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The ESSKA paediatric anterior cruciate ligament monitoring initiative

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Abstract
Purpose To survey and describe the treatment of paediatric anterior cruciate ligament (ACL) injuries performed by orthopaedic surgeons affiliated with the European Society for Sports Traumatology, Knee Surgery and Arthroscopy (ESSKA).
Methods A closed e-survey was submitted to all registered members and affiliates of ESSKA in July 2013. All recipients were invited to participate in the survey by answering 34 questions online. The list of potential respondents was extracted from the ESSKA office database.
Results Invitation was sent to 2236 ESSKA members and affiliates, and received 491 (22 %) unique responses. Among the respondents, 445 (91 %) were orthopaedic surgeons, with 354 (72 %) stating that they were involved in treatment of paediatric ACL injuries. The main findings were that there are substantial differences with regard to preferred treatment algorithms, surgical techniques and long-term follow-up procedures. The summed estimate of skeletally immature children with ACL injury seen by the responders in 2012 was minimum 1923 individuals, and a minimum of 102 clinically relevant post-operative growth disturbances were registered.
Conclusion The present survey documents that the incidences of paediatric ACL injuries and idiopathic growth disturbances may be higher than previously estimated. Treatment algorithms and surgical techniques are highly diverse, and consensus could not be identified. It is worrying that only half the surgeons reported to follow-up children until skeletal maturity after surgical treatment. The results of this survey highlight the importance of international multicentre studies on paediatric ACL treatment and the development of an outcome registry to enable prospective data collections.
Level of evidence IV.

Keywords ACL · Paediatric · Surgery · Treatment · Growth disturbances · Rehabilitation

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Introduction

Instability and functional impairments following ACL tears in skeletally immature children have been increasingly recognized, and there have been an increasing number of publications on treatment of paediatric ACL injuries through

the past decade [4, 7, 26, 34]. Intrasubstance ACL ruptures are worrisome leading to impaired participation in desired activities, and the potential long-term health effects of early osteoarthritis [28]. Recent literature suggests an increased incidence of ACL injuries in children and that the perceived increased occurrence may be due to higher participation and early specialization in sports [1, 28]. However, no epidemiological studies are available with historical or new data to support the perceived increased incidence of paediatric ACL injuries, and thus, it may just as well be caused by increased awareness and advances in diagnostic methods.

The open growth plates on both sides of the knee joint warrant particular caution before surgical interventions with ACL reconstruction are performed in children [3, 23]. Treatment algorithms for ACL ruptures in skeletally immature children varying around the world and the optimal treatment of these injuries are still debated [6, 17, 40, 45]. Consequently, one of three different treatment algorithms is traditionally recommended to skeletally immature children after ACL injury [12, 22, 33]: a transphyseal surgical reconstruction, a physeal-sparing ACL reconstruction, or non-operative treatment with active rehabilitation and a possible delayed ACL reconstruction. Unfortunately, the methodological quality in research on treatment of ACL injuries in the younger populations has been documented to be poor with low Coleman Methodology scores, without adequately sized studies and use of prospective study designs [35]. Specific decision criteria to advise which of the algorithms a child should be recommended have not been established, and treatment decisions are traditionally based on the experiences and practice of the individual orthopaedic surgeon or institution.

The development of new surgical techniques with assumed lower risk of idiopatic growth disturbances has prompted many orthopaedic surgeons to advocate early ACL reconstructions also in children with open growth plates [1, 29]. However, there is still a concern that surgical interventions with drilling through and/or near the epiphyseal growth plates may injure the physis and result in growth disturbances. Previous publications have described several cases following different surgical techniques [5, 23, 42]. Furthermore, the maturation and adaptation of the graft within the growing knee is uncertain and concerns have been raised proposing an increased risk of graft rupture in adulthood due to thinner and weaker grafts [4, 39]. Additionally, the incidence of secondary meniscus injuries following non-operative treatment is proposed to be high in children [1, 17, 28], although it has not been established whether early or delayed surgical intervention affect the total number of meniscus injuries [13, 36].

