EFFECTS OF A MANUAL THERAPY ON TIBIOFEMORAL JOINT FORCES IN PATIENTS WITH ACUTE ANTERIOR CRUCIATE LIGAMENT RUPTURE

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The purpose of this study was to analyse the acute effects of the manual therapy RegentK on tibiofemoral joint forces and lower limb muscle forces in patients with an acute unilateral ACL rupture. Eight patients with an acute ACL rupture were recruited. Tibiofemoral joint forces and quadriceps, hamstring and gastrocnemius muscle forces were analysed during walking pre and immediately post the one time intervention using a musculoskeletal model.Results showed that tibiofemoral joint loading and muscle forces were altered in the injured compared to the uninjured limb, but no significant effect of the intervention could be shown. Joint and muscle force patterns, however, were highly individual. For future analyses the comparison with a matched-control group and the use of different methods to detect waveform-changes are recommended.

KEY WORDS: musculoskeletal modelling, muscle forces, intervention.

INTRODUCTION: Anterior cruciate ligament (ACL) injuries are the most frequent injuries at the knee, with 70% of them occurring during athletic activity (Senter & Hame, 2006). One of the main rehabilitation goals for patients with ACL deficiency is to regain as fast as possible joint function, the range of knee motion as well as the ability to walk without limitations. This can be currently accomplished by either conservative treatment, or by surgical reconstruction technique. There is no clear evidence for the benefit of the later procedure (Delince & Ghafil, 2012; Levy, 2010), as ACL reconstruction does not necessarily reduce the risk of osteoarthritis(Leiter, Gourlay, McRae, de Korompay, & Macdonald, 2013). Knowing that some evidence exists on the spontaneous healing of the ACL (Costa-Paz, Ayerza, Tanoira, Astoul, & Muscolo, 2012), it is important to analyse conservative therapies, which have potentially reduced risks (no surgery) and have equal, or even better outcomes (e.g. quadriceps strength, reduced asymmetries,…), compared to surgical interventions in order to provide scientifically based sports medicine treatment recommendations.
RegentK is a manual technique, for treating injuries of the musculoskeletal system especially of the knee. It is originated from neuromuscular therapy with the aim to stimulate the self-healing process of the injured body by applying high pressure to the skin and concomitantly to the structures under the skin (i.e. connective tissue and muscles). Three months after RegentK was applied to patients with acute ACL rupture, promising functional and morphological adaptations (e.g. 47% demonstrated an end-to-end homogeneous ACL in MRI) were reported (Ofner, Kastner, Wallenboeck, Pehn, Schneider, Groell et al., 2014). Further, immediately after the intervention patients with acute ACL-rupture walked significantly faster with increased step length and stride frequency and decreased contact time (Ofner, Strutzenberger, Alexander, & Schwameder, submitted).
Amongst various parameters that have been shown to be influenced by the injury tibiofemoral joint (TFJ) forces were found to be altered during gait in ACL deficient (Gardinier, Manal, Buchanan, & Snyder-Mackler, 2013) and ACL reconstructed (Sanford, Williams, Zucker-Levin, & Mihalko, 2013) individuals. Furthermore, different TFJ loading patterns were observed between non-copers and copers reflecting different walking strategies by these groups (Alkjaer, Henriksen, & Simonsen, 2011). Gardinier et al. (2013) reported decreased TFJ forces in the injured compared to the uninjured knee during gaitseven months after the ACL rupture. Furthermore, Sanford et al. (2013) reported abnormal TFJ compression forces in 50% of the ACL reconstructed patients (average 93 months after reconstruction). Therefore, studying effects of ACL ruptures and corresponding manual therapies on TFJ forces is important for a better understanding of the injury and its post injury mechanism (e.g. development of osteoarthritis).
Following, the aim of the current study was to analyse the acute effects of RegentK on TFJ forces and lower limb muscle forces in patients with an acute unilateral ACL rupture.

