NURSING INFORMATION JOURNAL
Page 249-260

NURSING INFORMATION JOURNAL
Volume: 5, Issue: 2, 2026
Review Article
e-ISSN 2809-0152
DOI https://doi.org/10.54832/nij.v5i2.1366

PREVALENCE OF MOTOR IMPAIRMENTS IN CHILDREN WITH ACUTE LYMPHOBLASTIC LEUKEMIA DURING CHEMOTHERAPY: A SYSTEMATIC REVIEW

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ABSTRACT
Motor impairments are a frequent and disabling consequence of vincristine-based chemotherapy in children with acute lymphoblastic leukemia (ALL). These deficits can compromise daily functioning and long-term quality of life. This systematic review aimed to synthesize evidence on the prevalence and characteristics of motor impairments among pediatric ALL patients undergoing chemotherapy. A comprehensive search was conducted across PubMed, ScienceDirect, Scopus, ClinicalKey, and ClinicalKey Nursing, supplemented by citation tracking. Observational studies published up to May 2025 were screened using the PEOS framework. Ten eligible studies involving 580 children were included. Outcomes assessed encompassed fine motor precision, manual dexterity, coordination, balance, agility, and strength. Motor impairments were consistently reported across all studies, with prevalence varying by treatment phase and country. During induction, prevalence ranged from 48% (USA) to 62.5% (Netherlands). In consolidation, rates reached 75.5% (Colombia). The highest prevalence was observed in the maintenance phase, with Turkey reporting 83.9% overall impairment and specific deficits in fine motor integration (70.6%), strength (74.4%), and upper-limb coordination (61.1%). Finland showed the lowest overall prevalence (31.8%). Motor impairments are common and persistent in children with ALL receiving vincristine-based chemotherapy, particularly during the maintenance phase. These findings underscore the need for standardized monitoring protocols, early detection, and timely rehabilitation strategies to mitigate long-term functional decline and optimize quality of life in pediatric oncology care.

Keywords: Acute Lymphoblastic Leukemia; Motor Impairments; Systematic Review; Vincristine

Article History:
Received: 03 December 2025
Revised: 04 March 2026
Accepted: 26 March 2026

INTRODUCTION
Although childhood cancer is rare, it remains a leading cause of death in children and adolescents worldwide. Cancer in children are characterized by a shorter incubation period, faster spread, and greater invasiveness (Silva, Pianovski, & Costa, 2024). Acute lymphoblastic leukemia (ALL) is the most common cancer in children and adolescents. In 2021, the number of childhood ALL cases increased by 59.06% (±168,879) cases worldwide compared to the

previous period. However, in the same year, the number of ALL-related deaths and disability-adjusted life years (DALYs) decreased significantly by 66.71% and 66.13% (Ding et al., 2025). According to data from The Global Cancer Study (GLOBOCAN), Indonesia has recorded 8312 cases of cancer in children aged 0–19 years. Of these, leukemia dominates with 3457 cases (41.6%), followed by brain cancer with 874 cases (10.5%), and lymphoma with 605 cases (7.3%) (IARC, 2022).

Chemotherapy remains the primary treatment modality for cancer management. Vincristine is the most commonly used combination regimen for various types of malignancies, such as treating ALL. Although chemotherapy has high efficacy in the treatment of childhood ALL, it has a range of significant toxic effects on children (Devi & Allenidekania, 2019). Similar to other chemotherapy agents, vincristine can cause intolerable side effects, most notably vincristine-induced peripheral neuropathy (VIPN). Studies have reported that the prevalence of VIPN range from approximately 10% to 90% in children and around 78% in adults, with symptoms tending to appear at cumulative doses above 4 mg/m^2 (Puscasu, Negres, Zbârcea, & Chirită, 2024).

Indirectly, neurotoxic effects have a long-term impact on the quality of life of ALL patients. The symptoms of VIPN most often reported include sensory disturbance and motor impairment including weakness, gait, balance difficulties and reduced fine motor skill (Alwhaibi et al., 2023; Triarico et al., 2021). Neurotoxic disorders progressively impair their ability to perform daily activities due to impaired skill motor. Prevalence of motor impairment is reflected in finding that 20% to 80% of children with ALL undergoing chemotherapy score below-average on motor function assessment (Hamari et al., 2020; Kabak, Ipek, Unal, Uysal, & Duger, 2021) .

