SPATIOTEMPORAL GAIT VARIATION IN AGE MATCHED DOWN SYNDROME CHILDREN AND TYPICALLY DEVELOPING CHILDREN: A LITERATURE REVIEW

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ABSTRACT

Introduction:

Down syndrome is a nonhereditary genetic condition, firstly described in 1866 by John Lagdon characterized by an extra abnormal chromosome set which is placed on the 21st chromosome. This condition also called trisomy 21 due to one extra chromosome which makes 47 chromosomes in total instead of normal 46 chromosomes. All the Down syndrome children show some degree of motor delay, postural issues, gait impairment, balance issue, sensory and cognition impairment on the basis of their severity level. Due to generalized hypotonia and flaccid posture, delay in walking, abnormal gait patterns specially at spatiotemporal aspect noticed. When compared with typically developing children, it has been noticed that stride length and step length in Down syndrome children found to be 65-75cm and 30-40cm subsequently, velocity around 0.6-0.8 m/sec which is much lesser than in typical children. Whereas cadence and base width was greater due to large base of support taken by Down Syndrome children to avoid fall which is approximate 10-14cm which is much larger compared to age-matched typically developing children.

Purpose and relevance: The purpose of this review is to provide a vision into how Down syndrome children have different gait patterns for spatiotemporal area in age-matched typically developed children.

Methodology: This includes those studies involving gait analysis on Down syndrome children and typical children for comparison purpose. Google Scholar, education Source, and PubMed were the primary medical databases for this review to retrieve 15 article results about Down syndrome and their gait development. Further resources such as websites and textbooks were also used.

Result: Typically developed children and Down syndrome children have different gait patterns. Stride length and step length in Down syndrome children found to be 65-75cm and 30-40cm subsequently, velocity around 0.6-0.8 m/sec which is much lesser than in typical children. Cadence was more than 130 steps/min and step width is 10-14cm due to increased base of support to avoid falling frequency. Whereas typical gait pattern includes an optimal base of support represented as base width which is around 8-10cm, cadence of 80-130 steps per minute which decreases with developing age due to their leg length, velocity of 1.0m/sec-1.2 m/sec, stride length is 100-110cm and step length found to be around 45-55cm.

Conclusion: Down Syndrome children have different and unique gait patterns because of their physiology of the body structure and so this type of study for therapeutic intervention is needed to examine and work with the children with Down syndrome to obtain objective data to implicate in therapy to get better balance and improve gait patterns.

Keywords: Down syndrome, gait, spatiotemporal, cadence, stride length

Introduction

Down syndrome is a nonhereditary genetic condition, firstly described in 1866 by John Lagdon where extra abnormal chromosome attaches on 21st chromosome which is represented by trisomy 21 (4). This condition affects not only physical health but also mental health involved with it. This may result into global developmental delay where physically child having slow growth including milestones and low IQ (Intelligent Quotient) level. Down syndrome not only related with intellectual disability but also problems seen in physical area, which can be easily diagnosed even just after birth with physical examination and external features (2). This condition can affect physical growth as well as mental growth resulting in global developmental delay including gross

and fine motor delay, speech delay, hearing problems, vision issues and mental retardation or other cluster of manifestation can also be present (9) depending on severity of the condition. This can be found equally in both males and females, affecting 1 in 600 to 1 in 1000 live births. Maternal age plays a very important role because as age increases, chances of having Down syndrome children also increase. Literature also supports that maternal age more than 35 years can be reason for Down syndrome child. One previous Down syndrome child can be also reason for further investigations. This condition can be easily identified by its phenotype, external features including low set of ears; mongolian facies, flaccid muscles and single line on palm ect. Further this can be confirmed with genetic test carried out with blood testing called karyotyping. Average life expectancy of Down syndrome children has been increased from 12 year which was in 1940 to approximate 60 years in present day with all available facilities (5). Down syndrome children presented with motor delay due to decreased tone in the trunk and limbs called generalized hypotonia and flaccid posture. This result in delays in walking, abnormal gait patterns after achieving walking later age, and altered posture with balance issues (1). Down syndrome also exhibits abnormal coordination due to the concurrent contraction of agonists and antagonist muscles. Generally Down syndrome children show approximately delay of 1 to 3 years to achieve independent gait which may varies in different cases depending on severity of the condition. Generally, children who have typical development according to their age, initiate walking at age of 1 year, running by 2 years onwards and other gross motor milestones developments at their time but in case of Down syndrome children who have slow development in all aspect achieve walking beyond 3 years and this also can go longer according to severity of condition. After achieving walking and they even show altered pattern in spatiotemporal parameters which need to take care with therapeutic intervention. So, constant therapeutic intervention for achieving better and independent gait (12). Development delays are present due to poor tone and unstable muscle pattern activation which is not well-organized (12). Poor balance is also the culprit for not achieving the milestone at their age and so gait alteration in different aspect seen especially at spatiotemporal area. Problems that exist in Down syndrome children are generalized hypotonia,

