The Review Of
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Delayed Motor Development And Musculoskeletal Dysfunction: The Role Of Emergency Screening, Nutrition, And Physiotherapy

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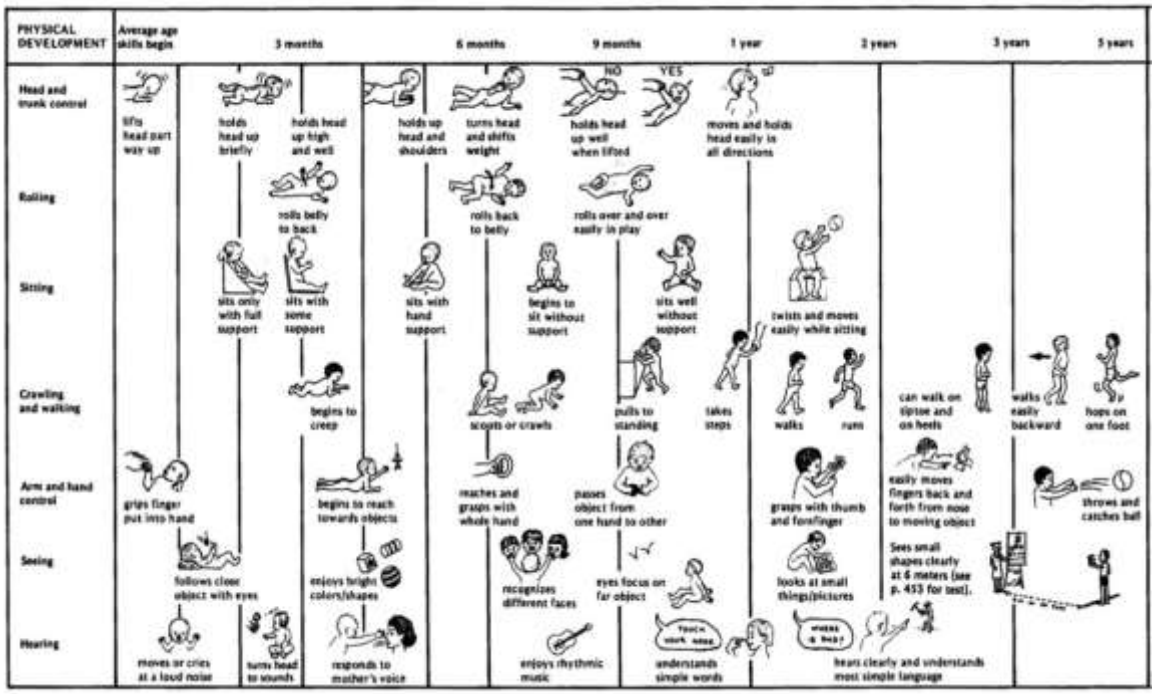
ABSTRACT
Delayed Motor Development and its musculoskeletal complications are still one of the most critical pediatric issues, still prevalent in 10-15 percent of the pediatric population worldwide. The complications lead to lifelong disability in mobility, coordination, participation, and quality of life. The current systematic review outlines the recently available evidence on causative, detection, and current practices of Delayed Motor Development from 2020-2025 and how individual aspects of Emergency Screening, Nutritional Modalities, and Physiotherapeutic Modalities are interconnected towards effective DMD control. The primary cause can still be prematurity, genetic, nutrient deficiencies, and environmental conditions, further worsening musculoskeletal conditions of hypotonia, contracture, and deformity problems respectively. The emergency screening performed during acute practices can be used as a priority precursor towards adopting screening on-time, with studies indicating that ASQ has proven enormous sensitivity as a screening tool for risk factor-possessed babies respectively. The role of addressing nutrient inadequacies towards optimizing Vitamin D, calcium, and protein has been proven vital towards enhanced musculoskeletal mass and bone mineral content, with evidence supporting that reduced Supplementations towards rickets have diminished related milestones delay respectively. Benefits of Neuro-Developmental and Task-Oriented Physiotherapeutic Modalities towards speeding milestones and inhibiting secondary complications are represented

Keywords: Delayed motor development, musculoskeletal dysfunction, developmental screening, pediatric nutrition, physiotherapy interventions, gross motor milestones, early childhood intervention, cerebral palsy, prematurity risks, nutritional deficiencies.

