

Original Research Article

Computed dynography, a method for evaluation of gait pattern in treated cases of congenital talipes equino varus

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ABSTRACT

Background: Club foot is characterized by inversion, adduction and equinus. Currently, evaluation of children treated for congenital talipes equino varus (CTEV) includes clinical and radiological examination as well as assessment of function. However, none of the methods is ideal. There should be objective methods for better evaluation of function in treated CTEV. Gait analysis is the emerging method in objectively assessing the functional outcome. The aim of the study was to compare the selected measures from vertical ground reaction force variables and gait parameters of treated CTEV children with plantigrade feet, to healthy age and gender matched control group.

Methods: We took 31 children with treated CTEV with mean age 8.21 years and compared with 31 age and gender matched controls. The patients were initially treated under a standard protocol. Gait cycle properties, step time parameters and vertical ground reaction force variables were recorded and comparison of unilateral and bilateral cases of treated CTEV was done with that of controls.

Results: Data showed that despite good clinical results and overall function, residual intoeing, lateral foot walking, mild foot drop, weak plantar flexor power, possible residual inversion deformity of the foot, increased frequency and decreased duration of cycle and asymmetry in gait were the main characteristics of gait of children with treated CTEV. In unilateral cases single and double support times were decreased and in bilateral CTEV double support times are increased.

Conclusions: The study confirms that in clubfoot patients who underwent full treatment, gait parameters do not reach normal levels. Gait analysis can be used to quantify gait pattern characteristics and is helpful in evaluation and further development of treatment of patients.

Keywords: Club foot, Gait analysis, Computed dynography

INTRODUCTION

Club foot is a deformity characterized by inversion, adduction and equinus. It causes disability either from original deformity or because from secondary problems associated with treatment.¹ After early conservative or surgical treatment, clubfoot children are periodically reviewed and reassessed. Evaluation of children treated for congenital talipes equino varus (CTEV) includes clinical and radiological examination as well as assessment of

function, level of pain and patient satisfaction.^{1,2} Functional assessment is usually based on questionnaires. All these methods do not include objective measurements of performance of foot during gait or other physical activities. As a result, the indications for further treatment as well as good functional outcome are not clearly defined.¹⁻⁴

Several studies have been done to assess objectively the functional outcome of children treated for CTEV using

gait analysis. But only limited aspects of gait analysis have been covered.^{1,2} A few studies have been done on video assisted analysis of club foot patients. To our knowledge, no previous study has compared the functional performance in children with treated CTEV and a good clinical result, with that of normal children. This study will try to set an objective standard for the optimal function in treated CTEV.

It was hypothesized that “there would be no significant difference between normal individuals and CTEV children for gait parameters and vertical ground reaction forces.”

The aim of the study was to compare the selected measures from vertical ground reaction force variables and gait parameters of treated CTEV children (unilateral and bilateral both) to a normal healthy age and gender matched control group with the new modality of assessment “computed dynography”.

METHODS

The present study was conducted on patients of orthopaedic department of hospital in central India (Sri Aurodindo Institute of Medical Sciences and Post-graduate Institute, Indore). It was done over a period of 1 year from December 2017 to January 2018 in conjunction with department of physiotherapy.

Patients with previous treatment of CTEV are usually followed up until skeletal maturity at our hospital at CTEV clinic. Patients between ages of 6 and 12 years who had previous conservative or surgical treatment for CTEV and were not awaiting any further treatment (Pirani score <1) were invited to participate in the study. A total of 33 patients were recruited consecutively through the clinic and informed consent for participation in the study was obtained from their parents or their caretakers. The local ethics committee granted approval for the study.

Two patients were excluded from the study because of insufficient data from their gait analysis, leaving 31 children in the study. There were 9 girls and 22 boys with a mean age of 8.21 yrs. Of the 19 patients with unilateral CTEV 11 were left sided and 8 were right sided. There were 12 patients of bilateral CTEV where we studied only the more severely affected foot.

