Böker E[1], Janke C[1], Brunn S[2], Brock D[3], Jurig K[4], Witt M[1]

Evaluation of the Rehabilitation Process after ACL Rupture in Childhood and Adolescence

Evaluation des Rehabilitationsprozesses nach VKB-Ruptur im Kindes- und Jugendalter

ORIGINALIA

ACCEPTED: September 2022

PUBLISHED ONLINE: October 2022

Böker E, Janke C, Brunn S, Brock D, Jurig K, Witt M. Evaluation of the rehabilitation process after ACL rupture in childhood and adolescence. Dtsch Z Sportmed. 2022; 73: 203-209. doi:10.5960/dzsm.2022.545

1. LEIPZIG UNIVERSITY, *Faculty of Sport Science, Sports Biomechanics, Leipzig, Germany*
2. ASEVIDA REHA-ZENTRUM GMBH, *Leipzig, Germany*
3. KINDERZENTRUM AM JOHANNISPLATZ, *Leipzig, Germany*
4. UNFALLKASSE SACHSEN, *Meißen, Germany*

Summary

› **Problem:** Serious knee injuries are gaining epidemiological importance. Especially in childhood, a very significant increase in knee ligament injuries, in particular ACL ruptures, can be observed. In Saxony alone, more than 70 ruptures of the anterior cruciate ligament occur each year as a result of accidents during physical education (PE). Six months after surgery, the students are normally classified as fully fit for sports and are allowed to participate in PE without restrictions. However, the number of reinjuries is very high which limits the quality of life of those affected in the long term and places a heavy financial burden on insurance companies.

› **Methods:** Therefore the status quo in the rehabilitation of schoolchildren after ACL rupture was assessed using a multilevel test battery and taking into account known risk factors such as gender, motor competence and BMI.

› **Results:** The results show that there are large interindividual differences in the funktional outcomes as well as a large discrepancy between rehabilitation status and return to physical education.

› **Discussion:** In order to effectively manage the process of rehabilitation and return to school sports, individual information is necessary in the multimodal setting. To this end, all those involved should be sensitized and trained.

KEY WORDS:
Knee Injury, Return-to-Sport, Biomechanics of Sports, Prevention, School Sports

Zusammenfassung

› **Hintergrund:** Schwere Knieverletzungen erlangen epidemiologisch eine zunehmende Bedeutung. Speziell im Kindesalter ist ein sehr deutlicher Anstieg von Kniebandverletzungen, insbesondere der VKB-Rupturen zu beobachten. Allein in Sachsen treten pro Jahr mehr als 70 Rupturen des vorderen Kreuzbands als Unfallfolge im Rahmen des Schulsports auf. Sechs Monate nach der Operation werden die Schüler im Normalfall als voll sporttauglich eingestuft und dürfen uneingeschränkt am Schulsport teilnehmen. Die Zahl der Wieder-/Verletzungen ist allerdings sehr hoch, was die Betroffenen in ihrer persönlichen Lebensqualität langfristig einschränkt und die Versicherungen finanziell stark belastet.

› **Methodik:** Im Rahmen der Studie wurde der Status quo in der Rehabilitation von Schülern nach VKB-Ruptur mit einer mehrstufigen Testbatterie und unter Berücksichtigung bekannter Risikofaktoren wie Geschlecht, motorische Kompetenz und BMI erfasst.

› **Ergebnisse:** Die Ergebnisse zeigen, dass es große individuelle Unterschiede im funktionellen Outcome sowie eine große Diskrepanz zwischen Rehabilitationszustand und dem Wiedereinstieg in den Schulsport gibt.

› **Diskussion:** Um den Prozess der Rehabilitation und die Rückkehr in den Schulsport effektiv steuern zu können, sind im multimodalen Setting individuelle Informationen notwendig. Dazu sollten alle Beteiligten sensibilisiert und geschult werden.

SCHLÜSSELWÖRTER:
Knieverletzung, Return-to-Sport, Biomechanik, Prävention, Schulsport

Introduction

Serious knee injuries are gaining epidemiological importance. Especially in childhood, a very significant increase in knee ligament injuries, particularly anterior cruciate ligament (ACL) ruptures, can be observed (20). Various risk factors are known from literature. Boys are overall more frequently affected than girls (16), but in game sports girls run a 2- to 5-fold increased risk of ACL injury (17). In Saxony, more than 70 ACL ruptures occur at school each year (13). In its current guideline, the German Society for Trauma Surgery recommends testing of full sports fitness after 6 month and allows knee-impacting sports. However, longitudinal studies show a high prevalence of re-injury (4), which is associated with a significant long-term impact on personal quality of life and high costs for care.

