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REVIEW ARTICLE

Improving Cardiovascular Health in Pediatric Populations with Sedentary Lifestyles due to Neurologic Disease

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ABSTRACT: Children affected by neurological disorders such as Spina Bifida, Cerebral Palsy, and Charcot-Marie-Tooth disease often face significant physical mobility challenges. These challenges can lead to a sedentary lifestyle that negatively impacts cardiovascular health. This review explores the connection between these neurological disorders, the cardiovascular health of affected children, and ways to combat the possible negative effects of these disorders. For example, Spina Bifida can result in lower limb weakness or paralysis, Cerebral Palsy may cause walking difficulties due to spastic muscles and poor balance, and Charcot-Marie-Tooth disease can impair muscle strength and motor coordination due to weakened peripheral nerves. These physical limitations reduce the capacity for regular physical activity, increasing the risk of cardiovascular diseases such as hypertension, obesity, and heart disease. Research indicates that exercise programs, particularly resistance training, can improve cardiovascular health and quality of life for children with these conditions. Understanding the impact of these disorders on cardiovascular health is critical for developing appropriate interventions to improve long-term health outcomes for affected children.

KEYWORDS: Translational Medical Sciences, Disease Treatment and Therapies, Cerebral Palsy, Charcot-Marie-Tooth Disease, Spina Bifida.

Introduction

Genetic and congenital diseases such as Spina Bifida, Cerebral Palsy, and Charcot-Marie-Tooth disease affect millions of children in the United States. Spina Bifida (SB) is estimated to affect 1 in 2500 people worldwide,[1] Cerebral Palsy (CP) is estimated to affect 1 in 500 people worldwide,[2] and Charcot-Marie-Tooth (CMT) disease impacts an estimated 2.6 million people worldwide.[3] These conditions can result in significant physical impairments: SB may lead to paralysis or weakness in the legs, CP can disrupt muscle control and voluntary movements, and CMT disease weakens the peripheral nerves, causing difficulties with mobility.

Children with these diseases often face barriers to physical activity, leading to sedentary lifestyles that can have serious consequences for their cardiovascular health. A sedentary lifestyle during the developmental part of these children's lives can lead to many long-term negative musculoskeletal and cardiovascular outcomes, which can lead to obesity, cardiovascular disease, diabetes, high blood pressure, and heart attacks. Maintaining cardiovascular fitness is crucial, yet there is a scarcity of research addressing the best methods for improving cardiovascular health in children with physical mobility impairments.

This review, conducted using academic databases and highly cited journal articles, aims to fill this gap by exploring the most effective strategies for promoting cardiovascular health in these children. While previous research has focused on the challenges of specific conditions, few studies have provided a comprehensive overview of interventions that address cardiovascular health across a spectrum of disabilities. By synthesizing existing research and identifying areas where more studies are needed, this review will offer an important resource for healthcare providers, researchers, and families seeking to improve the quality of life for affected children.

Discussion

Disease Overview & Physical Implications.

SB, CP, and CMT disease can all negatively impact a patient's life because these conditions all share neurological, motor function, and chronic impacts.

Spina Bifida:

SB is a birth defect in which the vertebral column is exposed at birth. There are three main types of SB: myelomeningocele (the most severe), lipomeningocele, and spina bifida occulta (the most mild).[4] Spina bifida often results in varying degrees of weakness in the legs, leading to muscle imbalances, which impacts the proper development of the musculoskeletal system. Lipomeningocele is characterized by a fatty tumor overlying the spinal cord, muscle weakness, and decreased sensation.[5] Serious symptoms of SB myelomeningocele include exposed tissues and nerves, though skin sometimes covers the myelomeningocele sac.[6] The exposed tissue degenerates, resulting in a neurological deficit. The child often has a degree of muscle weakness and less sensation in the skin depending on where the spinal cord is affected, as well as trouble with bladder and bowel function, including incontinence. The nerves below the area where the myelomeningocele sac is located usually do not function properly, leading to weakness and in some cases, resulting in paralysis. In SB myelomeningocele, babies usually have a buildup of fluid in their brain, which puts pressure on the cerebral tissue. This condition is known as hydrocephalus.[6] Another common condition with SB myelomeningocele

