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# Gait Analysis of Postoperative Club Foot

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## ABSTRACTS

Thirty-one postoperative congenital club foot children, comprizing 15 bilateral cases and 16 unilateral cases, were reviewed after a follow-up period of three to twelve years.

The feet were assessed kinesiologically by checking the ground reaction force. The relationship between the clinical results and the ground reaction force was studied and the available parameters in the ground reaction force for the assessment of the postoperative club foot children are $F(X_2)$, $F(Z_2)$, $T(X_0)$ and $F(Y_2)$. The residual deformity of the calf muscle can be evaluated by the measure of $F(X_2)$ and $F(Z_2)$, the pes equinus by $T(X_0)$ and the adduction of the forefoot by $F(Y_2)$.

## INTRODUCTION

Since 1974, 80 cases of congenital club foot in children were treated in Nagasaki University Hospital using Turco's method. (postero-medial release)[9] The clinical results of the postoperative congenital club foot children were mainly checked using a routine method by which we examined the range of motion of the ankle joint, the outward appearance of the foot and the roentgenographic changes of the foot. (such as the talo-calcaneal[2)6)] angle, the tibio-calcaneal angle[7)] and the talus-first metatarsal angle) This routine method is only a static assessment for club foot, and the kinesiological assessment of the postoperative club foot, such as the walking pattern remained unknown. Recently, we have been trying to evaluate the clinical results of the postoperative club foot children from the viewpoint of the ground reaction force. The purpose of this study is to find out what the parameters are in the ground reaction force for the assessment of the postoperative club foot children.

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## PATIENTS AND METHODS

Thirty-one patients with congenital club foot, which comprized 15 bilateral cases and 16 unilateral cases, were studied. The age range of the patients was six to thirteen years old and the follow-up period was three to twelve years. In order to compare the club feet with the normal feet, thirty-six normal children between the age of six and ten, and forty normal adults were also studied. (Table 1)

There was a walkway about 8 meters long, in the center of which, two large-sized force plates (250cm in length and 40cm in width) were embeded. Each subject was asked to walk on the walkway, and while walking, he was asked to place his feet on the two force plates separately, and then the ground reaction force of both feet were recorded. (Fig. 1) Ten to fifteen trials for each subject were undertaken and at least twenty steps by each foot were recorded. The data of the ground reaction force of each foot were calculated and normalized by a microcomputer (PC-9801 F, NEC, JAPAN) and the normalized reaction force was plotted out in graphic form and then analyzed. (Fig. 2)

| NORMAL | | CONGENITAL CLUB FOOT | | |
|---|---|---|---|---|
| AGE | TOTAL | BILATERAL | UNILATERAL | TOTAL |
| 6.0 | 6 | 2 | 4 | 6 |
| 7.0 | 8 | 2 | 1 | 3 |
| 8.0 | 9 | 2 | 3 | 5 |
| 9.0 | 8 | 2 | 1 | 3 |
| 10.0 | 5 | 7 | 7 | 14 |
| ADULTS | 40 | | | |
| TOTAL | 76 | 15 | 16 | 31 |

