FMAXIMUM ISOMETRIC STRENGTH IN PATIENTS WITH ACUTE UNILATERAL ANTERIOR CRUCIATE LIGAMENT RUPTURE

Nathalie Alexander, Gerda Strutzenberger, Josef Christian and Hermann Schwameder

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

This study evaluated isometric leg extension strength in a group of ACL patients. The specific aims of this work were to determine whether differences in leg extension strength existed between the injured and uninjured leg, and whether a between-gender difference existed for the ratio of the maximum force generated by the injured and uninjured legs (the maximum force ratio). Thirty patients of both genders with an acute unilateral ACL rupture were recruited. Maximum isometric force was measured for both legs in a leg press machine at a knee angle of 100°. Results showed significant differences existed between the injured and uninjured legs, while no gender differences were evident for the maximum force ratio. In conclusion, an ACL rupture affects leg extension strength and including both males and females in one group may be possible in future work.

KEY WORDS: gender, maximum leg extension strength, static leg press.

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). ACL ruptures are associated with pain, knee instability, reduction of quadriceps strength and functional restrictions during daily life and sporting activities. Several tests are described in the literature to evaluate quadriceps strength, including, amongst others, isokinetic (Carter & Edinger, 1999; Wilk & Andrews, 1992; Wilk, Romaniello, Soscia, Arrigo, & Andrews, 1994) and isometric strength tests (Hohmann & Bryant, 2006; Lewek, Rudolph, Axe, & Snyder-Mackler, 2002; Snyder-Mackler, Delitto, Bailey, & Stralka, 1995).

The recovery of quadriceps muscle strength after knee injuries was shown to be important for functional and athletic use of the lower extremity (Barber, Noyes, Mangine, McCloskey, & Hartman, 1990; Noyes, Barber, & Mangine, 1991; Snyder-Mackler et al., 1995). This is commonly accepted, even though other studies have not confirmed this correlation (Anderson, Gieck, Perrin, Weltman, Rutt, & Denegar, 1991). Quadriceps strength is commonly described using the ratio of the injured and uninjured limbs (the maximum force ratio – F_{max} ratio). Approximately six months after ACL reconstruction F_{max} ratio may range from 59.5% to more than 90% (Carter & Edinger, 1999; Shelbourne & Foulk, 1995; Wilk & Andrews, 1992; Wilk et al., 1994). Despite these diverse values, it is generally agreed that quadriceps strength does not return to normal levels by this time post-surgery. Some studies have even shown an increase of quadriceps strength deficit when comparing pre and post ACL reconstruction (Keays, Bullock-Saxton, & Keays, 2000). Furthermore, a significant relationship between strength, and knee angles and moments during gait has been found (Lewek et al., 2002). Therefore, it should be of interest to develop a treatment that leads to a reduction of strength deficits. Knowing that some evidence exists on the spontaneous healing of the ACL (Costa-Paz, Ayerza, Tanoira, Astoul, & Muscolo, 2012; Fujimoto, Sumen, Ochi, & Ikuta, 2002), it is important to analyse conservative therapies, which have potentially reduced risks and have equal, or even better outcomes, compared to surgical interventions in order to provide scientifically based sports medicine treatment recommendations.

The overarching aim of our research direction was to evaluate the acute effects of two different intervention approaches on isometric maximum leg extension strength. Prior to the commencement of that research, this informative study was conducted. The aims of this study were to firstly, determine whether differences in isometric leg extension strength existed between the injured and uninjured legs, and secondly, to determine whether a between-gender difference existed for the ratio of the maximum force generated by the injured and uninjured legs (i.e., F_{max} ratio).

METHODS: Thirty patients (15 female/ 15 male) with an acute unilateral ACL rupture (< 4 weeks) were recruited for this study (Table 1). The ACL rupture needed to be clinically diagnosed with an MRI scan. Further inclusion criteria were: a) time of rupture between one to four weeks before testing, b) age between 18-50 years, c) at least one episode of giving-way of the knee since the ACL rupture, d) extension or flexion deficit (> 1-5°), e) activity level of minimum one hour per week prior to injury and f) the ability to walk a distance of 10 m without a walking aid. Participants were excluded if a) the injured leg was exposed to surgery, which also included arthroscopies, and b) if the participant suffered from metabolic or auto-immune diseases. The study was approved by the ethics board and informed consent was given by all participants.

Table 1: Anthropometric data of the patients.

	age (yr)	height (cm)	body mass (kg)	days after injury	female/male patients	right/left injured	injury incident
mean	33.9	174.2	69.8	18.3	15/15	18/12	24 x skiing 3 x soccer 2x volleyball 1 x slipping
SD	8.9	9.4	11.6	11.4			

After a warm-up, that included 10 minutes of walking and 2-3 near-maximal contractions on the testing device, maximum leg extension force on each leg was measured isometrically using a leg press machine with the knee positioned at 100° (maximum knee extension = 180°). Knee angle was assessed by manual goniometry (Figure 1). For each leg three contractions were performed and a rest period of two minutes was given between the trials. During contractions, patients had to build up their respective maximum voluntary contraction and maintain the isometric force plateau for at least three seconds. Patients were given verbal encouragement and visual online-feedback of their force-time curves was provided. Trials were repeated if maximal effort was not sustained for the given period or patients judged the attempt to be less than maximal.

Figure 1: Measurement setup in the static leg press machine.

