Original Clinical Article

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Distal rectus femoris surgery in children with cerebral palsy: results of a Delphi consensus project

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Abstract

Purpose: The purpose of this study was for an international panel of experts to establish consensus indications for distal rectus femoris surgery in children with cerebral palsy (CP) using a modified Delphi method.

Methods: The panel used a five-level Likert scale to record agreement or disagreement with 33 statements regarding distal rectus femoris surgery. The panel responded to statements regarding general characteristics, clinical indications, computerized gait data, intraoperative techniques and outcome measures. Consensus was defined as at least 80% of responses being in the highest or lowest two of the five Likert ratings, and general agreement as 60% to 79% falling into the highest or lowest two ratings. There was no agreement if neither threshold was reached.

Results: Consensus or general agreement was reached for 17 of 33 statements (52%). There was general consensus that distal rectus femoris surgery is better for stiff knee gait than is proximal rectus femoris release. There was no consensus about whether the results of distal rectus femoris release were comparable to those following distal rectus femoris transfer. Gross Motor Function Classification System (GMFCS) level was an important factor for the panel, with the best outcomes expected in children functioning at GMFCS levels I and II. The panel also reached consensus that they do distal rectus femoris surgery less frequently than earlier in their careers, in large part reflecting the narrowing of indications for this surgery over the last decade.

Conclusion: This study can help paediatric orthopaedic surgeons optimize decision-making for, and outcomes of, distal rectus femoris surgery in children with CP.

Level of evidence: V

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Keywords: cerebral palsy; stiff knee; surgical indications; rectus femoris; consensus

Introduction

Cerebral palsy (CP) affects approximately one in 500 children and remains the most common motor disease of childhood. Recent advances in pre-, peri-, and post-natal care have not dramatically lessened the rate of CP, which currently affects > 17 million people worldwide. As lifespans have increased in people with CP, there are now more adults than children with CP, and the long-term impact of gait deviations are increasingly important.

Muscles crossing two joints have long been known to be problematic in children with CP, and the rectus femoris has frequently been implicated as a contributing factor to stiff knee gait. Stiff knee gait, typically characterized by decreased magnitude and/or delayed timing of peak knee flexion in swing phase, has been reported in > 50% of patients with CP presenting for 3DGA testing,[1] and can lead to foot drag, tripping and falling (Fig. 1). Various surgical approaches to stiff knee gait have been used over time, such as proximal or distal rectus femoris release and distal rectus femoris transfer (DRFT).[2-17] Computerized movement analysis data are often useful in the assessment of patients with stiff knee gait but there remains considerable variability in interpretation of underlying mechanisms and surgical decision-making.

The goals of this study were to use the modified Delphi technique to establish areas of consensus for the use of distal rectus femoris surgery for the treatment of children with CP and stiff knee gait, and to also identify where there is less agreement and a need for more evidence. To meet these goals, an expert panel of paediatric orthopaedic surgeons with extensive experience in both the fields of gait analysis and the treatment of children with CP responded to statements regarding surgical indications, findings on physical examination and computerized 3D gait analysis (3DGA), intraoperative methods and outcome assessment for rectus femoris surgery in ambulatory children with CP.

Materials and methods

We used modified Delphi consensus methodology to identify indications (including those for physical examination, observational gait analysis and computerized gait analysis (CGA)), intraoperative considerations and outcomes measures for distal rectus femoris surgery in ambulatory children with CP.[18-21] The research design for the group has been described previously.[20,21] Institutional review board approval for the study and from each participating member was obtained.

We convened a 16-member panel of fellowship-trained paediatric orthopaedic surgeons who had expertise in CGA and surgery for children with CP, as previously reported.[20,21] Each member of the panel had a mean of over 20 years of experience (10 to 41) in the orthopaedic care of children with CP and a mean of 19.8 years (7 to 31) of experience using CGA in children with CP. No members withdrew.