**Table 1.** Subjects and Age Distribution

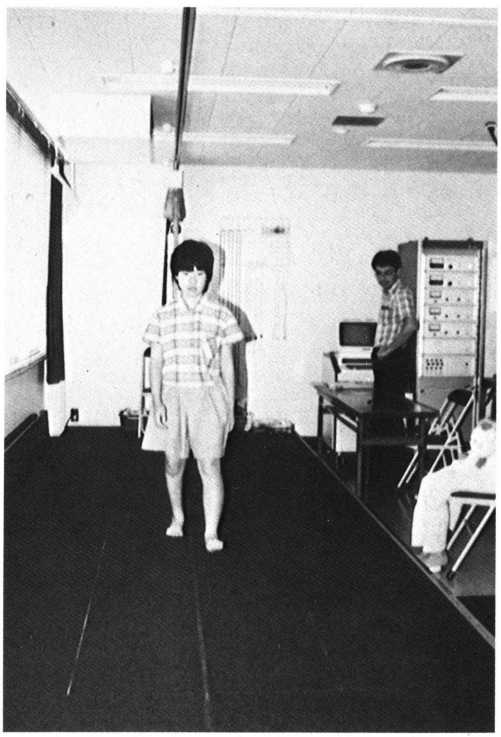

**Fig. 1** In the center of the walkway, two large sized force plates were embeded. Each subject was asked to walk on the walkway and to place his feet on the two force plates separately.

The normalized reaction force is shown in Fig. 3[8] The vertical axis is the percentage of the body weight of the subject and the horizontal axis is the normalized time (%) of the period of the stance phase in one step. The Y axis is the lateral component of the ground reaction force. The X axis is the forward-backward component and the Z axis is the vertical component. $Y_1$, $X_1$ and $Z_1$ are the peak points of the restraining period. $Y_2$, $X_2$ and $Z_2$ are the same in the prospelling period. $Y_0$, $Z_0$ are graphed as a valley between the restraining period and the prospelling period. $X_0$ is the turning point of the restraining period to the prospelling period.

