Can we treat cerebral palsy without quantitative gait analysis?

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Introduction

Questioning the role of quantitative gait analysis (QGA) in children with cerebral palsy (CP) may seem misplaced in 2022 since this term is being increasingly employed in the daily practice of physicians treating CP. Nevertheless, such interrogations remain pertinent due to the relatively limited availability of gait analysis laboratories, the importance of a technical interpretation of its results, and a need for a multidisciplinary approach when translating its results to draw up therapeutic strategies.

This exam is mostly used in ambulating children. This implies that the child must be able to walk 10 to 12m repeatedly, preferably without the assistance of devices that could disrupt the recording process, while respecting a linear trajectory while walking, and eventually landing in single support on the force plates placed on the floor. Although kinetic data could be ignored, this would resemble gait analysis using simpler devices, such as a normalized video or EMG-video.

These conditions would thus restrict the use of this analysis method, constituted at its bare minimum of an optoelectronic motion capture system (infrared cameras and passive or active skin markers), force plates built into the floor, a wired or wireless portable EMG, and a computer allowing the recognition and analysis of movement trajectories, collection of the data from the force plate, the calculation of joint moments and joint powers in the mechanical system, and finally receiving the EMG signal.

It is important to underline that gait analysis is but a complementary exam. Patient management should never be solely reliant on the results of the GQA. The provided information should be interpreted by the clinician in charge of the patient and correlated to the patient’s clinical examination and medical history. A therapeutic strategy should be elaborated, cosigned in a report, and dependent on the results of pre-therapeutic tests or post-therapeutic evaluation.

Target population

Some studies have shown that this tool may be used from a young age [1]. All children with CP who might potentially support the constraints imposed by the test may be candidates for this complementary exam. Exam conditions (with or without devices or technical aid) depend on the clinical problem, the patient's functional capabilities, and the technical ability of obtaining interpretable data (in fact, some technical aids may obstruct the vision of the markers from the receptive cameras thus leading to a loss of spatial data, but increasing the number of cameras improves these conditions and reduces this masking effect of the technical aids – i.e., walking stick, walker…)

Theoretically, all ambulating PC children are potential candidates for gait analysis. As such, the question remains:

What should be expected of this exam?

Retrieved data

This exam provides a different view than the conventional gait known by physicians. It breaks down the visualized movement into multiple quantifiable and more objective bits of information. The movement is transformed into joint ranges of motion, movement speed, lever arms, muscle strength, applied or restituted kinetics, developed strength or slowing down, and muscle activation.

How is this exam interpreted?

Apart from temporospatial parameters such as cadence, walking speed, step length, and cycle length, the first easily accessible and interpretable parameters include kinematic data. Although these may substitute video analysis, they are in fact complementary. The physician's clinical outlook requires a visualization of the patient's gait, since this outlook entails a global vision that includes lower limb function, such as the movements of the upper limbs and the trunk. Movement analysis comes later to add precision to the geometric reality of the observed movements: placement of these movements in a three-dimensional space, the sequence of movement, and joint ranges of motion. These data on their own are the essential information.

The second easily accessible parameters include kinetic data: i.e., the data concerning the forces at play in the mechanical system representing the lower limbs. These are divided successively into two:

- Joint moments: Practically speaking, they correspond to the muscle groups in action. This would answer the question: which muscle would be active at a given instant during the gait cycle? The answer to this question must be considered relative to the effective movement of the concerned joint. If a joint that is being flexed is subjected to a flexion moment, then the flexor muscles are activated and participating to the flexion: this generates force. However, if a joint that is being extended is subjected to a flexion moment, then the flexor muscles are resisting joint stretching and extension: it absorbs the force.

- Muscle strength: 2 types of data are available
    - Firstly, the translation of the above-described phenomenon. A muscle that tends to create movement in the same direction as its effective shortening is a producer of energy: it generates force. Inversely, the same muscle that works in the opposite direction of the joint's effective movement (flexor against extension) counteracts the movement and thwarts it, thus reducing its energy: it absorbs energy.
    - Secondly, the amount of strength generated by a joint during movement. Does this strength constitute normal levels? It would appear that, during the gait cycle, the energy that is introduced to conserve movement and maintain ambulation is placed at the hips at the start of the stance phase (hip extensors, primarily the gluteus maximus and hamstrings) and at the start of swing phase (hip flexors, particularly the rectus femoris) and at the ankle at the end of stance phase (ankle plantar flexors: primarily triceps surae). Such information is primordial when considering the efficiency of the lower limbs mechanical system.