Introduction

Delayed motor development (DMD) is considered to be a considerable delay in meeting the age-related gross and fine motor skills, such as rolling, sitting, crawling, or walking, and commonly with musculoskeletal disfunction including muscle weakness, joint instability, or abnormal posture (van Abswoude et al., 2020). DMD is present across the world with the prevalence between 10-15% under under five years of age, with more prevalence in low and middle-income countries because of the socioeconomic characteristics (Kohl et al., 2021). Within high-risk populations, including preterm babies or genetically disadvantaged individuals, there can often be an excess of 30 percent prevalence, which results in the subsequent cascade of cognitive, social, and emotional development (Seneviratne et al., 2024).

Physical development chart highlighting delays



DMD etiology is a multifactorial concept, that includes neurological, genetic, environmental and nutritional aspects. As an example, neural development is disrupted by preterm birth, which leads to hypotonia and delayed gross motor development, and neural development is affected by nutritional deficiency, worsening dysfunction (Chandrasekaran et al., 2023). The untreated DMD case may lead to chronic diseases such as cerebral palsy or scoliosis, which creates significant health care and family health-related challenges (Ruiz-Ariza et al., 2023).

Emergency screening is an important part of an early diagnosis, especially in acute care where delays can initially present after sickness or trauma (Grala et al., 2024). The use of standardized tools allows making a timely referral, capturing neuroplasticity windows of early childhood (Webster et al., 2023). Nutrition is bottom-up because micronutrient deficiencies have a direct impact on bone density and muscle activity; such interventions as vitamin D supplementation have been promising in reversing delays (Fardellone et al., 2023). Physiotherapy helps to develop motor skills by means of special exercises and treatment and avoid secondary complications (Hestbek et al., 2025).

Baby And Toddler Milestones Guide - Family Focus Blog

The purpose of this review is to define the key causes and risk factors affecting pediatric outcomes, examine current emergency screening techniques, determine the role of nutrition in supporting growth and recovery, review evidence-based physiotherapy interventions, and present practical

recommendations for integrated management. Drawing on literature published between 2020 and 2025, the review synthesizes contemporary evidence to address existing gaps in pediatric care. By bringing together clinical, nutritional, and rehabilitative perspectives, it highlights approaches that support holistic child development, strengthen early intervention, and reduce the risk of long-term disability.

Causes and Risk Factors

The causes and risk factors of DMD and musculoskeletal dysfunction require an understanding to be able to prevent and intervene. The abnormalities of typical motor milestones are also a feature of DMD, which can be the result of a combination of biological, environmental, and socioeconomic factors (van Abswoude et al., 2020). Mainly, neurological impairment, including cerebral palsy or hypoxic-ischemic encephalopathy, affects the control of muscle tone and coordination by the central nervous system (Sanchez-Garcia et al., 2024). Genetic disorders such as Down syndrome or muscular dystrophy also cause intrinsic weaknesses of musculoskeletal systems, and hypotonia results in crawling or walking delays (Gralla et al., 2024).

The risk factors are of great importance because in immature musculoskeletal systems, dysfunction is predisposed due to poor muscle mass, bone density, etc. (Kohl et al., 2021). Research shows that preterm babies have motor delays in 40-50 percent of the cases, and the consequences in the long term are gait and posture (Ruiz-Ariza et al., 2023). These problems are also increased by the environmental elements, such as poor physical stimulation or sedentary habits; as an example, gross motor lags are higher in children in urban settings with a lack of play areas (Webster et al., 2023).

Nutritional deficiencies are a alterable etiology more so in developing areas. Vitamin D deficiency is the cause of rickets, resulting in bowed legs and late ambulation, and protein-energy malnutrition is the cause of impaired muscle protein synthesis (Chandrasekaran et al., 2023). In the recent reviews, they note that the 20-30% higher risk of musculoskeletal disorders is associated with micronutrient deficiencies during early childhood (Fardellone et al., 2023). These risks are exacerbated by socioeconomic disparities and in low-income families, children with undernourishment experience compounded delays because of the lack of access to the healthcare system (Seneviratne et al., 2024).

