Worldwide children's walking disabilities that are caused mainly by cerebral palsy display multiple conditions of both permanent and non-developing motor dysfunction that in turn upsets posture, mobility, or muscle tone in general. In order to estimate the influence of instrumented gait analysis on the walking ability in cerebral palsied children the Dynaport Mini-mod, based on a tri-axial accelerometer was employed. A Dynaport Minimod was used for collecting the spatial and temporal gait data. An evaluation of the gait data carried out via online services application for 80 children with cerebral palsies from April 1st, 2018 to October 30th, 2019. The Dynaport Minimod is capable of capturing most of the spatiotemporal gait parameters which indicate that this technique is quite cooperative and objective in the detection of gait changes and the evaluation of consequences, respectively. The most useful practice for the managing of children with cerebral palsy is a gait analysis system in which its clinical utilization is considered to be a developing technology especially in providing guidance to service planning centres and hospitals.

**Key words:** Cerebral palsy, Gait analysis, Dynaport Minimod, spatiotemporal gait data

**Background:** Worldwide children’s walking disabilities that are caused mainly by cerebral palsy display multiple conditions of both permanent and non-developing motor dysfunction that in turn upsets posture, mobility, or muscle tone in general. In order to estimate the influence of instrumented gait analysis on the walking ability in cerebral palsied children the Dynaport Mini-mod, based on a tri-axial accelerometer was employed.

**Material/Methods:** A Dynaport Minimod was used for collecting the spatial and temporal gait data. An evaluation of the gait data carried out via online services application for 80 children with cerebral palsies from April 1st, 2018 to October 30th, 2019.

**Results:** The Dynaport Minimod is capable of capturing most of the spatiotemporal gait parameters which indicate that this technique is quite cooperative and objective in the detection of gait changes and the evaluation of consequences, respectively.

**Conclusions:** The most useful practice for the managing of children with cerebral palsy is a gait analysis system in which its clinical utilization is considered to be a developing technology especially in providing guidance to service planning centres and hospitals.
INTRODUCTION

Cerebral palsy (CP) originally called ‘cerebral paresis’ was first described as an abnormal condition in 1861 by W.J. Little; a British orthopaedist in his lectures given to medical students. Children with CP display various motor problems that might alter with their growth and development and ultimately result in gait abnormalities [1].

Gait disturbances are usually caused by both primary motor and secondary problems in which the primary motor problem is directly correlated with central nervous system (CNS) lesions and has an impact on muscle tone balance, strength, and specific muscle motor control [2,3]. Whereas secondary problems principally affect the muscle contractures and as a result, osseous malformations will form slowly over time as a result of growth and primary motor defects [4].

The prevalence of CP per thousand children in rich countries is reported to be the lowest, (2.11) while in low and middle-income countries (LMIC) is higher (3.4–10), with the highest Figures being recorded in Africa (1.8–2.3) [5,6]. Therefore, it is highly recommended to determine the preventive risk factors to ease the management and treatment of CP patients [6].

Generally, many factors affecting the prevalence of CP worldwide such as the level of maternal health, a low weight neonate, premature birth, numerous pregnancies, [7] neonate/child healthcare and the new-born illness rates per country in which the basic etiology is not clearly known but which is highly dependent on socioeconomic factors [8].

Currently, in Sulaymaniyah, there is an increase in the number of children with CP that generally face far too many complications when attending hospital for treatment and physical rehabilitation, as their management and control are so difficult for the parents especially the mothers [2].

Presently, studies on the treatment mechanism for CP in Iraq are not often conducted, thus we aim to study the influence of the Tri-Axial Accelerometer using gait analysis system in the managing of children with CP in the city of Sulaymaniyah, Northern Iraq, which might be crucial to develop some controlled management strategies that benefit patients and their families.

Clinical Gait Analysis

Walking is essential to enable the successful continuation of daily life for us all. However, the evaluation of gait deviations in ambulatory patients with CP is fraught with problems, and treatment has usually been limited to a physical inspection and observational gait analysis [9].

Gait analysis is typically assessed by the visual observation of a patient while walking, but this method of evaluation has some shortfalls such as lacking objective data that includes the force centre, step and swing times, step length, and also the distribution of weight itself. The availability of this information is important in the diagnosis and treatment of gait problems’ problems that cannot be observed properly simply by a visual analysis method [10,11].
As a result of gait abnormality complexity and here particularly pathological gait conditions, clinical gait analysis is advanced as the preferable system to find, compute and comprehend the shortfalls within a given patient, for it is completely united with the clinical decision-making of patients with compound gait syndromes [12]. This alternative system investigates a patient’s walking pattern by collecting and analysing numerous data on the gait appearances of the patient. Additionally, this system supplies thorough information on the 4 focal data categories that are spatiotemporal, kinematics, kinetics, and electromyography; data which give an accurate model in the assessment of a patient with gait non-conformities [13].