A recent analysis of paediatric ALL, found that clinical neuropathy symptoms were observed in 47.4% of patients during treatment and persisted in 51.6% of patients after treatment (Kroczka et al., 2020). Although decreased motor skills in children with ALL undergoing chemotherapy are a common condition, prevention and management of this condition are often overlooked, partly due to wide variation in reported prevalence across studies. These impairments are generally associated with the cumulative dose of vincristine, which remains the first-line drug in the treatment of ALL. However, Further in-depth research on this condition is needed to improve strategies, symptom management, and optimal rehabilitation. Therefore, a systematic review was conducted, using an evidence-based approach, to examine and identify the prevalence of motor impairment among children with ALL undergoing chemotherapy.

METODH

Study Design

This systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guideline (Page et al., 2021).

Search methods

We searched five databases PubMed, ScienceDirect, Scopus, ClinicalKey, and ClinicalKey Nursing and enhanced the search through citation tracking to identify relevant literature on the prevalence of motor impairment. All articles were managed using EndNote 21 and screened for eligibility based on the PEOS framework. The PEOS framework was used to formulate of the research questions in this systematic literature review. A combination of Medical Subject Headings (MeSH) terms was used to identify eligible studies: ((Motor Activity) OR (Motor Function) OR (Motor Skills) OR (Fine Motor) OR (Gross Motor)) AND (Chemotherapy*) AND ((Acute Lympho* Leukemia) OR (Leukemia)). Additional studies were identified through citation tracking to identify more relevant studies. Two reviewers independently extracted the data and discussed their findings. When consensus was reached, the results were reviewed by the other reviewers for verification. Any disagreements that arose during the discussion were resolved in consultation with the third reviewers until a final agreement was achieved.

Inclusion and Exclusion Criteria

We included observational studies with the following criteria: (1) The study participants were children diagnosed with acute lymphoblastic leukemia (ALL); (2) The participants were undergoing chemotherapy or were in the induction, consolidation, or maintenance phase; (3) The selected articles were published from inception until May 2025; (4) The outcomes analyzed included fine motor precision, fine motor integration, manual dexterity, upper-limb coordination, bilateral coordination, balance, running speed and agility, and strength; and (5) Only observational studies were included in this systematic review and studies not published in English were excluded.

Data Extraction

Data were extracted using a structured data extraction form, which included participant characteristics (e.g., country, sample size, age, height, weight, and BMI), study characteristics (e.g., author and year of publication), outcome measurements (e.g., tools used and measurement time points) and prevalence data. The prevalence of motor impairment was extracted from articles that met the inclusion criteria. If the article did not report prevalence directly, the data were calculated based on manual estimates from the relevant article such, a boxplots; Mean ± SD; or median (IQR)). Data extraction was performed independently by two reviewers. Any discrepancies between the reviewers were resolved through discussion or by involving other reviewers.

Quality Apprasial

The methodological quality of the included studies was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist appropriate for observational studies. Each study was independently evaluated by two reviewers based on criteria such as clarity of inclusion criteria, validity and reliability of exposure and outcome measurements, identification and management of confounding factors, and appropriateness of statistical analysis. Each item was rated as “Yes”, “No”, “Unclear”, or “Not Applicable”.

The overall quality of the studies was categorized into three levels: high quality (score >70%), moderate quality (50–70%), and low quality (<50%). Any discrepancies between reviewers were resolved through discussion or consultation with a third reviewer to reach consensus. All studies included in this review were considered to have high methodological quality, with scores ranging from 72.7% to 100%. This indicates that the evidence synthesized in this review is generally reliable, although variations in study design and measurement tools should still be considered when interpreting the findings.

Data Analysis

Data analysis was conducted using a descriptive synthesis approach due to the heterogeneity of study designs, outcome measures, and reporting formats. Quantitative meta-analysis was not performed because of variations in assessment tools (e.g., BOT-2, M-ABC, MOON test), differences in outcome domains, and inconsistencies in reporting prevalence data across studies.