Musculoskeletal dysfunction Musculoskeletal dysfunction is commonly secondary to DMD and leads to prolonged immobility resulting in contractures or scoliosis. In cerebral palsy, the abnormality of joints is caused by spasticity, which additionally impairs the progression (Lavelle et al., 2024). There are further complications such as risk factors such as maternal smoking or infections during pregnancy (Hestbek et al., 2025).

Common Causes and Risk Factors of DMD and Musculoskeletal Dysfunction

Category	Examples	Impact on Development	References
Neurological/Genetic	Cerebral palsy, Down syndrome	Hypotonia, delayed milestones	Sánchez-García et al. (2024); Gralla et al. (2024)
Perinatal	Prematurity, low birth weight	Muscle weakness, bone fragility	Kohl et al. (2021); Ruiz-Ariza et al. (2023)
Nutritional	Vitamin D deficiency, malnutrition	Rickets, reduced muscle strength	Chandrasekaran et al. (2023); Fardellone et al. (2023)
Environmental/Socioeconomic	Limited stimulation, poverty	Poor coordination, delayed ambulation	Webster et al. (2023); Seneviratne et al. (2024)

illustrates risk factor interactions

PEDIATRIC SEPTIC SHOCK COLLABORATIVE
TRIAGE TRIGGER TOOL

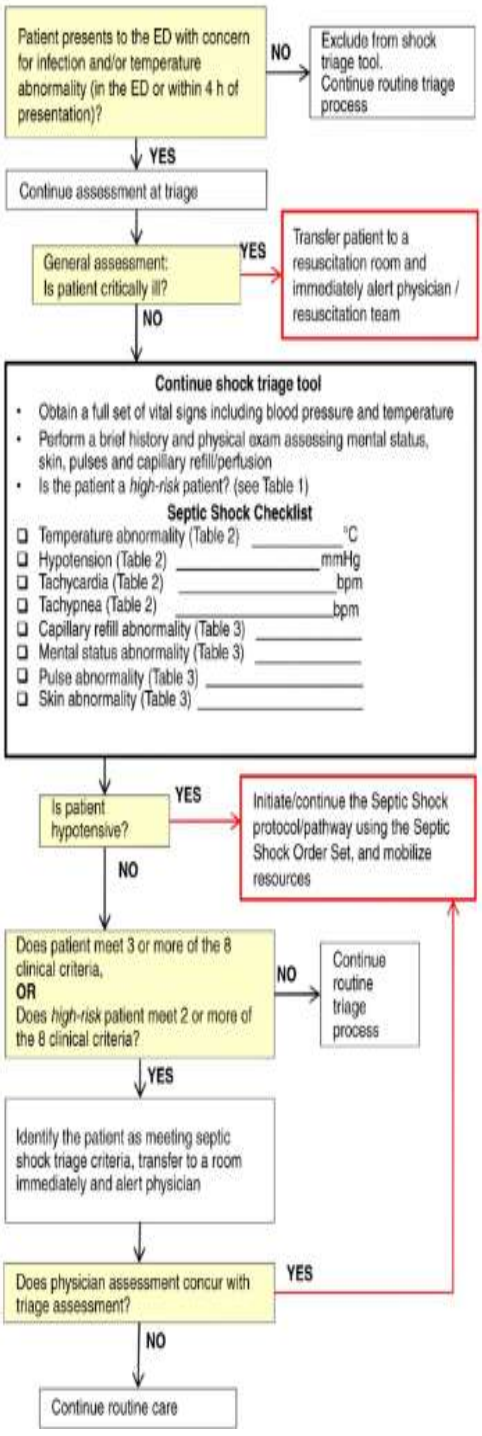


Table 1. High risk conditions

- Malignancy
- Asplenia (including SCD)
- Bone marrow transplant
- Central or indwelling line/catheter
- Solid organ transplant
- Severe MR/CP
- Immunodeficiency, immunocompromise or immunosuppression