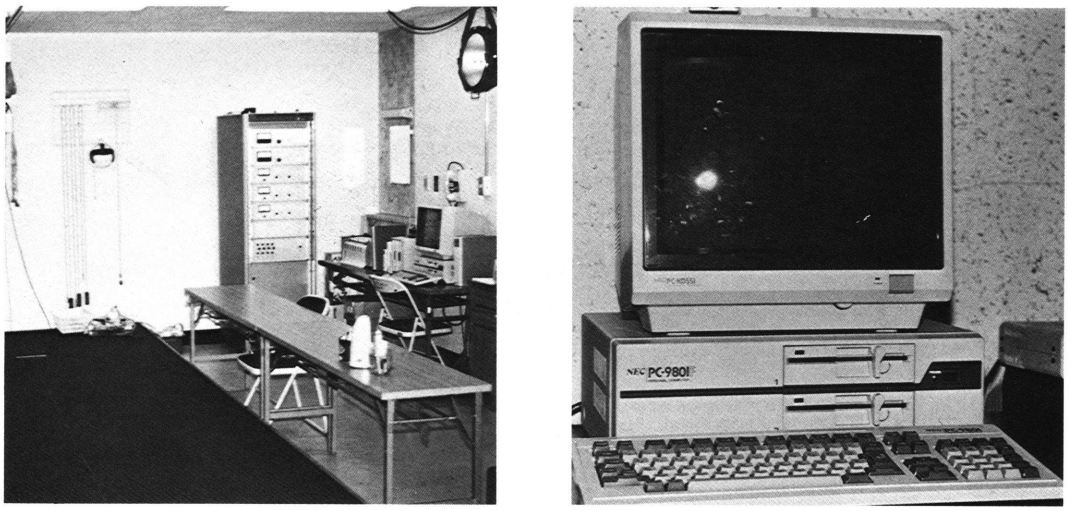


**Fig. 2**

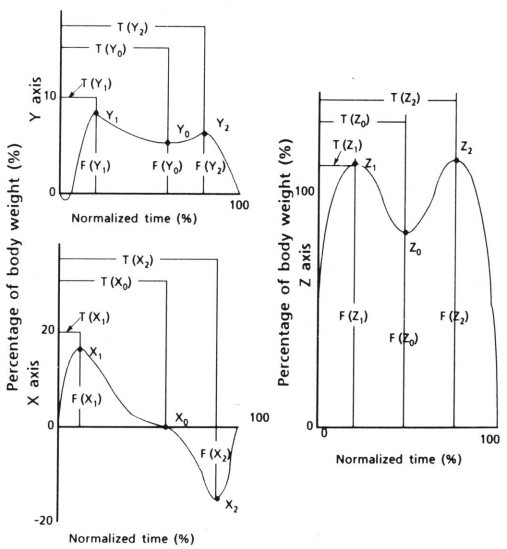


**Fig. 3** Normalized Ground Reaction Force.

$F(Y_1)$, $F(Y_0)$, and $F(Y_2)$ are the amplitude of the points of $Y_1$, $Y_0$, and $Y_2$ in the lateral component. $F(X_1)$ and $F(X_2)$ are the amplitude of the points of $X_1$ and $X_2$ in the forward-backward component. $F(Z_1)$, $F(Z_0)$, and $F(Z_2)$ are the amplitude of the points of $Z_1$, $Z_0$ and $Z_2$ in the vertical component.

$T(Y_1)$, $T(Y_0)$, $T(Y_2)$, $T(X_1)$, $T(X_0)$, $T(X_2)$, $T(Z_1)$, $T(Z_0)$ and $T(Z_2)$ are the normalized time of point $Y_1$, $Y_0$, $Y_2$, $X_1$, $X_0$, $X_2$, $Z_1$, $Z_0$ and $Z_2$.

The clinical results of the patients were evaluated according to the criteria as shown in Table 2, which were modified from Turco's criteria.[9] The results were rated as excellent, good, fair and failure. The range of motion of the ankle joint, the ability of tip toe gait and the roentgenograms of the feet of each subject were also examined. In the radiographic measurement, the talo-calcaneal angle[2)6)] (Antero-posterior view and lateral view), tibio-calcaneal angle[7)] and talus-first metatarsal angle were included.

In order to investigate the correlation between the ground reaction force and the clinical results, we fed the ground reaction force data into the computer accompanied with the data of the clinical results and the clinical factors such as the range of motion of the ankle joint, the ability of tip toe gait and the radiographic measurements. The items of the imput are shown in Table 3. According to Dr. NOGUCHI's study,[8)] each measurement of the ground reaction force except for $T(Y_1)$, $T(Y_2)$, $T(Y_0)$, $T(X_1)$, $T(X_2)$, $T(Z_1)$, $T(Z_2)$ in the

**Criteria of Clubfoot Assessment**
**in Nagasaki Univ. Hospital**

*Excellent*

1. FEET ARE ALMOST NORMAL WITH COMPLETE CORRECTION AND ONLY VERY MINOR RESIDUAL DEFORMITY.
2. FEET ARE PLANTIGRADE AND CAN DO TIP-TOE-GAIT.
3. NO TOE-IN GAIT.
4. DORSIFLEXION IS MORE THAN 10 DEGREES.
   PLANTAR FLEXION IS MORE THAN 35 DEGREES.
5. ROENTOGENOGRAM SHOWS A * NORMAL TARSAL RELATIONSHIP.

*Good*

1. FEET SHOWS COMPLETE CORRECTION OF DEFORMITY WITH PLANTIGRADE. BUT THERE ARE SOME SLIGHT RESIDUA NOT FOUND IN THE FEET WITH EXCELLENT RESULTS.
2. NO TOE-IN-GAIT.
3. TIP-TOE-GAIT IS POSSIBLE.
4. DORSIFLEXION IN LESS THAN 10 DEGREES.
   PLANTAR FLEXION IS MORE THAN 30 DEGREES.
5. ROENTOGENOGRAM SHOWS A NORMAL TARSAL RELATIONSHIP.

*Fair*

1. FEET ARE PLANTIGRADE, WITH EITHER OVERCORRECTION OR SOME LOSS OF INITIAL CORRECTION.
2. TOE-IN-GAIT.
3. TIP-TOE-GAIT IS IMPOSSIBLE OR CAN NOT DO WELL.
4. DORSIFLEXION IS LESS THAN 5 DEGREES.
   PLANTAR FLEXION IS LESS THAN 30 DEGREES
5. ROENTOGENOGRAM SHOWS A SMALL TALO-CALCANEUS ANGLE AND LARGE TIBIO-CALCANEUS ANGLE.