The extracted data were organized based on key variables, including study characteristics, participant demographics, treatment phases (induction, consolidation, and maintenance), and types of motor impairments. The prevalence of motor impairment was summarized and compared across studies and treatment phases. Where prevalence data were not explicitly reported, they were calculated or estimated from available statistical data such as mean, standard deviation, median, interquartile range, or graphical representations. The findings were then grouped and presented narratively to identify patterns, trends, and differences in motor impairment prevalence across countries and chemotherapy phases.

RESULT

Search Outcome

The selection of studies was conducted in two phases. The first phase, two independent reviewers screened the titles and abstracts of all retrieved records based on the inclusion criteria. In the second phase, full text articles were obtained and independently assessed for eligibility by the same reviewers. Any disagreement during either phase was resolved through discussion or by consulting other reviewers. Initial data collection using five different databases resulted in 858 articles. The resulting studies were screened using EndNote 21 software. The screening results contained 60 duplicate articles that were removed, leaving 798 articles for the first screening and further review. The remaining articles were then assessed based on their titles and abstracts, and articles that did not meet the inclusion criteria, such as participant characteristics, exposure, outcomes, and study design were excluded. From this step, 33 articles were retained and move into the second screening, which involved full-text assessment and resulted in 5 articles. In addition to using database searches, the authors conducted citation tracking to further identify relevant articles. In the end, 10 articles were selected for analysis. The complete PRISMA procedure is illustrated in Figure 1, the flow diagram below.