To provide updated knowledge on the current treatments for paediatric ACL injuries, the purpose of this study was to survey and describe the treatment of paediatric ACL injuries performed by orthopaedic surgeons affiliated with the European Society for Sports Traumatology, Knee Surgery and Arthroscopy (ESSKA).

Materials and methods

A closed e-survey was submitted to all registered members and affiliates of ESSKA at July 1, 2013. All recipients were invited through their registered email address to participate in the survey by answering 34 questions in an online survey. The list of potential respondents was extracted from the ESSKA office database in Luxembourg. One reminder was sent July 15, 2013 to the respondents who had not submitted their answer following the first invitation. The survey did not collect sensitive data, and no approval from the medical ethical committee was needed.

The online registration was carried out using an online survey tool (Questback V. 9.6, Questback AS, Oslo, Norway). The survey tool had previously been successfully used by our research group [16, 34], and the project manager (HM) had experience with the method. The invitation email included information about the purpose of the study and a link to the closed online registration form where the responses were entered and automatically captured. The survey was voluntary, and no incentives were offered for participation. All communication through the registration was encrypted. The respondents consented to participation in the study and the subsequent publication of anonymous data when they followed the link into the online registration tool. Each invitation was unique, and the investigation closed for the unique link when the answers were submitted to prevent multiple entries from the same individual. All responses were automatically registered in a secure database linked to each respondents email address, and they were accessible only for the project manager who extracted the data anonymously for analysis.

The survey content was developed by the project group (HM, LE and RS), and the checklist for reporting results of internet e-surveys (CHERRIES) [10] was consulted during the development phase. The questions were tested for content validity and refined in a meeting with an invited expert group of orthopaedic surgeons with extensive experience in treatment of paediatric ACL injuries at the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) conference in Toronto, Canada, in May 2013. The survey included 30 items (Appendix A) and adaptive questioning was used to reduce the number and complexity of the questions. Thus, a respondent within the target population of surgeons involved in treatment of paediatric ACL injuries would need 10–15 min to fulfil the questionnaire, while a respondent without involvement in

Table 1 Summary describing the respondents' professional experience

	Yes	No
Are you an orthopaedic surgeon? ($n = 491$)	445 (91 %)	46
Do you perform adult ACL reconstructions? ($n = 491$)	426 (87 %)	65
Do you treat paediatric ACL injuries? ($n = 491$)	354 (72 %)	137
Do you perform paediatric ACL reconstructions yourself? ($n = 354$)	304 (86 %)	50

paediatric ACLs would finish in 1 min. The possibility of reviewing and changing answers was available with a Back button; however, the link and questionnaire were closed and no changes were possible after submission. The questions were related to the respondents' professional experience with treatments and results from paediatric ACL injuries, preferred treatment algorithms, details on surgical preferences and technique, rehabilitation and follow-up procedures. The specific questions (Appendix A) and the distribution of responses (Appendix B) are available in online appendix. Data analysis was performed on descriptive parameters extracted from the online data repository.

Results

An invitation to participate in the study was sent to 2236 ESSKA members and affiliates, and received 491 (22 %) unique responses. Fourteen (0.01 %) invitees declined participation. Forty-five per cent of the responses (221 out of 491) were registered following the initial invitation. Among the respondents, 445 (91 %) were orthopaedic surgeons, with 354 (72 %) stating that they were involved in treatment of paediatric ACL injuries. The experience of the orthopaedic surgeons performing adult ACL reconstructions was high with 398 (89 %) doing more than 10 per year. An overview of the respondent demographics is provided in Table 1.

Among the respondents involved in treatment of paediatric ACL injuries, 192 (54 %) reported that they had seen more than six injuries during 2012. In total, the number of paediatric ACL injuries seen by study participants in 2012 was at least 1923.