Good preoperative functional status can positively influence postoperative genesis in adult knee injuries (18, 11). This makes the decline in participation in physically active extracurricular activities, e.g. club sports (8, 21) and the associated poorer functional status of children all the more problematical. ›

Scan QR Code and read article online.

CORRESPONDING ADDRESS:
Eva Böker M.Sc.
Scientist, Leipzig University
Faculty of Sport Science
Sports Biomechanics
Jahnallee 59, 04109 Leipzig, Germany
✉: biomechanik@uni-leipzig.de, eva.boeker@uni-leipzig.de

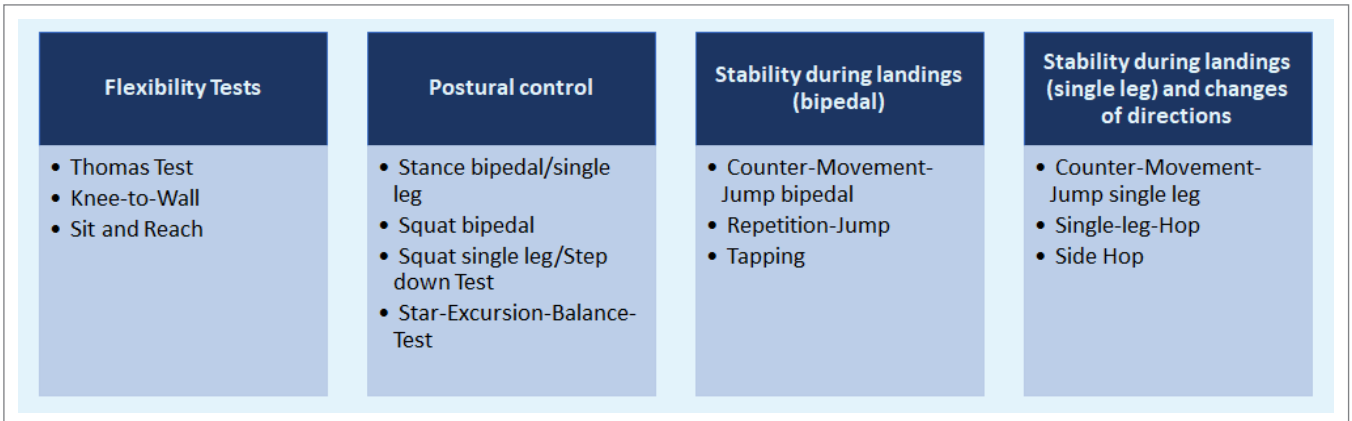

Figure 1

The motoric test battery with the different test categories.

Table 1

Anthropometric data with Mean±SD.

	N=53	MALE (N=18)	FEMALE (N=35)
Age (y)	15.07±1.12	15.04±2.01	15.08±1.12
Body height (cm)	167.44±10.64	173.39±12.50	164.38±8.16
Body mass (kg)	68.39±19.99	73.94±24.93	65.54±16.60
BMI	24.04±5.32	24.05±5.82	23.98±5.14
Surgery (N)	34	12	22
Conservative (N)	19	6	13

With regard to BMI, there is evidence that high BMI is associated with longer rehabilitation duration and poorer functional outcome (15, 5).

Despite the high importance of ACL rupture in childhood, especially for long-term participation in sports and exercise, no age-specific recommendations exist within rehabilitation guidelines to date. Both the German and the American guidelines explicitly refer to injury management in adults. The statements on the rehabilitation process in children are deficient (7, 25). After completion of the early wound healing phase (3 months post-surgery), everyday activities should be possible again. The release for all loads (e.g. jumps, side steps)is considered possible in adults after 6 months. In contrast, Beischer et al. (2020) reported a 7-fold increased risk of re-injury in adolescents with a return to sports after less than 9 months (3). Appropriate tests are recommended to monitor the rehabilitation process (return-to-sport or return-to-competition tests). However, there is an overall lack of evidence-based, individualized treatment guidelines based on functional knee parameters instead of fixed time courses (9). The individualization of the prevention and rehabilitation process requires targeted group-oriented diagnostics in a multidimensional setting.

The primary aim of this study is to assess the current standard in rehabilitation after ACL rupture in children and adolescents in Saxony with the help of quantitative data. The secondary aim is to quantify the dependence of rehabilitation outcomes on known risk factors, such as gender, motor competence and BMI. All treatment options were included as a first step.

Recommendations for the management of the rehabilitation process and the sensitization of all actors involved are developed.

Materials and Methods

To date, 53 subjects aged 10 to 17 years were examined in cooperation with the German Accident Insurance Fund (table 1). From 2019 to date, all pupils were included who suffered an ACL rupture while attending school and who voluntarily participated in the study. Concomitant injuries were not a criterion for exclusion. All subjects live in Saxony and go to high school or vocational school. Students from both urban and rural areas were included. The study received a positive vote from the Ethics Committee at the Medical Faculty of Leipzig University (376/18-ek, December 17, 2018).