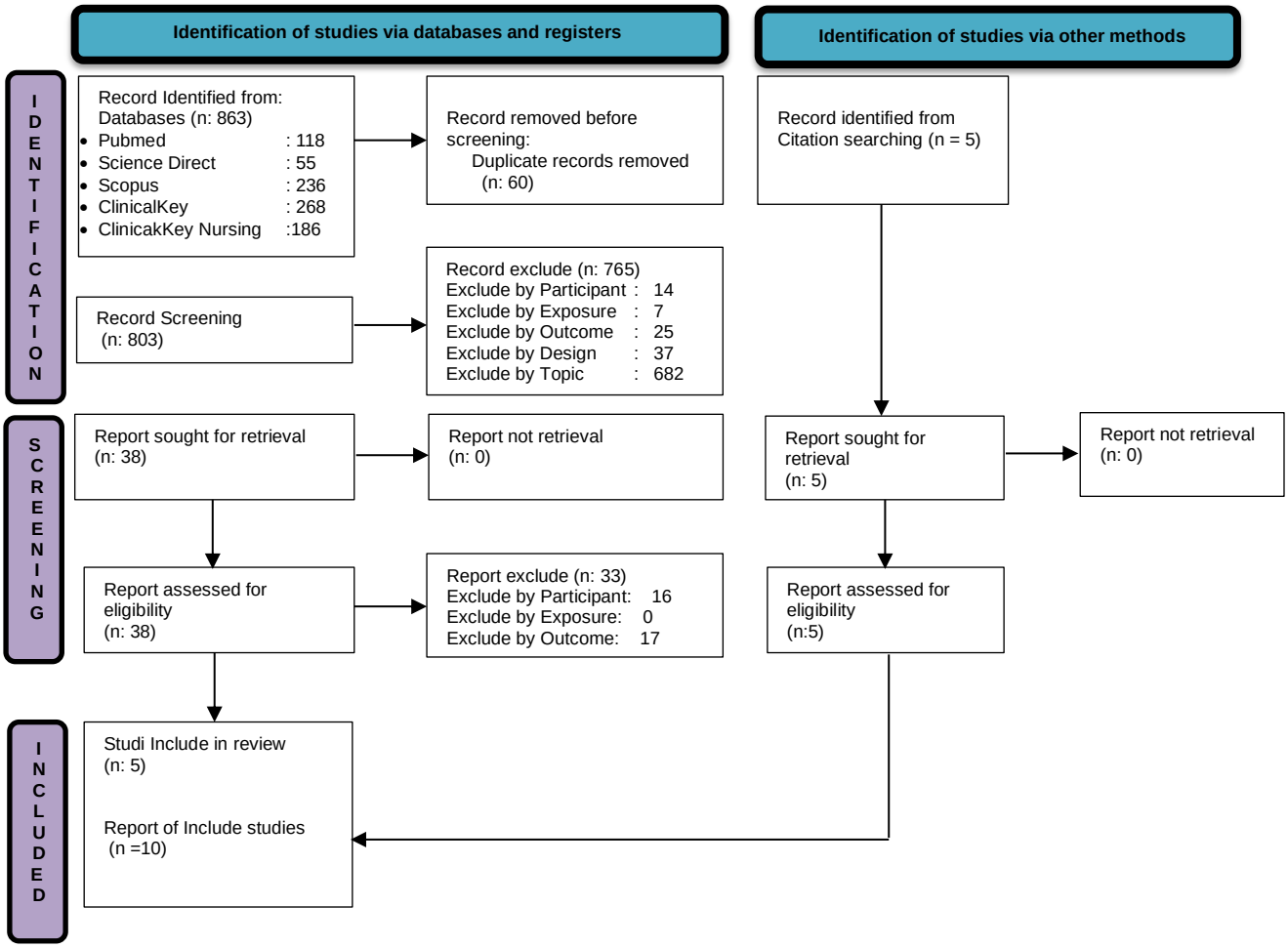

Figure 1. PRISMA Flow Diagram

Quality Assessment Results

An analysis of 10 studies meeting inclusion criteria involved 580 participants and was conducted in 9 countries. Study designs included observational studies only, using cohort and cross-sectional approaches. Participants were under 18 years of age (mean age range: 5.62–12.6 years). In addition to age, participant characteristics such as height, weight, and BMI have

also been reported in several studies and are considered potential factors influencing test results. Participants had been diagnosed with acute lymphoblastic leukemia and were undergoing chemotherapy in either the induction, consolidation, or maintenance phases.

Identification of motor impairments varied depending on the assessment tools used, which covered domains such as fine motor integration and precision, manual dexterity, coordination, balance, speed and agility, and strength. Most of the included studies primarily used the Bruininks-Oseretsky Test of Motor Proficiency Second Edition (BOT-2), while others employed the Movement Assessment Battery for Children Second Edition (M-ABC) and the MOON Test. The use of different measurement instruments may have contributed to variability in the reported prevalence rates, as each tool differs in its constructs, scoring systems, sensitivity, and normative references. Therefore, direct comparability between studies should be interpreted with caution. Additionally, not all included studies reported total composite scores; some presented only subdomain scores. This inconsistency limited the ability to synthesize findings quantitatively and represents an important methodological limitation of this systematic review. Motor impairments were most frequently identified during the maintenance phase, although several studies also reported impairments during the induction and consolidation phases.

Tabel 1. Characteristic of Study (n = 10)

No	(Author, Year), Study Country, Title and DOI	Aim	Design	Participants	Measurement		Outcome
					Tools	**Time Assessment**	
1	**(Reinders-Messelink et al., 1999)** Netherlands, Medical and Pediatric Oncology, 33(6), *DOI:* https://doi.org/10.1002/(SICI)1096-911X(199912)33:6<545::AID-MPO4>3.0.CO;2-Y	Investigated motor performance among children with Acute Lymphoblastic Leukemia during chemotherapy	Cohort	17 Mean age: 7.1 (2.2)	M-ABC	• Induction • Maintenance	• Total Impairment • Manual Dexterity • Balance
2	**(Sabarre et al., 2014)** Canada, *Canadian Journal of Occupational Therapy*, 81(4), DOI: https://doi.org/10.1177/0008417414539926	Examined the fine motor skills and function of children with Acute Lymphoblastic Leukemia (ALL) under maintenance vincristine	Cohort	15 Mean age: 9.6 (2.7)	M-ABC	Maintenance	• Total Impairment
3	**(Götte et al., 2015)** Germany, *European Journal of Pediatric*, 174(6), DOI: https://doi.org/10.1007/s00431-014-2460-x	Identification motor performance at the end of the acute treatment phase and reveals potential risk factors for motor deficits	Cross-sectional	53 Mean age: 12.6 (3.90) years BMI: 18.9 (4.0) kg/m^2	MOON test	Maintenance	• Upper-Limb Coordination • Balance • Speed • Manual Dexterity • Strength
4	**(Ness et al., 2015) United States,** *Leukemia & Lymphoma*, 56(4), DOI: https://doi.org/10.	Describes skeletal, neuromuscular and fitness impairments with acute	Cross-sectional	n: 211 i: 109 c: 102 Mean age: 10 (3.5) years	BOT2-SF	Induction	• Total Impairment

