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Role of Gait Analysis in Management of Cerebral Palsy

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Abstract

Cerebral palsy (CP) is a complex neuromuscular disorder characterized by impaired movement and coordination, often resulting in significant gait abnormalities. The spectrum of motor function impairment varies greatly among individuals with CP, influenced by muscle control issues and specific types of cerebral palsy, including spasticity and ataxia. Gait analysis, comprising both observational and instrumented techniques, is essential for assessing gait patterns and identifying abnormalities. While observational gait analysis provides qualitative insights, instrumented gait analysis offers a detailed and objective assessment through motion capture technology, allowing for comprehensive evaluation of joint angles(Kinematics) and forces(Kinetics).

Understanding gait patterns is crucial for making informed clinical decisions regarding therapeutic interventions such as surgery and orthotic management. Literature has demonstrated that gait analysis significantly improves surgical recommendations and outcomes, highlighting the importance of incorporating detailed gait data into treatment planning. However, limitations such as variability in data accuracy, the complexity of methods, and hesitancy among some orthopaedic surgeons to adopt these techniques need to be addressed.

The integration of gait analysis into clinical practice represents a paradigm shift in the management of cerebral palsy, transitioning treatment from an art to a science. It enables clinicians to tailor interventions based on individual biomechanical profiles, ultimately enhancing the functional ability and quality of life for patients. Continued research and standardized practices are essential to maximize the effectiveness of gait analysis in this population, ensuring that children with cerebral palsy receive the most appropriate and effective care.

Keywords: Gait Analysis, Cerebral Palsy, Instrumented Gait Lab

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Introduction: Cerebral palsy (CP) is a complex neuromuscular condition that affects movement and coordination. The impact of CP on motor function varies widely, but it frequently leads to difficulties in muscle control and coordination. One of the most noticeable effects of CP is on motor function particularly gait. The varied clinical presentation of spasticity, ataxia, dystonia, hypotonia and loss of selective motor control can lead to challenges such as an unsteady or uneven walk, difficulty in balancing, and increased fatigue. The severity of gait impairment varies among individuals which is largely influenced by the type of CP and the specific muscles affected and the lever arm disorders [1].

Gait analysis is a comprehensive assessment tool used to evaluate and understand the gait patterns, analyze specific abnormalities and is a supplementary tool in addition to the clinical findings in decision making for gait correction surgeries in individuals with CP[2].

Gait Analysis

Gait analysis is the systematic study of human walking and running patterns. The first

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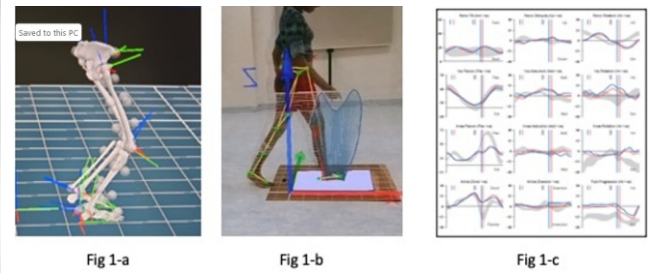

Figure 1: Fig 1-a Reflective markers captured by high speed cameras and processed to create a 3-dimensional model. Fig 1-b Force plate capturing the ground reaction force to create kinetic data. Fig 1-c Waveform representation of Kinematics in gait report

description by Gage and subsequent studies to identify the hemiplegic and diplegic gait patterns are still followed by most of the clinicians involved in CP management. The various types of gait analysis are:

1. Observational Gait Analysis (OGA)/ Visual gait analysis (VGA)- This technique involves visually examining the gait of an individual or using video recordings to slow down and analyze movements of different segments i.e. pelvis, hip, knee, ankle and subsequently quantifying them using scoring system like Edinburgh visual gait score [3].

It provides a qualitative assessment, allowing clinicians to identify obvious deviations from normal gait patterns. OGA is widely used due to its simplicity and cost-effectiveness, though it relies heavily on the observer's experience and expertise.

2. Instrumented Gait Analysis (IGA)/3D Gait Analysis: This advanced technique involves the use of motion capture systems, typically with reflective markers placed on the body and multiple high speed cameras capturing movement in sagittal, coronal and transverse planes. The collected data is processed to create a three-dimensional model of the individual's gait cycle. The data offers a comprehensive and highly detailed view of gait mechanics, including joint angles (Kinematics), Joint forces, Moments and GRF (Kinetics) using the force plates and temporospatial parameters (Fig. 1). This technique is particularly valuable for complex cases, providing insights that can't be appreciated on VGA or through simpler measurement tools. Additionally, it gives an objective data which can help to identify abnormal muscle activation using additional tools like electromyography (EMG)[4, 5].