Table 2. Vital signs (PALS)

Age	Heart rate	Resp rate	Systolic BP	Temp (°C)
0 d – 1 m	> 205	> 60	< 60	< 36 or > 38
≥ 1 m – 3 m	> 205	> 60	< 70	< 36 or > 38
≥ 3 m – 1 r	> 190	> 60	< 70	< 36 or > 38.5
≥ 1 y – 2 y	> 190	> 40	< 70 + (age in yr × 2)	< 36 or > 38.5
≥ 2 y – 4 y	> 140	> 40	< 70 + (age in yr × 2)	< 36 or > 38.5
≥ 4 y – 6 y	> 140	> 34	< 70 + (age in yr × 2)	< 36 or > 38.5
≥6 y – 10 y	> 140	> 30	< 70 + (age in yr × 2)	< 36 or > 38.5
≥ 10 y – 13 y	> 100	> 30	< 90	< 36 or > 38.5
> 13 y	> 100	> 16	< 90	< 36 or > 38.5

Table 3. Exam abnormalities

	Cold shock	Warm shock	Non-specific
Pulses (central vs. peripheral)	Decreased or weak	Bounding	
Capillary refill (central vs. peripheral)	≥ 3 s	Flash (< 1 s)	
Skin	Mottled, cool	Flushed, ruddy, erythroderma (other than face)	Petechiae below the nipple, any purpura
Mental status			Decreased, irritability, confusion, inappropriate crying or drowsiness, poor interaction with parents, lethargy, diminished arousability, obtunded

Emergency Screening and Early Identification

Detection and management of developmental motor delay (DMD) requires early screening since in most cases, early detection could lead to missed times of optimal neuroplasticity during which interventions are most effective (Gralla et al., 2024). The evidence suggests that early neural adaptation is a determinant of motor and cognitive recovery so timely screening is a clinical priority. Quickly screening patients in acute and emergency care setting, especially after infection, trauma, or an acute illness, allows the clinician to identify regression or new delays that otherwise would be missed (Sanchez-Garcia et al., 2024). This is of particular significance to infants and young children whose developmental patterns may shift quickly in case of physiological stress

This image illustrates key gross motor development milestones

The use of early identification is centered on the use of validated screening tools. Ages and Stages Questionnaire (ASQ) is an instrument that is highly practical because it assumes the ability to measure various areas of development, such as gross motor skills, and has a sensitivity of about 90 percent in infants (van Abswoude et al., 2020). In emergency departments, clinicians should be encouraged to observe red flags that include loss of previously realized milestones, inability to regain function, or delay following acute illness, which all should be referred to (Kohl et al., 2021). This practice is supported by professional advice as the American Academy of Pediatrics suggests universal developmental screening at ages 9, 18, and 30 months and developmental surveillance at every healthcare visit (Webster et al., 2023).

In case of high-risk groups, such as premature infants and even children with neurological weakness, more rigorous measures should be conducted. The Bayley Scales of Infant and Toddler Development allows technology to be used to take a more in-depth assessment of motor, cognitive, and language objects and identify impairments earlier and more accurately (Ruiz-Ariza et al., 2023). Regarding the population of the study, evidence within the range of 2020 to 2025 confirms that the introduction of structured screening programs can lower the diagnostic delay by six to twelve months, which results in better functional and developmental outcomes (Lavelle et al., 2024). Pediatric intensive care units have demonstrated the effectiveness of routine screening of post-illness functional impairments to reduce the risk of long term disability as it provides the opportunity to plan rehabilitation earlier (Hestbek et al., 2025).