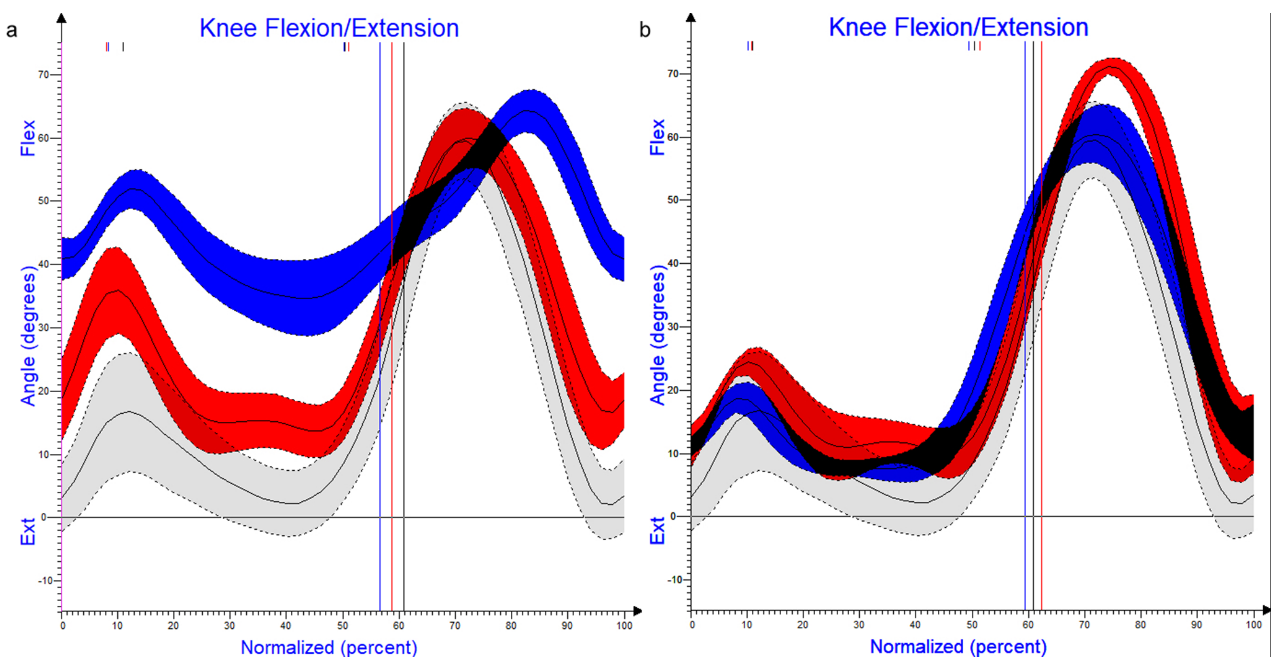

Fig. 1 a) Shows a left stiff knee preoperatively in a five-year-old male with left unilateral cerebral palsy (Gross Motor Function Classification System II) who frequently trips and falls twice daily. Grey is the plot for 'controls', red is the right leg and blue is the left in the graph. The left knee is very flexed in stance phase, has decreased slope from pre-swing through initial swing, delayed knee flexion in swing phase, and the total arc of range of movement during gait is only approximately 30°; b) shows significant postoperative improvements in left knee extension in stance phase, the slope of left knee flexion in pre-swing until initial swing, and a total arc of approximately 50° following single event multilevel surgery for which the knee surgery included left hamstring lengthening and left distal rectus femoris transfer (reproduced with permission of Children's Orthopaedic Center, Los Angeles, California).

The panel agreed to and created a structured series of statements which could be assessed using a five-point Likert scale regarding indications, intraoperative considerations, postoperative care and outcomes measures for distal rectus femoris surgery in ambulatory children with CP. The five rounds of statements and feedback were supplemented with face-to-face meetings of the expert panel as described previously,[20] and subsequently by video teleconferences due to the ongoing COVID-19 pandemic. For each round of statements, an electronic survey was created in Redcap (Version 9.1.0; Vanderbilt University, Nashville, Tennessee) and sent to all panel members.

'Consensus for agreement' occurred when at least 80% of experts selected one of the highest two responses on the five-point Likert scale (strongly agree or agree). 'Consensus for disagreement' occurred when at least 80% of the panel selected one of the lowest two responses (strongly disagree or disagree). 'General agreement' occurred when 60% to 79% chose one of the highest two responses, and 'general disagreement' if 60% to 79% chose one of the lowest two responses. There was 'no consensus' if < 60% of the panel responses were in either the highest or lowest two categories for a given statement. These thresholds were established based on historical recommendations found in the literature.[18,19] Opportunity for comments was provided for all statements.

Results

There were 33 statements regarding rectus femoris surgery which were assessed by the panel. Consensus was reached for 13 statements (12 for and one against), general agreement for four and no consensus for the other 16 (Table 1). Six of the 16 statements where no consensus was reached addressed technical surgical details of transfer surgery.