	3109/10428194.2014.944519	lymphoblastic leukemia (ALL)					
5	**(Nama et al., 2020) Canada,** *Pediatric Hematology and Oncology*, 37(1), DOI: https://doi.org/10.1080/08880018.2019.1677832	Estimation of prevalence of both fine and gross motor dysfunction	Cohort	n: 71 Mean age: 7.6 (2.3) years Height: 120.3 (103.5-150.9) cm Weight: 23.6 (16.4-101.7) kg	BOT-2	• Consolidation • Maintenance	• Fine Manual Control • Manual Coordination • Body Coordination • Strength
6	**(Hanna et al., 2020)** Egypt, *Pediatric Blood & Cancer*, 67(7), DOI: https://doi.org/10.1002/pbc.28385	Different types of fine motor impairments in Egyptian children diagnosed with ALL	Cross-sectional	n: 108 i: 54 c :54 Mean age: 5.62 (1.11) years Height: 113.72 (11.83) cm Weight: 20.74 (3.61) kg BMI: 15.92 (1.32) kg/m^2	BOT-2	Maintenance	• Total Impairment
7	**(Hamari et al., 2020)** Finland, *Children*, 7(8), DOI: https://doi.org/10.3390/children7080098	Monitor the effect of vincristine on motor performance	Cohort	n: 36 Mean age: 7.8 (3.3) years	MABC-2	• Consolidation • Maintenance	• Total Impairment • Balance Upper-Limb • Coordination
8	**(Kabak et al., 2021) Turkey,** *Perceptual and Motor Skills*, 128(3), DOI: https://doi.org/10.1177/0031512521002065	Investigate the gross and fine motor functioning and basic cognitive performance of children with ALL who were receiving chemotherapy	Cross-sectional	46 i: 25 c: 21 Mean age: 9.94 (2.175) years Height: 146.9 (11.89) cm Weight: 37.51 (12,41) kg BMI: 17.29 (3.67) kg/m^2	BOT2-SF	• Induction • Consolidation	• Total Impairment • Fine motor precision • Fine motor integration • Manual Dexterity • Upper-Limb Coordination • Bilateral Coordination • Balance • Running speed and agility • Strength
9	**(Kabak et al., 2021) Turkey,** *European Journal of Pediatric*, 180(4), DOI: https://doi.org/10.1007/s00431-020-03833-y	Determine impairments in physical function, activity limitation, and participation restriction	Cross-sectional	n: 30 Mean age: 8,45 (3.33) years BMI: 18.71 (3.24) kg/m^2	BOT-2 SF	Maintenance	• Total Impairment
10	**(Tejeda-Castellanos et al., 2023)** Mexico, *BMC Pediatric*, 23(1), DOI: https://doi.org/10.	Evaluate fine motor skills; precision, motor integration, manual dexterity, and upper-limb	Cross-sectional	29 Mean age: 7.87 (1.32) years Height: 121.1 (11.21) cm	BOT-2	Maintenance	• Fine motor precision • Fine motor integration • Manual Dexterity

1186/s12887-023-04316-3	coordination in children with Acute Lymphoblastic Leukemia (ALL)	Weight: 23.86 (5.33) kg	• Upper-Limb Coordination

Analytical Findings result

Prevalence Motor Impairment in Induction Phase

Ten studies identified motor impairments at different stages with varying prevalence rates. In the induction stage, a United State study using the BOT-2 total score reported motor impairments in 48% of patients (Ness et al., 2015). The highest prevalence in this stage was reported in the Netherlands of 62.5% on the total score and several specific scores, namely manual dexterity at 25% and balance at 50% (Reinders-Messelink et al., 1999). Meanwhile, in Turkey also reported motor impairments in this stage, although the data were categorized together with the induction and consolidation stages, with a total prevalence of 56% for motor impairments (Kabak, Ekinci, Uysal, Cetin, & Duger, 2021).

