ABSTRACT

Introduction Proximal humerus fractures (PHFs) comprise <3% of all fractures in children and adolescents. While it is accepted that minimally displaced PHFs can be treated conservatively, the management of severely displaced PHFs remains controversial, especially in older children. This study will aim to analyse the functional and quality-of-life outcomes of children with PHFs, in order to inform their optimal management.

Methods and analysis We will conduct a retrospective cohort study to evaluate the outcomes of patients who were diagnosed with a paediatric PHF at the Women’s and Children’s Hospital (WCH) in South Australia. The primary outcome will be each participant’s pain and quality-of-life outcome, determined by use of the Quick Disabilities of the Arm, Shoulder and Hand, Shoulder Pain and Disability Index and Paediatric Outcomes Data Collection Instrument. Secondary outcomes will include rates of non-union, persistent deformity and complications. The information for these variables will be acquired during a brief clinic appointment, and from the medical records and WCH radiology database. Multivariable logistic regression will be performed to determine the clinical variables associated with a worse clinical outcome.

Ethics and dissemination The study has been approved by the Women’s and Children’s Health Network Human Research Ethics Committee (protocol number: 2021/HRE00250). The study findings will be submitted to peer-reviewed scientific journals for publication and disseminated at conference presentations.

Trial registration number Australian New Zealand Clinical Trials Registry (ACTRN12622000176763).

INTRODUCTION

Proximal humerus fractures (PHFs) comprise between 0.45% and 2% of all fractures in children and adolescents, and 3%–6.7% of all physeal fractures,1-4 with an estimated incidence between 31.4 and 680 fractures per 100 000 children per year, and at least a 3:1 male preponderance.1,5-8 There are two common responsible mechanisms, namely a backwards fall onto an out-stretched hand with the arm hyperextended and externally rotated, or direct trauma to the lateral aspect of the shoulder.1,3,6,7,9 The usual cause of injury is age-dependent. In neonates, physal separations can occur as a result of birth trauma.3,7,9 PHFs in older children typically result from moderate-energy trauma during high-contact sports (such as football, horse-riding and gymnastics) or motor vehicle accidents.1,3 A PHF occurring in an otherwise healthy infant should be considered suspicious for nonaccidental trauma.7

In 1965, Neer and Horowitz introduced a system to classify the severity of PHFs based on the degree of displacement.10 Neer-Horowitz (NH) grade-I fractures are either non-displaced or displaced by less than 5 mm, grade-II are displaced between 5 mm and one-third of the width of the proximal humeral shaft, grade-III are displaced greater than one-third but no greater than two-thirds of the shaft width and grade-IV are displaced by more than two-thirds of the shaft width.11 Eighty-five per cent of paediatric PHFs are either non-displaced or minimally displaced (NH grade-I or grade-II), with only 15% being severely displaced (NH grade-III or grade-IV).4,11 PHFs that occur prior to skeletal maturity rarely lead to a functional or cosmetic deficit for a number of reasons.7 First, they have a profound ability to remodel, due to the proximal humeral growth plate being responsible for 80% of overall humeral longitudinal growth.6,12-15 Second, the periosteum in the immature humerus is metabolically active, which enhances its ability
to rapidly consolidate fractures and heal.\textsuperscript{1,16} Third, the glenohumeral joint has the widest range of motion of any joint in the body, meaning it can accommodate a large degree of displacement and angulation without causing any significant functional impairment.\textsuperscript{6,17,18} Because of these unique attributes, paediatric PHFs have historically been treated non-operatively, regardless of their severity.\textsuperscript{2,19}