There was consensus regarding several potential indications for distal rectus femoris surgery, including stiff knee gait and frequent tripping. For the purpose of the survey, a stiff knee gait was defined as a decrease in the magnitude of peak knee flexion in swing phase, a decrease in the arc of movement between peak knee extension and peak knee flexion and/or a delay in peak flexion. There was general agreement that distal rectus femoris surgery is better than proximal rectus femoris release for stiff knee gait in children with CP. The panel reached consensus that distal rectus femoris surgery is indicated in a patient with a stiff knee in swing phase and a positive prone rectus (Duncan-Ely) test, but no consensus regarding whether the Duncan-Ely test is a useful predictor of outcome (Fig. 2).

The panel reached consensus both that distal rectus femoris surgery should be considered for stiff knee gait in both Gross Motor Function Classification System (GMFCS)[23] I and II children and against considering it in those at GMFCS level IV. There was consensus that the overall results of distal rectus femoris surgery are worse in GMFCS III patients than in those at GMFCS I and II levels.

The panel often uses data from 3DGA in surgical decision-making. The panel reached consensus that distal rectus femoris surgery may be indicated if dynamic electromyography (EMG) shows an overactive rectus femoris on the EMG in swing phase (81% agreement) and that the combination of rectus overactivity in swing and a stiff knee pattern in swing in the kinematics reached consensus with even greater agreement (94%). The panel reached consensus that gait velocity is an important predictor of the outcome of distal rectus femoris surgery.

Important outcomes measures were sought, and there was general agreement that the most important kinematic outcome following distal rectus femoris surgery is the slope of knee flexion in pre-swing until initial swing. There was no consensus about whether the most important kinematic outcome was maximum knee flexion in swing or whether it was the total range of the knee from stance to swing phase.

Discussion

A panel of paediatric orthopaedic surgeons with expertise in both the treatment of children with CP and the clinical application of computerized movement analysis used an iterative process to determine consensus for clinical indications, physical exam findings, computerized gait data, intraoperative considerations and techniques, and outcomes measures regarding distal rectus femoris surgery in children with CP. The panel chose to use the Delphi method, which is recognized as a structured process to quantify areas of consensus or not. Adapted from the original it has been used in healthcare as a standard for developing clinical guidelines, to make sure they reflect the consensus of medical experts. The quality of the existing literature regarding distal rectus femoris surgery for children with CP is not high enough to meet the necessary conditions to allow for a meta-analysis.

The panel noted the importance of treating stiff knee gait as part of a comprehensive treatment plan addressing gait pathology, which often occurs in multiple planes and at multiple levels. Rectus femoris surgery has long been performed for stiff knee gait, proximally or distally, including rectus release or lengthening or DRFT.[7,14-16,24-27] Sutherland et al[15] reported rectus femoris release surgery in 1975 and Gage et al[7] reported excellent results of DRFT in 1987.

One major issue which has led to variable outcome of rectus femoris surgery is that there is discordance about the definition of stiff knee gait, which is also represented in the findings of our study. The panel did not reach