Prevalence motor impairment in consolidation phase

In the consolidation phase, the prevalence of motor impairments was also substantial. A study in Colombia reported motor impairments in 75.47% of patient based on the total score, along with impairments in specific scores, namely manual dexterity (52.83%) and balance (50%) (Nama et al., 2020). Similar findings were reported in Finland, with total impairments of 30.08%, manual dexterity (37.13%), and balance (25.77%) (Hamari et al., 2020).

Prevalence motor impairment in maintenance phase

Analysis of several relevant studies shows that the highest number of motor impairments is found in the maintenance phase. In this phase, measurements are not only made using the total score but also include a wider range of specific scores than the other two phases. The highest prevalence of motor impairments was reported in Turkey, with a total impairment of 83.86% and specific impairments in fine motor integration (70.62%), manual dexterity (59.82%), upper-limb coordination (61.05%), and strength (74.36%) (Kabak, Ipek, et al., 2021). In the Netherlands reported total motor function impairment of 47.06% and specific manual dexterity scores of 17.65% and balance scores of 50% (Reinders-Messelink et al., 1999). Motor impairments were also reported in Colombia with a prevalence of 57.14% (Sabarre, Rassekh, & Zwicker, 2014) and 49.06% (Nama et al., 2020).

Some studies identify motor impairments using only a few specific scores. In Germany, motor impairments were identified with fine motor integration at 87.23% and strength at 84.85% (Götte, Kesting, Winter, Rosenbaum, & Boos, 2015). In Egypt, one focused on fine motor impairments, with a prevalence of manual dexterity of 76.65% and upper-limb coordination of 64.99% (Hanna, Elshennawy, El-Ayadi, & Abdelazeim, 2020). Meanwhile, another study in Mexico reported a manual dexterity impairment of 37.5% (Tejeda-Castellanos et al., 2023), which is similar to in Colombia manual 41.51% (Nama et al., 2020).

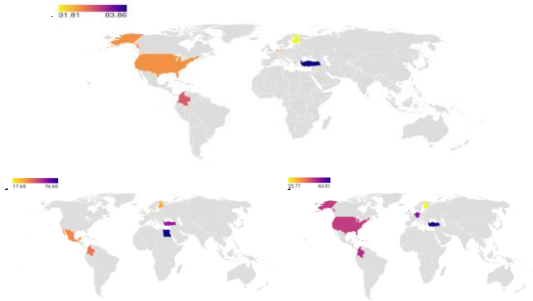

Figure 2 Distribution of the three most prevalent motor impairment in childhood Acute Lymphoblastic Leukemia (ALL) (a) total impairment (c) manual dexterity (c) balance according to country.

Risk of Bias

The methodological quality of each included study was evaluated using the JBI Critical Appraisal Checklist (Joanna Briggs Institute). Each questionnaire item was rated as 'Yes', 'No', 'Unclear', or 'Not Applicable'. Studies were considered high-quality if they scored above 70%, moderate-quality if they scored 50-70%, and low-quality if they scored below 50% on any JBI checklist item (Dijkshoorn et al., 2021). All studies included in this systematic review demonstrated high methodological quality, with overall scores ranging from 72.7% to 100%. Specifically, 30% of the studies scored 72.7%, 10% scored 87.5%, 10% scored 81.8%, and the remaining studies achieved a score of 100%.