Since the study by Neer \textit{et al} in 1965, conservative management has remained the mainstay of treatment for minimally displaced (grade-I and grade-II) PHFs in children, whereas the management of grade-III and grade-IV fractures remains controversial, particularly in adolescents with limited remodelling potential.\textsuperscript{4,10} There is now an apparent consensus in the contemporary literature that adolescents managed conservatively for severely displaced PHFs are at risk of a less than desirable clinical outcome.\textsuperscript{8,13,20,21} In keeping with this, a recent trend towards operative treatment has been identified over the past decade.\textsuperscript{1} Numerous algorithms for the treatment of paediatric PHFs based on patient age and grade of displacement have been proposed,\textsuperscript{2,5,8} although there is considerable heterogeneity as to the proposed thresholds for surgery, and no generally accepted evidence-based guideline has been established.\textsuperscript{4,8,21-23} Based on their retrospective analysis of 28 patients with NH grade-III and grade-IV PHFs, Dobbs \textit{et al} recommended a protocol for patients following closed reduction. For patients <7 years old, postreduction angulation of up to 70° can be accepted; for patients aged 8–11 years, up to 60° can be accepted and for patients $\geq$12 years, up to 45° can be accepted. It was concluded that deformities greater than these thresholds for these groups of patients require open reduction and internal fixation.\textsuperscript{5} The protocol suggested by Binder \textit{et al} was more aggressive for patients over 10 years old. They recommended conservative management for children <10 years old with up to 20° angulation, and surgery for children >10 years with more than 20° angulation, citing an increased risk of soft tissue interposition in fractures with more than 20° of angulation.\textsuperscript{11} The protocol proposed in the systematic review by Hohloch \textit{et al} was considerably more conservative.\textsuperscript{5} They recommended non-operative management for patients aged <10 years old with a severely displaced PHF, and surgical treatment for those $\geq$15 years. As can be seen, there are considerable discrepancies in the various treatment algorithms that have been proposed to date. Furthermore, as PHFs represent less than 3% of fractures in children, studies that have investigated this subject tend to be retrospective analyses of small cohorts of patients, with only a short period of follow-up and low follow-up rates.\textsuperscript{5,7} Consequently, there is a paucity of high-quality studies that have examined long-term functional and quality-of-life outcomes following paediatric PHFs from which to derive an evidence-based guideline regarding management options.\textsuperscript{4,5} Our study will aim to analyse the functional and quality-of-life outcomes of a large cohort of children and adolescents with PHFs, in order to inform their optimal management. A secondary aim is to determine the clinical factors that predict a worse clinical outcome for paediatric PHFs, including patient demographics, fracture pattern and treatment methodology. The hypothesis is that adolescent patients treated non-operatively have a higher risk of a poor clinical outcome, especially when the initial displacement of their fracture is greater.

**METHODS AND ANALYSIS**

**Study setting**

This will be a retrospective cohort study. The study will be conducted at the Women’s and Children’s Hospital (WCH) in South Australia, the tertiary referral paediatric centre for orthopaedics for the state of South Australia and surrounding regions of south-western New South Wales and western Victoria.

**Patient and public involvement**

Patients were not involved in the design or proposed methodology of the study. The findings of the study will be disseminated to the study participants by mail, at the conclusion of the study.

**Eligibility criteria**

The principal investigator will identify potential participants from the medical records and radiology database of the WCH based on a diagnosis of a PHF when under the age of 18 years. The diagnosis will be confirmed on examination of the plain-film radiographs. The inclusion and exclusion criteria for the study are listed in table 1.

**Case ascertainment**

The study will begin with a retrospective analysis of the medical records at the WCH as well as the records at the private practices of WCH-coemployed orthopaedic surgeons. The records of consecutive patients diagnosed and managed with PHFs between 1 January 2010 and 1 June 2020 will be reviewed. Cases will be ascertained from the inpatient and outpatient records using International Classification of Diseases codes. Additionally, the WCH radiology database (Kestrel) will be reviewed using keyword search for “shoulder”, “humerus” and “fracture” to identify fractures of the proximal humerus that have occurred between 1 January 2010 and 1 June 2020.

**Recruitment**

Once potential participants have been identified, their vital status will be reviewed in the state-wide clinical information system to ensure that families of deceased patients are not contacted. Each potential participant will be mailed a copy of the Letter of Invitation to Participants, the Participant Information Sheet and the Informed Consent Form. If they do not opt out of the study by emailing or calling the principal investigator, they will then be contacted via telephone 2 weeks later and given verbal information about the research project. During this telephone call, the participant will be asked to sign
the informed consent form if they have not already done so.