*Failure*

1. INITIAL CORRECTION IS LOST WITH RECURRENCE OF THE DEFORMITY AND FURTHER SURGERY IS INDICATED.
2. COSMETICALLY UNACCEPTABLE PLANO VALGUS.

* modified from Turco's method

**Table 2.** Criteria of Clubfoot Assessment in Nagasaki Univ. Hospital

1. Case No. 2. Age 3. Sex
4. Subjects (normal Subject / bilateral club foot / unilateral club foot)
5. Clinical results (normal / failure, fair / good, excellent)
6. dorsiflexion (ankle) 7. plantar flexion (ankle)
8. ability of tip toe gait 9. Talo-calcaneal angle (A-Pview)
10. Talo-calcaneal angle (lateral view) 11. Tibio-calcaneal angle
12. Talus-first metatarsal angle 13. F (X1) %
14. $F(X_2)$ % 15. $F(Y_1)$ % 16. $F(Y_0)$ %
17. $F(Y_2)$ % 18. $F(Z_1)$ % 19. $F(Z_0)$ %
20. $F(Z_2)$ % 21. $T(X_1)$ % 22. $T(X_0)$ %
23. $T(X_2)$ % 24. $T(Y_1)$ % 25. $T(Y_0)$ %
26. $T(Y_2)$ % 27. $T(Z_1)$ % 28. $T(Z_0)$ %
29. $T(Z_2)$ %

**Table 3.** Itemes of the input

normal children changed with age. For example, $F(Z_2)$ versus age as shown in Fig. 4. In order to exclude the change caused by age, a normalization was performed on the club foot children according to the formula described in Table 4.

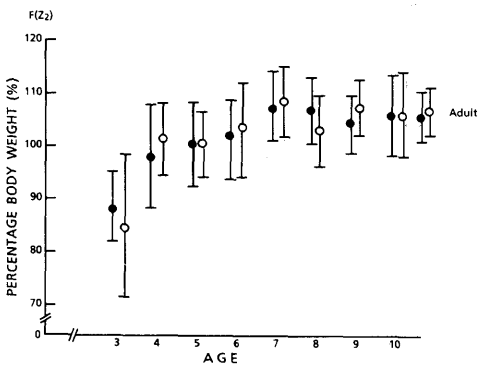


**Fig. 4** Vertical Component ($F(Z_2)$) of G.R.F. versus Age

$$C' = C \times \frac{A}{B}$$

C' : the normalized measurement of the club foot children's G.R.F.

C : the measurement of the club foot children's G.R.F. before normalization

A : the measurement of the normal adults' G.R.F.

B : the measurement of the normal children's G.R.F.

G.R.F. : ground reaction force

**Table 4.** Method of Normalization

## RESULTS

The correlation table between the ground reaction force and the clinical results, clinical factors are shown in Table 5.

| | | C.R. | D.F. | P.F. | T.T.G. | T-1stM | Ti-C |
|---|---|---|---|---|---|---|---|
| $F(X_2)$ | B | * | | * | ** | * | −*** |
| | U | *** | | *** | *** | *** | −** |
| $F(Z_2)$ | B | ** | | * | ** | | −*** |
| | U | *** | | ○ | ** | | −*** |
| $F(Y_2)$ | B | −* | | | | −** | |
| | U | | | | | | |
| $T(X_0)$ | B | *** | *** | | *** | | |
| | U | *** | *** | | ** | | |

B : bilateral club foot U : unilateral club foot
C.R. : clinical results *** P<0.01
D.F. : dorsiflexion ** 0.01≦ P<0.02
P.F. : plantar flexion * 0.02≦ P<0.05
T.T.G. : tip toe gait ○ 0.10≦ P<0.20
T-1stM : Talus-1st Metatarsal angle

**Table 5.** Correlation table between ground reaction force and clinical results & clinical factors.

$F(X_2)$, $F(Z_2)$ and $T(X_0)$ were in high positive correlation to the clinical results both in the bilateral and unilateral cases.