METHODS: Eight male patients (age: 38 ± 7 yrs, height: 1.79 ± 0.08 m, mass: 80.4 ± 8.0 kg, days after injury: 22 ± 16) with an acute unilateral ACL rupture (< 4 weeks, diagnosed with an MRI scan) were recruited for this study. Informed consent was given by all participants and the study was approved by the ethics board. The data collection involved a pre-test followed by one hour of manual therapy (RegentK) and a post-test. Pre- and post-tests consisted of marker placement, a 5 minutes warm-up, followed by the gait analysis.
For the gait analysis participants were asked to walk barefoot at a self-selected speed on a 10 m walkway with two integrated force plates (AMTI, Advanced Mechanical Technology Inc., USA; 1000 Hz). Reflective markers were attachedto the participants according to the Cleveland Clinic Marker set (Motion Analysis Corp, Santa Rosa, USA) and the position marked for identical post-therapy placement. Kinematic data were captured using an eight-camera motion capture system (Vicon, Oxford Metrics Ltd, UK; 250 Hz). One representative out of five valid trials was used for further analysis. Processed kinematic and kinetic data were imported into the inverse dynamic musculoskeletal modelling software Anybody(v 6.0, AnyBody Technology A/S, Aalborg, Denmark). A standard model available in the software (AMMR 1.6.2, MoCapModel) was used to calculate 3D-TFJ forces and muscle forces. TFJ forces were measured in the coordinate system of the tibia. TFJ and muscle forces were normalized to bodyweight (N/kg) and each trial was time normalized to stance phase duration. Mean and maximum compression, shear and medio-lateral TFJ force as well as mean and maximum muscle forces of the gastrocnemius, hamstring and quadriceps muscle groupswere calculated for the stance phase.Additionally, walking speed was defined pre and post- intervention.
Statistical tests for normality were undertaken and found to meet the requirements of parametric statistics. Therefore, differences were compared using repeated-measures ANOVA andin case of significance, a Bonferroni post-hoc test was used.

RESULTS: Walking speed did not differ significantly between pre and post testing (pre: 1.28 ± 0.20 m/s; post 1.35 ± 0.22 m/s, p = 0.079). Significant effects of the injury (injured vs uninjured limb) revealed differences for the pre-test in mean quadriceps and maximum and mean gastrocnemius force, while for the post-test significant differences occurred in the maximum TFJ compression and gastrocnemius force (Table 1 & 2).

Table 1: Maximal (SD) tibiofemoral joint and muscle forces.

Forces (N/kg)	pre		post	
	injured	uninjured	injured	uninjured
TFJ compression *	34.3 (3.6)	40.5 (7.5)	36.2 (4) †	41.1 (6.4)
TFJ shear	1.1 (0.9)	2.6 (2.1)	1.2 (0.6)	2.7 (2.0)
TFJ medio-lateral *	6.5 (0.8)	7.2 (1.3)	6.8 (0.9)	7.3 (1.0)
quadriceps	13.4 (4.9)	13.7 (6.2)	14.4 (3.9)	15.9 (4.4)
hamstrings	8.8 (2.6)	9.8 (2.8)	10.0 (2.5)	11.1 (2.9)
gastrocnemius *	16.7 (2.9) †	24.9 (7.4)	18.6 (2.3) †	25.2 (6.8)

* indicates significant main injury effects; † indicates significant post-hoc injured/uninjured differences.

Table 2: Mean (SD) tibiofemoral joint and muscle forces.

Forces (N/kg)	pre		post	
	injured	uninjured	injured	uninjured
TFJ compression	21.6 (1.3)	23.2 (2.7)	21.5 (1.5)	23.2 (2.2)
TFJ shear *	-0.2 (0.7)	0.2 (0.5)	-0.2 (0.4)	0.3 (0.6)
TFJ medio-lateral	4.1 (0.5)	4.1 (0.5)	4.0 (0.4)	4.2 (0.4)
quadriceps *	6.2 (2.7) †	4.4 (2.3)	5.9 (1.8)	5 (1.5)
hamstrings	1.9 (1.0)	2.4 (0.8)	1.9 (0.5)	2.2 (0.7)
gastrocnemius *	6.4 (1.3) †	8.6 (2.1)	6.4 (0.9)	8.2 (2.3)

* indicates significant main injury effects; † indicates significant post-hoc injured/uninjured differences.

No significant effects of the intervention or the interaction between intervention and injury were found. Effect sizes of hamstrings and quadriceps muscle forces showed, however, that more than a third of the variations are caused by differences between pre and post intervention (hamstrings: $\eta^2 = 0.351$, quadriceps: $\eta^2 = 0.371$). TFJ compression forces are presented as ensemble mean for all participants (Figure 1-all) and for two individual patients (Figure 1-P02 & P05) showing, representatively for all TFJ and muscle forces analysed, that resulting forces are highly individual.