extreme ligament laxity, and poor postural stability and balance. This also affects the gait development in spatiotemporal aspect which results in decreased stride and step length, more cadences as usual, and reduction of gait velocity with larger step width. Larger step width is obtained in Down syndrome children to overcome poor balance so that walking can be obtained with a larger base of support to decrease fall frequency (21,7). Pedralli & Schelle (2013) reported that children with Down syndrome delay in achieving all gross milestones as sitting by 1 year, standing by 1.5 years, and walking by approximately 2 years. Approximately 50-80% of Down syndrome children have gait issues which show a big ratio. Gait and balance can be improved with prolonged therapy for independent gait patterns in Down syndrome children (6). The purpose of this review is to provide a vision into how Down syndrome children have different gait patterns for spatiotemporal area in age-matched typically developed children.

Methodology:

Primarily 15 articles were retrieved on the basis of topic gait in typically and down syndrome children from Google Scholar, education Source, and PubMed. These were the primary medical databases for this review published in English with full text available. Only abstract published have been excluded from review. We shortlisted articles after using keywords like “Down syndrome, gait, spatiotemporal, cadence, stride length” used one & alternatively. Further resources such as websites and textbooks were also used.

Some of specific issues seen in Down syndrome children

Down syndrome children can be depicted with number of congenital anomalies including cardiovascular anomaly, hematopoietic anomalies like leukemia, musculoskeletal anomalies like abnormal gait, poor balance control, atlantoaxial joint instability, flaccid muscles, generalised hypotonia, and nervous system anomalies include gross and fine motor delay, speech delay and dementia. These children also may have some of behavioural issues and oral anomalies like cleft lip or palate and dental anomalies (5). These signs can be presented in isolation or a combination of them (12). Presentation of Down syndrome may vary with its severity of condition.

Approximately 50-80% of children from total Down syndrome show gait abnormality including posture disturbance. Down syndrome children presented with motor delay due to decrease tone in the trunk and limbs, and this results in generalized hypotonia in limbs and trunk showing flaccid posture. This is the reason for delay in walking, abnormal gait patterns, and altered posture with balance issues subsequently (1). Down syndrome also exhibits abnormal coordination due to the concurrent contraction of agonists and antagonists' muscles. These children show a delay of approximately 1-2 years for achieving independent gait which can be delayed even for longer if severity of the condition is more. The child experience gait and balance malfunctions due to insufficient strength, decreased tone, and delayed motor milestones which includes altered spatiotemporal and kinematic parameters. The gait and balance ability of normally developed children improve with their age and growth, but in the case of Down syndrome children, this remains low despite the attainment of independent gait after years of therapy. This includes decrease stride and step length, decreased cadence, and reduction in gait velocity with larger step width. Larger step width is obtained in Down syndrome children to overcome poor balance so that walking can be obtained with a larger base of support to decrease falling frequency (21,7). So, constant therapeutic intervention for better independent gait and balance is important (12). Pedralli & Schelle (2013) reported that children with Down syndrome delay in achieving all gross milestones as sitting come by approximately 1-1.5 years, standing by 1.5-2 years, and walking by more than 2 years. Approximately 50-80% of Down syndrome children have gait issues which show a larger ratio. If these children with Down syndrome are not provided with constant therapy for walking, they will never achieve a good posture, balance and better gait pattern. When a child with Down syndrome starts walking in their later ages, they usually walk like a typical 1-year child who walks with wide base of support, smaller step length and stride length with slower velocity. This kind of gait pattern need to examine and work on for the parents, caregivers and clinicians to obtain better balance and gait pattern in a long run. This is the reason children with Down syndrome need constant therapy to normalize and live their life without fear of falling and losing balance.

Why gait is important to evaluate in Down syndrome?

