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Duchenne Muscular Dystrophy: A Critical Integrative Review from Modern and *Ayurvedic* Perspectives

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Abstract

Duchenne Muscular Dystrophy DMD is the most severe and prevalent X-linked recessive neuromuscular disorder of childhood caused by mutations in the dystrophin gene on chromosome Xp21 leading to absence of dystrophin and progressive skeletal cardiac and respiratory muscle degeneration due to sarcolemmal instability calcium dysregulation mitochondrial dysfunction oxidative stress inflammation and fibrosis. This review analyzes the molecular pathogenesis clinical features and contemporary management of DMD and correlates them with *Ayurvedic* concepts such as *Adibala Pravritta Vyadhi Beeja Dosha* and *Mamsa Dhatu Kshaya* to develop an integrative framework. Classical texts including *Charaka Samhita* and *Sushruta Samhita* were reviewed with contemporary literature and the disease was mapped through *Dosha, Dushya* ,*Srotas* and Samprapti Ghataka. The condition resembles *Vata Pradhana Tridoshaja* pathology involving *Mamsa* and *Meda Dhatu Kshaya Dhatvagni Mandya* and *Srotorodha*. Integrative management with *Vata Shamana Brimhana Panchakarma* such as *Abhyanga, Shashtika Shali Pinda Sweda, Basti* and Rasayana like *Ashwagandha* may support muscle nourishment and functional preservation though further clinical trials are needed.

Keywords: Duchenne muscular dystrophy, dystrophin, *Beeja-dosha*, *Mamsa Kshaya*, *Panchakarma*, *Rasayana*

1. Introduction

Duchenne Muscular Dystrophy (DMD) is a progressive, inherited neuromuscular disorder characterized by early onset muscle weakness and relentless deterioration of skeletal and cardiac musculature. The global incidence is estimated at approximately 1 in 3,500–5,000 live male births [(1–3)]. The disease is caused by mutations in the dystrophin gene, one of the largest genes in the human genome [(4, 5)].

Clinically, DMD presents during early childhood with delayed motor milestones, difficulty climbing stairs, frequent falls, toe walking, and the classical Gowers' sign. Progressive muscle degeneration leads to loss of ambulation typically by the second decade of life, followed by cardiomyopathy and respiratory failure [(6-9)].

Despite advances in molecular diagnostics and corticosteroid therapy, DMD remains incurable [10-13] . Emerging gene therapies offer hope but are still under evaluation [14-17] .

In *Ayurveda*, congenital disorders are described under *Adibala Pravritta Vyadhi*, arising from defects in *Beeja* (genetic material) (4). This review attempts to establish a structured integrative correlation between molecular pathology and *Ayurvedic Samprapti*.

2. Molecular Genetics and Pathogenesis

2.1 Dystrophin Gene

The dystrophin gene extends over nearly 2.4 million base pairs and consists of 79 exons. Most mutations involve large deletions which account for about 65–72 percent of cases while duplications are seen in approximately 6–10 percent. Other genetic changes include frame-shift mutations and point mutations. The lack of dystrophin leads to disruption of the dystrophin–glycoprotein complex which weakens the integrity of the sarcolemma and makes muscle fibers more susceptible to damage

2.2 Cellular Pathophysiology

Dystrophin is essential for maintaining the stability of the muscle cell membrane during contraction and its absence makes the sarcolemma fragile leading to microtears and structural instability of muscle fibers [18,19]. Membrane damage allows excessive influx of calcium into the muscle cells which activates proteolytic enzymes and results in myofiber necrosis [20-22]. Elevated intracellular calcium further impairs mitochondrial function by disrupting oxidative phosphorylation and reducing ATP synthesis thereby promoting apoptotic cell death [23,24]. Mitochondrial dysfunction along with increased activity of NADPH oxidase leads to the generation of reactive oxygen species which causes oxidative stress and aggravates muscle damage [25–29]. Persistent muscle fiber necrosis attracts macrophages and T lymphocytes maintaining a chronic inflammatory state through continuous release of inflammatory cytokines. Over time this ongoing degeneration and inflammation activates fibrotic pathways mediated by Transforming Growth Factor Beta Angiotensin II Myostatin and Connective Tissue Growth Factor resulting in progressive collagen deposition and replacement of functional muscle tissue with fibrotic tissue [30-35].