Data collection and assessment tools
Participants who consent to participate in the study will complete a structured questionnaire over the telephone. This questionnaire will include the Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH), the Shoulder Pain and Disability Index (SPADI) and the Paediatric Outcomes Data Collection Instrument (PODCI).24–26

The original Disabilities of the Arm, Shoulder and Hand (DASH) score takes into account daily activities, symptoms and social function, and has been shown to have strong reliability and validity for assessing patients with PHFs.27 From the original 30-item DASH questionnaire, the shorter 11-item QuickDASH was developed, which reduces the completion time and the administrative burden. The items in the QuickDASH were selected from the original instrument on the basis of having the highest reliability, validity and responsiveness within each domain of the DASH.28 The SPADI questionnaire was created in 1991 by Roach et al and consists of two components—one that assesses the participant’s pain levels, and one that assesses the participant’s ability to carry out various functional activities. The QuickDASH and SPADI have been validated for use via telephone.29 30 The PODCI is a well-validated musculoskeletal health questionnaire that addresses a child’s mobility, upper limb function, sports and physical function, pain and happiness.31 While there is precedence for the PODCI being administered via telephone in previous studies,32 33 the authors were not able to identify any study which has evaluated its validity for telephonic review. Additionally, participants will complete a questionnaire developed by the researchers that asks demographic and clinical questions related to the participant’s current occupation, highest level of education, comorbidities and other musculoskeletal injuries that they have sustained.

At the conclusion of the telephone interview, participants will be invited to have either an in-person clinic appointment, or an online video meeting, to allow for a standardised clinical examination to assess their range of motion and strength. Participants who agree to an in-person clinic appointment will be asked to bring their signed consent form with them, so that a scanned copy can be made for our records. Those who undergo a video interview will be asked to scan and email their signed consent form to the principal investigator. The range-of-motion examination will involve three tests, namely the hand-to-neck, hand-to-scalpula and hand-to-opposite-scalpula tests.34 Together, these tests assess movement of the shoulder joint in all dimensions, and they have been found to have strong intraterster and interterster reliability.31 Table 2 outlines the scoring system for these tests.

Participants who are examined in-person will also undergo an assessment of their shoulder’s strength. Shoulder strength in forward-elevation, extension, abduction, adduction, internal rotation and external rotation will be scored out of 5, as according to the classification tool of the American Spinal Injury Association (see table 3).35

The strength of participants who undergo a video meeting will be assessed using the techniques introduced by Laskowski et al.36 In these techniques, shoulder internal rotation and external rotation are assessed by the participant’s ability to perform these movements against resistance, provided by either a doorframe or another person. Abduction strength is assessed by asking the participant to abduct their arm 90° and apply self-resistance with the opposite arm. This technique could also be used to assess forward elevation, by asking the participant to maintain their arm 90° of forward elevation while applying a downward force with the opposite arm.

Outcomes
Primary outcome measures
The primary outcome measure will be pain and quality-of-life outcomes, as determined by the QuickDASH, SPADI and PODCI questionnaires. Consistent with the methodology of two previous studies that have investigated paediatric PHFs, by Canavese et al and Khan et al,16 37 a poor outcome for the QuickDASH will be defined as a score of 2 or more out of a possible 11 points. To the authors’
knowledge, no previous study has used the SPADI to measure functional outcomes of PHFs in the paediatric population. A poor outcome will be defined as a SPADI score of greater than 3 out of a possible 10 points, based on the findings of the studies by Chester et al, Merolla et al and Kuhlmann et al, who found that the mean SPADI scores for their cohorts of patients with shoulder pathology were between 3 and 4 out of a possible 10 points. Similarly, the authors were not able to identify any previous study that has measured the functional and quality-of-life outcomes of paediatric PHFs by use of the PODCI. However, multiple previous studies have used the PODCI to quantify outcomes following supracondylar humeral fractures in children, and have considered a score of less than 90 at final follow-up to be poor. Based on the finding of these studies, a PODCI score of less than 90 will be defined as ‘poor’.