All the patients were treated under a standard protocol. Treatment included serial manipulation and casting up to the age of 3 to 6 months. Then patients were assessed clinically and radiologically. If there was no improvement, surgery was planned. In case of improvement, casts were continued weekly. After application of final cast for 3 weeks, patient was given a modified Dennis Brown bar with shoes attached at 70 degrees external rotation. Of the 31 patients with club feet, 18 patients were treated with serial manipulations and casts only and 13 patients underwent surgery. The surgery performed was a step wise release of the posterior, medial and lateral structures of the

foot as required. The cincinnati incision was used. Post operatively moulded plaster casts were applied for 2 to 3 months, followed by night splintage and CTEV shoes were continued thereafter. 31 normal control children who were age and sex matched were recruited from outpatient clinics. They were not known to have any musculoskeletal or neurological abnormalities.

Gait analysis

Ultraflex (Gait analysis system) by Infotronics Medical Industrial Engineering was used for data collection.¹⁴ Ultraflex is a portable modular programmable system with 16 channels. It has computer dynography (CDG). The complete ultraflex gait analysis system consists of following parts:

CDG shoes with sensors: CDG shoes are designed to measure and record the normal forces under foot while walking. Each shoe contains 8 Load sensors at sole. Cables attached to sole transfer the normal forces data to Ultraflex unit for recording.

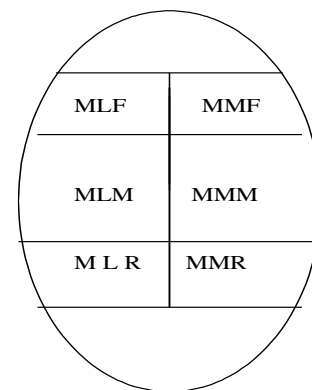


Figure 1: Distribution of sensor zones on CDG shoe.

MMF-midsole medial front, MLF-midsole lateral front, MMM-midsole medial middle, MLM-midsole lateral middle, MMR-midsole medial rear, MLR-midsole lateral rear.

Measurement unit: Ultraflex unit is a portable measurement unit that records normal ground reaction forces while walking. All measurements are be stored in the memory card while conducting the new measurements

Ultraflex optical link cable: Ultraflex optical link cable is glass fibre cable for high speed transfer.

Cords: Used to connect ultraflex measurement unit to the computer used for data analysis.

Straps: Used to fix the cord with the body so that the patients have no problem in walking.

Methods of data collection

Each subject was made to wrap an ultraflex unit around the waist and a pair of CDG shoes of approximate size was put

on foot. The subjects were then given 2 minutes of familiarization time. After the familiarization time the subject were made to walk at natural speed straight in a ten meters corridor. Data was then taken for 20 seconds of gait cycle. The recorded data was then transferred to processor by link cables. Data analysis was done from fifth to fifteenth second of gait as it was supposed to represent natural gait pattern.

Gait parameters and vertical ground reaction forces assessment is done by measuring the following data -

Gait cycle properties: It includes gait cycle duration, frequency and symmetry.

Step time parameters: It includes single support time, double support time, stance time, step time and single swing time.

Vertical ground reaction forces variables and force graphics: It includes heel on, mid stance and toe off.

Statistical analysis

All data was reduced to its mean in each sensor by the software in the CDG. Only step time parameter and vertical ground reaction forces measures obtained by force graphics and histogram are meticulously noted. Now, mean of each group of data is calculated and comparisons were done. For statistical significance critical value of 't' was calculated. Statistical significance was called when $t > 2.01$ in case of unilateral patients, $t > 2.00$ in bilateral cases.

RESULTS

All data was noted and comparisons were done between affected limbs of unilateral CTEV, more severely affected limb of bilateral CTEV and normal limb of unilateral

CTEV with that of controls. This was done on the basis of gait cycle properties, step time parameters and vertical ground reaction force (VGRF) variables obtained by histogram and force graphics. We observed that although gait of patients of treated CTEV patients looks apparently similar to control subjects, but significant differences were observed through gait analysis.