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is Chiari malformation type 2.[7] This condition causes the brainstem to become longer and lower than usual in the spinal canal. This elongated brainstem causes arm weakness, trouble with breathing and swallowing, and in some cases, causes pressure on the brain. Depending on where the myelomeningocele sac is, SB myelomeningocele can also negatively affect a child's capacity to move by causing paralysis in the legs.[7] Many children with SB frequently require the use of a wheelchair due to lower limb weakness, paralysis, or, in some cases, amputation. These mobility problems greatly impact the amount the child can physically move or exercise. This most severe form of SB will be the focus of the literature review.

Cerebral Palsy:

CP is a group of neurological disorders that affect the brain and permanently impact muscle coordination and body movement.[8] The damage or abnormalities inside the developing brain disrupt movement, posture, and balance control. The causes and effects of CP are different from person to person. CP does not progress over time throughout a child's development. As a result, it is not uncommon for some people with CP to need assistance walking while others do not. Orthotics help children with CP, providing stable support to facilitate the development of walking skills.[9] Orthotics can also help prevent deformities by properly aligning the limbs, allowing for better weight distribution and minimizing discomfort during movement. In some people, CP affects the entire body while in others, it may affect only one limb. Children with CP may have exaggerated reflexes, their limbs may appear floppy, or they may have stiff muscles, a condition known as spasticity.[10] Spasticity can cause a reduced range of motion in the joints and is one of the most common symptoms of children with CP. Thus, variation in muscle tone among children with CP is commonly observed and may lead to muscle imbalance, reduced coordination, and increased contraction.

Charcot-Marie-Tooth Disease:

CMT is a group of inherited disorders that cause nerve damage.[11] Neurological damage usually affects the peripheral nerves. Thus, CMT mainly affects the arms and legs. CMT often causes weaker muscles, loss of sensation, difficulty walking, and muscle contractions. Symptoms usually begin in the lower limbs, such as the feet or legs, but can also affect the upper extremities.[12] Some physical impacts of CMT include decreased ability to run, frequent tripping or falling, and decreased sensation or loss of feeling in the legs and feet. CMT can progress and the symptoms can spread to other parts of the body, though the severity varies greatly from person to person.[13] Foot abnormalities and difficulty walking invariably become major problems for people with CMT.

Throughout the lifespan of a person with CMT, lower limb weakness and leg cramps are often noted to correlate with Quality of Life (QOL). In particular, the ability to toe-heel walk has been noted to correlate with QOL.[14] In addition, muscle cramps, tremors, and distal weakness have all been shown to impact QOL adversely. Interviews with patients with CMT have identified that difficulty in moving, ambulation, and activity impairment were the most frequently mentioned life-altering themes. In one study, the most prevalent symptoms found were foot and ankle weakness (with 99.7% of people having this problem), impaired balance (98.6%), mobility limitations (97.5%), and hand/finger weakness (97%).[14] CMT's effect on the limbs can cause a decrease in physical activity in which one can partake. Instability and weakness can often cause children to avoid partaking in physical activities. Among the 214 symptoms identified by Johnson *et al.*, difficulty running had the highest population impact score.[14] Running plays a huge part in childhood sports and many physical activities that help maintain cardiovascular health.

The three diseases of focus, SB, CP, and CMT share a deleterious effect on the nervous system, which leads to lower limb weakness or lack of coordination of the lower extremities of affected children, making it difficult to exercise. This, in turn, negatively impacts the cardiovascular system. Although SB, CP, and CMT have different root causes, they share many common symptoms that can lead to difficulty maintaining good cardiovascular health. The physical effects of SB, CP, and CMT are illustrated in the diagram in Figure 1.

