GROUND REACTION FORCES OF PATIENTS WITH AN OPERATIVELY TREATED RUPTURE OF THE ACL

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KEY WORDS: gait analysis, force platform, ground reaction forces, ACL

INTRODUCTION: Instrumented gait analysis is rarely used in the field of rehabilitation. In order to apply gait analysis not only in research but also in interdisciplinary cooperation between technicians and therapists in the field of rehabilitation, it is necessary to find a limited number of parameters expressive enough to support the development of new therapy plans. A well known problem in gait analysis is the identification of pathological gait patterns compared with normal gait patterns (HOPF). Even healthy test persons exhibit intra-personal differences (WIEDMER, LEONHARDT). Therefore, the purpose of this study was to identify distinct differences in gait patterns between normal and ACL reconstructed patients.

METHODS:

Subjects for this study (Table 1) included 91 subjects with no lower limb pathologies and 31 patients who had an ACL reconstruction (ACLR). After familiarization, the subjects were asked to walk barefooted over two AMTI force platforms, which were integrated into a footbridge (Figure 2). Each test candidate had to repeat the test six times. Only five of these attempts were used for the evaluation.

	healthy subjects	ACL patients
number of subjects	91	31
Men	56	29
Women	35	2
Age	23.5 ± 9.5	25.3 ± 5.6
Weight	76.8 ± 12.9	81.1 ± 10.7

Table 1: characteristics of the subjects
mean value ± standard deviation

Fig. 1 shows the Cartesian coordinate system of the force platform used. The forces in the x-direction correspond to the mediolateral, in the y-direction to the dorsoventral, and in the z-direction to the normal ground reaction forces (SCHAFF). The torque is the free moment with reference to an axis normal to the x-y-plane going through the center of pressure (COP) during the stance phase.

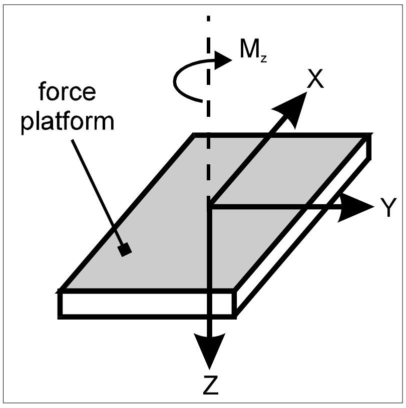

Figure 1: force platform

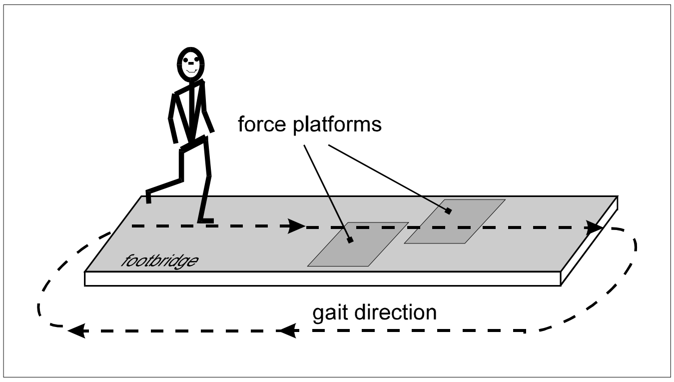

Figure 2: footbridge with integrated force platforms

RESULTS: The gait pattern of the examined ACL patients exhibits pathological changes compared to healthy persons. This is valid especially concerning the vertical forces when the heel is put on the ground (Fz_1) or when the ball of the foot is pushed away (Fz_3). The local minimum (Fz_2) of the force is less distinctive for the injured side, yielding smaller differences ΔF_{12} and ΔF_{32}.The reason for this could be a reduced flexion in the hip joint, knee joint and ankle joint during the stance phase. An asymmetry of the gait pattern of ACL patients is strengthened by the fact that the maximum force value (Fz_1) is reached at a later moment during the stance phase of the injured side. Due to this fact and to the smaller amount of the maximum force, ACL patients exhibit a very weak increase in the force for the injured side.

Concerning the dorsoventral thrust, the ACL patients also show deficits for the injured side compared to the control group (SCHMALZ). The braking force is strongly reduced when the heel is put on the ground.

	healthy persons		**ACL patients**	
	right side	Left side	injured side	healthy side
vertical force F_{z1}*	106.8 ± 6.7	107.1 ± 6.4	101.6*** ± 4.1	106.6 ± 10.2
vertical force F_{z2}*	80.6 ± 5.1	81.7 ± 5.1	87.3*** ± 3.9	84.2 ± 5.3
vertical force F_{z3}*	109.8 ± 5.4	108.9 ± 5.8	102.0*** ± 4.9	107.2 ± 4.9
ΔF_{12}*	25.9 ± 10.7	25.3 ± 10.0	14.3*** ± 6.9	22.3 ± 12.7
ΔF_{32}*	28.9 ± 8.7	27.1 ± 9.3	14.7*** ± 7.6	22.9 ± 8.8
tF_1**	23.6 ± 3.1	23.6 ± 3.4	28.4*** ± 4.7	21.7 ± 3.6
tF_3**	77.5 ± 2.4	77.5 ± 2.4	74.8 ± 3.0	76.6 ± 2.6
braking force*	15.1 ± 3.3	13.7 ± 2.7	10.0*** ± 2.1	14.9 ± 3.5
prop. Force*	18.3 ± 3.2	19.9 ± 3.1	17.1 ± 2.7	15.5 ± 2.4
impulse [Nms]	79.9 ± 122.1	131.9 ± 107.4	-47.5 ± 119.7	5.3 ± 114.8

