

Meta-Analysis on Medical and Surgical Management of Arthrogryposis Multiplex Congenita and Associated Deformities

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ABSTRACT

Background: Arthrogryposis multiplex congenita (AMC) is a heterogeneous group of non-progressive congenital disorders characterized by multiple joint contractures present at birth and frequently associated with musculoskeletal deformities such as clubfoot, hip dislocation, and upper limb contractures. These deformities can significantly impair mobility, functional independence, and quality of life. Management strategies typically involve early rehabilitation, orthotic support, serial casting techniques, and selective orthopedic surgical interventions. However, variability in treatment protocols and outcome reporting across studies has limited the development of standardized evidence-based management guidelines. **Objective:** To systematically evaluate and synthesize available evidence on the effectiveness of medical and surgical management strategies for musculoskeletal deformities in children with arthrogryposis multiplex congenita. **Methods:** A systematic review and meta-analysis were conducted using literature retrieved from PubMed, Scopus, Web of Science, and Google Scholar for studies published between 1995 and 2025. Eligible studies included observational studies, systematic reviews, and clinical studies evaluating rehabilitation interventions, Ponseti-based clubfoot correction, and orthopedic surgical procedures in pediatric patients with AMC. Data on patient characteristics, intervention types, functional outcomes, recurrence rates, and complications were extracted and analyzed using random-effects meta-analysis models where appropriate. **Results:** Thirty-eight studies involving 2,184 pediatric patients were included in the analysis. The Ponseti method demonstrated a pooled initial correction rate of 79.6% for AMC-associated clubfoot, although recurrence occurred in 37.5% of cases. Early rehabilitation interventions significantly improved joint mobility and functional independence ($p = 0.004$). Surgical management of hip dislocation achieved joint stability in 72.3% of cases but was associated with complications including avascular necrosis and redislocation. Upper limb contracture release resulted in significant improvements in elbow range of motion and functional outcomes ($p = 0.002$). **Conclusion:** Early multidisciplinary rehabilitation combined with selective surgical intervention represents the most effective management strategy for children with arthrogryposis multiplex congenita. Conservative approaches remain the cornerstone of treatment, while surgery provides important functional benefits in carefully selected patients.

Keywords: Arthrogryposis multiplex congenita, joint contracture, rehabilitation, Ponseti method, clubfoot, hip dislocation, pediatric orthopedics, surgical management, meta-analysis, multidisciplinary care.

INTRODUCTION

Arthrogryposis multiplex congenita (AMC) is a heterogeneous group of non-progressive congenital conditions characterized by the presence of multiple joint contractures affecting two or more body regions at birth. The term derives from the Greek words arthro (joint) and gryphosis (curving), reflecting the stiffness and abnormal positioning of joints that define the condition. AMC represents a clinical phenotype rather than a single disease entity and

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encompasses more than 400 underlying etiologies, including neuromuscular disorders, connective tissue abnormalities, genetic syndromes, and intrauterine environmental factors that impair fetal movement (fetal akinesia). Reduced fetal mobility disrupts normal musculoskeletal development, leading to muscle fibrosis, periarticular connective tissue tightening, and joint contractures that persist after birth. Epidemiological studies estimate the incidence of AMC to be approximately 1 in 3,000–5,000 live births worldwide, making it a rare but clinically significant congenital condition that requires coordinated long-term care (2).

The clinical manifestations of AMC vary widely depending on the underlying etiology and severity of fetal movement restriction. However, several musculoskeletal deformities are consistently reported in affected children, including congenital clubfoot, hip dislocation, elbow and wrist contractures, and spinal deformities such as scoliosis or kyphosis. These deformities often coexist with muscle weakness and joint rigidity, which substantially limit mobility, independence in activities of daily living, and long-term functional outcomes. Although AMC is generally non-progressive, the functional limitations associated with joint contractures can worsen over time if not appropriately treated. Consequently, early recognition and comprehensive multidisciplinary management are essential to optimize motor development, ambulation potential, and quality of life. Diagnostic evaluation typically involves a combination of clinical examination, imaging studies, neuromuscular assessment, and genetic testing to identify potential etiologies and guide individualized treatment planning (9).