At present, the quantitative measurement capacity of instrumented 3D-gait analysis makes it a gold standard technique for gait evaluation especially for decision making and walking prognoses in children with CP. This technique is usually applied in a signal analysis laboratory that covers the physical inspection, videotaping for visual gait analysis, and time distance parameter calculations needed for such a prognosis [14].

Furthermore, the 3D-gait analysis is shown to be clinically effective as an evaluation tool for patients with abnormal gait patterns. Thus, the evaluation of joint motion kinematically and joint power kinetically may be obtained through the employment of thoughtful markers, numerous recording cameras, refined computer software, and force plate data. Advocates of recent gait analysis quote the augmented capacity to text and count preoperative defects in all levels. These properties help the orthopaedist to find the pathologic and satisfactory constituents of gait, to devise a specific plan, and for their simultaneously correction [15].

Gait analysis creates dependable data that permits for treatment evaluation and directs additional action in related patients; however, disparagers of modern gait analysis consider that the old approaches are enough in themselves for gait defect evaluations. It is obvious that not all clinicians have access to gait analysis, and therefore ambulatory patients with CP are often sent to laboratories with gait services. These topics are studied, analyzed, integrated, and interpreted in order to deliver a sequence of treatment choices that include improvements in bracing, different muscle releases and transfers, as well as osteotomy [16].

**Spatiotemporal gait parameters**

This research also studied the possibility of spatio-temporal gait parameters analysis using an accelerometer. The principal requirement for gait analysis requires the assessment of spatio-temporal gait parameters and the scrutiny of activities within succeeding walk cycles [17]. These parameters also require the finding of consequent foot contacts such as step length and duration, but equally critical is the determination of the commencement and termination of step cycles. Thus, human gait is conservatively defined as the gait cycle (Fig. 1) which involves 2 primary stages termed stance and swing that stand for the lower limbs. The first phase comprises the foot on the ground while the second phase complies with the foot when it is in the air for the duration. The gait cycle as such
starts when the foot hits the floor and terminates once the same foot hits the floor for the subsequent time [18,19].

**Computerized gait Analysis**

Computerized or three-dimensional gait analysis is another reason this research was conducted. The importance of this analysis lies in the comparison of the surgical recommendations made by experienced clinicians in gait analysis, and this through using the evidence obtained from clinical observations with that collected from the computer-based data [16].

The process of computerized gait analysis includes 3 main steps namely clinical examination, videotaping, and 3D-gait analysis [20]. In this respect, Zijlstra, and Hof, 1997 were of the view that a simple configuration of trunk speeding up with stable correlation to spatiotemporal gait parameters will occur during normal walking. They also noted that three-dimensional (3D) displacements of the lower trunk during walking are well predicted by an inverted pendulum model of the body’s centre of mass trajectory [21].

In arrangement with model predictions, the amplitude and timing of pelvic displacements relied on the spatiotemporal parameters of the step cycle. The reversed pendulum model expects a basic pattern of lower trunk acceleration during walking and relations between acceleration features and spatiotemporal gait parameters [22]. As a consequence, spatiotemporal gait parameters could be mainly detected through the advancements of the lower trunk. Despite this technique, the Dynaport Minimod is fortified with a tri-axial accelerometer to achieve evidence as to an individual’s moving effort; particularly the walking conditions in children with CP [23].
Instantly, the acceleration signals are used for several applications such as the analysis of gait, walking balance, and physical activity. In this regard, the Dynaport Minimod can be used to check a gait performance test by attaching it to the patient’s waist by means of a special belt to measure the value of gait which is the evaluation of the spatiotemporal gait parameters. The provided software assists professionally in conducting a pre-defined test protocol. The gait test is implemented by a straight walking trajectory over a limited distance to appropriate the accessible area. The gait test comprises hardware, the managing software, and one or more selected modules, reachable unobtrusively over the website services [24].

**MATERIAL AND METHODS**

The Dynaport Minimod accelerometer (McRoberts BV, Hague, Netherland) is a small, lightweight tool with dimensions of 5.6 cm x 6.1 cm x 1.5 cm and a weight of 54 g and was used for collecting the spatial and temporal gait data that were saved on the SanDisk (SD) card.

**Patients**

This study was performed on 80 ambulatory children with CP, of which 42 (60%) were females and 38 (40%) were males with an age range of 2.5 to 12 years, and who attended the Children Rehabilitation Centre (CRC) in Sulaymaniyah, Iraq.

**Methods**

The Dynaport Minimod accelerometer was attached to the lower lumbar spine, near to the sacrum by means of a special belt included with a manufacturing device to avoid its movement. The device runs under the Dyrector MT 1.3.1 version assembled via Bluetooth and connected to computerized systems. Then, an evaluation of the gait data was carried out via an online service application provided by McRoberts BV, Hague, Netherland Corporation.