Gait cycle properties

Frequency was increased in both bilateral and unilateral cases, cycle duration was decreased in both bilateral and unilateral cases and symmetry was mainly disturbed in unilateral cases.

Cyclogram and histogram

Cyclogram shows that the center of gravity is shifted towards affected side in unilateral CTEV patients and thus the symmetry is also disturbed. Gait line shows that center of pressure is also shifted towards lateral side in the affected foot in club foot patients.



Figure 2 (A and B): CDG shoes with sensors.

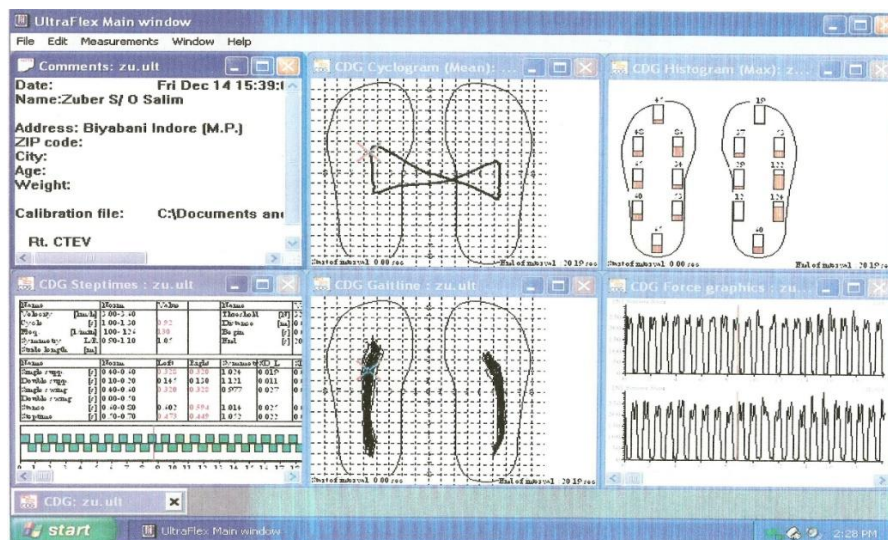


Figure 3: Observation sheet of a single patient.

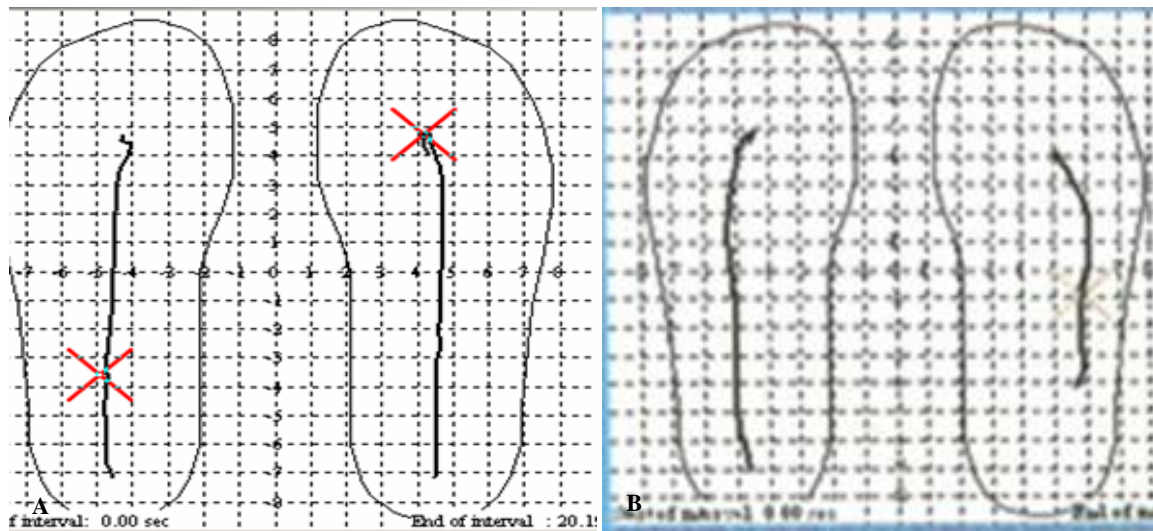


Figure 4: Gait line; (A) Normal, (B) CTEV.