| Table 2 | Scoring system for the range-of-motion tests<sup>34</sup> |
|---------|-----------------------------------------------------|
| **Hand to neck (shoulder flexion and external rotation)** | |
| 0 | The fingers reach the posterior midline of the neck with the shoulder in full abduction and external rotation, without wrist extension |
| 1 | The fingers reach the midline of the neck, but do not have full abduction and/or external rotation |
| 2 | The fingers reach the midline of the neck, but with compensation by adduction in the horizontal plane or by shoulder elevation |
| 3 | The fingers touch the neck |
| 4 | The fingers do not touch the neck |
| **Hand to scapula (shoulder extension and internal rotation)** | |
| 0 | The hand reaches behind the trunk to the opposite scapula or 5cm beneath it in full internal rotation |
| 1 | The hand almost reaches the opposite scapula, 6–15cm beneath it |
| 2 | The hand reaches the opposite iliac crest |
| 3 | The hand reaches the buttock |
| 4 | Subject cannot move the hand behind the trunk |
| **Hand to opposite scapula (shoulder adduction)** | |
| 0 | The hand reaches to the spine of opposite scapula in full adduction without wrist flexion |
| 1 | The hand reaches to the spine of opposite scapula in full adduction |
| 2 | The hand passes the midline of the trunk |
| 3 | The hand cannot pass the midline of the trunk |

**Secondary outcome measures**

Secondary outcome measures will include objective clinical and radiological assessments, including rates of union and non-union for fractures treated with the different treatment modalities, persistent deformity, degree of fracture angulation and NH grade of fracture displacement at final follow-up, complications of treatment (such as infection and need for reoperation), and shoulder strength and range of motion. The information for these variables will be acquired during the clinic/video appointment, and from the medical records and radiology database at the WCH and the private rooms of WCH-coemployed orthopaedic surgeons. The radiological assessment of each participant’s fracture will be carried out by the principal investigator, who is an orthopaedic registrar at the WCH, on examination of the plain-film radiographs.

**Baseline data**

The following data will be obtained from the medical records and radiology database at WCH:

- Current age, gender, ethnicity.
- Age at fracture relative to expected age of skeletal maturity, as per the Menelaus rule-of-thumb.<sup>43</sup>
- Radiographic evidence of skeletal immaturity or maturity at the time of fracture, as evidenced by an open or closed proximal humeral physis on X-ray, respectively.
- Mechanism of injury.
- Fracture pattern.
- Treatment methodology.
- Duration of follow-up.
- Radiological outcome.
- Complications of treatment.

| Table 3 | Scoring system for strength assessment<sup>35</sup> |
|---------|-----------------------------------------------------|
| 0 | Total paralysis |
| 1 | Palpable or visible contraction |
| 2 | Active movement, full range of motion with gravity eliminated |
| 3 | Active movement, full range of motion against gravity |
| 4 | Active movement, full range of motion against gravity and moderate resistance in a muscle-specific position |
| 5 | Normal active movement, full range of motion against gravity and full resistance in a muscle-specific position expected from an unimpaired person |
Data collected during interview and clinic appointment

The following data will be obtained during the telephone interview and subsequent clinic appointment:

- Comorbidities and medications.
- Pain and quality of life outcomes (QuickDASH, PODCI and SPADI questionnaires).
- Shoulder strength and range-of-motion.

Participant timeline

Table 4 outlines the process by which participants will be identified, consent will be obtained, and data will be collected from each participant.

Sample size calculation

Our sample size estimation, justification and power calculations were made by a University of Adelaide statistician, on the basis of the studies by Canavese et al and Khan et al, which suggest that between 26% and 37% of paediatric patients with a PHF will experience a poorer outcome, defined as a QuickDASH score of 2 or more out of a possible 11 points.16 37

Five items will be investigated as potential risk factors for a poorer clinical outcome: age at fracture, gender, fracture severity, comorbidities and treatment methodology. The data analysis will be with multivariable logistic regression, which requires a minimum of 10 events per variable to ensure adequate power and model stability. To allow for more complex relationships (eg, interactions or non-linear functions) in the data, this will be increased to 15 events per variable. The risk factors of interest translate into 10 predictors. As per the findings of previous studies, it is reasonable to expect that 30% of patients will have a QuickDASH score of at least 2.16 37 If 10 predictors are used, this equates to a required sample size of 500 participants.