The majority (59 %) of participants stated that they preferred a surgical treatment algorithm for paediatric ACL injuries, and hamstring tendon autograft was the preferred choice for 91 % of the surgeons performing paediatric ACL reconstructions. Transphyseal surgical techniques were most commonly reported for both the femoral (67 %) and tibial (91 %) approach. A majority (62 %) preferred drilling of the femoral tunnel through an anteromedial portal. Extracortical graft fixation with a button was most common on the femoral side (78 %), while the fixation techniques were more varied on the tibial side (Fig. 1).

Forty-eight (14 %) participants reported to have seen clinical relevant growth disturbances after paediatric ACL reconstructions in the past, giving a total number of observed growth disturbances of at least 102. Corresponding numbers for non-clinical relevant growth disturbances were minimum 196 observations. About half of the participants (53 %) reported that they performed skeletal age determinations before deciding on performing surgical treatment. Forty-two per cent administered long standing radiographs to evaluate skeletal growth after surgical

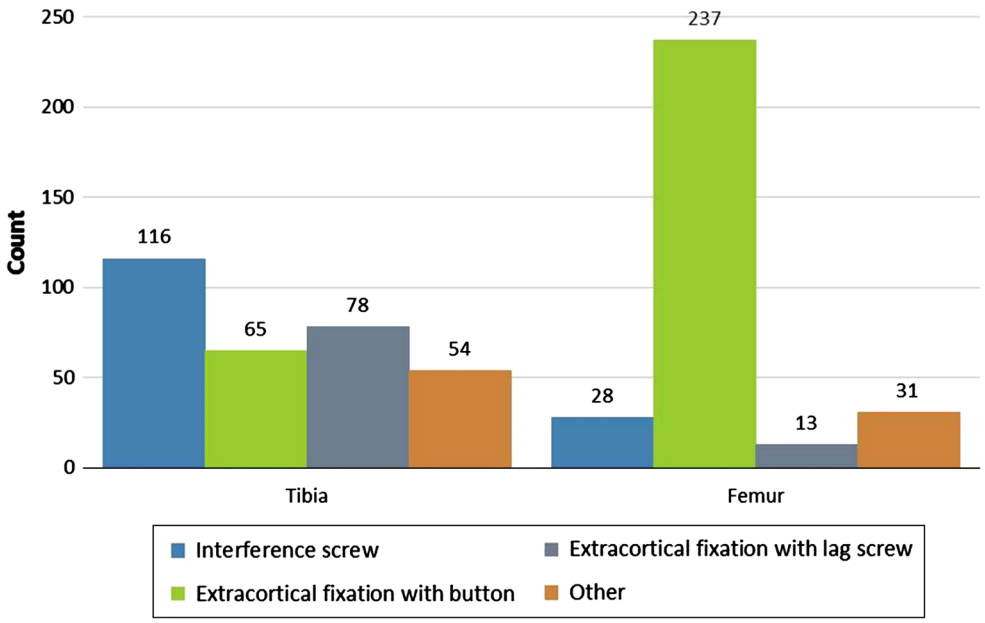

Fig. 1 Distribution of participants preferred method for tibial and femoral graft fixation

treatment, while 36 % used other methods and 21 % did not perform post-surgical measures of skeletal growth. The majority (83 %) recommended rehabilitation before surgical treatment, usually supervised by a physiotherapist. Post-surgical restrictions with bracing were recommended by 55 %.

The most common reasons reported for graft failures were new trauma (49 %), tunnel positioning (28 %), and stretching of the graft (14 %). Fifty-one per cent of the surgeons did not follow up their operated patients until the end of bone growth; 6 % ended the follow-up after 6 months, 4 % after 9 months, 29 % after 1 year and 12 % at the time of return to sports.