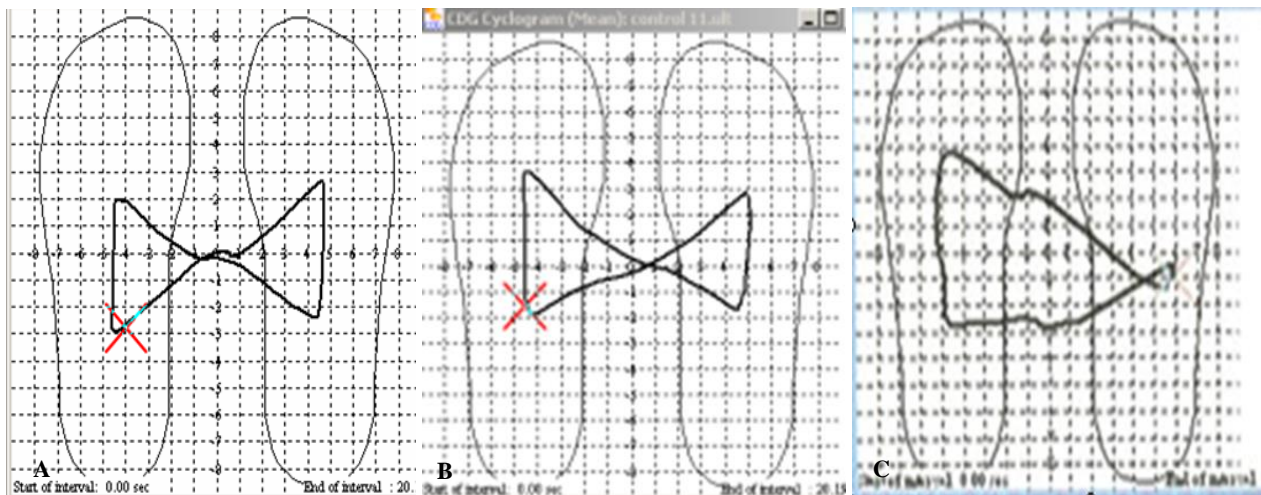


Figure 5: Cyclogram centre of gravity (A) normal, (B) bilateral, (C) unilateral.

Table 1: Comparison of step time parameters of affected limb of unilateral CTEV with control group.

Step time parameter	Control (mean in sec)	Unilateral (mean in sec)	't'
Single support time	0.34	0.318	4.80
Double support time	0.131	0.121	0.43
Stance time	0.660	0.599	2.71
Step time	0.708	0.459	2.77
Single swing time	0.416	0.363	2.14

Table 2: Comparison of step time parameters of more severely affected limb of bilateral CTEV with control group.

Step time parameter	Control (mean in sec)	Bilateral (mean in sec)	't'
Single support time	0.34	0.272	5.79
Double support time	0.131	0.164	2.61
Stance time	0.660	0.588	2.06
Step time	0.708	0.444	2.37
Single swing time	0.416	0.354	5.74

Table 3: Comparison of step time parameters of normal limb of unilateral CTEV with control group.

Step time parameter	Control (mean in sec)	Unilateral -normal side (mean in sec)
Single support time	0.34	0.352
Double support time	0.131	0.142
Stance time	0.660	0.621
Step time	0.708	0.50
Single swing time	0.416	0.385

Table 4: Comparison of VGRF over each sensor of more affected limb of bilateral CTEV group with unilateral CTEV and control group.

Sensors	Control (mean) (N)	Unilateral (mean) (N)	't'	Bilateral (mean) (N)	't'
Toe	55	17.5	4.73	13	2.94
MMF	44	22	4.88	25	4.08
MLF	40.5	55	5.78	50	9.39
MMM	42	19.5	2.25	24	1.97
MLM	15	93	8.58	107	4.41
MMR	51.5	7.5	2.19	8	4.31
MLR	62.5	98.5	2.99	87	2.26
Heel	22	14	4.59	17	2.49

Table 5: Force graphics.

