AN INSTURMENTED HANDRAIL STAIRWAY VALIDATION

Matija Radovic[1], Nicholas Hanson[1], Palav Deka[1], Shing-Jye Chen[1]

[1]School of Health Physical Education and Recreation (HPER)
Biomechanics Laboratory
University of Nebraska at Omaha, USA

INTRODUCTION

Stairs negotiation is one of the most common activities of daily life. For those who are aged developing with neuromuscular disease, climbing stairs is a great challenging task that leads to falls (Williamson and Fried, 1996). To prevent falling during stair negotiation, assistive handrail has been designed to provide safety maintaining body stability on stairs. However, to directly quantify handrail forces necessary to provide body support during stairs negotiation is very limited. The purpose of this study was to validate an instrumented handrail of a 4-step stairway system by determining any cross talks among steps where force plates were embedded and detecting any vibration created by the current design of the handrail.

METHODS AND PROCEDURES

A 4-step stairway was built with light weighted rigid aluminum frames to rigidly support the stairs. Each step of the stairs was embedded with one AMTI force plate (OR6-7-1000) which was independently supported (see Figure 1a). Two individual right and left handrails are lightweight tubular metal rails. Each handrail has a continuous tubular loop and is directly secured to one end of a rectangular long support beam (L (1.2m) x W (0.2m) x H (0.3m); mass: 44 kg). The base of the support beam was securely anchored to another AMTI (handrail) force plate beneath the stairway. Thus, three dimensional (3D) handrail forces were measured. To validate static 3D handrail forces, a 90N torus plate was vertically suspended and redirected its downward force to the anterior/posterior (AP) and medial/ lateral (M/L) directions via a pulley system. Three testing sites (P1, P2, P3) of each handrail were tested (Figure 1). The 90N object was then compared to the forces measured directly from the handrail force plate.

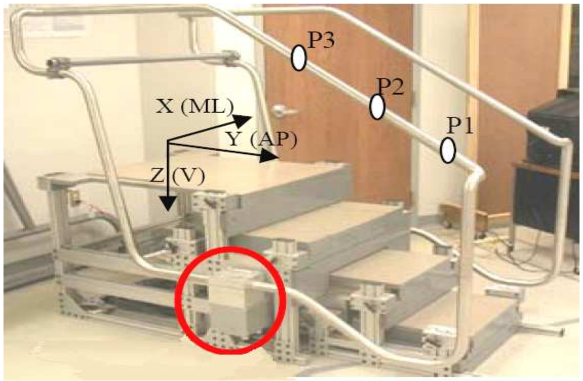

Figure 1: Instrumented 4-step staircase and two handrails which directly measure 3Dforces.

To determining any cross talks among the force plates and vibration from the handrails, the suspended 90N object was swung into ML and AP directions to simulate a dynamic handrail grasping condition when a subject climbing the stairs. The three handrail locations (P1, P2, P3) were tested again during the dynamic swinging. The natural frequency of the swinging object was predetermined to differentiate noise created by the handrail. The calculated frequency was between 0.6-0.7 Hz based on the moment of inertia (I) and mass (m) of the torus plate, and the distance (L) from the center of the plate to the suspended site of the handrail (see Equation 1) .

$$f = \frac{1}{2\pi}\sqrt{\frac{mgL}{I}}$$

The known frequency of the swung plate was compared to that of the 3D handrail forces measured during the dynamic swing test. In addition to the dynamic swing test, one subject was asked to fast ascend and descend the stairs (2 steps/sec) while grasping one side of the handrails. Maximum errors were computed for the 3D handrail forces during the static, and cross talks among the plates were also computed during the dynamic. Power Spectrum Density of the forces measured from the handrail and each step plate was analyzed using a “Hann” window by a custom made Matlab program (MathWorks, Inc). All forces of the stairway and handrail were amplified using the AMTI MSA-6 amplifier (with built-in 1000 Hz low pass filter) and acquired by a data acquisition system (EvaRT 5.0, Motion Analysis Co, Santa Rosa, CA). All forces were sampled at 1200 Hz for 5 seconds.

RESULTS

Results showed that maximal errors during the static was smallest in the vertical direction at three locations (P1: 0.08%, P2: 0.13% and P3: 0.13%) and in the M/L direction (P1: 0.83% and P2: 11.7% and P3: 0.69%), but the greatest errors in the AP direction (P1: 9.68 %, P2: 8.72 % and P3: 9.88 %). The greatest cross talks were found among the 3D handrail forces at the P1 (5.36%) during the dynamic swinging in both AP and ML directions, and the least found at the P2 (0.28%) and P3 (0.34 %). No force crosstalk among the step and handrail force plates were detected during the subject’s fast stair walking. The natural frequency of the 3D handrail forces was found to be reliable in all force directions during the dynamic swing test (see Table 1.). The highest frequency of 3D handrail forces during ascending and descending was detected at 50 Hz and 35 Hz, respectively.

	P 1 (Hz)	P 2 (Hz)	P 3 (Hz)
Handrail	Right / Left	Right / Left	Right / Left
A-P	0.6 / 0.7	0.7 / 0.7	0.6 / 0.6
M-L	0.6 / 0.74	0.6 / 0.74	0.6/ 0.6
Vertical	1.3 / 1.3	1.3 / 1.2	1.3 / 1.3

Table 1. Natural frequency responses when a 90N torus plate was dynamically swung at three handrail locations.

DISCUSSION

The crosstalk and maximum errors of the handrail forces were found to be within the reported ranges (Chapdelaine, 2005). The frequencies of the handrail forces were higher during a fast climbing than during a dynamic pendulum motion. This high noise frequency of the touched handrail could be filtered. No crosstalk was found among the force plate signals while the handrail force was measured.

SUMMARY

Both static and dynamic tests of the current instrumented handrail stairway system validate the instrumented handrail stairway system with least cross-talk at midway of the handrail and no cross talks among the steps and the handrails.

REFERENCES

Williamson JD, Fried LP (1996). *J Am Geriatr Soc* 44:1429-1434.
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