Table 1 Statements for rectus femoris surgery

Statement	Consensus for statement (% agree)	General Agreement for statement (% agree)	No consensus (% agree, % neutral, % disagree)	Consensus against statement (% disagree)
Distal rectus femoris surgery is better than proximal rectus femoris release for stiff knee gait in children with CP.		X (75%)		
I do distal rectus femoris surgery (transfer or release) less frequently than I did earlier in my career.	X (88%)			
The results of distal rectus femoris surgery are better in unilateral than in bilateral subjects.			X (13%, 75%, 13%)	
The results of distal rectus femoris surgery are comparable in unilateral and bilateral subjects.			X (19%, 75%, 6%)	
Distal rectus femoris surgery may be indicated for stiff knee gait in children with CP.	X (94%)			
Distal rectus femoris surgery may be indicated for children with CP and stiff knees and frequent tripping.	X (94%)			
A child with CP is better off with a straight and stiff knee than with crouch and a more supple knee in swing.	X (81%)			
Distal rectus femoris surgery for stiff knee gait should be considered in GMFCS I patients.	X (88%)			
Distal rectus femoris surgery for stiff knee gait should be considered in GMFCS II patients.	X (94%)			
Distal rectus femoris surgery for stiff knee gait should be considered in GMFCS III patients.			X (44%, 50%, 6%)	
Distal rectus femoris surgery for stiff knee gait should be considered in GMFCS IV patients.				X (81%)
The overall results of distal rectus femoris surgery are worse in GMFCS III patients than in GMFCS I and II patients.	X (88%)			
Rectus femoris transfer is rarely necessary after SDR.			X (50%, 38%, 12%)	
The prone rectus (Duncan-Ely) test is a useful predictor of outcome in distal rectus femoris surgery.			X (56%, 13%, 31%)	
Distal rectus femoris surgery is indicated in a patient with a stiff knee in swing phase and a positive prone rectus (Duncan-Ely) test.	X (88%)			
Dynamic EMG showing an overactive rectus femoris is swing phase is an indication for distal rectus femoris surgery.	X (81%)			
Distal rectus femoris surgery is indicated in a patient with CP who has both a stiff knee in swing phase and an overactive rectus on EMG testing.	X (94%)			
Gait velocity is an important predictor of the outcome of distal rectus femoris surgery.	X (81%)			
Knee flexion velocity is an important predictor of the outcome of distal rectus femoris surgery.		X (68%)		
Hip flexor power is an important predictor of the outcome of distal rectus femoris surgery.	X (81%)			
Knee flexor power is an important determinant of the outcome of distal rectus femoris surgery.			X (25%, 56%, 19%)	
The results of rectus surgery are dependent on hip flexor and ankle plantar flexor strength.		X (75%)		
Results of distal rectus femoris release is comparable to DRFT.			X (38%, 19%, 43%)	
When DRFT is performed, the best recipient for the rectus transfer is the semitendinosus.			X (38%, 50%, 12%)	
When DRFT is performed, the gracilis is the best recipient for the transfer.			X (31%, 50%, 19%)	
When DRFT is performed, the sartorius is the best recipient for the transfer.			X (6%, 50%, 44%)	
When DRFT is performed, the iliotibial band is the best recipient for the transfer.			X (0%, 50%, 50%)	
When DRFT is performed, the recipient for the transfer does not impact patient outcomes.			X (43%, 38%, 19%)	
When performing distal rectus femoris surgery, I most typically perform this at the time of index SEMLS surgery.			X (56%, 13%, 31%)	
When performing distal rectus femoris surgery, I most commonly perform this at a subsequent (follow-up) surgery rather than at the index SEMLS surgery.			X (31%, 25%, 44%)	
The most important kinematic outcome following distal rectus femoris surgery is maximum knee flexion in swing phase.			X (56%, 25%, 19%)	
The most important kinematic outcome following distal rectus femoris surgery is the total range of the knee (maximum knee flexion in swing minus maximum knee extension in stance).			X (25%, 50%, 25%)	
The most important kinematic outcome following distal rectus femoris surgery is the slope of knee flexion in pre-swing until initial swing.		X (68%)		

CP, cerebral palsy; GMFCS, Gross Motor Function Classification; SDR, selective dorsal rhizotomy; EMG, electromyography; DRFT, distal rectus femoris transfer; SEMLS, single event multilevel surgery

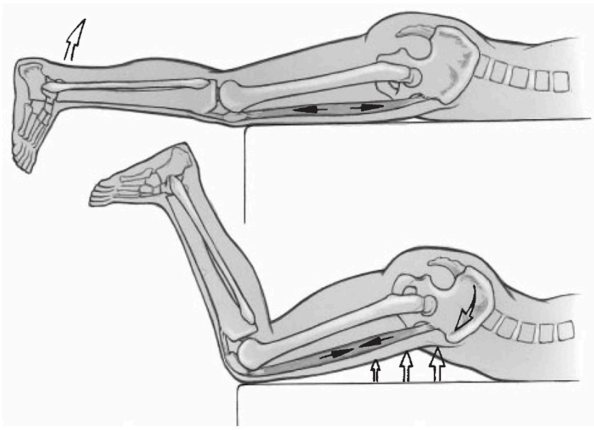

Fig. 2 The prone rectus (Duncan-Ely) test is performed by rapidly flexing the knee in a prone patient. The prone rectus test is positive if the ipsilateral hip flexes with rapid knee flexion (reproduced, with permission, from Wenz W, Doderlein L[22]).

consensus which is the most important parameter to be changed by the rectus femoris surgery. Typically, stiff knee gait occurs in patients with sufficient knee extension during stance phase but decreased knee flexion during swing phase.