Gait and balance control is the most important part of the ability to safely achieve proper movements and other motor tasks needed for daily activities. Gait is also altered when the balance is not appropriate. Due to delayed milestones and generalized hypotonia, gait in children with Down syndrome have been affected even after the child starts walking (10). As these children do not achieve their physical gross motor milestones at the proper time and due to ligament laxity, these children start walking very late which is also not in their normal pattern when compared with typically developing children (10). Motor abnormalities include poor posture and balance, altered gait pattern with slower speed of walking resulting in decreased performance. There is a direct relationship between poor tone and excessive laxity with impaired gait, balance, and posture control (23). Down syndrome children show two manifestations which are ligament laxity and muscle hypotonia. Due to these reasons, children with Down syndrome compensate for their muscle and ligament dysfunction by dealing with activities of daily living including gait and maintaining posture. Literature shows that when children with Down syndrome compared to typically developing children, had reduced spatiotemporal parameters of gait including step length, stride length, slower gait velocity, and wider base width with a greater number of cadence (23). Gait patterned also changes in these children which include decrease in stride length, step length, and gait velocity and increased cadence and step width to avoid fall. Wider step width is seen in Down syndrome children to overcome poor balance so the larger base of support helps them to walk and also reduce falling frequency in Down syndrome children. Altered spatiotemporal gait parameters have been found in Down syndrome children due to ligament laxity and generalised hypotonia in the whole body (23). This results in excessive flexibility in the body resulting in inability to achieve milestone at their adequate age (10). Zago et al., show in a review study that children with Down syndrome not only show decreased gait performance in spatiotemporal but also altered kinematic parameters while walking. This includes increased knee flexion during the mid-stance phase, a decrease during the swing phase, and decreased planter flexion during toe-off. These show a decrease in ankle ranges. In the stance phase, there is more anterior pelvic tilt and

decreased hip flexion whereas in the swing phase decreased knee flexion is seen in Down syndrome children.

How do gait pattern and balance show differences in Down syndrome children from typically developed children?

According to Jung et al., (2017) children with Down syndrome shows great variation in gait parameters which includes shorter stride and step length and a wider step width between the spatial gait parameters. Wider step width is due to instability which is because of weak lower limb strength and poor balance control. Down syndrome is the reasons for physical imbalance and developmental delays due to their poor muscle tone, poor strength and nutritional imbalance showing movement restrictions. Also, hypotonic posture and flaccid muscles in Down syndrome children shows decreased balance compared to typically developing children. Stride length is related to the leg length. Children having longer leg length had represented with larger stride and step length. Children with Down syndrome are unable to position their feet far apart between the terminal swing phase and the initial stance phase and as an alternative position them close together, resulting in a shorter stride and step length. Short stride and step length result in slow gait velocity and a greater number of cadences. This is the only reason how Down syndrome children tend to have a wider base width due to low stability. Typical gait pattern includes an optimal base of support represented as base width which is around 8-10cm (centimetre), cadence of 80-130 steps per minute which decreases with developing age due to their leg length, velocity of 1.0m/sec -1.2 m/sec (meter/second), stride length is 100-110cm and step length found to be around 45-55cm (12). Cadence in Down syndrome children is approximately more than 130-180 steps per minute which is more than normal (16). Cadence and step width are indirectly related to age, whereas step length, stride length and velocity are directly related to age. So, as age increases cadence and step width deceases till an optimal level whereas stride length and step length increase. This occurs due to their anthropometric structure including short height, shorter leg length, poor balance to propagate, shorter arm and leg span, and generalized hypotonia (10). Velocity is a factor of

distance and time taken to cover the distance, so it also increases till adulthood then get falls in elderly age. The Stride length and step length in Down syndrome children were found to be around 65-75cm and 30-40cm subsequently (16). Velocity in this age group is found around 0.6-0.8 m/sec and base width shows a larger base of support taken by Down Syndrome children to avoid falls which is approximately 10-14cm which is much larger compared to age-matched typically developing children (12). A few works of literature suggested that before the maturation of gait in early age, children with Down syndrome had the same spatiotemporal variables when compared with the control group but after the gait maturation there was a significant difference in Down syndrome children and control group. The studies show a decrease in step length of approximately 10cm drop from typically developing children and also a decrease in gait velocity which is reduced by 0.4m/s from typically developing children. In their whole life span of Down syndrome children, they show reduced stride and step length, decreased gait velocity, and increased base of support indicating a larger base width. Horvat et al., (2013) show children with Down syndrome show decreased performance in terms of their spatiotemporal parameters when compared with typically developing children of the same age.