$F(Y_2)$ was in high negative correlation to the clinical results only in the bilateral case.

$F(X_2)$ was also in high positive correlation to the plantar flexion of the ankle joint, the ability of tip toe gait and the talus-first metatarsal angle, but in high negative correlation to the tibio-calcaneal angle.

$F(Z_2)$, like $F(X_2)$, was also in high positive correlation to the ability of tip toe gait and high negative correlation to the tibio-calcaneal angle.

There are no obvious correlation between the other elements of the ground reaction force and clinical results. Also, no obvious correlation between the talo-calcaneal angle and the ground reaction force was found.

## DISCUSSION

There have many reports on the long-term results of the postoperative club feet.[3)5)9)] The customary evaluation of the postoperative club feet was performed cosmetically (by examining the leg length discrepancy, calf size, heel position and shape, etc.), functionally (by examining the range of motion of the ankle joint, the ability of tip toe gait) and radiographically (by measuring the talo-calcaneal index,[1)] tibio-calcaneal angle, talo-calcaneal angle and talus-first metatarsal angle).

The assessments stated above were all of the static method, and there were few kinesiological assessments reported. O. KAMEYAMA (1984)[4)] reported a electromyographic and kinesiological evaluation of the treated congenital club foot patient's walking. In the evaluation of the treated club foot patients, he had the result that the electromyographic and kinesiological evaluation showed about the same grades as was obtained by the clinical evaluations in most of the cases. However, some cases showed poor results in the electromyographic and kinesiological evaluation, even though they had good clinical results. He concluded that in addition to the conventional clinical evaluation, the kinesiological assessment was also important.

For the out-patients of the club foot children, the electromyographic examination is somewhat difficult and needs much time. Thus we think it would be more convenient and easier to use the force plate to examine the ground reaction force of the club foot children. The children are only asked to walk on the walkway about ten to fifteen times and from the ground reaction force we can gain a considerable amount of data kinesiologically. In the evaluation of the postoperative club foot children, it will be of great advantege to use both the customary clinical assessment and the kinesiological assessment simultaneously.

From the correlation table, it is clear that $F(X_2)$ and $F(Z_2)$ are in high positive corr-

elation to the plantar flexion of the ankle joint and the ability of tip toe gait. Thus, when the plantar flexion of the ankle joint is limited and the power of the gastrocnemius muscle is weak, the ability of tip toe gait will become poor and the vector of the sagittal plane at the time of push off in walking will be small. In other words, $F(X_2)$ and $F(Z_2)$ will become smaller. The most common residual deformity of the postoperative club foot children is atrophy of the calf muscle, thus the ability of tip toe gait is poor and the ground reaction force $F(X_2)$ and $F(Z_2)$ were almost all smaller than that of the normal subjects. (Fig. 5)

$T(X_0)$ is in high positive correlation to the clinical results and the dorsiflexion of the ankle joint. It is easily understood that when the dorsiflexion of the ankle joint is small or limited, the gait pattern will tend to be that of a stumping gait (Fig. 6) and the time of the restraining period of the forward-backward component will become shorter. In other words the value of $T(X_0)$ will become smaller. The postoperative club foot children who have limited dorsiflexion of the ankle joint will show a shorter $T(X_0)$ than the normal subjects. (Fig. 5)

In addition, the greater the adduction of the forefoot, then, at the time of push off in walking, the smaller the forward-backward component $F(X_2)$ and the larger the lateral component $F(Y_2)$ will be. (Fig. 7) In other words, the postoperative club foot children who have a residual deformity of the adduction of the forefoot will show a larger $F(Y_2)$ than the normal subjects. (Fig. 5)