Physiotherapist guiding child with developmental delay

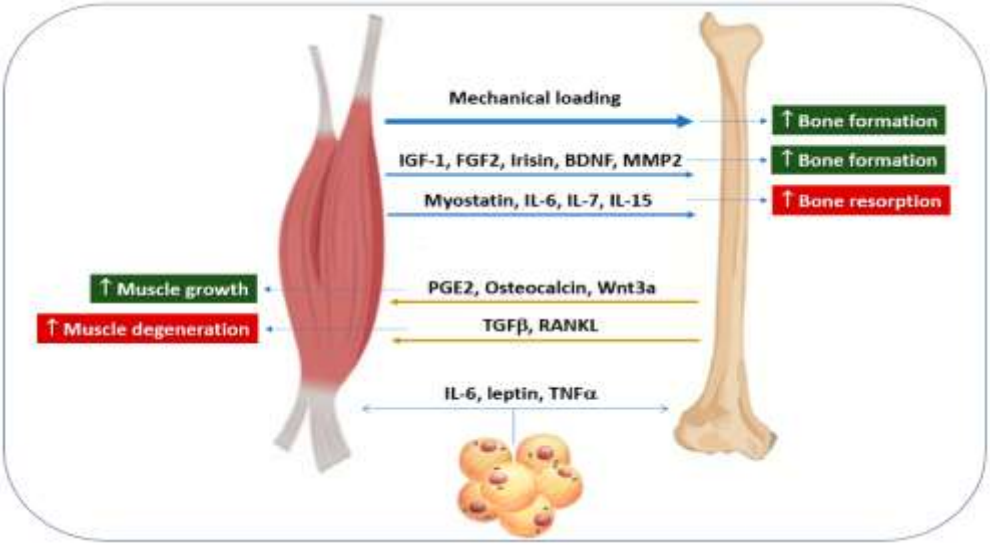
Although the advantages have been shown, obstacles to successful screening still exist. The implementation is still influenced by limited training of clinicians, time and resource shortage, especially in rural or underserved environments (Seneviratne et al., 2024). Screening at home through

telehealth has become an effective way to enhance access to developmental testing and expert consultation, as well as contribute to prompt referral and care continuity (Fardellone et al., 2023). These strategies will enable early detection of a person and decrease the development of extreme dysfunction. The role of nutrition in the prevention and management of DMD and related musculoskeletal dysfunction is based on the fact that it aids in bone, muscle, and neural growth (Chandrasekaran et al., 2023). Vitamin D, calcium, iron, and protein deficiencies have a close link with delayed motor development and motor impairment, which leads to rickets, anemia, and premature muscle wasting (Fardellone et al., 2023). Malnutrition has been proposed to increase hypotonia in cerebral palsy children and augment the chances of getting contractures, which worsens functional mobility (Sanchez-Garcia et al., 2024).

Vitamin D deficiency, nearly half of all children in the world, inhibits the absorption of calcium and bone mineralization, causing skeletal weakness and impaired walking (Gralla et al., 2024). Doses between 400 and 2,000 IU per day have been related to a positive effect on motor functioning in six months, especially when administered at an early age (Kohl et al., 2021). Proper protein consumption promotes the growth and repair of muscles, and it has been shown that infants undernourished with low protein consumption are at increased risk (25 percent) of developmental motor delay (Ruiz-Ariza et al., 2023). Antioxidants and omega-3 fatty acids also help to increase neural connectivity and coordination, which improves the general motor performance (Webster et al., 2023). The use of fortified formulas in preterm babies has been found to decrease the rate of motor impairment by about 30 percent (Lavelle et al., 2024). Nutritional screening can be implemented in the emergency and acute care facilities to identify deficiencies in time and avoid further deterioration of the development outcomes (Seneviratne et al., 2024).

