ESTIMATION OF POTENTIAL RISK OF ACL RUPTURE IN FEMALE SOCCER PLAYERS AND EFFECTIVENESS OF A PREVENTION TRAINING PROGRAM

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The purpose of this study was to make an estimation of the potential risk of ACL rupture in female soccer players by means of video based analysis and controlled by biomechanical testing as well as to relate to effects by carrying out an 8 week specific training program. Results show that video based screening seems to be suitable in order to achieve a good estimation of the risk for ACL injuries without large expenditure. The performed ACL prevention training program shows a slight reduction of the potential risk of ACL rupture.

KEY WORDS: ACL, prevention, soccer.

INTRODUCTION: Rupture of the anterior cruciate ligament (ACL) is a serious knee injury with a long phase of rehabilitation. Often there are fatal results for the athlete up to sports disability. Most frequent situations for ACL ruptures are landing from a jump, stopping and plant and cut manoeuvres. High risk sports are team handball, soccer and basketball (Petersen et al. 2005[1]). Approximately 70% of ACL injuries occur in non-contact situations. Studies have shown a considerably higher incidence of ACL rupture within female athletes. The rate is 2.4 to 9.5 times higher than in male athletes. Different possible factors of risk are discussed. As anatomical causes joint angle positions of lower extremity, laxity and condylar space are taken into consideration. Referring to hormonal factors female oestrogen, relaxin or menstruation are discussed. From biomechanical point of view muscle strengths, activation patterns, functional stability, propriozeption and neuromuscular control of the knee leading muscles are mentioned. Dynamic knee valgus is discussed as a major to the risk factor for ACL rupture. Additionally external conditions like outfit, shoes or playing ground are to be considered. Based on existing results programs were made to prevent ACL ruptures by means of explanation, propriozeption or jump exercises or consist of a combination of all three aspects. Sports specific programs for soccer and team handball were made out up to now (Petersen et al. 2005[2]).

The effectiveness of prevention programs is not yet regarded as secured. There still exists no screening test for the individual estimation of risk. Therefore it is the aim of the present study to make an estimation of the potential risk of ACL rupture in female soccer players by means of video analysis and based on biomechanical testing and additionally to relate the results to effects by carrying out of a specific training program.

METHODS: In the study participated 16 healthy female U17-soccer players (16.5 y, 63.0 kg, 170.2 cm) without injuries or former ACL ruptures. A pre-test and a post-test consisting of a jump test and a strength test were carried out at an interval of 8 weeks. Statistical analysis was performed for the data of 13 players; the data of 3 players had to be excluded from the study because of various injuries between pre- and post-test.

The jump test consisted of a series of drop, squat and counter movement jumps with 3 trials each. Drop jumps with a falling height of 39 cm were performed with regard to the dynamic knee valgus. Squat and counter movement jumps were performed with regard to the jump height. Two 3-dimensional force plates (Kistler) were used for recording of ground reaction forces and jump heights with a measuring frequency of 1000 Hz. Two video cameras (JVC, 50 Hz) in frontal and dorsal plane were used to determine dynamic knee valgus via knee angle and internal rotation in landing. Video and force plate data were synchronised and stored with the software Simi-Motion.

The strength test consisted of 3 exercises with 3 MVC's each of the abductors (ABD) as well as of the external rotators in a knee angle of 45 degrees (ARO45) and 90 degrees (ARO90). For this, a mobile force transducer (Biovision) was attached with adjustable straps between both thighs across the kneecap and fixed in a hip wide and parallel position. MVC's were registered on a PDA with a measuring frequency of 1000 Hz with the Software PLab. MVC of the abductor muscles was measured by abduction of a stretched against a standing leg in an upright standing position. MVC of the external rotators was measured sitting on a chair with fixed feet on the floor by abduction of the flexed legs. The height of the sitting position was adapted to the knee joint angles of 45 respectively 90 degrees.

Videos of the drop jumps were analysed for to estimate the potential risk for ACL injury with regard to the dynamic knee valgus between the first contact to ground and the deepest bending position. The qualitative risk factor (rf) was defined from a value of 0 (no risk, neither knee valgus nor inward knee movement) to a value of 4 (very high risk, knee valgus with knee contact, fig. 1). Additionally the horizontal distance of knees and feet at the moment of ground contact as well as of the deepest bending position was measured by 2D analysis. Between pre- and post-test the players performed the PEP (Prevent injury Enhance Performance) ACL prevention program (Mandelbaum et al. 2005, Grimm, K. & Kirkendall, D. 2007) 2 times a week instructed by a physiotherapist. PEP contains a series of exercises consisting of warm-up, stretch, strength, plyometrics, agilities and knee-bent with a duration of 15 minutes in all. The results were processed by the means of Simi-Motion, Simi-Onforce, PLab and Excel, SPSS was used for statistical analysis.

