

Comparison of the Plantar Pressure Distributions at Different Degrees of Tilting: A Preliminary Report

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Abstract. [Purpose] The purpose of this study was to investigate the amount of plantar pressures on the lower limb during tilt table standing and to indicate the ideal degree of tilting for partial weight bearing. [Subjects and Methods] Fifteen healthy subjects between the ages of 20 and 30 were recruited as volunteers for this study. All the measurements were taken while standing on a tilt table according to different inclination angles. [Results] The plantar pressures for 60° tilt table standing were lower by 7–9% of total body weight than the pressures during tilt table standing at 90°, and the pressures for 30° tilt table standing were lower by 18–20% of total body weight than the pressures for tilt table standing at 90°. [Conclusion] Standing training on a 60° tilt table might be equivalent to 80% of full weight bearing training, and tilt table standing training at 30° might be equivalent to 60% of full weight bearing training.

Key words: Tilt table standing, Partial weight bearing, Standing training

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INTRODUCTION

The tilt table has the advantages of passive standing and improvement of renal function and circulation, including prevention of joint contracture, muscle atrophy, and osteoporosis¹⁻³⁾. By controlling the degree of tilt, the tilt table can be useful to initial weight bearing training of orthopedic patients who require partial weight bearing or are unable to support their full body weights due to lower limb injury or neurological damage.

In particular, orthopedic patients with uncemented total hip arthroplasty, fracture, or osteotomy are often instructed to bear partial weight on their injured or postoperative lower limb⁴⁻⁷⁾. The common level of partial weight bearing training prescribed by the orthopedic surgeon ranges from 20% to 50% of the patient's entire body weight⁸⁾.

However, a previous partial weight bearing study reported that the operated lower limb was actually loaded higher than the prescribed partial weight bearing during standing or walking⁹⁾. Hence, accurate information regarding the exerted weight distribution on the lower limb is necessary for orthopedic patients with restrictions of body weight bear-

ing.

Although the tilt table is useful in clinical practice, there has been no research into the weight distribution of the lower limb according to different angles of inclination during tilt table standing. Therefore, the purpose of this study was to measure the amount of weight bearing on the lower limb during tilt table standing and to indicate the ideal degree of tilting for partial weight bearing of orthopedic patients with restrictions of body weight bearing.

SUBJECTS AND METHODS

Seven healthy male subjects and eight female subjects between the ages of 20 and 30 were recruited as volunteers for this study. The baseline demographic characteristics of the subject enrolled in this study were as follows: the mean age, height, weight, and foot length of the subjects were 25.1±2.6 years, 165.3±6.8 cm, 61.1±7.8 kg, and 248.0±14.6 mm, respectively. Subjects were excluded if they had a diagnosed neurologic disease or disorder or a musculoskeletal problem in a lower limb. All subjects understood the purpose of this study and provided informed consent prior to participation in the study in accordance with the ethical standards of the Declaration of Helsinki.

Tilt table standing was performed on a motorized tilt table, the incline angle of which could be adjusted in the range of 90 to -8 degrees (OG Giken Co., Ltd, Okayama Japan). Subjects laid their back on the tilt table and were positioned with both foot flat and neutrally against the foot plate. Velcro straps at the knees and hips were used to sta-

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Table 1. Comparison of mean plantar pressure distributions of the four different angles of tilt

Parameters		0° (95%CI)	30° (95%CI)	60° (95%CI)	90° (95%CI)
CP(%TBW)	*DS	11.4±0.9 (9.4–13.4)	29.6±2.1 (25.1–34.0)	38.9±1.5 (35.8–42.1)	47.8±1.5 (44.5–51.0)
	*NDS	12.9±1.0 (10.6–5.1)	32.2±2.1 (27.7–36.6)	44.3±1.6 (41.0–47.8)	52.2±1.5 (49.0–55.5)
PCP(%TBW)	*DS	8.7±0.8 (7.1–10.3)	28.5±1.8 (24.6–32.5)	40.6±2.1 (36.0–45.2)	48.3±1.7 (44.7–52.0)
	*NDS	10.3±0.9 (8.3–12.3)	32.0±1.9 (28.0–36.0)	45.4±1.9 (41.2–49.5)	51.7±1.7 (48.1–55.3)