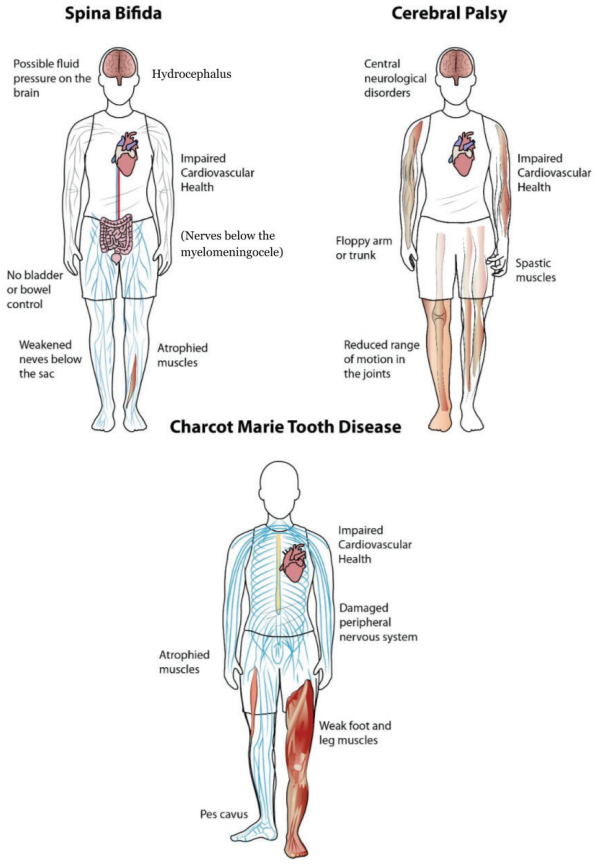

Figure 1: Physical effects of Spina Bifida, Cerebral Palsy, and Charcot-Marie-Tooth disease.

Cardiovascular Implications:

Cardiovascular health pertains to the well-being of the heart and the circulatory system. Cardiovascular diseases (CVD) can negatively impact this system, with risk factors such as obesity, high blood pressure, and unhealthy cholesterol levels increasing the likelihood of developing CVD. SB, CP, and CMT all

share the possible sequela of a sedentary lifestyle, which negatively affects the child's cardiovascular health and future. These sedentary behaviors during childhood increase the risk of developing high blood pressure (HBP).[15] HBP is one of, if not the single most important risk factor for CVD.[16] Children who maintain sedentary behavior throughout their childhood have an increased risk of developing HBP. More broadly, studies have shown that HBP is a critical risk factor for heart failure, atrial fibrillation, chronic kidney disease, heart valve diseases, aortic syndromes, and dementia, in addition to coronary heart disease and stroke.[16] The negative effects of SB, CP, and CMT on the cardiovascular system are depicted in Figure 2.

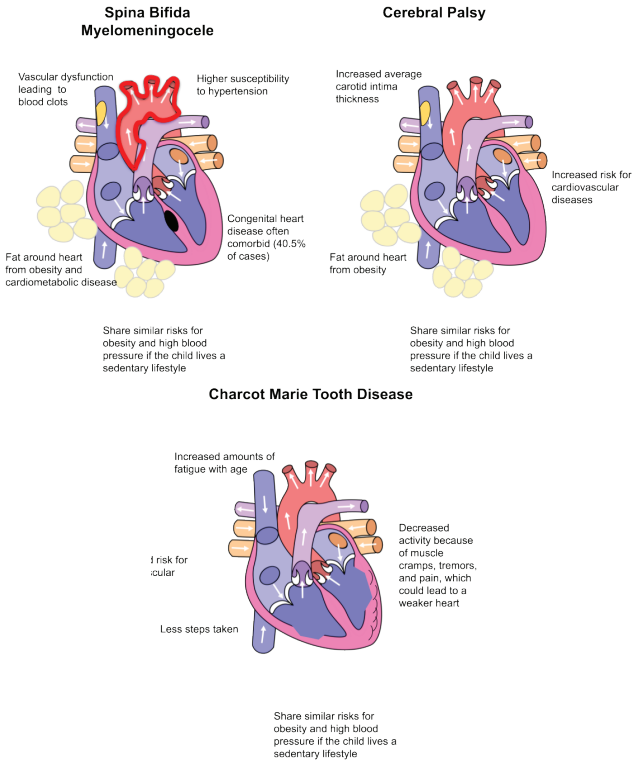

Figure 2: Cardiovascular effects of Spina Bifida, Cerebral Palsy, and Charcot-Marie-Tooth disease.