Quantifying Gait

The Sagittal gait patterns described by Winters further extended by Rodda and Graham to include coronal and transverse planes, provided an algorithm for classifying gait patterns in Unilateral and bilateral spastic CP. The gait patterns integrated decision making for appropriate selection of either Botulinum toxin injection, dosage of surgery for Single event multilevel surgery (SEMLS) and orthotics management [6].

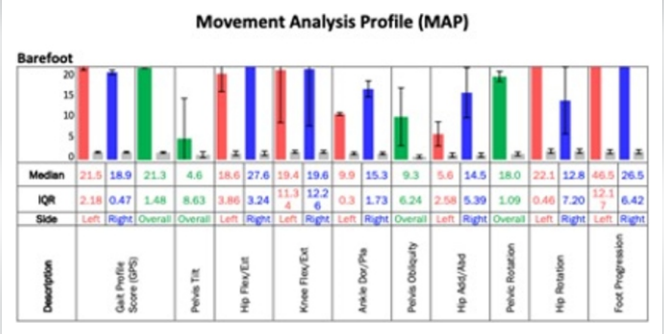

Figure 2: Quantification of Gait analysis with Gait Profile score and Motion Analysis profile

These patterns assisted clinicians to classify the patient in the clinic based on VGA, use similar terminology while describing the patient and thereby aid in decision making and comparing outcomes. However, in individuals with CP who exhibit asymmetrical gait or have complex gait patterns, relying solely on the visual analysis may not effectively guide the surgical dosage needed for treatment planning. In such cases, more comprehensive assessment tools like IGA would be helpful. The 3D gait reports have kinematic and kinetic waveform of each segment upper body, trunk, pelvis, hip, knee, ankle and foot. The force plate data gives the GRF and joint moments, the temporospatial data provides information regarding the stance and swing time, cadence, step length, stride length and speed.

Decision making and Gait Analysis

James Gage in his historical article from 1993 described that gait analysis had brought a "radical" change in the treatment of cerebral palsy. He mentioned that it was great preoperative and postoperative tool to critically assess the gait patterns and subsequent changes. Gait analysis led to improved understanding of the surgical procedures and thereby also discard certain procedures which caused more harm than benefit [5]. Over the last two decades a lot of research has taken place in the field of biomechanics with evidence-based publications. In a study by DeLuca et al which compared surgical recommendations from clinicians experienced in gait analysis, first using clinical exams and video data, then adding kinematic, kinetic, and EMG data. Among 91 patients with cerebral palsy, incorporating gait-analysis data changed recommendations for 52%, thereby reducing costs and risks of inappropriate surgeries. Changes included increased recommendations for gastrocnemius (59%) and rectus femoris (65%), while decreases were noted for hamstrings (61%), psoas (78%), hip adductors (83%), femur (86%), and tibia (64%) [7].

Lofterød and Terjesen studied the results of treatment in 55 CP children when orthopaedic surgeons followed gait analysis recommendations; they concluded that there were satisfactory Kinematic results with improvements for those who had surgery and no significant deterioration for those who were not

operated. Gait analysis was useful in confirming clinical indications for surgery, in defining indications for surgery that had not been clinically proposed, and for excluding or delaying surgery that was clinically proposed [8]. The Psoas lengthening procedures have decreased significantly among ambulatory CP individuals as the kinetic data suggested the decrease in the propulsion power of the Psoas and no significant increase in the hip extension in terminal stance. Instead correction of knee flexion deformity leads to correction of the GRF and leads to gradual correction of hip. Psoas intramuscular lengthening should be a preferred procedure with hip flexion deformity beyond 20 degrees and in non-ambulatory CP children [9, 10]. The understanding of biomechanics has led to the change in procedures the way they were performed as "Birthday Syndrome" to eventually SEMLS which now comprises of decision making as per an individual and defined as "dosage of surgery" which is a combination of lever arm correction and limited soft tissue procedures.