Figure 1 Example pictures for estimation of risk factor for ACL injury with regard to the dynamic knee valgus in deepest bending position, left: risk factor 0, right: risk factor 4, knee valgus with contact

RESULTS: Subjective video analysis in pre-test (pre) without knowledge of kinematic data shows a high potential risk for ACL injuries (pre rf: 3.0 ±1.0) respectively 10 from 13 players are rated with a risk-factor of 2.5 and higher (table 1). Risk is reduced significantly in the post-test (post rf: 2.5 ±1.2, p=.006), but 8 players remain in the high risk group.
Quantitative analysis shows a straight leg position at the moment of first ground contact and a significant horizontal approximation of the knees at the deepest bending position (pre 5.0 ±2.5cm, post 5.5 ±2.0 cm, p=.000). There is also a significant trend for an increasing knee distance at initial ground contact (pre 23.7 ±3.2cm, post 24.5 ±3.5 cm, p=.064). During landing there are no further significant changes, neither in horizontal distances nor in approximations of feet or knees between pre- and post-test. Subjective estimation of potential risk correlates significant with decreasing horizontal distance of the knees during landing at ground contact (pre r=-.74, p=.004, post r=-.67, p=.013), in the deepest point (pre r=-.95, p=.000, post r=-.89, p=.000) and concerning the approximation of knees (pre r=-.73, p=.005, post r= .74, p=.004). The vertical movement of the knee joint while landing is reduced significantly in the pre-test (pre 10.5 ±2.3cm, post 9.7 ±1.9cm, p=.047).
There is no significant change in the maximum jump heights in each kind of trial. The landing index (LI) of drop jump as the quotient of Jump maximum ground reaction force while landing and body weight is reduced significantly in the post-test (pre 4.4 ±0,5, post 3.8 ±0.6, p=.006). The maximum strengths of abductor muscles and external rotators at 45 degrees are significantly raised in the post-test between 7-13% (ABD: pre 217 ±36N, post 233 ±24N, p=.033, ARO45: pre 204 ±32N, post 231 ±42N, p=.011, external rotators at 90 degrees show a significant trend (ARO90: pre 222 ±29N, post 239 ±47N, p=.085).

Table 1 Main results

	Parameter	pre-test	post-test	t-test (p)
1	risk factor, subjective [0-no, 4-high risk]	3.0 ±1.0	2.5 ±1.2	.006
2	horizontal knee distance at initial ground contact [cm]	23.7 ±3.2	24.5±3.5	.064
3	horizontal knee distance at deepest bending position [cm]	18.6 ±4.4	19.0 ±4.3	.334
4	horizontal approximation of knee during landing [cm] * t-test between 2 and 3	-5.0 ±2.5 (p =.002)*	-5.5 ±2.0 (p =.000)*	
5	horizontal foot distance at initial ground contact [cm]	23.7 ±3.7	24.0 ±4.0	.375
6	vertical movement of knee during landing [cm]	10.5 ±2.3	9.7 ±1.9	.047
7	landing index (max ground reaction force / body weight)	4.4 ±0.5	3.8 ±0.6	.006
8	ABD - MVC abductor muscles [N]	217 ±36	233 ±24	.033
9	ARO45 - MVC external rotator muscles at 45° knee angle [N]	204 ±32	231 ±42	.011
10	ARO90 - MVC external rotator muscles at 90° knee angle [N]	222 ±29	239 ±47	.085

DISCUSSION: The results distinctly show a dynamic knee valgus while landing in drop jump discussed as a major risk factor for ACL rupture. There is a good agreement between video based estimation and biomechanical determined knee valgus motion. However, the video based screening appears to be influenced by two parameters. An increase of valgoid leg position at ground contact leads to a higher risk score as well as the approximation of knees up to the deepest bending position. Both parameters do not correlate with each other. However, they refer independent from each other to unfavourable motion patterns dependent on generated lever arms.
The ACL preventing training program (PEP) leads to a slight reduction of risk factor on principle, even if a high risk level remains. In addition to the subjective estimation, the landing index respectively the initial impact is also reduced significantly i.e. landing in post-test becomes softer than in pre-test. However, the vertical motion of the knees is also reduced ac-

cording to the training program. On the one hand, this may be interpreted as an optimization of the landing mechanism in connection with a softer landing. On the other hand, it is reported that a lesser bent knee while landing favours ACL injuries (Devita et al. 1992). The resulting effect remains uncertain. The raised strengths of abductors and external rotators may be speculated as a factor for stabilization and optimization of knee joint movement respectively for reduction of the risk situation. Finally it should still be mentioned, that team coaches report a clearly raised flexibility and agility of the players as a result of the PEP-program.

CONCLUSION: Video based screening seems to be suitable in order to achieve a good estimation of the potential risk for ACL injuries without large expenditure. But the results also show a remaining high potential risk in spite of an 8-week ACL preventive training program. Consequently, the effectiveness of the propagated prevention program needs some further investigation. From the biomechanical point of view the mechanisms promoting ACL rupture have to be cleared up. In particular the antagonistic coordination of quadriceps and hamstring muscles to stabilise the knee joint and to prevent an anterior glide of the tibia and condylar impingement favouring ACL injuries seems to be very important. The influences of muscular fatigue and the resulting changes in muscular coordination within long activity times to the incidence of ACL injuries are not yet investigated but may also be relevant. Further studies should deal with the activation patterns of thigh muscles in the recovered and fatigued state with female and male athletes with different expertise level and should improve knowledge for an optimization of training programs for neuromuscular control and activation to prevent respectively to reduce the potential for ACL rupture.

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