Data was filtered using a Butterworth low pass filter (cut-off frequency = 20 Hz). The trial with the highest force reading, F_{max} was used for further analysis. These data were then normalized to body weight (BW). The F_{max} ratio was then expressed as the injured leg F_{max} / uninjured leg F_{max} × 100. Statistical analysis was undertaken using SPSS V20.0 software. Tests for normality were undertaken and the assumptions surrounding parametric statistics held. Therefore, differences in F_{max} between the uninjured and injured leg was analysed via a

Student's t-test for paired-samples. Gender differences in the F_{max} ratio were analysed using a Student's t-test for independent-samples.

RESULTS: Table 2 shows the absolute and normalized F_{max} and the difference between the uninjured and injured legs for both females and males as well as for the entire group (total). The absolute F_{max} for female patients was significantly lower on both legs when compared to male patients. However, no significant differences were found for normalized values. F_{max} ranged from 0.86 to 2.31×BW for the uninjured leg and from 0.35 to 1.91×BW for the injured leg, respectively. The mean difference between both legs was 0.5×BW (Table 2).

Table 2: Presentation of absolute and normalized F_{max} and difference between uninjured and injured leg for female and male patients and the total group.

	F_{max} absolute [N]			**F_{max} normalized [×BW]**		
	uninjured	injured	difference	uninjured	injured	difference
female	876 ± 245*	603 ± 209*	273 ± 190	1.42 ± 0.29	0.99 ± 0.33	0.43 ± 0.30
male	1226 ± 245	870 ± 306	387 ± 364	1.63 ± 0.34	1.15 ± 0.39	0.52 ± 0.48
total	1051 ± 299	737 ± 291	330 ± 291	1.53 ± 0.33	1.07 ± 0.37	0.48 ± 0.40

* indicates significant difference between female and male patients.

Figure 2a shows F_{max} for of the uninjured and injured legs. The injured leg was significantly ($p < 0.001$) weaker when compared to the uninjured leg (Figure 2a). Furthermore, F_{max} ratio of female and male patients showed no significant ($p = 0.657$) differences (Figure 2b). The mean isometric F_{max} ratio for the total group indicated that the injured side produced 71.8 ± 25.9% of F_{max} of the uninjured side, with a range from 24.9 to 103.8%.

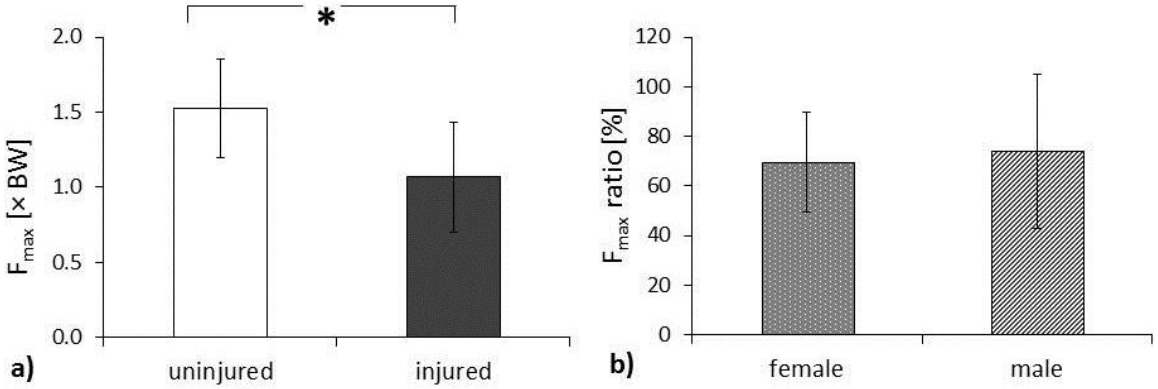

Figure 2: a) maximum force (F_{max}) of the uninjured and injured legs and b) F_{max} ratio of female and male patients.

DISCUSSION: Significant differences in F_{max} were found between the injured and uninjured legs, while no gender differences concerning the effect of an acute unilateral ACL rupture on F_{max} were observed. The F_{max} ratio is in agreement with results previously reported from either ACL-deficient (Lewek et al., 2002) or ACL-reconstructed patients (Gokeler, Schmalz, Knopf, Freiwald, & Blumentritt, 2003). The range of the F_{max} ratio and difference between the uninjured and injured legs was quite high, which suggests that results may have been highly dependent on the individual state of the injury. Three patients had a stronger injured than uninjured leg, which can be explained by the fact that the injured leg was their dominant one. The results are in agreement with literature that outlines differences between the dominant and non-dominant legs (Petschnig, Baron, & Albrecht, 1998) as well as research showing that patients with an ACL rupture can achieve more than a 100% F_{max} ratio (Lewek et al., 2002). All other patients showed a stronger uninjured than injured leg. Out of these, two patients showed an above average stronger (> 1.4×BW) uninjured leg compared to the injured one. As both patients also had an above average F_{max} value (> 2×BW), those high differences might be explained by the combination of a strong uninjured leg and an injured

leg with a loading deficit. Looking at absolute F_{max}, it can be seen that female patients were weaker than males. However, no significant gender differences were found concerning differences in the F_{max} ratio. Therefore, it can be concluded that the effects of an acute unilateral ACL rupture on F_{max} are similar for male and female patients.

CONCLUSION: Acute unilateral ACL ruptures lead to a significant decrease of F_{max} in the injured compared to uninjured leg. However, since no significant gender differences were found concerning the effect of an ACL rupture on F_{max}, it can be concluded that the effects are similar for male and female patients. Therefore, patients of both genders can be included as one group in future research examining the acute effects of two different single manual interventions on leg strength measured by the isometric F_{max}.

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