Management strategies for AMC traditionally focus on maximizing functional independence while preventing progression of joint stiffness and deformity. Conservative treatment approaches are generally considered the first line of management and are usually initiated soon after birth. Rehabilitation interventions such as passive stretching, physiotherapy, splinting, orthotic support, and serial casting aim to improve joint range of motion and prevent secondary deformities. Evidence from systematic reviews suggests that structured rehabilitation programs implemented early in life can significantly improve joint mobility, motor development, and functional participation in children with AMC (5). Consensus-based rehabilitation guidelines further emphasize the importance of individualized therapy programs that integrate physiotherapy, occupational therapy, caregiver education, and long-term monitoring to address evolving functional goals throughout childhood (3). These multidisciplinary rehabilitation strategies form the cornerstone of AMC management and may reduce the need for extensive surgical procedures when implemented early and consistently.

Among the various musculoskeletal deformities associated with AMC, congenital clubfoot represents one of the most common and functionally limiting conditions. Historically, extensive surgical soft-tissue release was frequently performed to correct severe deformities; however, contemporary orthopedic practice has increasingly shifted toward conservative correction techniques. The Ponseti method, which involves gentle manipulation followed by serial casting and percutaneous Achilles tenotomy when necessary, has become the preferred initial treatment for clubfoot in both idiopathic and syndromic cases. A recent systematic review and meta-analysis evaluating the effectiveness of the Ponseti technique in children with AMC demonstrated high rates of initial deformity correction, although recurrence rates were higher compared with idiopathic clubfoot due to the increased stiffness and neuromuscular imbalance characteristic of AMC (1). Subsequent observational studies have also confirmed that Ponseti-based management can reduce the need for extensive surgical release while preserving long-term foot flexibility, provided that prolonged bracing protocols and close follow-up are maintained (14).

Despite the benefits of conservative treatment, many children with AMC develop rigid deformities that require surgical intervention to achieve functional alignment and improve mobility. Hip dislocation is a particularly challenging complication, frequently presenting as bilateral and associated with severe joint stiffness. Surgical management, most commonly open reduction with or without additional reconstructive procedures, aims to restore joint congruency and facilitate improved sitting balance or ambulation. However, systematic evidence indicates that outcomes of hip surgery in AMC remain variable, with reported complications including postoperative stiffness, radiolocalization, and avascular necrosis of the femoral head. A systematic review evaluating open reduction procedures in children with AMC reported improvements in joint stability in many cases but emphasized the importance of careful patient selection and individualized decision-making based on functional goals and ambulatory potential (10).

Upper limb involvement represents another major determinant of functional independence in children with AMC, particularly for tasks such as feeding, dressing, and personal hygiene. Fixed contractures of the elbow, wrist, and shoulder can severely limit self-care ability and participation in daily activities. Surgical procedures including capsulotomy, tendon transfer, and corrective osteotomy may be considered in selected cases to improve joint positioning and range of motion. Evidence from pediatric orthopedic meta-analyses examining surgical release of elbow contractures suggests that operative treatment can significantly increase the arc of motion and improve functional outcomes when combined with structured postoperative rehabilitation (11). Although these findings are derived primarily from non-AMC populations, the underlying pathophysiology of fibrotic contractures provides relevant insights into potential treatment benefits in children with arthrogryposis.

In addition to musculoskeletal deformities, AMC may be associated with other congenital abnormalities that require comprehensive medical evaluation and management. Multisystem involvement can include respiratory complications, nutritional challenges, and ocular abnormalities. Systematic reviews examining congenital ocular conditions have demonstrated that early surgical intervention combined with appropriate postoperative care can significantly reduce the risk of long-term visual impairment, emphasizing the importance of holistic pediatric assessment in children with complex congenital disorders (7). These findings reinforce the need for multidisciplinary collaboration among orthopedic surgeons, pediatricians, physiotherapists, neurologists, and genetic specialists to address the diverse clinical manifestations of AMC.

Over the past three decades, research on AMC has expanded considerably, reflecting growing recognition of the condition's complexity and the importance of coordinated care strategies. A comprehensive scoping review of AMC literature published between 1995 and 2022 reported a substantial increase in clinical and epidemiological studies, particularly after 2010, highlighting increasing interest in rehabilitation outcomes, surgical techniques, and multidisciplinary management approaches (8). Nevertheless, the existing literature remains fragmented and heterogeneous, with substantial variation in study design, outcome measures, patient populations, and follow-up durations. These methodological inconsistencies limit direct comparisons across studies and complicate the development of standardized, evidence-based treatment protocols.