All participants used patient-reported outcome measures (PROMs) to evaluate knee function, and the new child friendly questionnaires Knee injury and Osteoarthritis Outcome Score for Children (KOOS-Child) [37] and the paediatric International Knee Documentation Committee Subjective Knee Form (Pedi-IKDC) [24] were used by 14 and 15 %, respectively. The three most important criteria for success after surgical treatment were reported to be the Lachman test (83 %), the pivot shift test (79 %) and returning to sport (74 %), while corresponding criteria for non-operative treatment were absence of giving way episodes (81 %), returning to sport (62 %) and PROMs (53 %). The three most important criteria for allowing return to sport were clinical examination (87 %), time from surgery/injury (75 %) and muscle strength measurements (68 %).

Discussion

The most important finding of the present study was that there are substantial differences with regard to preferred treatment algorithms and long-term follow-up procedures among orthopaedic surgeons regarding the treatment of paediatric ACL injuries. Half of the respondents performed assessment of skeletal age prior to surgical treatment, and only 43 % reported follow-up until skeletal maturity. The results describe the current practice for treatment of ACL injuries in skeletally immature children among members and affiliates of ESSKA. Further, the summed estimate of children with ACL injury seen by the responders in 2012 were high ($n = 1923$), and the registration of minimum 102 clinically relevant post-operative growth disturbances is worrying.

A considerable strength of the survey is the unique contribution from 354 individuals who are active health care providers for this population. Among these, 304 reported to perform paediatric ACL reconstructions on a regular basis. Kocher et al. [23] performed a comparable survey in 2002, in which they surveyed members of The Herodicus Society and The ACL Study Group regarding their experience with the management and complications of paediatric ACL injuries. Among 170 invited orthopaedic surgeons, 122 responded that they were treating paediatric ACL injured patients. The results of the present survey indicate that the proportion of surgeons who advocate initial operative treatment is near doubled since 2002 (59 vs 34 %). Reasons for this increase may be the refinement of surgical techniques and a stronger belief in beneficial results from surgical treatments. However, we are not aware of any studies that have compared the outcomes of surgical treatment between the past and the present. Likewise, no studies with reasonable methodological quality have investigated the outcomes of surgical versus non-operative treatment in the paediatric population [33, 35]. However, primary active rehabilitation without surgical reconstruction has been documented to give favourable functional outcomes for a majority of children who have undergone supervised active rehabilitation programmes [34]. None of the surveys probed the rationale for choice of treatment, and other reasons such as increased availability through health care systems and insurance, patient and parent expectations, and surgeon experience may perhaps be influential factors. In other words, the line of distinction between surgically and non-operatively treated children with ACL injuries will need to be refined in the future.

The present survey documents a strong preference (91 %) of the hamstring tendon autograft for paediatric ACL reconstructions, which is probably due to previous reports of a lower risk of growth disturbances using soft tissue grafts [23]. Kocher et al. also reported a majority of hamstring autograft (70 %), but they also identified placement of the bone plug of the bone–patellar tendon–bone (BPTB) graft across the physis as the most common reason for the 15 growth disturbances reported in the survey. This finding is probably one of the main reasons for the abandonment of the BPTB graft in paediatric ACL reconstructive surgery as only 2 (0.01 %) out of 304 surgeons in the present study reported preference of the BPTB graft. A limitation regarding the question of BPTB graft use was related to the fact that the questionnaire did not specify whether patellar tendon grafts were used with or without bone blocks as specified in the so-called Clocheville technique [41]. Interestingly, the use of allograft appears to have increased as 5 % reported this to be their preferred graft in 2012 compared with 1 % in 2002, despite the fact that allografts have shown inferior results in terms of re-tear rates in young patients [18, 21]. The quadriceps tendon (1.6 %) plays only a minor role in the graft choice of primary paediatric ACL reconstruction [14].

