over 20 revolutions. The peak vertical pedal forces are decreased between 2% and 11% for the injured limb compared to the non-injured one. Peak anterior-posterior pedal forces reveal relative differences of -5% and 8% between the two legs. The measuring setup allows for individual diagnosis of the cycling pattern in patients with ruptured ACL and might give information for the rehabilitation process.

KEY WORDS: ACL rupture, cycling, pedal forces.

INTRODUCTION: The rupture of the ACL is a severe knee injury associated with pain, knee instability and functional restrictions during daily life and sport activities. ACL injuries are the most frequent ones at the knee with 70% occurrence rate during athletic activity (Senter & Hame, 2006). The main goal of ACL injury treatment is to regain functional stability of the knee joint motion and to enable a save return to sportive activity. Although most of the ACL are reconstructed by surgery treatment, in a minority of injuries patients want to avoid knee surgery and prefer a conservative rehabilitation treatment for actively stabilizing the knee joint and its structures. Specific physiotherapy programs have been developed in ACL injury rehabilitation (Zatterstrom, Friden, Lindstrand & Moritz, 1994; 2000). The decision for one or the other treatment is primarily based on personal impressions and personal recommendations mainly provided by medical doctors. Due to the lack of knowledge about the functional restrictions caused by ACL ruptures the decision for surgery or conservative treatment are hardly ever evidence based (Andersson, Samuelsson & Karlsson, 2009). Although cycling is commonly used in stabilizing and rehabilitative exercises, the biomechanical background is hardly described or discussed in the literature. Kvist (2005) studied the sagittal tibial translation during common rehabilitation exercised in ACL-deficient knee patients and found that cycling caused the smallest amount of tibial translation of all investigated exercises. A study presented by Ageberg, Roberts, Holmström & Friden (2004) used cycling in a fatiguing protocol to investigate the effect of the injured and non-injured limb on postural control. More biomechanical and functional background in cycling exercises is reported in a study presented by Hunt, Sanderson, Moffet & Inglis (2004). They found that ACL-injured patients generated significantly more power from the non-injured limbs compared with that from the injured limbs and the limbs from the control subjects. A deeper insight into functional restriction and individual cycling patterns could improve rehabilitation training and give meaningful information to patients, physiotherapists and clinicians. Therefore, the purpose of this study was to measure the pedal forces on the injured and non-injured limb in patients with unilateral ACL rupture during cycling at different power outputs. It was hypothesized that (1) the maximal forces would be smaller on the injured limb for all power outputs, (2) the force-time-courses would differ between the injured and non-injured limb and (3) inter-individual differences between the injured and non-injured limb would be observable.

METHODS: 5 male patients (age: 35±4 yrs, height: 177.5±7.6 cm, mass: 79.0±6.7 kg) with unilateral acute ACL-rupture (≤ 2 weeks before testing) participated in this study. The range of motion in the knee was sufficiently pronounced for conducting the cycling task. The study was approved by the ethics board and informed consent was signed by all participants. The cycling tests were the last item of a comprehensive testing-procedure including various functional tests. Therefore no cycling-specific warm up was conducted. The cycling was performed on a SRM ergometer (Schoberer Rad Messtechnik SRM GmbH, Germany), bike-settings were fitted individually and cleat shoes were used. Participants pedalled at a continuous cadence of 70 rpm, while intensity was increased by 40 W every 2 minutes, starting with an intensity of 60 W. Participants were instructed to pedal as long as comfortably manageable (in terms of pain) and all participants completed the 260 W condition, resulting in intensities of 60, 100, 140, 180, 220 and 260 W. Three-dimensional pedal forces were collected using a cycling measuring device (CycPed, 1000 Hz, Figure 1), of which the specification are presented in Alexander, Christian and Schwameder (submitted). For each loading condition data were collected in the last 30 seconds of the 2 min cycling. Peak values for vertical pedal force (Fz_{max}) and anterior-posterior pedal force (Fx_{max}) were identified for the injured and non-injured leg for each revolution. For each participant the mean of 20 revolutions was taken for further analysis.

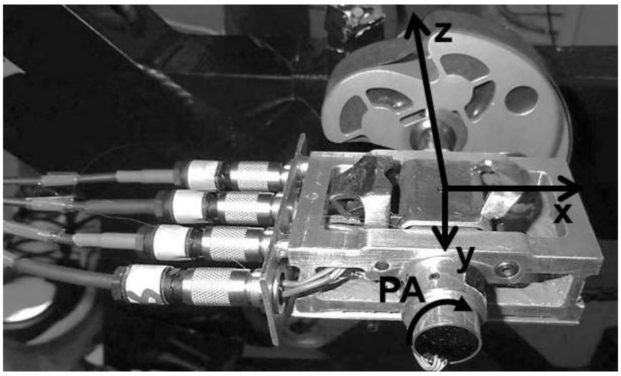

Figure 1: CycPed system for measuring forces in x- (anterior-posterior), y- (medio-lateral) and z- (vertical) direction as well as the pedal angle (PA).