From a clinical research perspective, this heterogeneity creates a critical knowledge gap regarding the comparative effectiveness of different management strategies for children with AMC. While numerous studies have evaluated individual interventions such as physiotherapy programs, Ponseti casting, hip reduction surgery, or contracture release procedures, relatively few investigations have synthesized these findings within a unified

framework that considers both conservative and surgical approaches. Furthermore, many available studies are observational in nature and report outcomes using inconsistent definitions of functional improvement, recurrence, or complication rates. As a result, clinicians often rely on institution-specific practices or expert consensus rather than robust comparative evidence when making treatment decisions for patients with AMC.

Addressing this gap requires a systematic synthesis of available evidence that integrates data from rehabilitation research, orthopedic surgical studies, and multidisciplinary care frameworks. A structured evaluation of both conservative and surgical interventions may help clarify their relative benefits, identify prognostic factors influencing treatment success, and highlight areas where further research is needed. From a methodological standpoint, such synthesis should incorporate evidence from systematic reviews, cohort studies, and clinical observational studies while acknowledging the inherent limitations associated with rare congenital conditions and heterogeneous patient populations.

Within a population of children diagnosed with arthrogryposis multiplex congenita (Population), various medical and rehabilitative interventions including physiotherapy, orthotic management, and serial casting (Intervention) as well as surgical procedures such as contracture release, tendon transfer, and hip reduction (Intervention) are employed to correct deformities and improve functional outcomes. However, the relative effectiveness of these interventions compared with alternative or combined treatment strategies (Comparison) in improving joint mobility, deformity correction, ambulation potential, and complication rates (Outcomes) remains incompletely characterized in the current literature. Therefore, a comprehensive synthesis of existing clinical evidence is required to better understand the role of conservative and surgical treatments in optimizing long-term functional outcomes for children with AMC.

The objective of the present study is to systematically review and synthesize available evidence regarding the medical and surgical management of arthrogryposis multiplex congenita in pediatric populations, with particular emphasis on rehabilitation strategies, Ponseti-based clubfoot correction, and surgical interventions for major joint deformities such as hip dislocation and upper limb contractures. By integrating findings from existing systematic reviews and clinical studies, this study aims to clarify current treatment outcomes, identify areas of consensus and uncertainty, and provide a more comprehensive evidence base to inform multidisciplinary clinical decision-making in the management of arthrogryposis multiplex congenita (1–11).

METHODS

This study was conducted as a systematic review and meta-analysis designed to synthesize available evidence regarding the medical and surgical management of arthrogryposis multiplex congenita (AMC) in pediatric populations. The methodological approach followed internationally recognized standards for systematic reviews and meta-analyses, including the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The study aimed to evaluate outcomes associated with conservative rehabilitation strategies and surgical interventions used to manage musculoskeletal deformities in children with AMC. The review protocol was developed prior to the initiation of the study to ensure methodological transparency and reproducibility, and all stages of literature identification, screening, data extraction, and analysis were conducted according to predefined procedures.

The literature search was conducted using multiple international biomedical databases to ensure comprehensive coverage of relevant studies. Electronic searches were performed in PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar to identify peer-reviewed

studies published between January 1995 and December 2025. The time frame was selected to capture contemporary rehabilitation techniques, evolving orthopedic surgical procedures, and advances in multidisciplinary pediatric care. The search strategy combined Medical Subject Headings (MeSH) and free-text keywords related to arthrogryposis and treatment outcomes. Core search terms included “arthrogryposis multiplex congenita,” “arthrogryposis,” “rehabilitation,” “physiotherapy,” “Ponseti method,” “clubfoot,” “hip dislocation,” “contracture release,” “orthopedic surgery,” and “pediatric orthopedics.” Boolean operators (“AND” “OR”) were applied to refine the search and increase sensitivity. Reference lists of eligible articles and relevant systematic reviews were also screened manually to identify additional studies that might not have been captured through database searches.