Since one of the key hypotheses of this study is that the adolescent group (aged 12–18 years) will have poorer outcomes than the younger group (2–11 years), power calculations were made to determine the level of power that the study would have to assess the difference in outcomes between these two groups, based on the number that will also be required to ensure a stable model when fitting a multivariable logistic regression model. With the assumed overall proportions being 30% and the hypothesis that the adolescent group will have worse outcomes than the younger group, the following calculations assume that 40% of the adolescent group (n₁) will have a poorer outcome, and 20% of the younger group (n₂) will have a poorer outcome. As shown in table 5, if 500 participants are recruited, this would confer 99.9% power.

Assuming 80% power to detect a proportion of 0.4 in the adolescent group and 0.2 in the non-adolescent group with a two-sided α of 0.05, with continuity correction applied this would require 91 patients per group, with an overall sample of n=182. As outlined above, however, we will attempt to recruit 500 participants so that the multivariable logistic regression model can be performed.

Data analysis

Multivariable logistic regression will be performed to determine the clinical variables that are associated with a worse clinical outcome. Subgroup analyses will also be performed on:

1. Participants aged 16–18 years old at the time they sustained the PHF.
2. Participants who sustained NH grade-III or grade-IV fractures.

Table 5  Power calculation for adolescent and younger group

| Total sample (n = n₁ + n₂) | Power (%) |
|-----------------------------|-----------|
| 950                         | 100       |
| 800                         | 100       |
| 650                         | 100       |
| 500                         | 99.9      |
3. Participants who were skeletally mature at the time of diagnosis.
   These subgroup analyses will allow us to assess the efficacy of treating adolescent patients conservatively rather than operatively, depending on the severity of their PHF.

ETHICS AND DISSEMINATION

Research ethics approval
The study has been approved by the Women’s and Children’s Health Network Human Research Ethics Committee (protocol number: 2021/HRE00250).

Safety considerations
As there is no intervention involved in this study, but rather simply a telephone interview with a structured questionnaire and a clinic appointment with a brief shoulder examination, the safety or well-being of the participants is unlikely to be compromised. The questionnaire is unlikely to cause any offence or distress. Participants will be allowed to have a family member present during the interview, to optimise their emotional security and support. Patients whose fracture was the result of reported or suspected child abuse, or required mandatory reporting, will be excluded from the recruitment process. Finally, any health concerns that are raised during the clinic interview will be addressed, and the participant will be offered a referral to the appropriate outpatient clinic or advised to consult their general practitioner about the health issue, if appropriate.

Consent
The principal investigator will obtain informed consent. The consent form will be completed by participants aged over 18 years, and by the guardian of participants who are under the age of 18 years.

Confidentiality
Clinical and radiological data will be collected using REDCap electronic data capture tools hosted at SA Clinical and radiological data will be collected using REDCap. Confidentiality under the age of 18 years. Consent form will be completed by participants aged over 18 years, and by the guardian of participants who are required mandatory reporting, will be excluded from the recruitment process. Finally, any health concerns that are raised during the clinic interview will be addressed, and the participant will be offered a referral to the appropriate outpatient clinic or advised to consult their general practitioner about the health issue, if appropriate.

Access to data
Access to the raw data set will be limited to the statistician and the principal investigator.

Dissemination policy
The study findings will be submitted to peer-reviewed scientific journals for publication, and will also be disseminated at local, national and international conference presentations.

Contributors
SRA, NW and SP developed the study. SRA is the principal investigator and drafted the protocol. NW and SP are the supervisors of the study, and have actively contributed in reviewing the protocol and methodology. KH is the statistician who is responsible for the statistical methodology and analysis. All authors have read and approved the final manuscript of the study protocol. All authors meet the ICMJE criteria for authorship.

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None declared.