Due to the subject number of 5, statistical analysis focuses on effect sizes based on Cohen's d (Cohen, 1992). Hence effect sizes were calculated (small: d≤0.04, medium: d = between 0.4 and 0.79, high: d≥0.8) between the injured and non-injured limb for each intensity

.

RESULTS: Mean (sd) values over all participants for all power output conditions are presented in Figure 2. Peak vertical and peak anterio-posterior pedal forces increase with increasing intensity. For the peak vertical pedal force (Fz_{max}) a decrease between 2% and 11% for the injured limb compared to the non-injured limb can be identified. Except for the 60 W-condition the differences continuously decrease with increasing intensity. Peak anterior-posterior pedal forces (Fx_{max}) are much lower compared with the peak vertical pedal forces with relative differences between the two limbs in the range of -5% and 8%. Effect sizes (Table 2) decrease with increasing intensity except of the peak vertical Fz_{max} for 60 W.

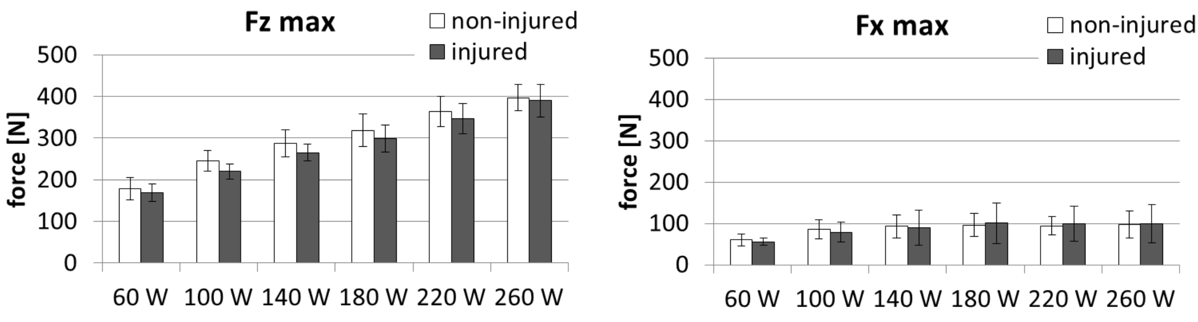

Figure 2: Mean (sd) values of peak vertical (Fz) and anterior-posterior (Fx) forces over all participants for all power output conditions.

Table 2
Effect size (Cohen's d) between injured (in) and non-injured (ni) limb for mean peak vertical (Fz_{max}) and anterior-posterior (Fx_{max}) forces

	60 W	100 W	140 W	180 W	220 W	260 W
d: Fz max ni-in	0.38	1.17	0.83	0.54	0.45	0.21
d: Fxmax ni-in	0.41	0.28	0.10	0.11	0.14	0.06

Individual time-courses of the vertical (Fz) and anterior-posterior (Fx) pedal forces of two selected participants for the condition 180 W/70 rpm are presented in Figure 3.