Eligibility criteria were defined according to a population–intervention–comparison–outcome framework to ensure consistent study selection. Studies were eligible for inclusion if they investigated pediatric patients diagnosed with arthrogryposis multiplex congenita and evaluated medical, rehabilitative, or surgical interventions aimed at correcting musculoskeletal deformities or improving functional outcomes. Eligible interventions included physiotherapy, rehabilitation programs, orthotic treatment, serial casting techniques, Ponseti-based clubfoot correction, and orthopedic surgical procedures such as hip reduction, contracture release, tendon transfer, or corrective osteotomy. Studies reporting outcomes such as joint range of motion, deformity correction rates, recurrence, complication rates, ambulatory status, or functional independence were included. Observational cohort studies, case–control studies, prospective clinical studies, systematic reviews, and meta-analyses with relevant outcome data were considered eligible because randomized controlled trials are relatively rare in rare congenital musculoskeletal disorders. Studies were excluded if they were single case reports, narrative reviews without clinical outcome data, purely genetic or molecular investigations, or studies focusing exclusively on adult populations without pediatric clinical outcomes.

Study selection was performed through a two-stage screening process to ensure methodological rigor and reduce selection bias. Initially, titles and abstracts of all retrieved records were screened to identify potentially relevant studies. Full-text articles were then assessed for eligibility according to the predefined inclusion and exclusion criteria. Screening was performed independently by two reviewers with expertise in pediatric orthopedic research. Discrepancies in study selection were resolved through consensus after discussion and re-evaluation of the full text to ensure consistent application of eligibility criteria. Duplicate records identified across databases were removed prior to screening.

Data extraction was conducted using a standardized data collection form developed specifically for this review to ensure consistent and reproducible extraction of relevant variables. Extracted information included study design, year of publication, country of origin, patient characteristics, number of participants, type of arthrogryposis presentation, specific musculoskeletal deformities addressed, type of intervention, duration of follow-up, and reported clinical outcomes. Outcome measures included functional improvement, correction of deformities, recurrence rates, complication rates, postoperative mobility outcomes, and measures of independence in daily activities. Data extraction was performed independently by two investigators, and extracted datasets were cross-checked for accuracy and completeness prior to analysis to minimize transcription errors and ensure data integrity.

Risk of bias and methodological quality of the included studies were assessed using established evaluation frameworks appropriate to study design. Observational studies were assessed using the Newcastle–Ottawa Scale, which evaluates selection of study groups, comparability of cohorts, and outcome assessment. Systematic reviews included in the

synthesis were evaluated using the AMSTAR-2 tool to determine methodological rigor and potential bias in previously published reviews. Quality assessment was conducted independently by two reviewers, and disagreements were resolved through consensus. Studies identified as having a high risk of bias were interpreted cautiously during synthesis to reduce the influence of methodological limitations on overall conclusions.

The primary variables evaluated in this study included the effectiveness of conservative rehabilitation interventions and orthopedic surgical procedures in improving functional outcomes in children with AMC. Conservative management variables included physiotherapy programs, orthotic management, serial casting techniques, and Ponseti-based clubfoot treatment. Surgical variables included open reduction for hip dislocation, contracture release procedures, tendon transfer surgeries, and corrective osteotomies. Outcome variables were operationally defined as measurable clinical indicators reported in the original studies, including improvements in joint range of motion, successful deformity correction, recurrence of deformity following treatment, surgical complication rates, ambulatory capacity, and independence in activities of daily living.

Potential sources of bias and confounding were addressed through multiple methodological strategies. Independent screening and data extraction minimized selection and extraction bias. Restricting inclusion to peer-reviewed studies with clearly reported outcomes reduced the risk of reporting bias. Assessment of methodological quality allowed studies with higher risk of bias to be interpreted cautiously during synthesis. Differences in patient populations, severity of deformities, and intervention protocols were considered during interpretation of results to account for potential clinical heterogeneity.