DISCUSSION

This systematic review aims to examine the prevalence of motor impairment in children with leukemia during chemotherapy. An analysis across studies shows that motor impairment occurs consistently throughout the treatment cycle, including the induction, consolidation, and maintenance phases. The trajectory of motor symptoms in children with ALL is variable, with fluctuations observed throughout treatment. While motor impairment can occur during induction and consolidation, the decline becomes most pronounced during the maintenance phase, indicating this as a critical period

Several studies report that children with ALL tend to experience declines in motor performance, both subtle and gross, in the final phase of chemotherapy. This is consistent with a study conducted in Turkey that showed a decline in motor function during the maintenance phase, amounting to 83.86% (Kabak, Ipek, et al., 2021). Similar impairments were also reported in the Netherlands with a lower incidence of 47.06% during the maintenance phase (Reinders-Messelink et al., 1999). This confirms that almost all children undergoing chemotherapy experience motor impairments until the maintenance phase. The decline in motor skills seen at the end of cancer treatment is likely not caused by a single factor, but rather a combination of several. The cumulative effects of therapy, neurotoxicity, lack of motor skill stimulation, and cancer-related symptoms are suspected to play a role in the decline in motor performance in children with ALL (Hamari et al., 2020).

Most of the studies we reported highlighted fine motor impairments, particularly manual dexterity, finger coordination, and visual-motor integration. These impairments were present from the early stages of chemotherapy but were most pronounced during the maintenance phase. A high prevalence was reported in Egypt, reaching 76.65% at the end of treatment (Hanna et al., 2020), whereas a study in Mexico reported only 12.50% (Tejeda-Castellanos et al., 2023). This difference is likely influenced by study procedures and criteria, but other factors such as physical activity level, varying therapy protocols, length of hospital stay, fatigue, and residual treatment effects cannot be ruled out (Kabak, Ipek, et al., 2021). Treatment effects can lead to growth retardation, with children becoming shorter with a relatively higher BMI, which is associated with poorer fine motor precision. Other studies have also suggested that varying protocols cause fine motor impairments in children with ALL, which are closely related to differences in chemotherapy dose, frequency, and timing in the ALL-SR and ALL-HR groups (Hanna et al., 2020).

Although relatively mild, children with ALL undergoing chemotherapy often exhibit gross motor impairment. This decline is more pronounced during the post-induction and consolidation phases. This condition is likely related to the more frequent administration of vincristine in the early phases of chemotherapy compared to later phase (Hamari et al., 2020). Longitudinal studies indicate that approximately half of children who experience declines in gross motor function in the early phase show improvement in the maintenance phase. However, in some children, gross motor impairments persist as a result of the burden of long-term therapy (Nama et al., 2020; Hamari et al., 2020). A study in Turkey also reported balance impairment as one aspect the gross motor dysfunction, with a prevalence reaching 63.01% (Kabak, Ipek, et al., 2021). Consistent with these findings, declines in hand-eye coordination, speed, muscle

strength, and flexibility have also been reported to impact children's ability to perform daily activities during chemotherapy (Götte et al., 2015). These balance disorders are associated with the intensive therapy in early months and systemic nature of ALL (Hamari et al., 2020).

The association between motor impairment and antineoplastic drug, vincristine, has not been consistently confirmed. A Dutch study reported that children with ALL receiving vincristine showed decline in motor function after several cycles of chemotherapy, although the contribution of other agents cannot be completely ruled out (Reinders-Messelink et al., 1999). In contrast, a Colombian study found no significant association between cumulative vincristine dose and fine motor skills. However, it reported a decline in motor performance during the maintenance phase, as no children achieved scores above the 50th percentile for manual dexterity (Sabarre et al., 2014). Similarly, an Egyptian study reported that varying cumulative doses of vincristine or dexamethasone had no significant effect on fine motor skills (Hanna et al., 2020). Discrepancies across studies are likely influenced by the relatively small sample size. Although vincristine-induced peripheral neuropathy (VIPN) is often associated with motor impairment, recent evidence suggests that motor deficits are more likely the result of a complex interaction.

All studies analyzed emphasize the importance of early detection and rehabilitative intervention in addressing motor impairments in children with ALL. The maintenance phase is considered the most appropriate period for assessment, as children re-adapt to normal life after a long and intensive period of therapy (Kabak, Ipek, et al., 2021). Standardized early detection and rehabilitative intervention not only prevent further functional decline but also support the growth and development of children (Hamari et al., 2020). Structured, evaluation-based rehabilitation programs (e.g: physical activity and exercise) are recommended during chemotherapy to maintain motor skills, improve mental health, and prevent future complications (Kabak, Ipek, et al., 2021).