Electromyography along with 3D gait analysis helps in judicious planning of rectus femoris procedures. Various studies have enabled better decision making for stiff knee gait pattern. The decrease in peak knee flexion in swing can be a concomitant feature with other gait pattern like crouch and rectus tendon procedures should not be performed prophylactically [11]. The Kinematic data also revealed that the proximal rectus femoris release along with distal rectus femoris transfer(DRFT) does not affect the pelvic tilt, while the distal rectus lengthening has better long term results for knee kinematics as compared to DRFT [12]

Molenaers et al suggested that the use of gait analysis helped them delay the age of first procedure or Botulinum Toxin A injection required in children with CP, thereby reducing the requirement of additional procedures [13].

Various articles have documented the alteration in decision making with the presence of IGA leading to good outcomes [14, 15], however there can be a variability of decision making and in absence of controls it is difficult to justify if the decision would have been the best. Also the decision making does not rely solely on the gait analysis report and has to be clinically supplemented with the gait analysis. Patient's management is a surgeon's decision rather than the biomechanist who reports the gait analysis. In a study by Chang et al [16], he evaluated 20 children with ambulatory cerebral palsy who were recommended for orthopedic surgery after gait analysis. Ten children did not follow through with the recommendations and opted for unspecified nonoperative treatments, while the other ten underwent the suggested surgeries. The surgical group showed a higher percentage of positive gait outcomes (44%) compared to the non-surgical group (26%). The authors concluded that gait analysis significantly improves gait performance when used to guide surgical intervention. There are no randomised control trials to compare the outcomes in presence or absence of IGA recommendations.

Outcomes with Gait analysis

Post operatively assessing the outcomes or analysing the impact of procedures, formulating rehabilitation protocols or need for secondary surgery and prescription for an orthosis are important aspects of follow up gait studies and aid in continuous management of the patient [17].

The outcome of surgeries is subjective in absence of a gait analysis report and could be labelled as good or better. With the presence of IGA the graphs of the gait report show deviation, but they need to be quantified. The Gait indices such as Gillete gait Index [18], Gait deviation index [19], Gait Profile Score (GPS) and motion analysis profile [20] (Fig. 2) are beneficial for quantifying results post intervention which can be used for documentation and research purpose.

Limitations of Instrumented Gait analysis

The most important limitation is the variability and reproducibility of the gait analysis data. The variability could be patient based- presence of dystonia in mixed type of CP could lead to different gait patterns, the energy level of patient at the time of analysis may cause a difference of data. Presence of different software's, marker application techniques (Helen Hayes, Baker's etc) and reporting techniques can cause variations, errors in data acquisition and processing (Ghost Markers, swapping markers, outdated cameras with low resolution or low frames/seconds or outdated softwares, error in calibration of lab) are multiple factors leading to variations. Noonan et al studied the variability by evaluating 11 ambulatory CP patients at four different centres for Gait analysis and there was variability in the kinematic data generated across the four centres [21].

The gait report is not a prescription for surgery and requires corelation with the clinical findings, radiological findings and should be utilised as one of the components of the diagnostic matrix. The entire process of gait analysis requires a specialised team with a surgeon, biomechanist and a bioengineer. The process of maintaining the software and upgrading it is expensive.

Many pediatric orthopedic surgeons are reluctant to adopt gait analysis due to its complexity, cost, and time demands. The lack of consistent evidence showing improved outcomes allows some to dismiss it. Despite efforts to educate, the gait analysis community has not proven that it reliably leads to better decisions and patient outcomes at an acceptable cost. Consequently, resistance from surgeons and healthcare funders persists, resulting in inconsistent use. This deprives children with cerebral palsy of a valuable assessment tool or subjects them to unnecessary evaluations. There is a pressing

need for additional research, longitudinal studies and clinical trials to provide higher levels of efficacy [22-24].

Conclusion

Gait analysis offers a thorough understanding of gait abnormalities in individuals with CP. Each type of analysis, from observational to highly instrumented and three-dimensional methods, help in the effective assessment and identification of gait deviations and treatment of gait abnormalities to enhance functional ability and overall quality of life. Concluding thisarticle with an insightful statement from James Gage- the father of motion analysis "Until the advent of clinical gait analysis laboratories, the treatment of cerebral palsy was an art, not a science; Because today's technology has opened new doors of opportunity, tomorrow's orthopedists will need to be true "bioengineers" of the human frame if they wish to treat their patients well".

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Declaration of patient consent : The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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