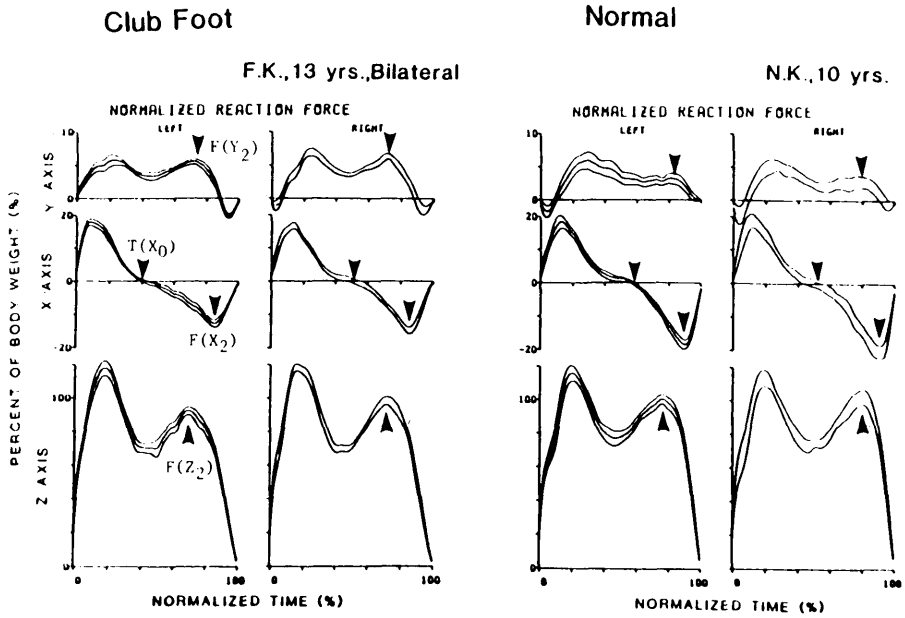


Fig. 5

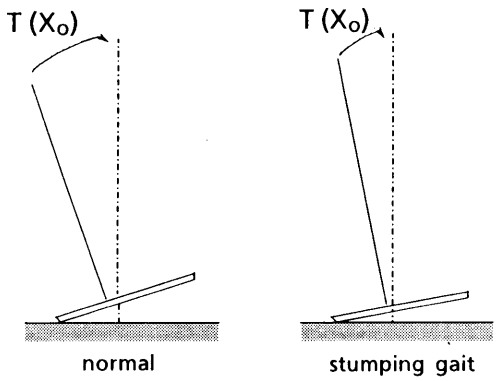


**Fig. 6** When the dorsiflexion of the ankle joint is limited the gait pattern will tend to be that of a stumping gait and $T(X_0)$ will become shorter.

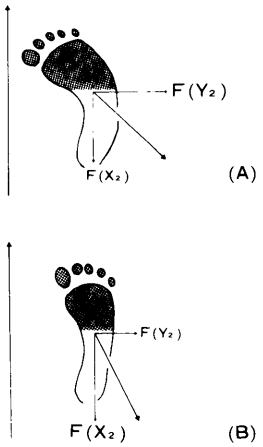


**Fig. 7 (A)** Foot with the residual deformity of the adduction of the fore foot $F(Y_2)$ will become lafger than that of the nomal foot.
**(B)** A normal foot

## CONCLUSION

1) The kinesiological assessment of the postoperative club foot children using the ground reaction force may be more convenient for the out-patients.

2) In the assessment of the postoperative club foot children using the ground reaction force, $F(X_2)$, $F(Z_2)$, $T(X_0)$ and $F(Y_2)$ are the available parameter.

3) The residual deformity of the calf muscle can be evaluated by the measurement of $F(X_2)$ and $F(Z_2)$, the pes equinus by $T(X_0)$ and the adduction of the forefoot by $F(Y_2)$.

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