3. Clinical Features

The clinical presentation of Duchenne muscular dystrophy usually begins in early childhood with delayed motor milestones such as late onset of walking along with frequent falls and a tendency to walk on toes. Children often experience difficulty in rising from the floor due to proximal muscle weakness. As the disease progresses classical features become evident including a positive Gowers' sign waddling gait exaggerated lumbar lordosis and pseudohypertrophy of the calf muscles. With advancing disease several systemic complications may develop such as dilated cardiomyopathy respiratory insufficiency progressive scoliosis and mild intellectual disability [36,37]. Most affected children gradually lose the ability to walk and become wheelchair dependent by the age of 10–12 years [38].

4. Diagnosis

Diagnosis of Duchenne muscular dystrophy is based on clinical suspicion supported by laboratory and genetic investigations. Serum creatine kinase levels are markedly elevated often reaching 10 to 100 times above normal reflecting ongoing muscle degeneration [39] . Genetic testing using techniques such as Multiplex Ligation-dependent Probe Amplification or PCR identifies more than 95 percent of dystrophin gene mutations and serves as the confirmatory test [40,41]. Muscle biopsy may be performed in selected cases and typically shows absence of dystrophin on immunohistochemistry [42]. Cardiac evaluation with echocardiography and electrocardiography is also essential to assess early myocardial involvement and monitor cardiac function.

5. Modern Management

Management of Duchenne muscular dystrophy focuses on slowing disease progression and preventing complications through a multidisciplinary approach. Corticosteroids such as prednisone and deflazacort are the mainstay of treatment as they help preserve muscle strength and delay the loss of ambulation although long-term use is associated with significant adverse effects [43-45]. Cardiac care is an essential component and includes the use of angiotensin converting enzyme inhibitors and beta blockers to manage or prevent cardiomyopathy. Respiratory management involves regular pulmonary evaluation along with pulmonary rehabilitation breathing exercises and ventilatory support when required to address progressive respiratory muscle weakness. Recent advances in treatment include emerging molecular therapies such as exon skipping techniques gene therapy aimed at restoring dystrophin expression and CRISPR-based gene editing which holds promise for future disease modification [46-49].

6. *Ayurvedic* Perspective

6.1 *Nidana*

From an *Ayurvedic* viewpoint Duchenne muscular dystrophy can be understood as a congenital disorder arising due to defects at the genetic level. It is correlated with conditions such as *Beeja dosha* and *Beeja bhaga avayava dushti* which indicate abnormalities in the reproductive elements and their specific parts responsible for proper tissue formation. The condition is also categorized under *Adibala Pravritta Vyadhi* and *Sahaja Vyadhi* as it originates at birth due to inherent defects rather than external causes. *Acharya Charaka* has described that vitiation or defects in *Beeja* lead to congenital abnormalities and structural or functional disorders in the offspring .

6.2 *Samprapti*

The pathogenesis of this condition from an *Ayurvedic* perspective begins with *Beeja dushti* which leads to abnormal development of the fetus resulting in *Garbha vikriti*. Due to this congenital defect proper formation and nourishment of *Mamsa dhatu* does not occur leading to its functional weakness. This state promotes *Vata prakopa* which further causes *Dhatvagni mandya* resulting in improper tissue metabolism and

formation of *Ama*. The accumulated *Ama* causes *Srotorodha* especially in the *Mamsavaha* and *Medovaha srotas* leading to progressive *Mamsa kshaya* and *Bala kshaya.* As the disease advances there is *Gati vaigunya* due to neuromuscular weakness and eventually involvement of *Hridgata Vata* affecting cardiac function.