IMPLICATION AND LIMITATIONS

Implications

The findings of this systematic review have important clinical and research implications. Clinically, the high prevalence of motor impairments across all phases of chemotherapy highlights the need for routine motor function screening in children with acute lymphoblastic leukemia (ALL). Early identification of motor deficits allows healthcare professionals, particularly nurses, to initiate timely referrals for rehabilitation interventions. The results also emphasize the importance of implementing standardized assessment tools and structured rehabilitation programs, including physical activity, strength training, balance exercises, and fine motor skill interventions. Integrating these strategies into pediatric oncology care can help prevent long-term functional decline and improve quality of life.

From a research perspective, this review underscores the need for more standardized methodologies, including consistent outcome measures and reporting formats, to improve comparability across studies. Future longitudinal and interventional studies are recommended to better understand the progression of motor impairments and evaluate the effectiveness of rehabilitation strategies.

Limitation

This systematic review has several limitations that should be considered. First, the included studies showed heterogeneity in study design, assessment tools, and outcome reporting, which limited the ability to perform a quantitative meta-analysis. Second, variations in measurement instruments (e.g., BOT-2, M-ABC, MOON test) with different scoring systems and sensitivity levels may have contributed to inconsistencies in reported prevalence rates.

Third, some studies reported only subdomain scores rather than total motor impairment scores, which limited comprehensive data synthesis and direct comparison across studies. Fourth, the relatively small sample sizes in several included studies may reduce the generalizability of the findings. Finally, only articles published in English were included, which may introduce language bias and limit the inclusion of relevant studies from non-English source

CONCLUSION

Motor impairments are highly prevalent in children with ALL across all phases of chemotherapy, ranging from 30% to more than 80%, with the most pronounced decline observed during the maintenance phase. Routine motor screening should therefore be integrated into clinical care from the induction phase and continued throughout treatment, with particular attention during maintenance as a critical period for functional deterioration. Nurses play an essential role in early identification by monitoring functional changes, conducting simple observational assessments, and initiating timely referrals to rehabilitation professionals when impairments are suspected.

This review identified fine motor integration, manual dexterity, balance, and muscle strength as the most affected domains. Rehabilitation strategies should prioritize targeted interventions such as hand-function training, balance exercises, and progressive muscle strengthening, supported by structured physical activity programs adapted to the child's treatment tolerance. Interdisciplinary collaboration among pediatric oncologists, nurses, physiotherapists, and occupational therapists is crucial to ensure standardized assessment, early intervention, and individualized rehabilitation planning to optimize functional outcomes during chemotherapy.

SUGGESTIONS

The prevalence of motor impairments varies considerably among children with ALL undergoing chemotherapy across the induction, consolidation, and maintenance phases. Both gross and fine motor impairments are frequently reported, highlighting the need for systematic monitoring throughout treatment. Healthcare professionals, particularly nurses and rehabilitation providers, should implement routine motor assessments and closely observe changes in functional performance to ensure timely referral and intervention.

Regular monitoring combined with targeted rehabilitation strategies is essential to reduce motor dysfunction and optimize functional outcomes. Interventions should address modifiable factors, including structured physical activity, strength and balance training, and task-oriented fine motor exercises tailored to the child's treatment tolerance. These findings provide a practical foundation for developing standardized assessment protocols and phase-specific management strategies to support the quality of life of children with ALL during chemotherapy.

ACKNOWLEDGMENTS

Deep gratitude to all parties who have provided support in the process of compiling this systematic review.

STATEMENTS AND DECLERATION

There are no conflicts of interest associated with this research.

FUNDING

This research received no financial support from external sources and was entirely funded using the authors' personal resources.

AUTHORS CONTRIBUTIONS

Each author has made significant contributions at every stage of the research and has been given the opportunity to participate in discussions regarding the entire research process with the research team.

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