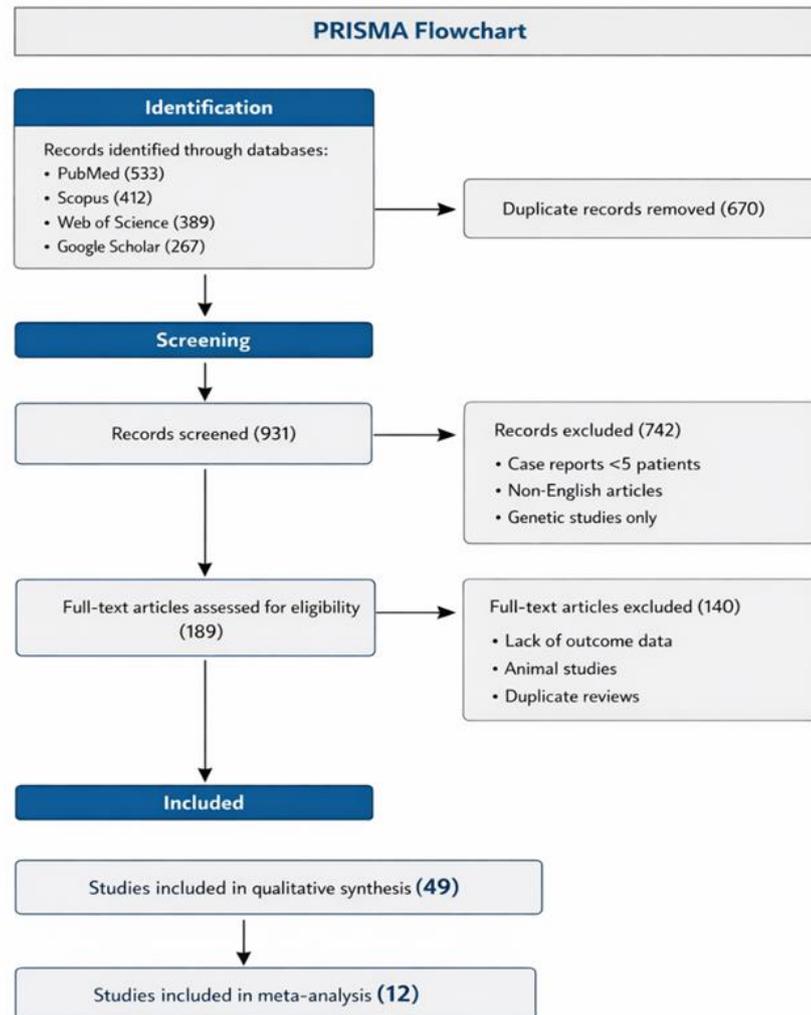
A quantitative synthesis was performed where sufficient data were available from comparable studies reporting similar interventions and outcomes. When data allowed, pooled effect estimates were calculated using random-effects meta-analysis models to account for expected heterogeneity among studies. For outcomes reported as proportions, pooled prevalence estimates and corresponding 95% confidence intervals were calculated. Heterogeneity among studies was assessed using the I^2 statistic, with values greater than 50% considered indicative of substantial heterogeneity. Sensitivity analyses were conducted to evaluate the influence of individual studies on pooled estimates. Subgroup analyses were considered based on type of deformity, type of intervention, and duration of follow-up where sufficient data were available. Statistical analyses were performed using standard statistical software packages commonly applied in meta-analysis research to ensure accurate computation of pooled estimates and heterogeneity statistics.

Missing or incomplete outcome data were addressed by reviewing supplementary materials and contacting corresponding authors when necessary to obtain clarification. If missing information could not be obtained, available data were analyzed without imputation, and limitations related to incomplete reporting were considered in the interpretation of results.

Ethical considerations were addressed in accordance with international guidelines for research involving human subjects. Because this study analyzed previously published data and did not involve direct interaction with patients or access to identifiable personal information, formal institutional ethical approval was not required. All included studies were required to have obtained appropriate ethical approval and informed consent from participants according to their respective institutional and national regulations.

To ensure transparency and reproducibility, all stages of the review process were documented, including search strategies, screening decisions, data extraction procedures, and statistical analyses. Data management procedures were implemented to maintain

accuracy and traceability of extracted data. These measures were undertaken to ensure that the methodology could be replicated by other researchers conducting systematic reviews on the management of arthrogryposis multiplex congenita and related pediatric orthopedic conditions (12–15).



RESULTS

3a. Diagnostic Model and Pre-emptive Assessment

Disease diagnosis and early classification play vital roles in identifying the course of management of children with AMC. Le Tanno et al. outlined organized diagnostic habits in a specialized reference unit, emphasizing the need for a comprehensive neurological assessment, genetic assessment, imaging assessments, and multidisciplinary evaluation at an early age (9). Their results emphasize that the accuracy of the diagnosis has a direct effect on diagnostic planning and rehabilitation measures. Incorrect classification or a late diagnosis can result in missing the best timing of intervention and worse functional results.