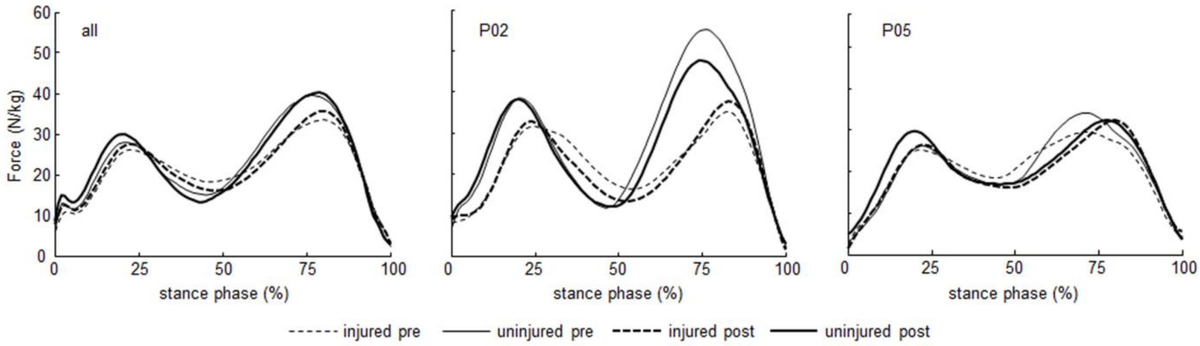

Figure 1: Tibiofemoral compression forces for all patients (left), P02 (middle) and P05 (right).

DISCUSSION: Results of the current study showed altered TFJ loading and muscle forces in the injured limb after acute ACL rupture, but no significant immediate effects of the intervention could be shown. Joint and muscle force patterns, however, were highly individual. In general, TFJ compression force patterns and magnitudes were in line with results of ACL patients (Gardinier et al., 2013; Sanford et al., 2013), healthy populations(Sritharan, Lin, & Pandy, 2012; Worsley, Stokes, & Taylor, 2011) and *in vivo*measurements (Kutzner, Heinlein, Graichen, Bender, Rohlmann, Halder et al., 2010). TFJ shear force patterns are in agreement with those of ACL reconstructed patients using musculoskeletal modelling (Sanford et al., 2013) and with the patterns measured *in vivo*from patients with an knee implant due to osteoarthritis (Kutzner et al., 2010), but are contradictory with results using static equilibrium modelling approaches (Kuster, Wood, Sakurai, & Blatter, 1994; Shelburne, Torry, & Pandy, 2005). Muscle force patterns were also in line with results of ACL patients (Gardinier et al., 2013; Sanford et al., 2013). TFJ forces and gastrocnemius muscle forces of the present study were reduced on the injured compared to the uninjured limb. Gardinier et al. (2013) also presented reduced TFJ contact forces on the injured limb in ACL deficient patients seven months after injury. Reduced TFJ shear forces were reported in the injured limb after ACL reconstruction compared to a control group (Sanford et al., 2013). Furthermore, using a model approach and removing the ACL also revealed decreased TFJ shear forces in the respective limb (Shelburne et al., 2005). In line with Sanford et al. (2013) the outcomes for TFJ and muscle forces were found to be patient-specific (Figure 1).
Significant effects of RegentK on temporo-spatial parameters, kinematics and kinetics during gaitwere found previously (Ofner et al., submitted). Amongst other alterations, patients were found to walk significantly faster. In the current study this effect was not shown, possibly explaining the lack of significant differences caused by the intervention. Effect sizes of hamstrings and quadriceps muscle forces showed, however, that more than a third of the variations are caused by differences between pre and post intervention testing. Visually analysing the waveforms individually for each patient, an improvement post intervention was found for six out of eight patients, for at least one analysed parameter. An improvement was defined when post intervention injured and uninjured waveforms were more in line compared to the pre intervention testing. Therefore, further methods such as principal component analysis might determine alterations caused by the intervention more holistically than the maxima and mean values alone could.Furthermore, the comparison of TFJ and muscle forces to a matched control group would be advantageous. We chose to compare the forces to the contralateral side with the risk of not detecting possible impairment, as unilateral injuries also affect the contralateral side (Ageberg, 2002). Other limitations were that the knee was modelled as a hinge joint and that ligaments, cartilage, fluid, and other soft tissues

were not included in this model, however, their contribution have been shown to be small (Shelburne, Pandy, Anderson, & Torry, 2004).

CONCLUSION: This study showed that maximum and mean TFJ and muscle forces were altered in the injured compared to the uninjured limb after acute ACL injury. No significant main effect of the RegentK intervention on these parameters could be shown, however, TFJ and muscle force alterations due to the intervention were highly individual. For future analyses the comparison with a matched-control group and the use of different methods to detect waveform-changes are recommended.

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