So far, no difference is apparent between conservatively (cons, N=19) and surgically treated subjects (surgery, N=34) with respect to all risk factors studied. Usually, the semitendinosus tendon or the combination of semitendinosus and gracilis tendons were used for ACL reconstruction. 21% of subjects (from a total of 43 subjects) participated in physical education (PE) 3 months after treatment, another 28% participated after 6 months, and another 25.5% each after 9 and 13 months.

The motor tests took place 3, 6, and 12 months after treatment. They consist of 3 flexibility tests (shortening of plantar flexors, knee extensors and flexors, and hip flexors) and 11 motoric tests checking postural control [stance bipedal (bp) and single leg (sl), squat bp and sl, mod. star excursion balance test] as well as stability during landings (counter-movement-jump bp and sl, tapping, repetition-jump, single-leg-hop) and changes of direction (side hop) (figure 1). An adaptive test procedure was used with defined termination criteria for the test, such as pain, non-fulfillment of the criteria or termination by the test person or the legal guardian.

Scoring was done using the limb-symmetry-index and by ranking into the reference values. A total score of 60 points could be achieved. Questionnaires were used to record physical activity in minutes per week before injury (abbreviated version MOMO (22)) and current knee functionality and knee pain (KOOS; German translation mod, after (19)) 3 and 6 months after treatment (maximum score 100). The collected data were merged and analyzed descriptively using Microsoft Excel 2019. SPSS IBM Statistics 27 was used to first test for normal distribution and plot and removal of outliers before further inferential statistical data analysis. Effect sizes were expressed in Eta squared for the ANOVAs and Cohen's d for the T-tests and interpreted according to Cohen (6).

Results

Due to the Coronavirus pandemic, the studies could not take place with all subjects at the planned time points. The number of subjects included therefore varies. The subjects have

an average physical activity level of 4.85±3.31 h sport/week.

Between post 3 and post 6, there are improvements in knee functionality (KF) and motor competence. The total KOOS increases significantly [Mpost 3= 76.81±12.764, Mpost 6= 84.72±10.377; T(24)=-3.209, p=.004, d=-.632]. Differences were evident in the subcategories Pain [T(24)=-3.029, p=.006, d=-.606], Quality of Life (QOL) [T (24)=-2.095, p=.047, d=-.419] and Sport and Play [T(24)=-2.448, p=.022, d=-.490].

Subjects achieve a mean motor score (MS) of 11.03±4.543 points (post 3), 15.68±6.115 (post 6) and 14.61±8.290 (post 12). The full score (60) is not reached by any subject (Max=34). The MS increases significantly from post 3 to post 6 [T(25)=-4.207, p<.001, d=-.825]. In the subsequent period between post 6 and post 12, no significant changes in MS are detectable [T(13)=.437, p=.669]. There is no relationship between KF and MS at post 3 (r=-.030, p=.884), post 6 (r=.207, p=.281) and post 12 (r=.179, p=.508).

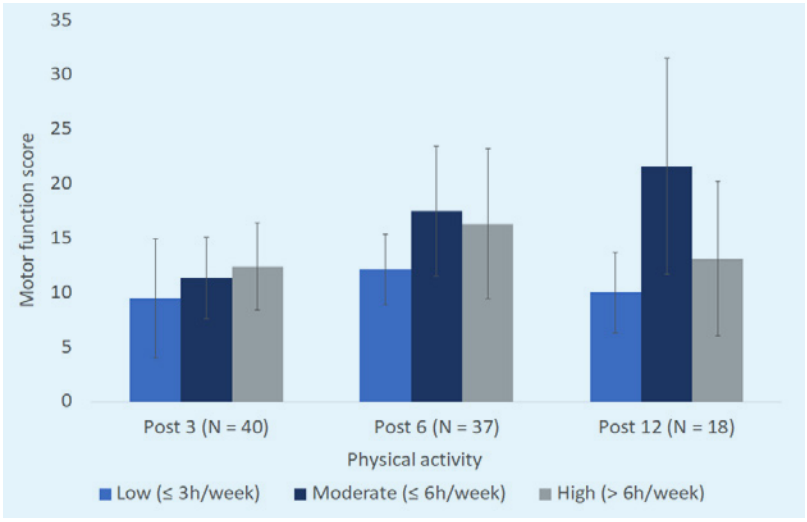

Figure 2

Motor function score as a function of physical activity to the different time points; Post 3: F(2,37)=1.419, p=.255; Post 6: F(2,34)=2.306, p=.115; Post 12: F(2,15)=13.452, p=.058.