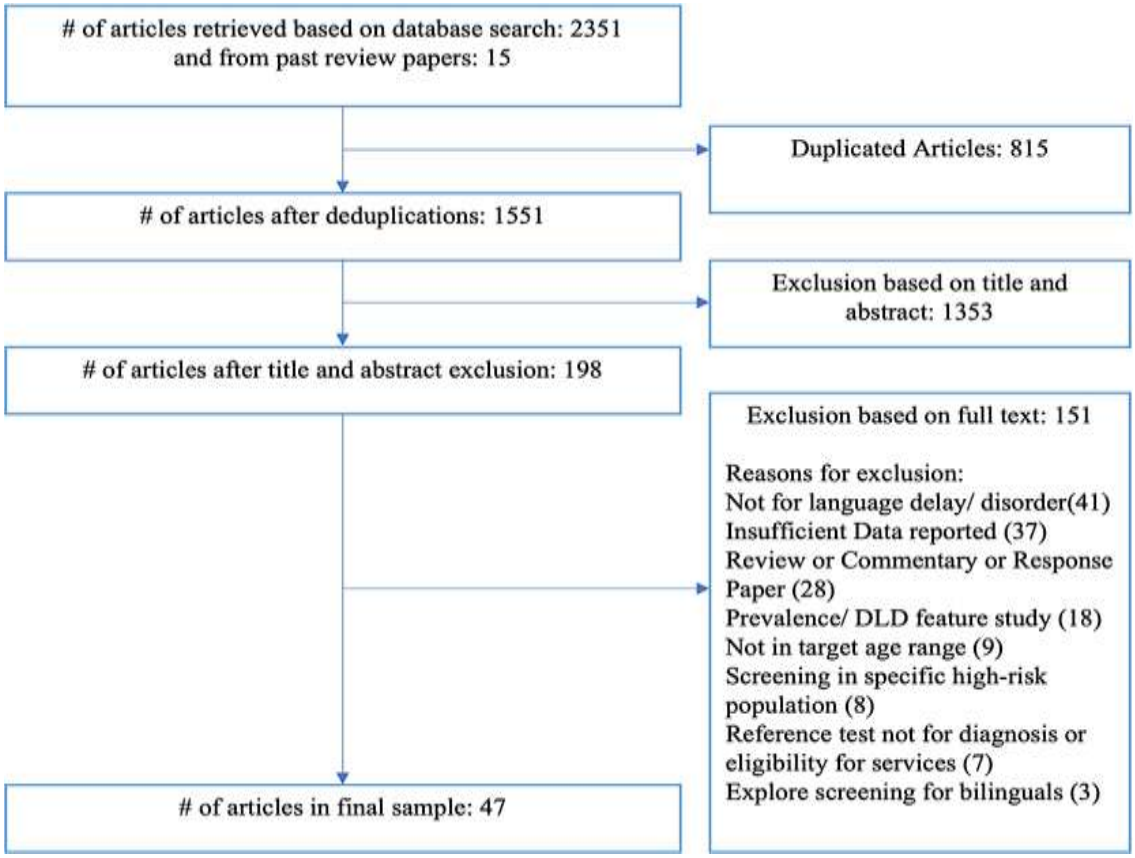
Physiotherapy is an essential part of DMD management, which is aimed at enhancing strength, coordination, balance, and functional independence (Hestbek et al., 2025). Neurodevelopmental Treatment (NDT) has been one of the most important strategies, especially among the children with cerebral palsy, as it tries to achieve normal tone and promote movement patterns as per the age (Lavelle et al., 2024). Tasks-specific exercises such as supported treadmill walking and repetitive functional training have proven to be effective in speeding up ambulation and gait, particularly in preterm babies and neurological vulnerable ones (Ruiz-Ariza et al., 2023).

Diagram of nutritional deficiencies impacting musculoskeletal development



Physiotherapy like stretching, positioning, and orthotics is necessary in preventing contractures and skeletal abnormalities in children with musculoskeletal dysfunction (Sanchez-Garcia et al., 2024). Programs of early intervention started as early as three months old are linked to the 50 percent better functional results in contrast to the delayed intervention (Kohl et al., 2021). The play-based therapy increases engagement and adherence to improve the gross and fine motor skills and psychosocial development (Webster et al., 2023).