Types of other exercises for improving gait in children with Down syndrome

There are umber of exercises have been proved to work for Down syndrome children depending on their representation. Generally Down syndrome seems to have lesser muscle tone and strength in their limb. This is the reason why they are unable to achieve their milestone timely and so having poor balance and walking pattern. Literature available in different studies shows a variety of exercises to improve gait in the Down syndrome population. Exercises help in improving tone like weight-bearing exercises for the upper limb, lower limb, and trunk include strengthening exercises, gait training, and treadmill walking (22). Core stability exercises, virtual reality-based exercises for balance control, backward walking training, whole body vibration, stretching, and balance exercises improve gait and balance control (14). Abonour et al., (2018) shows in his study that Down syndrome children have been benefitted with core stability exercises if given for minimum 8 weeks for 45-60 min, thrice a week to see the effect in dynamic balance. Core stability exercises

are beneficial because, Down syndrome children showing generalized weakness and flaccid posture. Trunk muscles are very important to make erect posture and they contribute in static and dynamic balance to maintain. So, core muscles strength is very important to maintain balance in Down syndrome children. Hippotherapy can improve balance and gait in Down syndrome children (18). Proprioceptive neuromuscular facilitation (PNF) includes several types of techniques like a slow reversal, rhythmic initiation, and agonistic reversal for the pelvis (13), hold-relax and contract-relax method (8) and exercises to improve gait and balance in different population like stroke (22), spastic diplegic (8), Huntington's disease (15) and others. Amini et al., (2016) showed in his study which is done on Down syndrome children that if backward walking training given for 8 weeks for 35 min twice a day, these children have been improved with dynamic balance. In a very recent study done by Qian et al., (2025) showed that Vojta therapy which is a neurorehabilitation approach that aims to ontogenetic postural function and automatic body posture control to increase gait functions has been used is Down syndrome children. This therapy has shown effects in walking speed, cadence, right step time, step length, stride length, and double support time.

Result: This review has shown that Down syndrome children show generalized hypotonia and flaccid posture which results in several issues. These issues not only include musculoskeletal issues but also cluster of issues related to different systems. Because of flaccid and hypotonic posture, gait and balance issues also manifested in Down syndrome children. This includes poor posture, resulting in altered spatiotemporal gait parameters. Typically developed children and Down syndrome children have different gait patterns so there is need to work on Down syndrome children to obtain proper gait and posture. Literature shows that when children with Down syndrome compared to typically developing children, had reduced spatiotemporal parameters of gait including step length, stride length, slower gait velocity, and wider base width and increase cadence which is number of steps taken per minutes. When gait of Down syndrome children compared with typically developing children, it has been observed that stride length and step length in Down syndrome children found to be 65-75cm and 30-40cm subsequently, velocity around 0.6-

0.8 m/sec which is much lesser than in typical children. Cadence was more than 130 steps/min and step width was greater, which is 10-14cm due to increased base of support while walking to avoid falling frequency. Whereas typical gait pattern includes an optimal base of support represented as base width which is around 8-10cm, cadence of 80-130 steps per minute which decreases with developing age due to their leg length, velocity of 1.0m/sec-1.2 m/sec, stride length is 100-110cm and step length found to be around 45-55cm (12).

Discussion: Due to delayed milestone and generalised hypotonia, gait and balance in children with Down syndrome have been affected even after child starts walking. As these children do not achieve their physical gross motor milestone at proper time and due to ligament laxity, these children start walking very late and though which is also not normal pattern. Motor abnormalities include poor posture and poor balance, altered gait pattern with slower speed of walking resulting in decreased performance. There is direct relationship in poor tone and excessive laxity with impaired gait, balance and posture control (23). Literature shows that when children with Down syndrome compared typically developing children, they had reduced step length, stride length, and slower gait velocity. Literature showed children with Down syndrome had slower performance in terms of walking capacity as they had slower velocity of walking, decreased step length and stride length also wide base of support shows increased step width as compared to healthy children (23). Typically developing children and Down syndrome having very different ambulatory pattern due to their physiology and body structure. They have different gait pattern and balance control from the same age group of typically developing children. Children with Down syndrome have a slower pace in all areas of gait especially in terms of spatiotemporal parameter which gives objective clue for all. The objective based data is also important for clinical practitioners to practice better way and to generate feedback from patients. This also can be used to motivate in right direction for parents and caregiver to focus on therapy part. Because Down syndrome children having unique gait and slower gait so this is the prime concern of parents as well as clinicians. There should be different therapeutic options to work with them to improvise them to make them better and fit in

society with other children. More number of studies needed on intervention for evidence base practice with Down syndrome children.

Conclusion: This type of study is needed to set the database for normative values in Down syndrome so that they can be differently treated from typically developing children of same age group. So different kind therapeutic intervention is needed to examine and work with the parents, caregivers, and clinicians to obtain better balance and improve gait patterns in the long run. Down syndrome children have different and unique gait patterns because of their physiology of the body structure and so this type of study for therapeutic intervention will help in examining and working with the children with Down syndrome.

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Abbreviations –

PNF- Proprioceptive neuromuscular facilitation

IQ- Intelligent Quotient

cm - centimetre

m/sec- metre/seconds

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