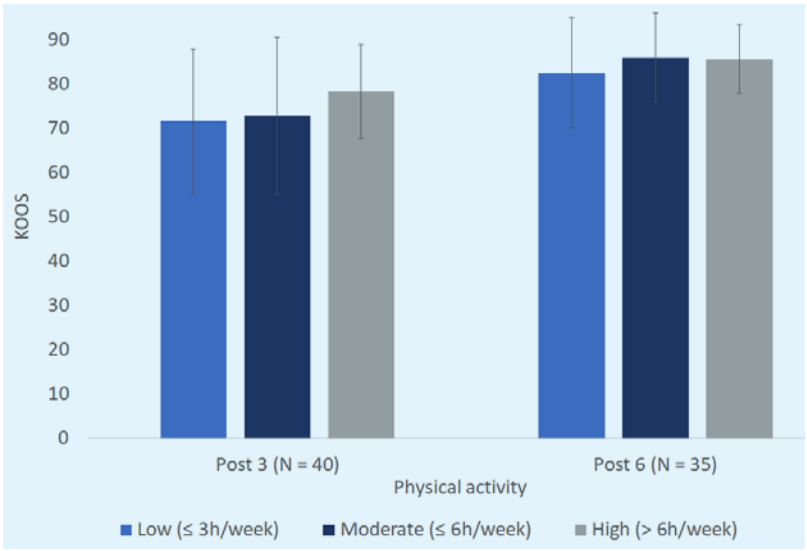

Figure 3

Knee functionality as a function of physical activity to the different time points Post 3: F(2,39)=.772, p=.469; Post 6: F(2,32)=.397, p=.676.

Influence of Physical Activity on Motor Competence and Knee Function

There are no significant differences between low, moderate and high activity subjects in terms of MS at any time point (figure 2). There is a tendency for more active subjects to achieve a higher MS than less active subjects at all time points. At post 6 and post 12, moderately active subjects achieve the highest score.

Especially at post 3, high activity subjects show a better KF compared to low activity subjects (figure 3). The differences are not significant. The largest difference between low and high activity subjects is observed in the Sport and Play subscale at both time points (post 3: Mlow activity=50.91±36.44, Mhigh activity= 69.54±26.45, F(2,39)=1.309, p=.282; post 6: Mlow activity= 69.73±22.46; Mhigh activity=80.36±16.22, F(2,34)=1.263, p=.297). In addition, there are large differences in Symptoms at post 6 (Mlow activity=81.32±14.74, Mhigh activity=90.48±10.48). The differences are not significant.

Influence of BMI on Motor Competence and Knee Functionality

In terms of BMI, a mean BMI is associated with a higher motor level at all time points (figure 4). The difference between the individual BMI groups is significant for post 3. The effect size is η^2=.200 and corresponds to a large effect.

Subjects with a low BMI benefit in terms of KF. At post 6 this difference is significant (p=.032, η^2=.194), which can be explained by the differences in the Sport and Play (p=.014, η^2=.072) and QOL (p=.010, η^2=.252) subscales (table 2). The differences between intermediate and high BMI behave inconspicuously.

Gender Differences in Motor Competence and Knee Functionality

In terms of MS, there are no significant differences between boys and girls at any time point (figure 5). Figure 5 shows a trend towards better motor development in girls at post 12.

In terms of KF the differences between boys and girls are significant in the subscales Symptoms (p=.013, d=.853) and Pain (p<.001, d=.871) (table 3). The total knee score is also better in boys than in girls at baseline. After 6 months, the differences are balanced. Girls then score higher, except in the Pain subscale. The greatest deficits at post 6 are found in girls and boys in the Sport and Play and QOL subscales.

Discussion

The aim of the study was to assess the current standard in rehabilitation after ACL rupture in children and adolescents and to quantify the dependence of rehabilitation outcomes on known risk factors.

The results show that there are large inter-individual differences in the functional outcomes as well as a large discrepancy between rehabilitation status and return to PE. Knee functionality (KF) improved at post 6, accompanied by an increase in the motor function score (MS), making daily activities ›

Table 2

Knee functionality as a function of BMI with Mean±SD.