The results should then be compared to Gage's 5 criteria for normal ambulation [2,3].

- Stable tripod
- Passing the foot during swing phase without foot catch
- Pre-positioning the foot at the end of swing phase for a proper heel attack
- Sufficient step length (knee extension at heel strike)
- Energy conservation during gait

Data analysis

The analysis of gait data requires a specialized operator in order to fully comprehend the data. Nevertheless, associating clinical findings with motion analysis data is the most essential part. As a result, this phase requires the input of the treating physician along with engineers who can convey the meaning of the data [4]. To this end, gait analysis at a laboratory that does not know the patient can only provide "raw" data along with an interpretation of the mechanical disorder, but in no case a therapeutic indication. Proper knowledge of the parameters of normal human gait is a prerequisite. The differences between the expected and actual outcomes will highlight the disturbances presented by each patient.

A local team, aided by a reference team, participate in confronting the clinical and gait analysis findings [5], thus eventually leading to a treatment decision. This is easily realized today via multidisciplinary conference calls.

Details on interpreting the data cannot be tackled in this chapter, but gait analysis may identify with high certainty after associating clinical data: joint range of motion limitations: deficiencies in range of motion (kinematic); muscle activation: muscle activation during the gait cycle (EMG, joint moments) and its consequences on movement (direction of the displacement – kinematic); strength deficit (reduced muscle strength); lever arm actions [1]. Undertaking an extensive approach to data analysis is an impossible task, especially since each piece of information must be confronted to the clinical findings in order to be confirmed. All data must also be evaluated relative to any modifications observed on other joints. Once the analysis of divergent findings has concluded, a therapeutic approach to analysis then follows: What treatment to suggest (surgical or medical), the feasibility of said treatment, and the functional or overall risks.

In order to have a succinct overall assessment of the situation, some authors have elaborated weighted aggregates of gait data in order to suggest a global index of the mechanical state of gait. The best-known example is the gait deviation index (GDI) [6].

Treatment decision

The therapeutic arsenal is well known by surgeons and the therapeutic suggestions could range from a single therapeutic intervention to multiple ones that are associated or combined. However, each patient should benefit from a specific analysis of their disorders and a therapeutic proposition adapted to their own situation.

As such, motion analysis does not allow the formulation of a therapeutic management plan.

Knowing this, what are the situations where such a complex process as motion analysis may be of use?

Quantified motion analysis is not a routing examination which could be used to simply observe patients. A simple video and a standardized clinical assessment are more than sufficient for the continued management of a patient and depend on the physician to be attentive to the sign of functional degradation on physical examination. Standardized clinical evaluations are very useful to this effect [7-10]. They may highlight a loss or stagnation of function and encourage a more profound investigation.

Surveillance of the patient’s assistive devices and the outcomes of a maintenance therapy by rehabilitation or Botox injections may be done via videography [10], treadmill, or through functional scales. The energy expenditure index (EEI), which is a good scale for the assessment of the functional degradation of a patient when compared to the patient’s performances in terms of temporospatial parameters and functional scales [8], should be used.

Motion analysis becomes indispensable when there is functional degradation prompting therapeutic reorientation or when the question of a surgical intervention, no matter which, is considered. This will allow to pinpoint the exact cause of functional alteration and the therapeutic intervention to undertake and will constitute the indispensable referential to an objective evaluation of the outcomes of the therapeutic intervention.

What evidence does motion analysis provide in the therapeutic decision-making in children with cerebral palsy?

The requirements of motion analysis in children with cerebral palsy has evidently put into question the pertinence of this investigation and the communication between engineers and physicians [4]. Studies analyzing the number of modifications induced by motion analysis on the therapeutic program have shown the influence of the data provided by this exam while highlighting the advantages of confronting this data to the patient's clinical context [5,11-13]. In these studies, the modification of the program under the influence of motion analysis data has been found in 52 to 89% of patients, by either adding one or more programed interventions due to the recommendations provided by motion analysis, by either renouncing one or multiple initially programmed interventions. More recently, randomized studies on the impact of motion analysis have shown the significant impact of motion analysis not only on therapeutic decision-making but also the treatment outcomes [14,15]. It should also be noted that the analysis of the disorders and of their post-operative modifications have allowed a better understanding of their pathophysiology and the refinement of the therapeutic procedures that are suggested from the data collected from the current practice of motion analysis [16].