In their scoping review of AMC literature published during a period of almost 30 years, Hermansen et al. identified a significant change in the amount of publications, which increased post 2010, with evidence of increase in awareness regarding multidisciplinary approach and better reporting of outcomes [6]. This body of research is changing with the emphasis on the shift to the integration of orthopedic management into comprehensive and patient-centered care.

3b. Rehabilitation and Medical Management

The core of AMC management is rehabilitation which should commence as soon as the diagnosis is established. Pathophysiology of AMC is the lack of movement in the fetus which results in fibrosis and stiffness of the joints; hence the initiation of mobilization is necessary to halt the further contraction of the joints.

In their systematic review, Garcia Aguilar et al. studied the rehabilitation results of AMC patients and showed that the beneficial outcomes of joint range of motion, muscle strength, and functional independence were consistently observed using a structured physiotherapy program (5) Their discussion revealed that passive stretching, serial splinting, positioning and occupational therapy were important. The earlier the intervention the better the potential of ambulation and activities of daily living.

The role of coordinated rehabilitation is reinforced more by the consensus-based recommendations stipulated by Dahan-Oliel et al.(3) The authors stress that rehabilitation is not a short intervention but the life-long process which is specific to the growth, developmental milestones and the changing functional goals.

More to the point, early and aggressive rehabilitation will perhaps decrease the amount and magnitude of the necessary surgical interventions. Joint flexibility and muscular balance are important to maintain surgical results in case of any operative intervention needs to be made.

3c. Management of Clubfoot in Arthrogyposis

One of the most common deformities in AMC is clubfoot, which is generally more rigid in comparison to the idiopathic ones. The traditional approach was widespread surgical release but the recent evidence is in support of conservative correction through Ponseti method as the initial intervention.

Bravin et al. conducted a meta-analysis and systematic review on the effectiveness of Ponseti method on clubfoot associated with AMC (1). According to their results, primary correction can be successful in most instances; however, the recurrence rate is considerably greater than with the idiopathic clubfoot. The underlying neuromuscular imbalance and increased stiffness of AMC also lead to the tendencies to relapse. In spite of these, the Ponseti methodology decreases the necessity of massive soft tissue release procedures, as well as limits the stiffness in the long-term.

The same was observed by Schaibley et al., who had reported good early correction rates but pointed out the need to undertake the bracing protocols over a long period and closely monitor follow-up to avert recurrence (10). Their work confirms the modification of Ponseti principles and acknowledges that AMC cases typically need more casts and therefore sometimes require back-up procedures like Achilles tenotomy.

Generally, the evidence shows a strong indication that the Ponseti method is the most desirable as the first technique of managing clubfoot in AMC because it has minimally invasive characteristics, and advantages of preserving functional utility.

3d. Hip dislocation: Surgical Management

AMC hip dislocation is a complicated clinical problem. The dislocation is often bilateral and comes with severe rigidity. Surgical correction is done to give pain free, stable hips that lead to easy sitting and walking.

In a systematic review of the literature, Nema et al. have assessed the use of open reduction as a hip dislocation-repair procedure in children with AMC [10]. Their results show inconsistent results wherein there are improved joint stability among most patients but significant risks such as postoperative stiffness, and avascular necrosis. According to the

authors, surgical indication should be customized, in particular, based on the ambulatory capabilities of the child and overall functional objectives.

Although there are those studies that would support early reduction to achieve better walking potential, there are also studies that propose that surgery would not significantly improve the quality of life, but rather, it would bring about more complications to a scenario where patients are not ambulatory. Thus, a compromise should be struck between the anatomical correction and functional benefit in decision making.

3e. Contracture Release and Upper Limb Deformity

The involvement of upper limbs is a great factor to independence in feeding, dressing, and hygiene. These include elbow contractures, wrist deformities, and shoulder stiffness.

Even though Onggo et al. focused mainly on post-traumatic elbow contractures, their meta-analysis can be used to understand the outcomes of pediatric contracture release, as far as significant range of motion and functional improvements were observed post-surgical release (9). The results can be applied to the case of AMC management whereby similar fibrotic contractures exist. Surgery is normally indicated for severe fixed contracture that restricts functional activities.

Post-operative rehabilitation procedures are very important in preserving surgical gains. Unless physiotherapy is intensive, stiffness re-appears.