		LOW (≤21,2)	INTERMEDIATE (≤26,2)	HIGH (>26,2)	STATISTICAL SIGNIFICANCE
Post 3	Symptoms	85.84±13.41	75.71±15.52	74.45±23.18	F(2,39)=1.736, p=.190
	Pain	84.79±15.71	79.55±16.99	83.28±16.08	F(2,39)=.455, p=.638
	Activities of Daily Living	95.36±5.88	91.94±8.62	88.64±19.57	F(2,39)=.976, p=.386
	Sport & Play	68.47±29.59	60.09±21.49	52.61±38.36	F(2,39)=.934, p=.402
	Quality of Life	60.12±23.33	53.61±17.74	59.29±19.33	F(2,39)=.446, p=.644
	Total score	78.92±14.34	72.18±12.56	71.65±18.53	F(2,39)=.989, p=.381
Post 6	Symptoms	88.69±12.45	85.71±12.92	85.39±11.89	F(2,32)=.252, p=.779
	Pain	95.76±7.37	87.50±10.83	92.00±6.35	F(2,32)=2.868, p=.071
	Activities of Daily Living	98.67±2.05	95.08±8.55	97.21±3.98	F(2,32)=1.246, p=.301
	Sport & Play	87.90±15.53	75.00±15.61	65.42±20.83	F(2,32)=4.857, p=.014
	Quality of Life	82.15±11.96	66.67±14.65	64.02±16.59	F(2,32)=5.393, p=.010
	Total score	90.63±7.79	81.99±10.47	80.81±9.70	F(2,32)=3.850, p=.032

Table 3

Knee functionality as a function of sex with Mean±SD.

		MALE	FEMALE	STATISTICAL SIGNIFICANCE
Post 3 (N=42)	Symptoms	88.27±13.968	73.92±18.037	T(40)=2.606, p=.013
	Pain	90.59±9.630	78.38±15.713	T(38.121)=3.108, p<.001
	Activities of Daily Living	96.59±8.303	89.79±13.697	T(40)=1.702, p=.096
	Sport & Play	62.83±34.508	59.43±28.296	T(40)=.341, p=.735
	Quality of Life	64.88±22.212	53.87±18.035	T(40)=1.726, p=.092
	Total score	80.63±13.785	71.08±15.073	T(40)=1.990, p=.053
Post 6 (N=35)	Symptoms	85.20±14.816	87.59±10.327	T(33)=-.561, p=.578
	Pain	93.38±9.465	90.66±8.580	T(33)=.882, p=.384
	Activities of Daily Living	96.75±8.009	97.13±3.550	T(33)=-.191, p=.849
	Sport & Play	75.85±23.641	76.79±16.327	T(33)=-.139, p=.890
	Quality of Life	69.52±18.945	72.22±14.514	T(33)=-.477, p=.637
	Total score	84.14±12.268	84.88±8.743	T(33)=-.207, p=.837

possible again. Nevertheless, none of the test persons shows a stable leg axis after 3, 6 and 12 months, because none of them completed all individual tests in the necessary quality. Despite severe performance deficits, 49% of the subjects participate in PE as early as six months after treatment. Given the complex movement requirements in PE and the severely limited knee joint stability, the premature return carries a very high risk of re-rupture or severe knee injuries of the contralateral side. Beischer et al. (2020) refer to a significantly increased risk of re-rupture when returning to sports before the ninth postoperative month (3).

Related to the motor competence of the subjects, our study shows that an intermediate BMI is associated with a higher MS. This could be due to muscular protection, which may not be fully ensured at low and high BMI. Biological age could provide information about a possibly retarded development. Low body weight and BMI reduce the risk of intra-articular pathologies in the knee joint and improve long-term functional outcomes after ACL reconstruction (5). Therefore, low and intermediate BMI have a positive effect on the development of mobility-related functional abilities (15). Obesity correlated with lower mobilization progress (15). Our results show that gender has no influence on motor development during rehabilitation.

Furthermore, we could show that more active subjects show a higher MS than less active subjects. This is in line with the results of Alshewaier et al. (2017), who showed in their review that a higher preoperative motor level positively influences the postoperative genesis and functional outcome of patients (children and adults) with ACL injury (1). However, the World Health Organization's physical activity recommendations for children and adolescents are increasingly rarely achieved (21). Sports clubs can help to improve physical performance and resilience (12). However, club memberships also decline in these vulnerable age phases (8). Therefore, in terms of prevention and successful rehabilitation, an increase in physical activity in children and adolescents must be aimed for. At the same time, a prevention program to stabilize the leg axes should be used to protect the knee joint. Such programs already exist in popular and competitive sports (e.g. FIFA11+ (23)). To enable all children to grow up healthy and to live a healthy life in old age, prevention programs should also be adapted and implemented for PE in the future. In Canada, the effectiveness of a

prevention program at a junior high school has already been demonstrated (10). To this end, it is important to sensitize sports instructors to the problem of reintegration into physical education after a severe knee injury, to the effect that medical clearance for PE by no means implies that the affected person is fully able to exercise. In addition, physicians should also be trained in an assessment of fitness for PE based on functional parameters.

Children with high activity level and low BMI benefit in terms of KF. The male subjects show good KF already at post 3 compared to the female subjects who only reach the level of the boys at post 6. Boys experience significantly less symptoms and pain than girls.