Meta-analysis of screening efficacy

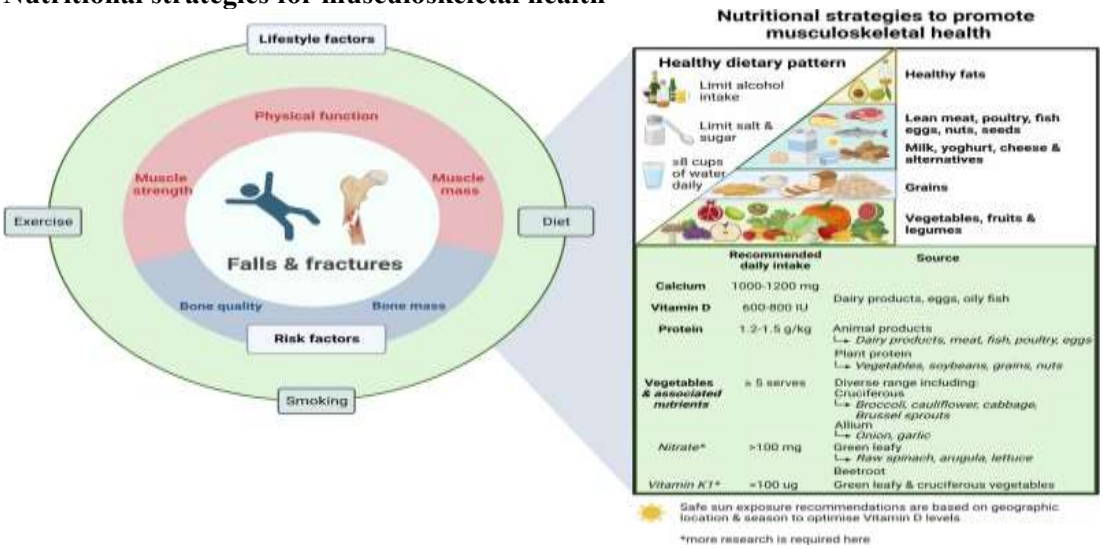


Randomised controlled studies that occurred after 2020 consistently indicate that organised physiotherapy programs alleviate the severity of developmental motor delays by about 30 to 40 percent (van Abswoude et al., 2020). Physiotherapy results are also improved when it is used in combination with specific nutritional support, and the study proves the synergistic effect on motor development and functional recovery (Chandrasekaran et al., 2023). The problem is that access to physiotherapy services is still low in rural communities; however, telephysiotherapy has demonstrated the potential to increase accessibility, education, and care continuity (Seneviratne et al., 2024). In general, the multidisciplinary management, which implies screening, nutrition, and physiotherapy, is crucial to ensure the best long-term results and promote the overall development in children with DMD.

Table 2: Key Nutrients and Their Impact on Motor Development

Nutrient	Role	Deficiency Effects	Intervention Outcomes	References
Vitamin D	Bone mineralization	Rickets, delayed ambulation	20-40% improvement in milestones	Chandrasekaran et al. (2023); Fardellone et al. (2023)
Protein	Muscle strength	Weakness, hypotonia	Enhanced growth velocity	Sánchez-García et al. (2024); Kohl et al. (2021)
Calcium	Skeletal structure	Fragility, contractures	Reduced fracture risk	Gralla et al. (2024); Ruiz-Ariza et al. (2023)
Iron	Oxygen transport	Anemia, fatigue	Improved coordination	Webster et al. (2023); Lavelle et al. (2024)