Surgical reconstruction of the ACL in a skeletally immature patient is advocated to provide ligamentous knee joint stability, and to potentially protect the menisci from subsequent injury. However, surgical treatment may also damage

the epiphyseal growth plates and result in various growth disturbances [3, 5, 23]. Thus, different approaches and techniques for tunnel drilling and graft fixation have been proposed to decrease the risk of idiopathic growth disturbances. In the tibia, the transphyseal drilling technique was reported to be favoured by 91 % of the surgeons, which is somewhat higher than reported by Kocher et al. (79 %). The proportion of surgeons who preferred transphyseal drilling in the femur was lower (67 %) compared with the tibia, and similar to the 2002 survey (68 %). The majority (62 %) of respondents reported that they drill the femoral tunnel through an anteromedial portal, and the results suggest that extracortical fixation with button was the preferred fixation method (78 %) on the femoral side of the knee joint. The tibial side graft fixation techniques were more diverse, although the design of the present survey does not detect the reasons for this diversity. Despite the fact that physeal-sparing drilling techniques have been developed with the intention of reducing the risk of growth disturbances, a meta-analysis by Frosch et al. [12] found that the rate of growth disturbances was higher in series using physeal-sparing reconstructions compared with studies using transphyseal reconstructions. The reasons for this finding are not clear, but it may be related to a greater level of difficulty of the physeal-sparing procedure requiring precise fluoroscopy-guided tunnel drilling as well as the greater potential risk of the eccentrically placed femoral tunnel as compared with the tibial tunnel which crosses the physeal plate in its centre [43].

Fifty-three per cent reported that they performed systematic skeletal age determination measures before deciding on surgical treatment for kids with ACL injury, with radiograph of the wrist (38 %) and radiograph of the knee (37 %) as the most common methods used (Appendix B). The reasons for not performing skeletal age determinations were not questioned in the survey; however, we find this result alarming due to the known risks related to surgical interventions through and nearby epiphyseal growth plates. Additionally, if the skeletal integrity is not documented prior to surgery, the possibility of accurate long-term assessment of malalignment is severely compromised. Further, almost one in five surgeons used MRI of the knee to evaluate skeletal age, although this method has not been validated for this purpose [9]. In 2012, Moksnes et al. [35] found that half of the included studies in a systematic review reported using standing longitudinal radiographs to evaluate lower limb alignment at skeletal maturity. This method is a requirement for the assessment of growth disturbances [44], and the proportion of respondents who reported adequate radiological follow-up of skeletal growth in the survey was as low as 42 %. Furthermore, only 49 % reported that they followed up operated children until the end of bone growth. The respondents of the survey reported to have seen a minimum of 102 clinically relevant growth disturbances, which is the highest number reported in the literature so far. However, the limit for what degree of frontal plane axial deformity that should be regarded clinically relevant has not previously been defined. The results of the present survey show that 85 % of the respondents regard a deviation of <3° as clinically non-relevant, although this should be investigated further in a designated study.

When surgical treatment of paediatric ACL injuries is performed, it is essential that suitable measures of skeletal development are included in both pre-surgical and post-surgical assessments. Furthermore, maturation and adaptation of the graft during the remaining skeletal growth is still unknown, and different authors have discussed the possibility of an increased risk of re-injuries in adulthood due to impaired biomechanical properties [2, 7, 30]. Park et al. [39] have suggested that the youngest patients are likely to have a graft with a smaller diameter in adulthood, and even though longitudinal growth of the graft has been demonstrated, the lack of increase in the width may be problematic in the long term [2]. Two recent publications from Calvo et al. [4] and Demange et al. [7] with long-term follow-up of transphyseal and non-anatomical ACL reconstructions, respectively, reported high incidences (15 and 25 %) of graft ruptures. Traumatic events were identified in three of four graft ruptures that correspond well to the experiences of the majority of respondents in the survey. High activity levels and early specialization may predispose children and adolescents to early failure [27, 32]. Thus, one must consider the possibility that a thinner graft through adolescent into adulthood may predispose young patients to re-injuries following lower energy traumas than adult graft sizes.