In adults, an active lifestyle leads to a higher pain tolerance (24) and in rehabilitation after meniscal surgery also to a higher KOOS (18). According to our study, the results of Everhart et al. (2020) can be transferred to children and adolescents with ACL rupture (11).

The children feel particularly limited in the area of sport and play at post 3 and 6, which could be due to the complex requirements for the knee (including jumping, twisting movements), which cannot yet be fulfilled at 6 months, as our results of the motor tests show. Other authors also show that a return to sports after 6 or 9 months is associated with deficits in biomechanical parameters (14, 2). Fear of re-injury is also considered the most common reason for post-surgery limitations (2), which could explain the low scores in the Sport and Play subscale. Psychological factors should therefore be given greater consideration in the rehabilitation of ACL ruptures.

The low quality of life of the rehabilitation patients is also striking. More active subjects are less satisfied with their quality of life than less active subjects. This can be explained by the fact that active subjects have a higher demand on their functional outcome so that they can continue their usual sporting activities after rehabilitation. For less active subjects, life satisfaction may be restored as soon as daily activities are possible.

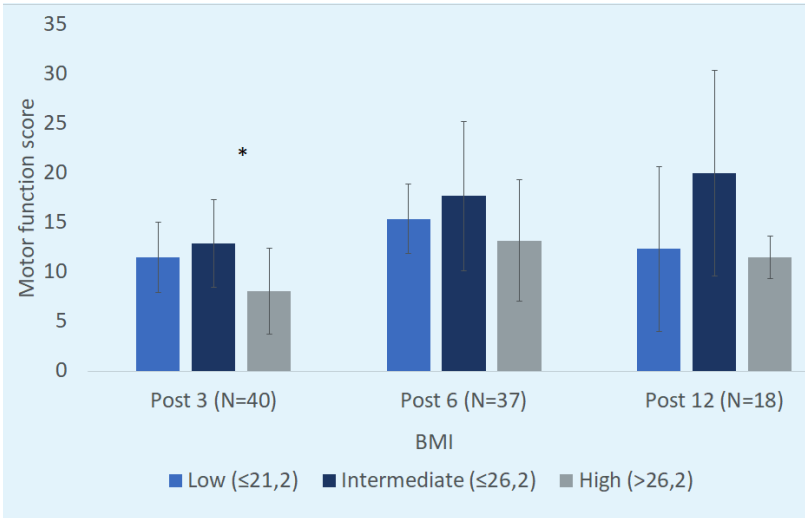

Figure 4

Motor function score as a function of BMI to the different time points; Post 3: F(2,37)=4,636; p=.016; Post 6: F(2,34)=1.673, p=.203; Post 12: F(2,15)=2.184, p=.147.

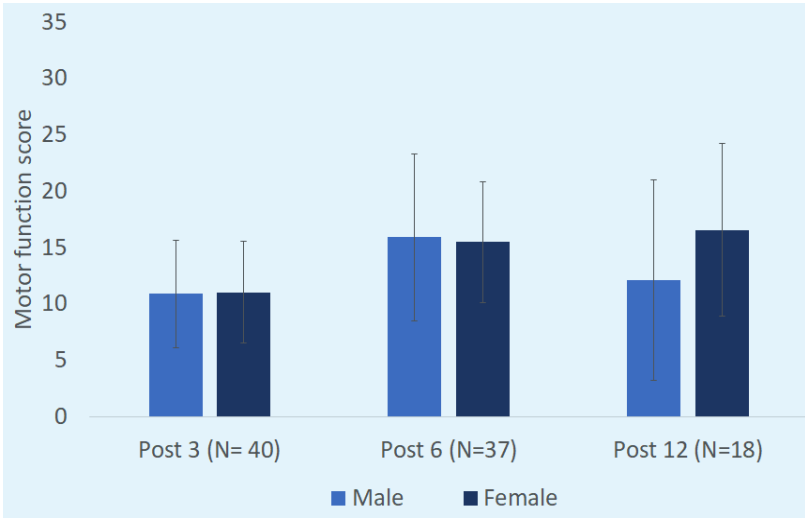

Figure 5

Motorfunction score as a function of sex to the different time points; Post 3: T(38)=-.097, p=.923; Post 6: T(35)=.194, p=.848; Post 12: T(16)=-1.149, p=.268.

The correlation of low BMI and high KF could be due to the lower external moments that occur with low body mass.

KF is significantly better in boys than in girls at baseline (significant differences in the subscales Symptoms and Pain (1)). This could be because girls are more vulnerable to pain than boys (26). Therefore, the management of pain should be considered especially for girls in the early rehabilitation phase. After 6 months, the differences are equalized. Girls then score higher, except in the Pain subscale. The better KF could subsequently lead to a higher MS.