Stiff knee gait may be defined as: 1) decreased magnitude/amplitude of peak knee flexion in swing; or 2) decreased knee arc of movement from stance to swing phase (arc = difference between the maximum knee flexion$_{swing}$ and maximum knee extension$_{stance}$); or 3) both. Depending on which criteria are used for definition, patients with severe crouch gait may be described as having a 'stiff knee'. In this context, it is important to mention that rectus femoris surgery was, and in some centres is still, being done in patients with crouch as a prophylactic procedure to prevent stiff knee gait after correction of stance phase knee flexion for crouch gait treatment.[28]

The panel reached consensus regarding several potential indications for distal rectus femoris surgery, including stiff knee gait and frequent tripping. There was consensus that distal rectus femoris surgery is indicated in a patient with a stiff knee in swing phase and a positive prone rectus (aka Duncan-Ely) test, but no consensus regarding whether the Duncan-Ely test is a useful predictor of outcome in distal rectus femoris surgery. These are seemingly incongruous findings but appear to indicate that knee stiffness is the primary indicator for distal rectus femoris surgery, and that the Duncan-Ely test appears to potentially be a secondary indicator for this panel. Previous authors have noted that a positive Duncan-Ely test is indicative of abnormal rectus femoris function in swing phase,[29] and others have noted that this test is a predictor of a good outcome following DRFT.[8] However, discrepant reports can be found in the literature,[30] which may explain the lack of agreement among the panel. Indications for distal rectus femoris surgery based on 3DGA data are discussed below.

There was no consensus about the reduction in the need for DRFT surgery after selective dorsal rhizotomy (SDR). Some of the panel speculate that the rate of stiff knee gait, and the need for DRFT, to be less in patients who have undergone SDR due to a decrease in rectus spasticity. Some studies have demonstrated improved knee flexion during swing phase after SDR.[31-33] The key question is whether a neurosurgical intervention (SDR) at a younger age for lower extremity spasticity, including co-contraction at the knee and stiff knee gait might be superior to, or obviate the need for, an orthopaedic surgery (DRFT) when the child is older. A more systematic approach to finally answer this question is needed in future research.[17]

There was general agreement (75% in the top two Likert categories) that distal rectus femoris surgery is better than proximal release for stiff knee gait in children with CP. This is consistent with the data from Sutherland et al,[16] who reported better results after DRFT than proximal rectus release in children with CP and stiff knee gait. Végvári et al[17] reported that adding proximal rectus femoris release did not enhance the outcome following DRFT at either one- or nine-years follow-up.

When asked if distal rectus femoris release was comparable with DRFT, the panel did not reach consensus. There were advocates for each of these procedures on this panel of surgeons, and a recognition that this question has not been sufficiently resolved by the existing literature. Most of the reports in the literature regarding rectus release describe excising 1.5 cm to 2.5 cm of tendon, rather than simply transecting the tendon.[4,24,25] Based on biomechanical model simulations, Fox et al[34] previously reported that most of the improvement in knee flexion following DRFT appears to be due to the removal of the rectus femoris muscle as a knee extensor, rather than from its transfer to a different site. Riewald and Delp[35] had previously called into question whether DRFT indeed generates a knee flexion moment based on electrical stimulation in four patients. Asakawa et al[36] also previously reported that there was typically acute angulation > 35° of the path of the muscle transfer following DRFT in 70% (7/10 extremities) of patients studied with MRI. Based on such reports, surgeons now make an additional effort to free the rectus femoris proximally from medial and lateral attachments prior to completion of the tendon transfer, in order to allow for a direct line of pull for the DRFT.

Some previous authors have reported superior results of DRFT compared with distal rectus release in patients with CP and stiff knee gait,[4,9] while other authors reported comparable results.[24,25] Since the level of evidence is low and is derived from retrospective studies there is a need for a randomized trial in order to finally answer this question.

Furthermore, the long-term effects of distal rectus release compared with those of DRFT have yet to be studied.[6,37]

Though the results of DRFT are typically favourable, not all patients benefit. In a randomized study of patients undergoing single event multilevel surgery (SEMLS) who had an indication for DRFT, Dreher et al[5] reported that patients randomized to DRFT had better outcomes than those who did not, but also noted that 33% did not benefit from DRFT, especially those patients with flexed knee gait in which the transfer was done as a prophylactic procedure. In another study, at a mean of nine years follow-up, Dreher et al[6] reported that 18% of patients had a "permanently poor result" and another 15% had recurrence following DRFT.