The importance of structured rehabilitation following an ACL injury or ACL reconstruction is undisputed [15, 25]. Pre-operative rehabilitation has become the norm to optimize the possibility of a successful outcome after ACL reconstructions [8], and high-quality studies suggest that performing structured post-injury rehabilitation will reduce the need for surgical interventions for a substantial number of ACL injured patients [11]. The results from the present survey show that the majority (83 %) of respondents encourage and perform pre-operative rehabilitation on a structured basis. The content of the rehabilitation protocols was beyond the scope of this survey, although interesting diversity was reported regarding post-operative immobilization with a knee brace. Bracing was recommended by 55 % of the surgeons who performed paediatric ACL reconstructions, although there was no consensus with regard to immobilization time. No studies have evaluated the effect of bracing on re-injuries in skeletally immature ACL reconstructed patients.

In order to assess knee function and facilitate safe return to sport, it is paramount that functional testing with valid and reliable outcome measures is performed. There is consensus that multidimensional test batteries which evaluate the different levels of function should be used [19, 31]. The present survey identified giving way episodes, return to sport and a high score on PROMs as success factors following non-operative treatment. Additionally, clinical tests were identified as important after ACL reconstruction. Interestingly, clinical examination, time from injury/surgery and muscle strength measurements were highlighted as the most important factors for advice on returning to sport. Thus, functional test batteries does not seem to be regarded essential for the assessment of knee function by orthopaedic surgeons involved in the treatment of paediatric ACL injuries. Comparably, Lynch et al. [31] investigated expert consensus of measures that define successful outcomes 1 and 2 years after adult ACL injury or reconstruction among 1779 members of international sports medicine associations. They identified five measures important for successful outcome after ACL injury or reconstruction: effusion, giving way, muscle strength, PROMs and return to sport.

Traditionally, adult PROMs such as Lysholm score with Tegner activity level, IKDC and KOOS have been used to assess knee function in paediatric patients. These questionnaires have been shown to be poorly understood by children and adolescents [20, 38], and should not be used to assess knee function in this population. Adapted questionnaires (KOOS-Child and Pedi-IKDC) with satisfactory psychometric properties have been developed, and the survey reveals a positive trend because approximately 15 % of the respondents report that they are currently using the child friendly questionnaires. This proportion may rise substantially in both the clinical setting and research due to increased familiarity in the near future.

The limitations of the present survey are related to the method of online e-surveys that often are subject to bias due to the possibility of a non-representative population of respondents. The identification and targeted invitation of ESSKA members and affiliates optimized the representative proportion in the present survey. Further, we did not implement any measures of quality assurance related to the data submitted by the respondents. This could have been done through an investigation of hospital records; however, this was beyond limits of the present project. Additionally, a test–retest reliability study providing the respondents with an identical survey would have increased the reliability of responses.

The clinical relevance of this study is foremost to increase the awareness on the diversity in the treatment of paediatric ACL injuries. Increased awareness should lead orthopaedic surgeons, physicians and physiotherapists to evaluate their clinical practice and seek evidence-based algorithms in future cases. Additionally, we hope that the survey can serve as a catalyst to future multicentre international clinical collaborations aimed at establishing evidence to develop guidelines for individualized treatment decisions.

Conclusion

The present survey documents that the incidences of paediatric ACL injuries and idiopathic growth disturbances may be higher than previously estimated. Treatment algorithms and surgical techniques are highly diverse, and consensus could not be identified. It is worrying that only half the surgeons reported to follow-up children until skeletal maturity after surgical treatment. The results of this survey highlight the importance of international multicentre studies on paediatric ACL treatment and the development of an outcome registry to enable prospective data collections. These findings may serve as a background and catalyst of future high-quality studies with adequate size, predefined treatment decision criteria and valid outcome measures.

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