Conclusions

Overall, the rehabilitation process after ACL rupture in children and adolescents is highly individualized and characterized by the following aspects:

- Children with a low BMI and a lack of muscular protection of the knee joint should be given more time for rehabilitation, especially in the phase of body length growth.
- Physically active children with an intermediate BMI have the best functional outcome. However, after 6 months, training progress stagnates in rehabilitation, so they may need to be transferred to other motivational structures (e.g. clubs) to provide effective training stimuli.
- Pain management should be considered, especially for girls, in the early rehabilitation phase.

To increase compliance, rehabilitation should be multimodal and involve all actors (physician, rehabilitation manager, physio/sports therapist, sports teacher, guardian, patient). To effectively manage the process of rehabilitation and return to PE, individualized information is necessary in the multimodal setting. To this end, all those involved must be sensitized and trained.

Conflict of Interest

This research was co-funded by Unfallkasse Sachsen. The funder had no role in the design of the study, in the analyses or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

References

(1) **ALSHEWAIER S, YEOWELL G, FATOYE F.** The effectiveness of pre-operative exercise physiotherapy rehabilitation on the outcomes of treatment following anterior cruciate ligament injury: a systematic review. Clin Rehabil. 2017; 31: 34-44. doi:10.1177/0269215516628617

(2) **ARDERN CL, WEBSTER KE, TAYLOR NF, FELLER JA.** Return to sport following anterior cruciate ligament reconstruction surgery: a systematic review and meta-analysis of the state of play. Br J Sports Med. 2011; 45: 596-606. doi:10.1136/bjsm.2010.076364

(3) **BEISCHER S, GUSTAVSSON L, SENORSKI EH, KARLSSON J, THOMEÉ C, SAMUELSSON K, THOMEÉ R.** Young Athletes Who Return to Sport Before 9 Months After Anterior Cruciate Ligament Reconstruction Have a Rate of New Injury 7 Times That of Those Who Delay Return. J Orthop Sports Phys Ther. 2020; 50: 83-90. doi:10.2519/jospt.2020.9071

(4) **BOURKE HE, SALMON LJ, WALLER A, PATTERSON V, PINCZEWSKI LA.** Survival of the Anterior Cruciate Ligament Graft and the Contralateral ACL at a Minimum of 15 Years. Am J Sports Med. 2012; 40: 1985-1992. doi:10.1177/0363546512454414

(5) **BOWERS AL, SPINDLER KP, MCCARTY EC, ARRIGAIN S.** Height, weight, and BMI predict intra-articular injuries observed during ACL reconstruction: evaluation of 456 cases from a prospective ACL database. Clin J Sport Med. 2005; 15: 9-13. doi:10.1097/00042752-200501000-00003

(6) **COHEN J.** Statistical power analysis for the behavioral sciences (2. Auflage). Hillsdale, 1988, NJ: Erlbaum.

(7) **DEUTSCHE GESELLSCHAFT FÜR UNFALLCHIRURGIE (DGU).** DGU-Leitlinie 012-005, Vordere Kreuzbandruptur 2018. https: // www.awmf.org/uploads/tx_szleitlinien/012-005l_S1_Vordere_Kreuzbandruptur_2019-02.pdf [15 January 2022].

(8) **DEUTSCHER OLYMPISCHER SPORTBUND E.V. (DOSB).** Bestandserhebung 2021. https: //de.statista.com/statistik/daten/studie/37043/umfrage/sportvereine-mitgliedschaft-nach-altersgruppen-und-geschlecht/ [14 January 2022].

(9) **DIETVORST M, BRZOSKOWSKI MH, VAN DER STEEN M, DELVAUX E, JANSSEN RPA, VAN MELICK N.** Limited evidence for return to sport testing after ACL reconstruction in children and adolescents under 16 years: a scoping review. J Exp Orthop. 2020; 7: 83. doi:10.1186/s40634-020-00298-8

(10) **EMERY CA, VAN DEN BERG C, RICHMOND SA, PALACIOS-DERFLINGHER L, MCKAY CD, DOYLE-BAKER PK, MCKINLAY M, TOOMEY CM, NETTEL-AGUIRRE A, VERHAGEN E, BELTON K, MACPHERSON A, HAGEL BE.** Implementing a junior high school-based programme to reduce sports injuries through neuromuscular training (iSPRINT): a cluster randomised controlled trial (RCT). Br J Sports Med. 2020; 54: 913-919. doi:10.1136/bjsports-2019-101117

(11) **EVERHART JS, MAGNUSSEN RA, POLAND S, DIBARTOLA AC, BLACKWELL R, KIM W, KAEDING CC, FLANIGAN DC.** Meniscus repair five-year results are influenced by patient pre-injury activity level but not age group. Knee. 2020; 27: 157-164. doi:10.1016/j.knee.2019.11.005

(12) **GRUPPE O.** Gesundheitskultur im Turn- und Sportverein: Sporttreiben zwischen Wohlbefinden, Gesundheit und Spaß. In Gesundheitssport im Verein. 1st ed., Uhlig T, Ed., Hofmann: Schorndorf, Deutschland. 1995; 2: 20-30.