3f. Multisystem and Related Conditions

AMC can also be linked with other congenital disorders including eye disorders. Hailaiti et al. showed that surgical treatment of congenital cataracts at an early age is a very effective means of decreasing the chances of postoperative amblyopia when supplemented by proper follow up treatment (5). This may not be quite relevant to the musculoskeletal management but it helps in highlighting the significance of thorough screening in children with congenital syndromes.

To maximize the long-term outcomes, multiple specialists should take part in multidisciplinary cooperation, such as orthopedic surgeons, physiotherapists, geneticists, neurologists, and pediatricians.

DISCUSSION

The present systematic review and meta-analytic synthesis evaluated the effectiveness of medical and surgical management strategies for children with arthrogryposis multiplex congenita (AMC), with particular emphasis on rehabilitation interventions, Ponseti-based clubfoot correction, and orthopedic surgical procedures for major joint deformities. The findings indicate that early multidisciplinary management combining structured rehabilitation with selective surgical intervention provides the most favorable functional outcomes. Consistent with the pathophysiological basis of AMC, where fetal akinesia leads to muscle fibrosis and joint stiffness, early mobilization and continuous physiotherapy appear to play a central role in preventing progression of contractures and preserving joint mobility. Across the included studies, early rehabilitation programs were associated with significant improvements in joint range of motion, motor development, and independence in daily activities. These findings reinforce the growing consensus that rehabilitation should be initiated soon after diagnosis and maintained throughout childhood to accommodate developmental changes and evolving functional needs (16).

The results also highlight the critical role of conservative orthopedic management in addressing congenital deformities commonly observed in AMC. Among these deformities, congenital clubfoot remains one of the most prevalent and clinically challenging conditions. The evidence synthesized in this review supports the Ponseti method as the preferred first-line treatment for clubfoot associated with AMC. Although the method demonstrates high initial correction rates, recurrence remains substantially higher than in idiopathic clubfoot due to the underlying neuromuscular imbalance and increased tissue rigidity characteristic of arthrogryposis. These findings are consistent with previously published observational studies demonstrating that AMC-associated clubfoot requires a greater number of casting sessions and prolonged bracing to maintain correction (17). Nevertheless, the Ponseti technique remains advantageous compared with extensive soft-tissue release surgery, as it preserves joint mobility and reduces the risk of postoperative stiffness and long-term functional impairment.

Surgical interventions remain an essential component of AMC management, particularly in cases where conservative treatment fails to achieve adequate deformity correction or functional positioning. Hip dislocation represents one of the most complex orthopedic challenges in children with AMC, frequently presenting as bilateral and associated with severe joint rigidity. The current analysis indicates that open reduction surgery can improve joint stability and facilitate improved sitting balance and ambulation potential in selected patients. However, complication rates including redislocation and avascular necrosis remain clinically relevant. These findings emphasize the importance of individualized surgical decision-making based on functional goals, ambulatory potential, and the overall clinical condition of the patient rather than solely anatomical correction (18).

Upper limb contractures represent another major determinant of functional independence in children with AMC, particularly for activities such as feeding, dressing, and personal hygiene. The results of the present synthesis suggest that surgical contracture release procedures can significantly improve the range of motion and functional positioning of the upper extremities when conservative measures alone are insufficient. However, postoperative rehabilitation plays a critical role in maintaining these surgical gains. Without structured physiotherapy following surgery, the fibrotic nature of the affected tissues may predispose patients to recurrence of stiffness or limited functional improvement. These findings align with broader pediatric orthopedic literature emphasizing the importance of integrating postoperative rehabilitation protocols into surgical treatment plans for joint contractures (19).

In addition to musculoskeletal deformities, AMC frequently presents with multisystem involvement that requires coordinated multidisciplinary care. Although orthopedic deformities are often the most visible clinical features, associated medical conditions such as respiratory compromise, feeding difficulties, and ocular abnormalities may influence long-term health outcomes and quality of life. Comprehensive care models that incorporate pediatricians, orthopedic surgeons, physiotherapists, neurologists, and genetic specialists have been shown to improve overall clinical outcomes by addressing both structural deformities and associated systemic conditions. These integrated care approaches are increasingly recognized as a fundamental component of effective AMC management (20).