Samprapti Ghataka

- ***Dosha*:** Vata predominance with Pitta *anubandha*
- ***Dushya*:** *Mamsa* and *Meda*
- ***Agni*:** *Dhatvagni mandya*
- ***Ama*:** Present
- ***Srotas*:** *Mamsavaha* and *Medovaha srotas*
- ***Vyadhi Swabhava*:** *Chirakari* and *Yapya* in nature

7. *Ayurvedic* Management

In *Ayurveda* Duchenne muscular dystrophy is considered a *Yapya Vyadhi* which means the condition can be managed to slow progression and improve quality of life. The line of treatment focuses on correcting *Vata* imbalance enhancing tissue nourishment and improving strength and vitality.

7.1 *Chikitsa Siddhanta*

The primary principles of management include *Vata shamana* to control degeneration *Brimhana* therapy to promote nourishment and weight gain *Rasayana* therapy for tissue rejuvenation and long term support *Basti pradhana chikitsa* as the main therapy for systemic *Vata* regulation and measures aimed at *Dhatu poshana* to improve the quality and strength of *Mamsa dhatu.*

7.2 *Panchakarma*

Among *Panchakarma* procedures *Abhyanga* is advised as it improves circulation reduces stiffness and enhances neuromuscular function [(50)]. *Shashtika Shali Pinda Sweda* is a nourishing sudation therapy that provides *Brimhana* effect and supports muscle tissue strength. *Basti* is considered *Ardha Chikitsa* in the management of *Vata* disorders and helps in systemic regulation of *Vata* improves metabolism and enhances nutrient absorption and tissue nourishment.

7.3 *Rasayana* Drugs

Several *Rasayana* drugs are beneficial in neuromuscular degeneration. *Ashwagandha* has shown improvement in muscle strength along with significant antioxidant effects. *Guduchi* possesses immunomodulatory and anti-inflammatory properties which help in controlling chronic inflammation . Other supportive drugs such as *Bala Shatavari* and *Kapikacchu* contribute to neuromuscular nourishment strength enhancement and overall functional improvement.

8. Integrative Correlation

Duchenne muscular dystrophy can be understood through an integrative approach by correlating modern pathological mechanisms with *Ayurvedic* concepts. The primary genetic defect responsible for the disease corresponds to *Beeja dushti* indicating a congenital abnormality at the level of hereditary elements. Progressive muscle fiber damage and loss seen in the disease can be correlated with *Mamsa kshaya* reflecting depletion of muscle tissue. The excessive production of reactive oxygen species and cellular damage due to oxidative stress may be interpreted as the combined effect of *Ama* formation along with Pitta involvement. The gradual replacement of muscle by fibrous tissue leading to stiffness and obstruction resembles *Srotorodha* affecting proper tissue nourishment and function. The progressive decline in muscle strength and functional capacity corresponds to *Bala kshaya*. Cardiac involvement in the form of dilated cardiomyopathy can be understood as *Hridgata Vata* indicating *Vata* vitiation affecting the cardiac musculature.

9. Discussion

Duchenne muscular dystrophy is a progressive multisystem degenerative disorder caused by a genetic defect that triggers multiple pathological mechanisms including calcium imbalance oxidative stress chronic inflammation and fibrosis. Current modern medical management helps in slowing the progression of the disease but does not reverse the underlying pathology. *Ayurveda* provides a holistic perspective by addressing systemic *Vata* imbalance improving *Dhatu* nourishment and enhancing overall tissue strength and vitality. An integrative approach combining both systems may help improve muscle endurance reduce stiffness enhance metabolic efficiency and support cardiopulmonary function. However there is a need for well-designed randomized controlled trials to establish the efficacy and scientific validation of such integrative management strategies.

10. Conclusion

Duchenne muscular dystrophy is a severe X-linked genetic disorder marked by progressive muscle degeneration resulting from deficiency of dystrophin. The underlying molecular pathology can be conceptually correlated in *Ayurveda* with *Beeja dosha* indicating a hereditary defect and *Mamsa dhatu kshaya* associated with predominant *Vata* involvement. Although no definitive curative therapy is currently available integrative management that combines modern supportive treatment with *Ayurvedic* principles such as *Panchakarma* and *Rasayana* may help improve functional capacity enhance quality of life and potentially slow disease progression. Further interdisciplinary and evidence-based research is essential to validate and strengthen this integrative approach.

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