Nutritional strategies for musculoskeletal health

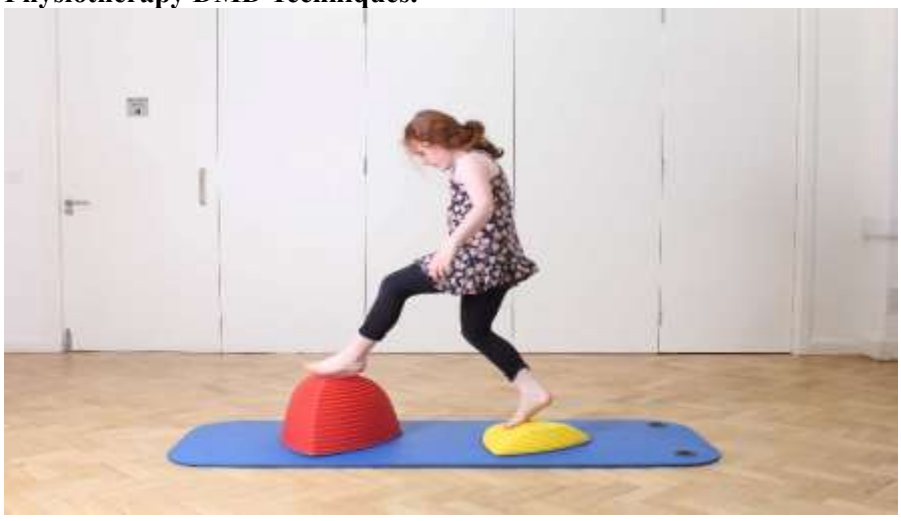


Integrated nutritional screening in emergency care prevents exacerbation (Seneviratne et al., 2024).

Physiotherapy Interventions

Physiotherapy is crucial in the process of DMD remediation, with the emphasis on the strength, coordination, and functional capabilities (Hestbek et al., 2025). Methods such as Neurodevelopmental Treatment (NDT) normalize the tone and encourage the milestones in cerebral palsy (Lavelle et al., 2024). Treadmill walking which is a treadmill training improves ambulation in preterm infants (Ruiz-Ariza et al., 2023). Stretching and orthotics help in the prevention of contractures in musculoskeletal dysfunction (Sanchez-Garcia et al., 2024). At 3 months, the early intervention programs produce an improvement 50 times better (Kohl et al., 2021). The play-based therapy leads to better interaction, which increases fine motor skills (Webster et al., 2023). The RCT evidence indicates that physiotherapy halves the delay severity (van Abswoude et al., 2020). Combined with nutrition, the effects are synergistic (Chandrasekaran et al., 2023).

Physiotherapy DMD Techniques.



The rural community has barriers such as access, which is solved by telephysio (Seneviratne et al., 2024). Multidisciplinary teams result in maximized outcomes.

CONCLUSION

Developmental motor delay (DMD) and musculoskeletal dysfunction still pose serious clinical and population health issues, especially when either diagnosis or treatment is delayed. It is shown that emergency-based screening is a vital factor in the early diagnosis, as clinicians will be able to determine

regression or new delay in cases of acute illness or injury and make timely referrals (Grala et al., 2024). In conjunction with screening, proper nutrition is necessary to enhance bone integrity, muscle strength, and neural development, which make motor impairments less severe and progressive (Fardellone et al., 2023). Physiotherapy also promotes these initiatives with better functional mobility, secondary complication prevention, and age-appropriate motor skills development with the help of evidence-based interventions. In a combination approach in an integrated care system, these strategies generate synergistic values, enhancing the short-term and long-term developmental outcomes as well as alleviating the burden on families and health systems. To focus on reducing disparities in screening and rehabilitation services, especially in underserved and rural communities, and to enhance longitudinal research to improve integrated models of care and promote a lifetime of functional independence should be promoted in future efforts.

RECOMMENDATIONS

In order to achieve better results with developmental motor delay (DMD) and musculoskeletal dysfunction children, a number of evidence-based recommendations must be prioritized. First, standard emergency screening should be brought to all pediatric acute care units to guarantee the timely detection of developmental regression or the development of delays at the most crucial neuroplastic stages (van Abswoude et al., 2020).

Second, regular nutrition evaluation should be part of the pathways of the pediatric care system because the early signs of deficiency of the most important nutrients like vitamin D, protein, and iron may help prevent the aggravation of motor impairments and contribute to the optimal growth and development (Chandrasekaran et al., 2023).

Third, it is necessary to introduce early and compulsory referrals to physiotherapy services of at-risk children since prompt intervention can positively influence the functional outcomes and minimize long-term disability (Lavelle et al., 2024). Moreover, the creation of universalized multidisciplinary practice is needed to advance the management of DMD in a coordinated way, meaning that the collaboration between pediatricians, dietitians, physiotherapists, and emergency clinicians should be provided (Kohl et al., 2021). Longitudinal studies assessing the long-term effectiveness of integrated interventions, and especially in the diverse and underserved groups, should be considered in future research to build solid evidence base and influence sustainable models of equitable pediatric care.

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