Spina Bifida:

Individuals with SB, particularly those with myelomeningocele, have a higher susceptibility to hypertension compared to the general population. Research indicates that the prevalence of congenital heart disease among those with SB myelomeningocele is approximately 40.5%.[17] Although the prevalence of diabetes and CVD in the SB population is not known, they may be at increased risk for metabolic and vascular dysfunction because of their body composition, physical function, and clinical blood test results. Studies have found that for adults older than 20, the obesity rates in people with SB were 37% higher than in the general population.[18] Children and young adults with SB reportedly have reduced aerobic fitness, muscular strength, and increased body fat. As a result of low aerobic capacity and muscle strength, activities of daily living may be relatively more difficult for people with SB.

Cerebral Palsy:

It was found in one study that adults with CP reported a higher prevalence of CVD than adults without CP.[19] The most commonly reported risk factor for CVD among adults with CP was obesity. CVD and circulatory system-related deaths are more prevalent in individuals with CP in comparison to the general population. Another study from England found that adults with CP have a 14-fold increased risk of mortality due to diseases of the respiratory system and a 3-fold increased risk of mortality due to diseases of the circulatory system.[20] The increased risk of mortality due to circulatory system diseases and common risk factors such as obesity originates from habits established in childhood. Therefore, early intervention and lifestyle modifications are crucial for improving cardiovascular health in children with physical mobility impairments. One study found that children with CP have a significantly greater average carotid intima-media thickness (CIMT) than children without CP.[21] CIMT measures the thickness of the two innermost layers of the carotid artery wall and is used to indicate atherosclerosis and CVD risk. The increased CIMT in children with CP suggests a higher risk of developing CVD later in life due to the early onset of vascular changes.

Charcot-Marie-Tooth Disease:

A study on CMT found that when comparing a control group with a group affected by CMT, there was no significant difference in calorie expenditure, energy expenditure, or time in sedentary, moderate, or vigorous activities.[22] However, in that study, it was found that people with CMT took significantly fewer steps each day. It was hypothesized that the discrepancy between energy expenditure and number of steps could be due to people with CMT having a higher energy requirement for walking. In children with CMT, muscle cramps, tremors, distal weakness, and fatigue can all play into a child not being as physically mobile and active.[14] This reduced mobility can contribute to the development of obesity, which, in turn, exacerbates cardiovascular health issues and elevates the risk of related complications. One study also showed that fatigue and pain increasingly became more impactful with age in those afflicted with CMT. Still, another study found that fatigue was the major barrier to physical activity in people with CMT.[23] Fatigue in individuals with CMT is a common concern and is a prevalent phenomenon affecting the person's body. Fatigue can be linked to stress and mental and physical exertion, which can affect overall functioning and QOL.[22] Personal factors, particularly physical function, are crucial in determining physical activity behaviors in individuals with CMT.

Overall, multiple studies on these 3 highlighted conditions conclude that physical activity and certain exercises tuned towards these conditions can help improve QOL and cardiovascular health.[24] One study reported positive effects of resistance training in children and that resistance training is feasible and safe even in vulnerable groups of children with disabilities. Research has been conducted to determine the best type of training for these different conditions.

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Exercise Interventions to Combat Cardiovascular Compromise:

Physical activity is necessary for proper skeleton growth and normal development of musculature and oxygen-transporting organs.[25] Because of impaired organ system function in children with SB, CP, and CMT, specialized exercise programs need to be made to address the physical needs of the millions of children affected by these three diseases. It is crucial to prioritize the cardiovascular health of affected children to ensure proper development and prevent the onset of additional diseases in adulthood that could be mitigated with appropriate care.