Conclusion

Although motion analysis may not be an indispensable tool for the management of cerebral palsy, it is nevertheless a rich source of information that could significantly influence the decision and the outcomes when a significant therapeutic intervention is considered. The irreversible nature of the surgical intervention that unavoidably influences the functional prognosis of children with cerebral palsy imposes the use of this exam and the confrontation of its provided information to clinical findings in a multidisciplinary team.

References:

[1] Samson W, Dohin B, Desroches G, Chaverot JL, Dumas R, Cheze L. Foot mechanics during the first six years of independent walking. J Biomech 2011;44(7):1321-7.

[2] Gage JR. The clinical use of kinetics for evaluation of pathologic gait in cerebral palsy. Instr Course Lect 1995;44:507-15.

[3] Ounpuu S, Gage JR, Davis RB. Three-dimensional lower extremity joint kinetics in normal pediatric gait. J Pediatr Orthop 1991;11(3):341-9.

[4] Simon SR. Quantification of human motion: gait analysis-benefits and limitations to its application to clinical problems. J Biomech 2004;37(12):1869-80.

[5] Kay RM, Dennis S, Rethlefsen S, Reynolds RA, Skaggs DL, Tolo VT. The effect of preoperative gait analysis on orthopaedic decision making. Clin Orthop Relat Res 2000(372):217-22.

[6] Schwartz MH, Rozumalski A. The Gait Deviation Index: a new comprehensive index of gait pathology. Gait Posture 2008;28(3):351-7.

[7]AlotaibiM,LongT,KennedyE,BavishiS.Theefficacy of GMFM-88 and GMFM-66 to detect changes in gross motor function in children with cerebral palsy (CP): a literature review. Disabil Rehabil 2014;36(8):617-27.

[8] Cristol C BC. Evaluation fonctionnelle de la marche par l'index de dépense énergétique. valeurs de références chez l'enfant. Ann Readapt Med Phys 1998;41:429-33.

[9] Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol 1997;39(4):214-23.

[10] Viehweger E, Zurcher Pfund L, Helix M, Rohon MA, Jacquemier M, Scavarda D, et al. Influence of clinical and gait analysis experience on reliability of observational gait analysis (Edinburgh Gait Score Reliability). Ann Phys Rehabil Med 2010;53(9):535-46.

[11] Kay RM, Dennis S, Rethlefsen S, Skaggs DL, Tolo VT. Impact of postoperative gait analysis on orthopaedic care. Clin Orthop Relat Res 2000(374):259-64.

[12] Lofterod B, Terjesen T, Skaaret I, Huse AB, Jahnsen R. Preoperative gait analysis has a substantial effect on orthopedic decision making in children with cerebral palsy: comparison between clinical evaluation and gait analysis in 60 patients. Acta Orthop 2007;78(1):74-80.

[13] DeLuca PA, Davis RB, 3rd, Ounpuu S, Rose S, Sirkin R. Alterations in surgical decision making in patients with cerebral palsy based on three-dimensional gait analysis. J Pediatr Orthop 1997;17(5):608-14.

[14] Wren TA, Otsuka NY, Bowen RE, Scaduto AA, Chan LS, Dennis SW, et al. Outcomes of lower extremity orthopedic surgery in ambulatory children with cerebral palsy with and without gait analysis: results of a randomized controlled trial. Gait Posture 2013;38(2):236-41.

[15] Wren TA, Otsuka NY, Bowen RE, Scaduto AA, Chan LS, Sheng M, et al. Influence of gait analysis on decision- making for lower extremity orthopaedic surgery: Baseline data from a randomized controlled trial. Gait Posture 2011;34(3):364-9.

[16] Sees JP, Truong WH, Novacheck TF, Miller F, Georgiadis AG. What's New in the Orthopaedic Treatment of Ambulatory Children With Cerebral Palsy Using Gait Analysis. J Pediatr Orthop 2020;40(6):e498-e503.