Table 2: ground reaction forces and moments ($\Delta F_{12} = F_{z1} - F_{z2}$); ($\Delta F_{32} = F_{z3} - F_{z2}$)

mean value ± standard deviation
* percent of the body weight
** percent of stance phase
*** significant p<0.05 (student-t-test)

An analysis of the maximum torque (internal and external rotation) exhibits no differences at all between the ACL patients and the healthy control group. For this reason, the current angular momentum has been calculated from the torque. This shows a distinctive difference between the two groups of subjects, which is possibly due to a disruption of the ratio between internal and external rotation for the ACL patients.

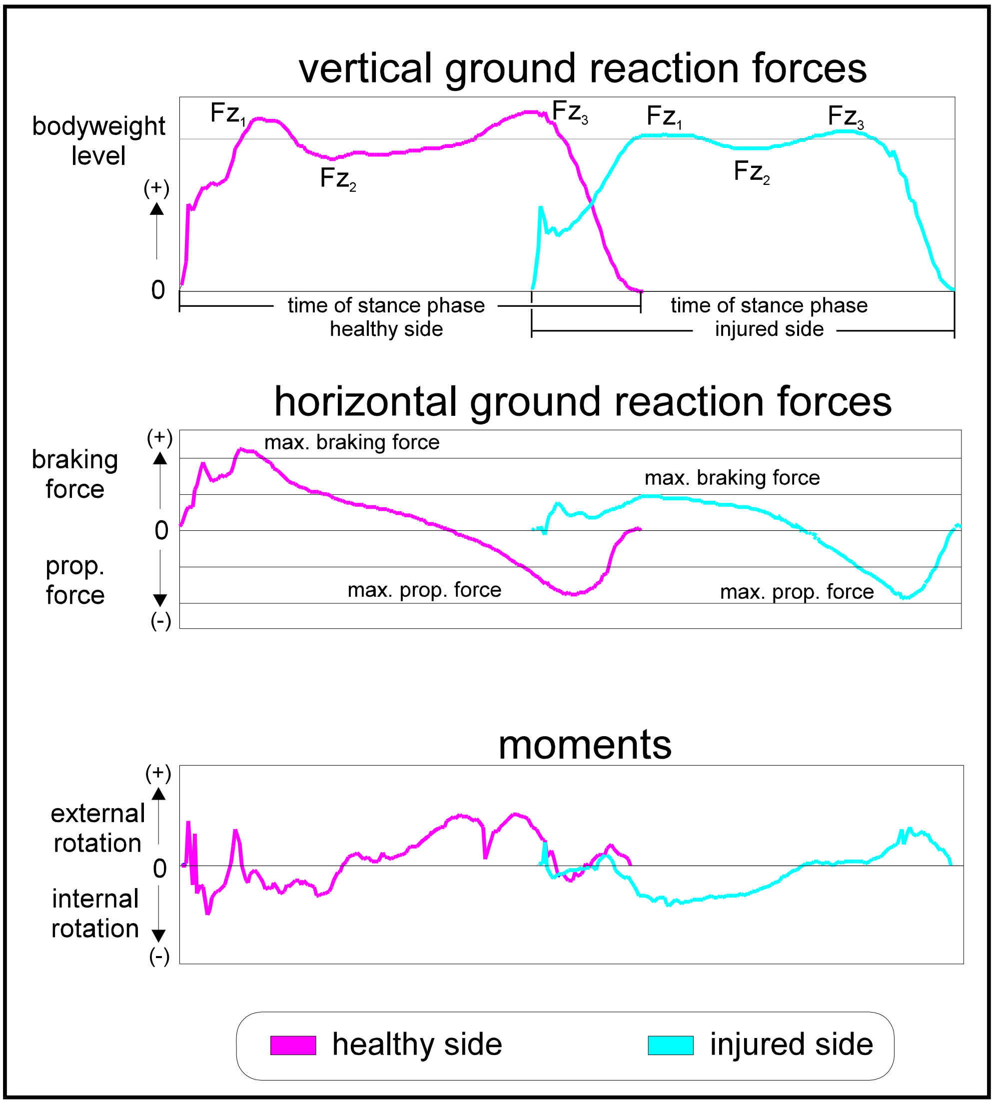

Figure 3: ground reaction forces and moments of an ACLR-patient, healthy (left) and injured (right) side

CONCLUSION: With the determination of the ground reaction forces and moments, the gait pattern during rehabilitation can be followed and controlled. The individual phases of the stance phase should be trained by specific exercises, so that a physiological gait pattern can be reached as soon as possible. Especially for sportsmen who are statistically very often injured by a rupture of the cruciate ligament (NEUMANN), this fact is important because the risk of long-term damage due to nonphysiological loading conditions during the exercises can be minimized.

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