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REFERENCES
1. Hannonen J, Hyvönen H, Korhonen L, et al. The incidence and treatment trends of pediatric proximal humerus fractures. BMC Musculoskelet Disord 2019;20:571.
2. Pahalavan S, Baldwin KD, Pandya NK, et al. Proximal humerus fractures in the pediatric population: a systematic review. J Child Orthop 2011;5:187–94.
3. Popkin CA, Levine WN, Ahmad CS. Evaluation and management of pediatric proximal humerus fractures. J Am Acad Orthop Surg 2015;23:77–86.
4. Cruz AJ, Kleiner JE, Gil JA. Inpatient surgical treatment of paediatric proximal humerus fractures between 2000 and 2012. J Child Orthop:5:187–94.
5. Höhloch L, Eberbach H, Wagner FC, et al. Age- and severity-adjusted treatment of proximal humerus fractures in children and adolescents—a systematic review and meta-analysis. PLOS One 2017;12:e0183157.
6. King ECB, Ihnow SB. Which proximal humerus fractures should be pinned? treatment in skeletally immature patients. J Pediatr Orthop 2016;36 Suppl 1:S44–8.
7. Shadrer MW. Proximal humeral and humeral shaft fractures in children. Hand Clin 2007;23:431–5.
8. Dobbs MB, Luhmann SL, Gordon JE, et al. Severely displaced proximal humeral physeal fractures. J Pediatr Orthop 2003;23:208–15.
9. Lefèvre Y, Journeau P, Angellaume A, et al. Proximal humerus fractures in children and adolescents. Orthop Traumatol Surg Res 2014;100:S149–56.
10. Neer CS, Horwitz BS. Fractures of the proximal humeral epiphyseal plate. Clin Orthop Relat Res 196:41:24??731–31.
11. Pavone V, de Cristo C, Cannavò L, et al. Midterm results of surgical treatment of displaced proximal humeral fractures in children. Eur J Orthop Surg Traumatol 2016;26:461–7.
12. Wang X, Shao J, Yang X. Closed/Open reduction and titanium elastic nails for severely displaced proximal humeral fractures in children. Int Orthop 2014;38:107–10.
13. Binder H, Tiefenboeck TM, Payr S, et al. Treatment of proximal humerus fractures in children and young adolescents. Wien Klin Wochenschr 2016;128:120–4.
14. Bahra C, Zippelies S, Ochs BG, et al. Proximal humeral fractures in children and adolescents. J Pediatr Orthop 2009;29:238–42.
15. Weber EW. Proximal humerus fractures in children. Techniques in Orthopaedics 2009;24:194–9.
16. Canavese F, Athlani L, Marenco L, et al. Evaluation of upper-extremity function following surgical treatment of displaced proximal humerus fractures in children. J Pediatr Orthop B 2014;23:144–9.
17. Kohler R, Trillaud JM. Fracture and fracture separation of the proximal humerus in children: report of 136 cases. J Pediatr Orthop 1983:3:326–32.
18 Baker C, Larson N, Shaughnessy W, et al. Rate of complications and subsequent shoulder complaints for Non-operatively managed pediatric proximal humerus fractures. *Front Surg* 2020;7:48.

19 Zivanovic DV, Slavkovic AR, Radovanovic ZL. Elastic stable intramedullary nailing of humerus fractures in children. *International Journal of Clinical and Experimental Medicine* 2018;11:2950–64.

20 Wei S-W, Shi Z-Y, Zhao Y-M, et al. Comparison of conservative treatment outcomes for proximal humeral epiphyseal fractures in patients of different ages. *Orthopedica* 2019;48:119–24.

21 Chaus M, Carry PM, Pishkenari AK, et al. Operative versus nonoperative treatment of displaced proximal humeral physeal fractures: a matched cohort. *J Pediatr Orthop* 2015;35:234–9.

22 Hutchinson PH, Bae DS, Waters PM. Intramedullary nailing versus percutaneous pin fixation of pediatric proximal humerus fractures: a comparison of complications and early radiographic results. *J Pediatr Orthop* 2011;31:617–22.

23 Beringer DC, Weiner DS, Nobile JS, et al. Severely displaced proximal humeral epiphyseal fractures: a follow-up study. *J Pediatr Orthop* 1996;18:31–7.

24 Beaton DE, Wright JG, Katz JN, et al. Development of the QuickDASH: comparison of three item-reduction approaches. *J Bone Joint Surg Am* 2005;87:1038–46.

25 Roach KE, Budiman-Mak E, Songsrudej N, et al. Development of a shoulder pain and disability index. *Arthritis Care Res* 1991;4:143–9.