Spina Bifida:

Compared to weight-bearing or high-impact exercises, resistance training can be a safer form of exercise for those with physical disabilities. The use of resistance to increase strength has been consistently identified as a feasible and safe form of exercise for children with various disabilities, including those with high levels of disease severity.[24] These children with lower limb weakness can benefit from a stronger upper body and increased strength. A study by Andrade *et al*. found that the global self-worth of children with SB increased along with their elbow-flexor strength.[26] Because of the physical limitations of SB myelomeningocele, aerobic exercises are limited to hand-cycling and pushing a wheelchair. This exercise is adapted to these children's abilities and helps improve upper body strength and cardiovascular endurance. Relatedly, spinal cord injuries (SCI) can cause paralysis and loss of sensation in the limbs.[27] Due to the nature of SB myelomeningocele and its many overlapping similarities with SCI, exercises made for SCI can transpose to exercises for people who have SB myelomeningocele. A study by Ginis *et al*. recommends that adults do 3 sets of exercises twice weekly for every functioning major muscle group.[29] For cardiometabolic health benefits, 30 minutes of moderate to vigorous-intensity aerobic exercise 3 times per week is recommended. Although the exact type of exercise program most effective for youths with SB is unknown, exercise still provides an overall general benefit and can improve their cardiovascular health.[18]

Cerebral Palsy:

Children with CP can have muscle tremors, floppy trunks, stiff muscles, and trouble with balancing and walking. These conditions can limit the child to a smaller spectrum of exercises than those in which a normal child can participate. While parental hesitancy to allow children to engage in resistance training is understandable, particularly due to concerns about exacerbating spasticity, research has shown that these fears are unfounded. Ultimately, it has been concluded that resistance training is still feasible for children with CP and does not worsen spasticity.[30] Although resistance training focuses on building muscle strength, it contributes to better circulation, heart function, and overall endurance. A 2010 study had the youths perform exercises including sit-to-stand, lateral step-up, and half knee-raise loaded with a weighted vest, which increased participants' muscle strength.[28] In another study, the exercises included shoulder press, lateral pull down, leg press, biceps curl, and hip abduction.[28] These exercises helped fight against muscle atrophy and increased muscular strength in children with CP. Many studies have found that cardiorespiratory exercises can increase cardiorespiratory endurance in adults and children with CP.[31] These aerobic exercises included cycling, propelling a wheelchair, running, swimming, bending, turning, and getting up from the floor. A 2022 study found that group exercises are more effective for children with CP than individual exercises in improving balance, gross motor function, and participation.[10] Group exercises can be used to facilitate desirable movement patterns. Positive and negative reinforcement strategies are given as feedback when working in a group setting. Group exercises that involved the parents not only improved the children's performance but also benefited the parents, as their active involvement in the exercises helped reinforce their memory of the different routines.

Charcot-Marie-Tooth Disease:

Children with CMT have an affected peripheral nervous system, which leads to muscle weakness, fatigue, and fine motor difficulties.[32] These physical impairments lead to children having greater difficulty with more high-impact activities, balance exercises, and heavy weightlifting. The difficulty children with CMT experience with hand coordination and weakness can make weightlifting dangerous if done incorrectly. As the condition of the peripheral nerves worsens and leads to muscle atrophy, exercise programs should be implemented as early as possible. Parents of children may fear that their children's muscles might not be able to adapt, but a study by Sman *et al*. showed that muscle adaptation is not affected in those with CMT.[33] Another study by Burns *et al.* utilized exercises to increase foot strength, including plantar flexion to dorsiflexion with weighted exercise cuffs. This exercise helped improve muscle strength and walking ability and attenuated the long-term progression of dorsiflexion weakness.[34] Foot strength and walking stability have huge effects on aerobics, allowing those children to walk, bike, and do many other physical activities with more confidence because of the increased foot and flexion strength. To reassure parents concerned about the potential negative impact of exercise on their children, a study found no cardiovascular or other adverse effects associated with exercise participation.[35] This study found that a 24-week moderate-intensity exercise program positively influences heart function in patients with CMT. An example exercise for the three diseases of focus is depicted in Figure 3.