Amplitude (N)	Control	Unilateral	't'	Bilateral	't'
Heel on	238	177	2.35	170	2.67
Mid stance	197	119	3.83	134	2.01
Toe off	252	178	1.14	195	2.80

Vertical ground reaction forces were mainly distributed over lateral border of foot. This finding was consistent in both unilateral and bilateral CTEV patients.

Step time parameters

All the times are reduced in both unilateral and bilateral cases except double support time which is increased in bilateral cases. Step time parameters of normal limb of unilateral CTEV are also abnormal showing that they may have compensated for the insufficient motion of the club foot.

Comparison of VGRF over each sensor of more affected limb of bilateral CTEV group with unilateral CTEV and control group

In both unilateral and bilateral club foot, force distribution is mainly along the lateral border of foot. Forces over MLF, MLM and MLR are increased. This shows that the child puts most of the weight on lateral border of foot.

Force graphics

Power generated during all the three phases of stance phase is less than controls in both unilateral and bilateral club foot patients. But the duration of mid stance phase is more as compared to controls. This shows that patient faces

difficulty in maintaining balance and takes more time in stabilizing the affected foot on ground.

DISCUSSION

The results of CTEV surgery have traditionally been assessed using radiographic techniques and measures of range of motion, yet the passive mobility of foot and ankle has little bearing on the ability of the patient to walk and run without pain. Functional measures of outcome started with Otis et al who assessed the results of clubfoot surgery with gait analysis measuring cadence parameters and gathering EMG data.⁶ Aronson et al studied the centre of pressure in treated cases of clubfeet and found that it gets shifted towards lateral side of foot in clubfeet as compared to controls.⁷ Our study also shows similar findings. The values of vertical ground forces were more on MLF, MLM and MLR (55N, 93N, 98.5N in unilateral and 50N, 107N, 87N in bilateral cases respectively) in club feet as compared to controls (40.5, 15 and 62.5) as shown by the histogram. Cyclogram shows that centre of gravity is shifted towards affected side in unilateral club foot, thus showing the asymmetry in walking.

The force generated during heel on phase was less than control subjects both in unilateral and bilateral CTEV patients. (Average in control group – 177 N, in unilateral CTEV 170 N, bilateral CTEV 238 N). This implies that dorsiflexor power is weak, that is, tibialis anterior power

is weak which leads to intoeing. This supports minor foot drop observed in treated CTEV patients.

This is supported by Asperheim et al, who observed abnormal stance phase activity of anterior tibialis on EMG, referred for residual intoeing after clubfoot release.⁸ Karol et al also observed residual intoeing during his study of gait analysis of treated clubfeet.⁹

Davies et al analyzed the gait of treated clubfeet patients.¹⁰ He observed reduced strength of plantar flexors, quadriceps weakness. Alkjaer et al studied nine adult patients with treated CTEV using video and force plates.¹¹ During his study subjects were asked to walk across two force platforms at a speed of 4.5 km/hr. Fifteen small reflecting spherical markers were placed on subjects. Five video cameras were used to record findings. They found weakness of plantar flexors. Patients with a good clinical result and evaluated by an established protocol were not included in any of these studies. Neither did they record any quantitative data. Our study supports these findings with the help of quantitative data. During push off phase, power generated in affected foot is significantly reduced in the CTEV group (average in unilateral- 178N, Avg. in bilateral-195N, average in controls- 252N). This implies that the normal forces exerted at the heel by the plantar flexors are reduced.

Davies et al studied children with treated CTEV (both unilateral and bilateral) and compared them with normal and age-matched children. They found weak ankle plantar flexors and a reduced range of movement of the ankle. Furthermore, they detected abnormal moments around the knees and hips which they attributed to the abnormalities of the ankle and foot.¹⁰

In our study distribution of ground reaction forces over 8 sensors were recorded during gait. Forces were mainly distributed along the lateral border of the foot. Davies et al found that lateral ground reaction forces in children with clubfoot was greater than that of normal children.¹² Aronson et al found increased stress along the fifth metatarsal whereas Widhe et al showed a shift towards the lateral.^{7,13} All these findings indicate a possible residual inversion deformity of the foot, which causes lateral border walking.