(13) **WITT M, JANKE J, BRUNN S, JAHN C, BROCK D.** Evaluation des Rehabilitationsprozesses nach ACL-Ruptur im Kindes- und Jugendalter. Dtsch Z Sportmed. 2021; 72: 128.

(14) **KELLER M, KURZ E, SCHMIDTLEIN O.** Interdisziplinäre Beurteilungskriterien für die Rehabilitation nach Verletzungen an der unteren Extremität: Ein funktionsbasierter Return to Activity Algorithmus. Phys Med Rehabilmed Kurortmed. 2016; 26: 137-148. doi:10.1055/s-0042-106599

(15) **LIEBL ME, SCHWEDTKE C, SCHRÖDER I, ELMER N, REISSHAUER A.** Der Einfluss des Body Mass Index auf die Mobilisation von Patienten in der Frührehabilitation. Phys Med Rehabilmed Kurortmed. 2018; 28: 114-119. doi:10.1055/s-0043-124373

(16) **MOUSTAKI M, PITSOS N, DALAMAGA M, DESSYPRIS N, PETRIDOU E.** Home and leisure activities and childhood knee injuries. Injury. 2005; 36: 644-650. doi:10.1016/j.injury.2004.07.051

(17) **MYKLEBUST G, MAEHLUM S, HOLM I.** A prospective cohort study of anterior cruciate ligament injuries in elite Norwegian team handball. Scand J Med Sci Sports. 1998; 8: 149-153. doi:10.1111/j.1600-0838.1998.tb00185.x

(18) **OBERHOFER E.** Heilung nach Meniskusoperation ist keine Frage des Alters. Orthopädie & Rheuma. 2020; 23: 22. doi:10.1007/s15002-020-2801-2

(19) **ÖRTQVIST M, ROOS EM, BROSTRÖM EW, JANARV PM, IVERSEN MD.** Development of the Knee Injury and Osteoarthritis Outcome Score for Children (KOOS-Child). Acta Orthop. 2012; 83: 666-673. doi:10.3109/17453674.2012.747921

(20) **PRALL WC, MAYR HO.** Läsionen des vorderen Kreuzbandes bei Kindern und Jugendlichen. Orthopädie & Rheuma. 2018; 21: 40-43. doi:10.1007/s15002-018-1444-z

(21) **KOCH-INSTITUT R.** Körperliche Aktivität von Kindern und Jugendlichen in Deutschland – Querschnittsergebnisse aus KiGGS Welle 2 und Trends. Journal of Health Monitoring. 2018; 3: 24-31. doi:10.17886/RKI-GBE-2018-006.2

(22) **SCHMIDT S, WILL N, HENN A, REIMERS A, WOLL A.** Der Motorik-Modul Aktivitätsfragebogen MoMo-AFB: Leitfaden zur Anwendung und Auswertung. KIT Scientific Working Papers 2016: 53: 1-72. doi:10.5445/IR/1000062199

(23) **SILVERS-GRANELLI H, MANDELBAUM B, ADENIJI O, INSLER S, BIZZINI M, POHLIG R, JUNGE A, SNYDER-MACKLER L, DVORAK J.** Efficacy of the FIFA 11+ Injury Prevention Program in the Collegiate Male Soccer Player. Am J Sports Med. 2015; 43: 2628-2637. doi:10.1177/0363546515602009

(24) **TESARZ J, SCHUSTER AK, HARTMANN M, GERHARDT A, EICH W.** Pain perception in athletes compared to normally active controls: A systematic review with meta-analysis. Pain. 2012; 153: 1253-1262. doi:10.1016/j.pain.2012.03.005

(25) **THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS BOARD OF DIRECTORS.** Management of Anterior Cruciate Ligament Injuries Evidence-Based Clinical Practice Guideline 2014. https: //www.aaos.org/globalassets/quality-and-practice-resources/anterior-cruciate-ligament-injuries/anterior-cruciate-ligament-injuries-clinical-practice-guideline-4-24-19.pdf [15 January 2022].

(26) **VIERHAUS M, LOHAUS A, SCHMITZ AK.** Sex, gender, coping, and self-efficacy: Mediation of sex differences in pain perception in children and adolescents. Eur J Pain. 2011; 15: 621.e1-8. doi:10.1016/j.ejpain.2010.11.003