The panel reached consensus that a stiff but straight knee is superior to a crouch gait pattern with a supple knee. The panel notes the critical role of good knee extension in stance, particularly as children reach skeletal maturity. Unfortunately, loss of knee extension in stance may occur following DRFT.[2,3,38] Sousa et al[14] noted worsened crouch following DRFT in patients functioning at GMFCS levels III and IV but not in those functioning at GMFCS I or II. De Morais et al[27] similarly reported worsened crouch following DRFT in patients functioning at GMFCS level III but not in those functioning at GMFCS levels I and II. These differences in outcome by GMFCS level, may relate to the severity of CP, spasticity, weakness, concomitant lever arm deformities, walking velocity or combinations of these factors.

GMFCS level was deemed to be an important surgical indicator and outcome predictor. The panel reached consensus that distal rectus femoris surgery should be considered for stiff knee gait in both GMFCS I and II children, but should not be performed in those functioning at GMFCS IV. There was no consensus for GMFCS III children. There was consensus that the overall results of distal rectus femoris surgery are worse in patients functioning at GMFCS level III than in those at GMFCS I and II levels. Rethlefsen et al[13] first documented that results of DRFT were best in GMFCS I and II children, intermediate in GMFCS III and poor in all eight patients in whom it had been done at a single institution. The same group later showed that DRFT results were best in patients functioning at GMFCS I and II, and those with hemiplegia.[14] De Morais et al[27] reported worsened crouch following DRFT in patients functioning at GMFCS level III but not in those at GMFCS levels I and II. There is a need to further investigate which patients functioning at GMFCS level III are those who profit from rectus femoris surgery.

Previous authors have reported some loss of knee flexion at longer term follow-up after DRFT. Õunpuu et al[11] reported surgical results in a cohort of 22 patients who underwent a combination of hamstring lengthening, DRFT and gastrocnemius recession at a mean follow-up on 11 years; they reported similar improvements at the knee 1.4 years following DRFT but noted a loss of 6° of peak knee flexion in swing between the first postoperative gait test 1.4 years postoperatively and the subsequent one 11 years postoperatively, as well as the loss of 3° of knee extension between the early and late postoperative studies. Végvári et al[17] similarly reported some deterioration of the surgical improvements following DRFT between the one- and nine-year postoperative gait studies, though there were still significant improvements both with regard to peak knee flexion in swing, peak knee extension in stance, timing of knee flexion in swing and the arc of knee range of movement from stance to swing phase.

There was a focus on 3DGA, including kinematics, kinetics and EMG assessment in these patients. The typical indications for distal rectus femoris surgery based on 3DGA are the combination of kinematic data showing a stiff knee in swing phase and EMG data showing an overactive rectus femoris in swing phase. The panel reached consensus that gait velocity is an important predictor of the outcome of distal rectus femoris surgery. There were mixed results regarding kinetic data on 3DGA, with general agreement that the results of rectus surgery being dependent on hip flexor and ankle power strength and consensus that hip flexor power is an important predictor of surgical outcome. There was no consensus about the importance of knee flexor power as a predictor of outcome.[14] Delayed timing of knee flexion in swing was pointed to as a significant clinical issue by panel members but was not formally assessed with a statement presented to the entire group. The timing of peak knee flexion in swing phase has been studied in many previous studies, but does not uniformly improve following DRFT.[5,38]

Technical and logistical aspects of the surgery vary among panellists. The panel could not reach consensus on whether distal rectus femoris surgery should be performed at the time of index SEMLS surgery or at a subsequent time. Most felt that there is not a pressing need to do such a procedure at the index operation and that many stiff knees may improve with multilevel and multiplanar correction with SEMLS. According to the results of a randomized trial it makes sense at least for patients with flexed knee gait not to add rectus femoris surgery to the index SEMLS and postpone it to the time of hardware removal if still indicated.[5] Further, there appears to be little downside in delaying distal rectus surgery, as comparable results can be obtained with delayed *versus* concomitant surgery.[2]

There was no consensus reached regarding whether the results of distal femoris release and DRFT are comparable. It is currently unclear whether this is due to equivalence of these procedures, or due to lack of data. There is even debate about how to do a distal rectus femoris release, by simply cutting it distally, resecting a portion of the tendon or doing a fascial 'striping' of the tendon on the underside of the muscle. Similarly, if DRFT is performed there was no consensus regarding the optimal recipient for the transfer, whether it be semitendinosus, gracilis, sartorius, iliotibial band or whether the recipient of the transfer impacts the outcome. Despite reported differences in moment arms of DRFT to different sites based on biomechanical modelling,[39] previous authors have found comparable clinical results between transfer sites.[10,30,40] The lack of consensus by the panel may be due to good results following transfer to each of these locations or due to insufficient data to prove such a difference.