26 Daltroy LH, Liang MH, Fossel AH, et al. The POSNA pediatric musculoskeletal functional health questionnaire: report on reliability, validity, and sensitivity to change. *pediatric outcomes instrument development group. pediatric orthopaedic Society of North America. J Pediatr Orthop* 1998;18:561–71.

27 Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECC). *Am J Ind Med* 1996;29:602–8.

28 Soutam M, Assens S, Burton C, et al. A retrospective cohort study of QuickDASH scores for common acute trauma conditions presenting for hand therapy. *J Hand Ther* 2017;30:41–8.

29 London DA, Stepan JG, Boyer MI, et al. Performance characteristics of the verbal QuickDASH. *J Hand Surg Am* 2014;39:100–7.

30 Schmidt S, Furer M, González M, et al. Evaluation of shoulder-specific patient-reported outcome measures: a systematic and standardized comparison of available evidence. *J Shoulder Elbow Surg* 2014;23:434–44.

31 Dedini RD, Bagley AM, Molitor F, et al. Comparison of pediatric outcomes data collection instrument scores and range of motion before and after shoulder tendon transfers for children with brachial plexus birth palsy. *J Pediatr Orthop* 2008;28:259–64.

32 Henderson ER, Pepper AM, Marullanda GA, et al. What is the emotional acceptance after limb salvage with an expandable prosthesis? *Clin Orthop Relat Res* 2010;468:2933–8.

33 Fishman FG, Barber J, Lorie GM. Outcomes of operative treatment of triangular Fibrocartilage tears in pediatric and adolescent Athletes. *J Pediatr Orthop* 2018;38:e1806–22.

34 Yang J-lan, Lin J-jenq, Lin JJ. Reliability of function-related tests in patients with shoulder pathologies. *J Orthop Sports Phys Ther* 2006;36:572–6.

35 ASIA and ISCoS International Standards Committee. The 2019 revision of the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)-What’s new? *Spinal Cord* 2019;57:815–7.

36 Laskowski ER, Johnson SE, Shelterd RA, et al. The telemedicine musculoskeletal examination. *Mayo Clin Proc* 2020;95:1715–31.

37 Khan A, Athiari L, Bouisset M, et al. Functional results of displaced proximal humerus fractures in children treated by elastic stable intramedullary nail. *Eur J Orthop Surg Traumatol* 2014;24:165–72.

38 Chester R, Jerosch-Herold C, Lewis J, et al. The SPADI and QuickDASH are similarly responsive in patients undergoing physical therapy for shoulder pain. *J Orthop Sports Phys Ther* 2017;47:536–47.

39 Merolla G, De Santis E, Cools AMJ, et al. Functional outcome and quality of life after rehabilitation for voluntary posterior shoulder dislocation: a prospective blinded cohort study. *Eur J Orthop Surg Traumatol* 2015;25:263–72.

40 Kuhlmann NA, Taylor KA, Roche CP, et al. Acute versus delayed reverse total shoulder arthroplasty for proximal humerus fractures in the elderly: mid-term outcomes. *Semin Arthroplasty* 2020;30:89–95.

41 Pawar DED, Dahodwala DTM, Bhadoro DS, et al. Outcome of delayed presentation of supracondylar humerus fractures in children. *Int. J. Orthop. Sci*. 2020;6:759–61.

42 Ernat J, Ho C, Wimberly RL, et al. Fracture classification does not predict functional outcomes in supracondylar humerus fractures: a prospective study. *J Pediatr Orthop* 2017;37:e233–7.

43 Menelaus MB. Correction of leg length discrepancy by epiphysial arrest. *J Bone Joint Surg Br* 1966;48:336–8.

44 Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;42:377–81.

45 Harris PA, Taylor R, Minor BL, et al. The REDCap Consortium: building an international community of software platform partners. *J Biomed Inform* 2015;55:103208.

46 Government of South Australia. General Disposal Schedule No. 28. Clinical and Client-Related Records of Public Health Units in South Australia [Internet]. Adelaide SA, 2014. Available: https://archives.sa.gov.au/sites/default/files/public/documents/20141024%20General%20Disposal%20Schedule%20No.%2028%20Final%20v1_copy.pdf [Accessed 4 May 2022].