Briefly, the measurements were conducted in an indoor gait laboratory on a 14-meter walkway; one sufficient for gathering gait data. In a four-way analysis of the variance model, gait analyses were carried out with significant speed-variability and step length of the preferred velocity (normal waking), fast velocity, slow velocity, and double tasks gait to obtain a difference and variation in the gait types. The duration for gait analysis for each patient was about 45 minutes.

**RESULTS**

The output results of the gait analysis are a huge amount of data representing the complete spatiotemporal parameters of waking analysis; here including four graphical analyses for each walking style.

In this regards, Fig. 2 shows the running style of the software compatible with the accelerometer mini mode whereas Fig. 3 shows the graphical analysis which represents the acceleration, movement intensity, vertical displacement and step...
pattern deviation regarding the time undertaken during walking between the left and right limbs for each trajectory of the gaits. Additionally, Fig. 4 shows graphical analysis that consists of spatiotemporal (walking distance and speed, number, length, and the frequency of steps with step time), symmetry, and regularity in x, y, and z-direction, and efficiency for both the left and right limbs for each of the walking styles.

Fig. 2. The output style of the Dyrector MT 1.3.1 for all trails of gaits

Fig. 3. The acceleration signals of walking in each step, including the movement intensity with vertical displacement
Fig. 4. Shows the same variables in double tasks gaits

Fig. 5. The spatiotemporal parameters with symmetry and regularity between left and right limbs
Fig. 6. The numerical data of gait analysis

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<th>Max Acc. Y</th>
<th>Max Acc. Z</th>
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Fig. 7. The numerical values of analysis of gaits
Furthermore, Fig. 5 shows graphical analyses that consist of stride-to-stride fluctuations, bilateral coordination, step pattern deviation, and step times for each trail of walking, and finally, Fig. 6 and 7 are Excel tabulations that contain all the numerical data for these aforementioned graphs.

**DISCUSSION**

Generally, the value of computerized gait analysis is putative and acknowledged internationally, especially in developed countries [25,26]. Using gait analysis in children with CP assists physicians to instantly recognize the main/specific reasons of atypical gait, as well as supplying more evidence to the modest optical examination of gait [27].

More recently, the conclusions drawn by gait analysis laboratories are preferable to optical monitoring gait analysis as these offer tentative data on gait which helps to differentiate normal gait from the pathologic and additionally also elucidate the magnitude of the deviations and abnormalities [28].

The source of variable outcomes is different, but mainly includes the patient itself, the renown of the laboratory that conducts the gait analysis, test procedure, test conductance, data analysis and interpretation, along with the medical advice and recommendations [9]. In this way, medical gait analysis becomes disputable, resulting in broad differences within the degrees of gait analysis application in the supervision of ambulatory CP cases in children [29,30].

Nowadays, the main goal in the handling of peoples with CP is to achieve a systematic estimation that covers the patient’s history from birth to now, a complete physical inspection, proper radiographs, discussion with medical professionals, and lastly an analysis mechanism of the gait [12,31]. Consequently, these trends result in improved assessment of the abnormalities and pathological deformities that affect people’s inherent gait at the current level of growth [32]. As soon as the major distortions are allocated, the orthopaedic plans to integrate these facts to devise a treatment choice, including simultaneously the arrangement of operations and another intercession [1].

However, the causes of CP vary but a understanding of the particular cause does not change the treatment management choices. Gait analysis has the potential to treat people with a neuromuscular disability, particularly those with CP [2,33].

When the Dynaport Minimod is used for the analysis of gait, it can detect detailed patient deformities, thus, it is considered to be an accurate tool for motor diagnosis and treatment. In this respect, the obtained information should be interpreted by an expert physician just before deciding on appropriate treatment choices and the management of proceedings such as a surgical operation/procedure, the injection of botulinum toxin, orthosis usage to assist relative movement, the application of physiotherapy, the oral administration of medications, or the use of a baclofen pump [34-36].
CONCLUSION

Visual observation per se is poor at describing gait in children, and the quantitative assessment of gait in children is increasingly being used in the management of gait disorders. While instrumented gait analysis offers supportive evidence to help orthopedist in the decision-making process for the treatment of patients with CP as its reputation for being of a high quality in the correct measurement of human movement is increasingly being recognized. However, conducting a recent population-based survey of CP in Iraq to determine the incidence of patients/1000 children highly recommend itself in the easing of management, control, and the successful treatment of cases. For this purpose, the strict adherence to management and prevention policies for CP intended for LMIC is most necessary.

Conflict of Interest
The authors declare no conflict of interest whatsoever.

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