The panel answered statements about important outcomes measures following DRFT. There was general agreement that the most important kinematic outcome following distal rectus femoris surgery is the slope of knee flexion in pre-swing until initial swing. Whether or not slope is quantified (typically in degrees per second), the slope of the stiff knee clearly differs from those of able-bodied subjects as seen on kinematic 3DGA graphs (Fig. 1). There was no consensus about whether the most important kinematic outcome was maximum knee flexion in swing or whether it was the total range of the knee from stance to swing phase.

Probably the panel's most important finding about rectus femoris surgery is that there was consensus among the panel that we do rectus femoris surgery (either transfer or release) less frequently now than earlier in our careers. Indications have narrowed considerably since these procedures were first described and many report doing such surgeries dramatically less frequently that previously.

The frequency with which this panel reached consensus or general agreement (52%) was much lower than the same panel reached previously regarding femoral rotational osteotomy (82%) and gastrocsoleus surgery (68%) but similar to that for medial hamstring lengthening (56%).[20,21] The inability to reach consensus was particularly striking regarding the statements regarding the technical aspects of surgery and postoperative outcome measures. The difficulty reaching consensus regarding rectus femoris surgery in children with CP reflects the complexity of this decision-making process.

This panel of international experts reached consensus regarding the following statements for rectus femoris surgery in children with CP:

1. Distal rectus femoris surgery may be indicated for stiff knee gait in children with CP.
2. Distal rectus femoris surgery may be indicated for children with CP and stiff knees and frequent tripping.
3. A child with CP is better off with a straight and stiff knee than with crouch and a more supple knee in swing.
4. Distal rectus femoris surgery for stiff knee gait should be considered in GMFCS I patients.
5. Distal rectus femoris surgery for stiff knee gait should be considered in GMFCS II patients.
6. The overall results of distal rectus femoris surgery are worse in GMFCS III patients than in GMFCS I and II patients.
7. Distal rectus femoris surgery is indicated in a patient with a stiff knee in swing phase and a positive prone rectus (Duncan-Ely) test.
8. Dynamic EMG showing an overactive rectus femoris in swing phase is an indication for distal rectus femoris surgery.
9. Distal rectus femoris surgery is indicated in a patient with CP who has both a stiff knee in swing phase and an overactive rectus on EMG testing.
10. Gait velocity is an important predictor of the outcome of distal rectus femoris surgery.
11. Hip flexor power is an important predictor of the outcome of distal rectus femoris surgery.

Conclusion

This panel of international experts with extensive experience in the treatment of children with CP and 3DGA have gone through an iterative process to provide useful information to help practicing paediatric orthopaedic surgeons facing difficult and complex decisions regarding stiff knee gait in children with CP.

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COMPLIANCE WITH ETHICAL STANDARDS

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No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

ETHICAL STATEMENT

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed consent: All subjects were given informed consent and agreed to participate in the project.

ICMJE CONFLICT OF INTEREST STATEMENT

RMK owns stock in Zimmer/Biomet, Medtronic, Pfizer, and Johnson and Johnson, is on the Editorial Board of the Journal of Pediatric Orthopaedics and his son works

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AUTHOR CONTRIBUTIONS

RMK: Conception and design, Analysis and interpretation of the data, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article, Collection and assembly of data.

KP: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

JM: Conception and design, Acquisition of the data, Analysis and interpretation of the data, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article, Collection and assembly of data.

KG: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

HC: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

JRD: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

UN: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

TFN: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

JR: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

ER: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

JS: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

BJS: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

MV: Conception and design, Acquisition of the data, Analysis and interpretation of the data, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article, Collection and assembly of data, Statistical expertise, Administrative, technical and logistical support.

MWS: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

TT: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

AVC: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

TD: Conception and design, Drafting of the article, Critical revision of the article for important intellectual content, Final approval of the article.

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