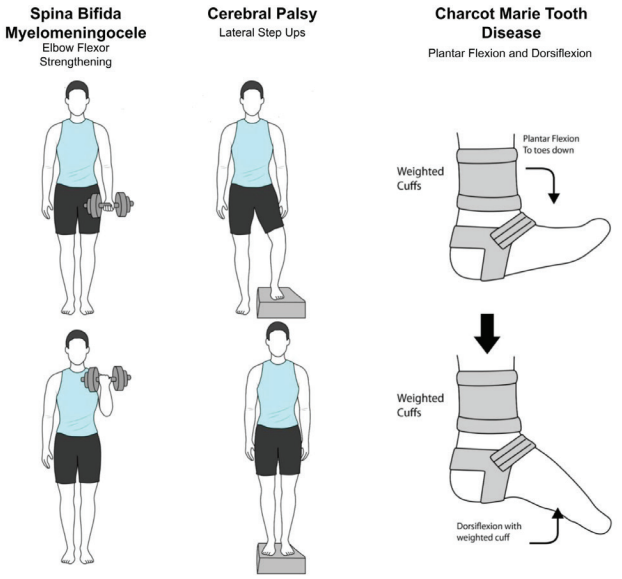

Figure 3: Schematic of exercises for Spina Bifida, Cerebral Palsy, and Charcot-Marie-Tooth disease. Note: Arm exercises can be performed while seated, especially for individuals who are not ambulatory.

Another method to help improve the cardiovascular health of children with these different neurological conditions is sauna bathing. Sauna bathing is the regulated exposure to high temperatures for a short period. A study by Laukkanen *et al*. found that sauna bathing positively affects arterial stiffness, blood pressure, and some blood-based biomarkers for cardiovascular disease.[36] Sauna bathing has also been linked to improvement in pain from disorders like osteoarthritis.[37] However, individuals with SB should use caution, as autonomic dysfunction can impair heat regulation, and autonomic dysreflexia may cause dangerous spikes in blood pressure. People with cardiovascular conditions may be advised to avoid sauna baths because the stressful environment of the sauna could burden their cardiovascular health.[37] Children with these neurological conditions, unless they have unstable CVD or are otherwise medically contraindicated, should be physically able to participate in sauna bathing under close supervision.

Conclusion

The results of this review suggest that children with neurologically based mobility challenges, such as SB myelomeningocele, CP, and CMT, are more likely to lead a sedentary lifestyle due to muscle weakness and limited mobility. This sedentary lifestyle increases the risk of cardiovascular diseases like hypertension, obesity, diabetes, and coronary heart disease.

Tailored exercises, such as handcycling for SB, lateral steps for CP, and dorsiflexion and plantar flexion exercises for CMT, can help maintain cardiovascular health despite mobility limitations. These adapted exercises can be critical for reducing the risks associated with a sedentary lifestyle.

Some key takeaways of this work include: 1) Resistance training is beneficial, even for the most vulnerable children with mobility impairments, as it helps to strengthen muscles and improve cardiovascular health. 2) Exercises can be adapted to meet the needs of children with conditions like SB, CP, and CMT, making physical activity achievable despite mobility limitations. 3) Early intervention with modified exercises is crucial, as it can have lasting positive effects on children's health into adulthood.

While this review provides insights into the cardiovascular risks and exercise adaptations for children with mobility impairments, some limitations exist. First, the data on specific exercise interventions is limited, and the studies reviewed may not represent the entire population of children with these conditions. Additionally, the long-term effectiveness of these adapted exercises on cardiovascular health is not well-documented. This leads to no precise measurements and details on which exercises are most effective for these children. Another limitation is the lack of research on whether children with these physical impairments will have potential contraindications when participating in sauna bathing. This gap in literature limits the ability to understand the possible positive and negative effects of sauna bathing on this group of children. Future research should aim to address these gaps and explore more comprehensive approaches to maintaining cardiovascular health in this population. When developing exercise programs for individuals with these conditions, potential vulnerabilities to injury should be considered.[38]

Maintaining cardiovascular health in children with mobility impairments demands tailored, condition-specific strategies. By adopting alternative exercise approaches, we can reduce the risks of a sedentary lifestyle and foster long-term well-being, empowering these children to lead healthier lives despite their mobility challenges.

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