From a broader research perspective, the findings of this review highlight several important gaps in the current evidence base. Despite the increasing number of publications addressing AMC management, most available studies remain observational in nature and are characterized by relatively small sample sizes, heterogeneous patient populations, and variability in outcome reporting. This heterogeneity limits the ability to conduct robust

comparative analyses across treatment modalities and reduces the certainty of pooled estimates. Furthermore, many studies focus primarily on short-term orthopedic outcomes such as deformity correction or joint mobility, while long-term functional outcomes including independence, quality of life, and adult mobility remain insufficiently investigated. These limitations underscore the need for prospective multicenter studies and standardized outcome reporting frameworks to facilitate meaningful comparisons across interventions (21).

Another important consideration is the variability in clinical phenotypes associated with AMC. The condition encompasses multiple underlying etiologies, including amyoplasia, distal arthrogryposis, and syndromic forms, each of which may present with different patterns of joint involvement and functional limitations. Future research should therefore aim to stratify patients according to specific phenotypic subtypes when evaluating treatment outcomes. Such stratification may help clarify whether certain rehabilitation or surgical interventions are more effective for particular subgroups of patients, ultimately enabling more personalized treatment strategies (22).

The strengths of the present study include the comprehensive evaluation of both conservative and surgical treatment approaches and the integration of evidence from multiple types of clinical studies. By synthesizing available research across rehabilitation, orthopedic surgery, and multidisciplinary care frameworks, the review provides a more holistic perspective on AMC management than studies focusing on individual interventions alone. The structured methodological approach, including predefined inclusion criteria and systematic data extraction procedures, also enhances the reliability of the findings.

However, several limitations must be acknowledged. First, the rarity of AMC limits the availability of large randomized controlled trials, resulting in a reliance on observational studies that may be susceptible to selection bias and confounding factors. Second, heterogeneity in patient characteristics, intervention protocols, and follow-up durations across the included studies may influence pooled outcome estimates. Third, inconsistencies in outcome measurement across studies made direct comparisons challenging and limited the scope of quantitative synthesis for some outcomes. Finally, long-term functional outcomes extending into adulthood remain underreported in the current literature, representing an important area for future investigation.

Overall, the findings of this study support the concept that successful management of arthrogryposis multiplex congenita requires early diagnosis, aggressive multidisciplinary rehabilitation, and carefully selected surgical interventions tailored to the functional needs of each patient. Conservative treatment strategies remain the cornerstone of care and can significantly improve joint mobility and motor development when initiated early. Surgical procedures remain valuable in addressing severe or refractory deformities but should be integrated within a comprehensive rehabilitation framework to maximize long-term functional outcomes. Continued advances in multidisciplinary care models, combined with improved research methodologies and standardized outcome reporting, will be essential to further refine treatment strategies and improve the quality of life for individuals affected by arthrogryposis multiplex congenita (16–22).

CONCLUSION

Arthrogryposis multiplex congenita (AMC) is a heterogeneous congenital condition that requires early, comprehensive, and multidisciplinary management to optimize functional outcomes. The evidence synthesized in this systematic review indicates that early conservative management, particularly structured physiotherapy, orthotic support, and serial

casting techniques, plays a central role in improving joint mobility and preventing progression of deformities. The Ponseti method remains the preferred first-line treatment for AMC-associated clubfoot due to its ability to achieve effective deformity correction while preserving long-term joint flexibility, although recurrence rates remain higher than in idiopathic cases and require prolonged follow-up and bracing. Surgical interventions, including open reduction for hip dislocation and contracture release procedures for upper limb deformities, provide meaningful functional improvements in carefully selected patients but must be integrated with postoperative rehabilitation to maintain surgical benefits and reduce recurrence. Overall, successful management of AMC depends on individualized treatment planning that balances conservative and surgical approaches according to the severity of deformities and functional goals of the patient. Future research should prioritize standardized outcome reporting, long-term follow-up studies, and multicenter collaborative research to strengthen the evidence base and support the development of evidence-based treatment algorithms for children with arthrogryposis multiplex congenita.

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DECLARATIONS

Ethical Approval: Ethical approval was by institutional review board of Respective Institute Pakistan

Informed Consent: Informed Consent was taken from participants.

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Concept: MNB; Design: AA; Literature Search: AH, SS; Study Selection and Data Extraction: AH, SJ; Analysis and Interpretation: MA; Drafting and Revision: NM

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