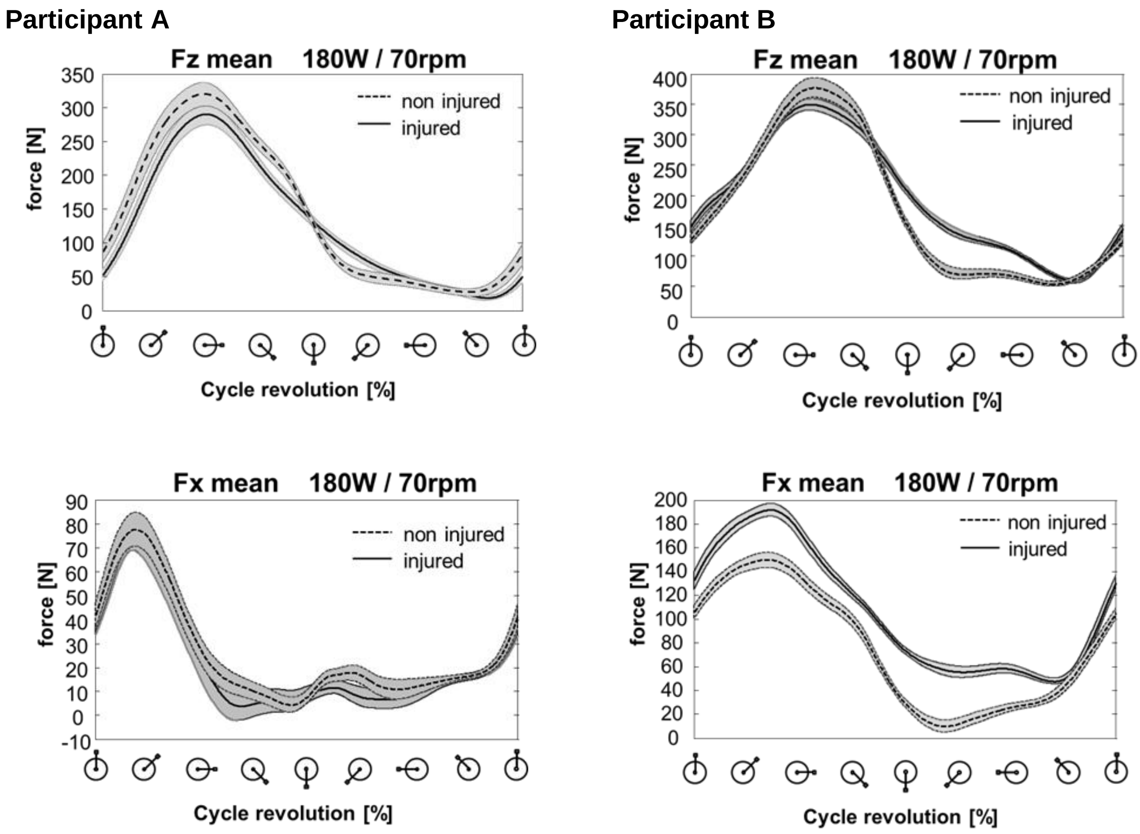

Figure 3: Time-courses of the vertical (Fz) **and** anterior-posterior (Fx) **pedal forces of two participants for the condition 180 W/70 rpm (mean/sd of 20 revolutions)**

DISCUSSION: The peak vertical pedal forces (Fz_{max}) are – as expected and hypothesized – significantly smaller on the injured limb compared with the non-injured one. Similar effects can be observed during the entire pushing phase (Figure 3). Consequently, the non-injured limb contributes a higher amount of power to the total power output during this phase. It is worth to note that the differences decrease with increasing intensity (except for the lowest intensity condition). In order to avoid unsteady pedalling at high loads the vertical forces (Fz) produced by the injured and non-injured leg seem to have to be balanced. The inspection of the force-time curves shows individual characteristics in both directions (Figure 3). While participant A continuously produces higher vertical forces from the upper to the lower dead point, participant B only presents this difference during the pushing phase. Regarding the anterior-posterior forces the differences between the two subjects are even more pronounced. The large differences between the two subjects with respect to the amount of the anterior-posterior forces, their shape and the lateral differences indicate high individual effect of ACL rupture on pedalling coordination.

CONCLUSION: It has been observed that acute unilateral ACL rupture affects the coordination pattern in cycling at different power outputs. Both the amount of pedal force and the time history of the forces applied to the pedals differ between the injured and non-injured limb. Furthermore, the effects are highly subject-specific. The measuring setup allows for individual diagnosis of the cycling pattern in patients with ruptured ACL and might support the decision process regarding the rehabilitation process of this type of injury.

REFERENCES:

Andersson, D., Samuelsson, K. & Karlsson, J. (2009). Treatment of anterior cruciate ligament injuries with special reference to surgical technique and rehabilitation: An assessment of randomized controlled trials. *Arthroscopy*, 25, 653-685.

Ageberg, E., Roberts, D., Holmström, E. & Friden, T. (2004). The effect of short-duration sub-maximal cycling on balance in single-limb stance in patients with anterior cruciate ligament injury: a cross-sectional study. *BMC Musculoskelet Disord*, 17(5), 44.

Alexander, N., Christian, J., & Schwameder, H. (submitted). A new pedal system measuring forces in three dimesnions. *Proceedings of ISBS 2013*.

Cohen, J. (1992). A power primer. *Psychol Bull, 112*(1), 155-159.

Friden, T., Roberts, D., Ageberg, E., Walden, M. & Zatterstrom, R (2001). Review of knee proprioception and the relation to extremity function after an anterior cruciate ligament rupture. *J Orthop Sports Phys Ther*, 31, 567-576.

Hunt, M., Sanderson, D., Moffet, H. & Inglis J. (2004). Interlimb asymmetry in persons with and without an anterior cruciate ligament deficiency during stationary cycling. *Arch Phys Med Rehabil*, 85(9), 1475-1478.

Kvist, J. (2005). Sagittal tibial translation during exercises in the anterior cruciate ligament-deficient knee. *Scand J Med Sci Sports*, 15(3), 148-158.

Senter, C. & Hame, S. (2006). Biomechanical analysis of tibial torque and knee flexion angle: implications for understanding knee injury. *Sports Medicine*, 36(8), 635-641.

Zatterstrom, R, Friden, T, Lindstrand, A. & Moritz, U (1994). The effect of physiotherapy on standing balance in chronic anterior cruciate ligament insufficiency. *Am J Sports Med*, 22, 531-536.

Zatterstrom, R, Friden, T, Lindstrand, A. & Moritz, U (2000). Rehabilitation following acute anterior cruciate ligament injuries – a 12-month followup of a randomized clinical trial. *Scand J Med Sci Sports*, 10, 156-163.