Published in: Proceedings of NACOB '98, pp.147-148, 1998.

COLLECTING VALID DATA FROM FORCE PLATES: HOW MANY SUBJECTS MUST ALTER THEIR GAIT?

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INTRODUCTION

The necessity for some subjects to alter their gait pattern in order to avoid double contact with the force plate(s) was demonstrated. A set of mathematical equations, expressing the probability of single contact as a function of the gait parameters, was developed. Two of the more commonly used force plate sizes, and gait information from The Ohio State University Gait Laboratory database were used as input to investigate the percentage of subjects that need to alter their gait pattern to allow for a valid data collection.

REVIEW AND THEORY

Two conditions are necessary to correctly measure ground reaction forces. First, the foot must be completely inside the surface of the measuring instrument, in this case the force plate. Second, there must be no other force applied to the instrument by the other foot or walking aids. When both conditions are met, single contact with the force plate occurs and the acquired data are considered valid.

The probability of a successful trial is related to the force plate (L_{FP}), foot (L_F) and gait step (L_S) lengths. In a previous work (Oggero et al., 1998), the equations expressing such relationships were obtained for one foot fall on one plate (p_{1sc}) and two feet on two identical plates mounted end to end (p_{2sc}) under the assumption of no possible separation in the direction orthogonal to the line of motion. Supposing that targeting is not allowed, the center line of the path is aligned with the middle of the force plate(s), and the subject can start from a random point along the walkway, if the force plate is shorter than the step, the aforementioned probabilities were found to be:

$$p_{1sc} = \frac{L_{FP} - L_F}{L_S} \qquad (1)$$

$$p_{2sc} = \frac{2L_{FP} - L_F - L_S}{L_S} \qquad (2)$$

Equation 2 can be equivalently written as

$$p_{2sc} = p_{1sc} + \frac{L_{FP} - L_S}{L_S} \qquad (3)$$

If the force plate is longer than the step, the probabilities were found to be:

$$p_{1sc} = \frac{2L_S - L_F - L_{FP}}{L_S} \qquad (4)$$

$$p_{2sc} = \frac{3L_S - L_F - 2L_{FP}}{L_S} \qquad (5)$$

where equation 5 can be equivalently written as

$$p_{2sc} = p_{1sc} + \frac{L_S - L_{FP}}{L_S} \qquad (6)$$

PROCEDURES

The percentage of the investigated population having a probability of zero, as computed using the above equations, was estimated. The population considered consisted of 280 patients (180 males, age 4 to 87, and 100 females, age 3 to 80), whose gait pattern was analyzed in recent years at The Ohio State University Gait Laboratory. This population encompassed different pathological conditions, including, among others, amputation, spastic diplegia, right or left hemiplegia, stroke, cerebral palsy, spastic quadriplegia or paraplegia, and traumatic brain injury. The force plate sizes considered were the most commonly used in gait analysis laboratories: 45 cm x 50 cm, and 40 cm x 60 cm, mounted with the longer side in the same direction as the line of motion.

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RESULTS

The percentage of the considered subjects that do not have single contact under the assumptions of no targeting allowed, random starting point, and center line of the gait path aligned with the center of the plate(s) is reported in Table 1 for the two force plate sizes examined. The cases of any one foot fall on one force plate (1 single contact) and two subsequent foot falls on two identical force plates mounted end to end (2 single contacts) are shown.

	45 cm x 50 cm	40 cm x 60 cm
one single contact	21%	32%
two single contacts	44%	42%

Table 1. Percentage of the considered subjects that have zero probability of valid trial.

DISCUSSION

Considering the formulae, it is evident, from equations 3 and 6, that the probability of one single contact is higher than the probability of two subsequent single contacts: the latter is the former plus a term, always negative, that decreases the resulting probability. Furthermore, the probabilities can be zero: this happens every time the numerator of the equations is zero or negative[1], either because the foot is longer than the force plate (equation 1) or the step is shorter than the force plate (equation 4). As no subject had the foot longer than the force plates considered, the zero probability was only due to a step length shorter than the force plate length. Since most of the pathological conditions of the considered population present a reduction of the step length, the percentage of subjects having a zero probability of good data collection is significant (Table 1). There is no random starting point that will yield to a successful trial for these subjects: independent of the starting position, they will always have double contact. The percentage of subjects with zero probability is higher in the case of two subsequent foot falls on two identical force plates mounted end to end than in the case of any one foot fall on one force plate. This is consistent with the fact that all subjects having double contact during the acquisition of any one foot fall on one force plate, will have double contact during two subsequent foot falls on two force plates mounted end to end (equations 3 and 6). Furthermore, other subjects can present zero probability when the second term of equations 3 or 6 is larger than the probability of the corresponding one single contact (equations 1 and 4). This can occur when the force plate is smaller than half the difference between step and foot length (from equation 3), or is bigger than three times the step length minus the foot length (from equation 6). Therefore, even people with a long step length can have zero probability. This explains why the percentage of people having zero probability of valid trial increases from one to two single contacts, as shown in Table 1.

All the individuals having zero probability of one or two single contacts must alter their gait pattern to place their feet completely on the force plate(s) while avoiding double contact. Targeting is necessary for these subjects unless lateral separation is used to avoid double contact. This can be achieved by mounting the force plates not end to end, but sideways or staggered, and having the subject walk along a path that passes between the two plates. Unless longer force plates are used, the plates must be mounted staggered to accommodate subsequent foot falls. It is then no longer possible to consider any one or two subsequent foot falls, since the position of the force plates determines the foot fall sequence (left-right or right-left). However, this plate configuration requires the subject to walk along a line. This is sometimes a problem and can give rise to alterations of the subject's normal gait pattern. The formulae for the probability presented here do not apply if lateral separation is used.

Since some subjects must alter their gait pattern in order to have a valid trial, the results of the gait analysis can be affected. This has to be taken into consideration, if clinical decisions will be made based on such results.

ACKNOWLEDGMENT

This study was supported in part by grant H133E30009 from the National Institute on Disability and Rehabilitation Research of the Department of Education, and by grant 1 R43 HD35401-01 from the National Institutes of Health.

REFERENCES

Oggero E. et al., *Biomed. Sci. Instrum.*, 34, 1998.

[1] Since the probability has to be between 0 and 1, a negative number is considered as zero probability.