Anterior ground reaction force was found to be weak which implies lack of push off that is weak plantar flexor activity.

Findings of cyclogram and histogram showed that in unilateral CTEV patients, centre of gravity is shifted towards affected side. Mean values of symmetry was disturbed more in unilateral club foot patients (0.98 in unilateral as compared to 1.01 in bilateral and 1.009 in controls).

Comparison of step time parameters was also done between normal foot of unilateral CTEV with that of control subjects. Step time parameters in normal foot of

unilateral CTEV were abnormal. This shows that the contra lateral limb in unilateral CTEV is not normal and has compensated for the insufficient motion of the clubfoot. Davies et al analyzed the gait of unilateral CTEV and found abnormal kinematics of unaffected limb when compared to controls.¹² Therefore he suggested that the kinetics and strength of the contralateral limb of children with unilateral clubfoot and that of normal children should also be compared. Our findings support this study.

Frequency measured denotes that walking ability is reduced in CTEV patients, that is, the number of steps/min was increased. Duration of gait cycle was found to be reduced. In unilateral cases single and double support times were decreased on affected side showing that the child hesitated in keeping the affected limb on ground and most of the time keeps his affected limb off the ground. In bilateral CTEV double support times are increased which shows that when patient bears weight on affected side, the contra lateral limb also supports it. Symmetry was found to be disturbed in unilateral CTEV patients. This is supported by the fact that they try to put most of the load on the normal limb.

The current study confirms that in clubfoot patients who have undergone full treatment and not awaiting any further treatment, gait parameters do not reach normal levels. Despite good clinical results and overall function residual intoeing, mild foot drop, weak plantar flexor power, a possible residual inversion deformity of the foot, increased frequency and decreased duration of cycle and asymmetry in gait were the main characteristics of gait of children with treated CTEV.^{2,3,9}

Unilateral CTEV patients favoured their affected limb by not putting as much force on it. This results in additional stress on unaffected leg and may lead to development of osteoarthritis and joint problems in later years.

We have not compared gait of conservative vs. operatively treated CTEV because initial grade of severity of clubfoot during start of treatment has not been taken into account. Of course, more severe grades must have been treated operatively. This was a limitation of our study.

In our setup's strength training is not generally included in the treatment of club foot subjects.¹¹ It is possible that strength training of plantar flexors in the club foot group would enable them to walk with a larger ankle moment, reducing the loads on the knee and hip joints.

Revision surgery in clubfeet should only be done when the problem or deformity has become unacceptably symptomatic producing functional problems and pain. It should always be remembered that repeated surgery will always produce additional stiffness within the foot and further loss of power.¹⁵ Thus there should be objective methods of assessment of function in treated CTEV. Early methods like radiology and clinical evaluation have limitations. Gait analysis is the new emerging method in objectively assessing the functional outcome. This study

showed that gait analysis including kinematics and dynamics of walking can be used to quantify gait pattern characteristics and may be helpful in evaluation and further development of treatment of patients with clubfoot.

CONCLUSION

The current study confirms that in clubfoot patients who have undergone full treatment and not awaiting any further treatment, gait parameters do not reach normal levels. In our study residual in toeing, mild foot drop, weak plantar flexor power, a possible residual inversion deformity of the foot, increased frequency and decreased duration of cycle and asymmetry in gait were the main characteristics of gait of children with treated CTEV. Strength training of plantar flexors in the club foot group would enable them to walk with a larger ankle moment, reducing the loads on the knee and hip joints. Thus, gait analysis can be used to quantify gait pattern characteristics and may be helpful in evaluation of patients needing further surgical intervention and further development of treatment protocols of patients with clubfoot.

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Ethical approval: The study was approved by the institutional ethics committee

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