* Significant difference (p<0.01)

CP, contact pressure; PCP, peak contact pressure; TBW, total body weight; DS, dominant side; NDS, non-dominant side

bilize the subject in an upright position. Target angles of tilt table standing for measuring plantar pressures were 0, 30, 60, and 90 degrees, respectively, and each angle was sustained for 1 minute with autonomic data collection.

Plantar pressures were measured using an F-scan System (Tekscan, South Boston, MA, USA). The pressure was recorded at 50 Hz for 4 seconds with a pressure-sensitive insole consisting of a 0.15-mm-thick sensor with an embedded grid of 960 pressure-sensing cells that were evenly distributed at a 0.5-cm interval. The sensor was connected to a cable, and data were transmitted through the cable to a portable computer.

For the test, the subjects wore their own shoes and were fitted with the portable equipment and the pressure sensitive insoles described below, which were trimmed to their shoe size. The F-scan System was calibrated to adjust for the subject’s body weight before each measurement. All the measurements were taken with the subjects standing on the tilt table according to different inclination angles. After the pressure was read and recorded, data were processed and averaged with custom-made software, F-Scan version 4.19F.

To compare the plantar pressures according to different degrees of tilting, the pressures at 90° of tilt table standing were interpreted to a standardized weight bearing (full weight bearing), and the feet were divided into the dominant and non-dominant side.

Statistical analyses were performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA). General characteristics (age, sex, height, weight, and foot length) of subjects were obtained using frequency analysis and descriptive statistics. Repeated measures ANOVA was performed to estimate differences in plantar pressures among four different tilting degrees. The level of statistical significance was 0.05.

RESULTS

Tables 1 and 2 show the contact and peak contact pressures of the dominant and non-dominant feet according to different degrees of tilting. The contact and peak contact pressures on both sides were significantly different. The contact pressure of each side during tilt table standing at 60° was lower by 8–9% of total body weight than during tilt table standing at 90°, and the contact pressure at 30° was

Table 2. Multiple comparisons of plantar pressure distributions of each angle of tilt

Parameters	(I) Degree	(J) Degree	MD (I–J)	
DS	0	30*	-19.2	
		60*	-28.5	
		90*	-37.0	
	30	60*	-9.3	
		90*	-17.8	
		90*	-17.8	
CP (%TBW)	60	90*	-8.5	
		30*	-20.2	
		0	60*	-32.7
	NDS	90*	-40.3	
		30	60*	-12.5
			90*	-20.1
DS	60	90*	-7.6	
		30*	-20.4	
		0	60*	-32.2
	90*	90*	-40.1	
		30	60*	-11.8
			90*	-19.7
PCP (%TBW)	60	90*	-7.9	
		30*	-22.0	
		0	60*	-35.8
	NDS	90*	-42.3	
		30	60*	-13.8
			90*	-20.3
60	90*	-6.5		

* Significant difference (p<0.01)

CP, contact pressure; PCP, peak contact pressure; TBW, total body weight; DS, dominant side; NDS, non-dominant side; MD, mean difference

lower by 18–20% of total body weight than during tilt table standing at 90°.

The peak contact pressure during tilt table standing at 60° was lower by 6–8% of total body weight than during tilt table standing at 90°, and the peak contact pressure at 30° was lower by 19–20% of total body weight than during tilt table standing at 90°.

DISCUSSION

If a patient needs partial weight bearing training, a physiotherapist should educate the patient regarding performance of partial weight bearing at the prescribed target load. Accurate information regarding the exerted weight distribution on the lower limb is necessary for orthopedic patients with restrictions of body weight bearing. Physical therapists utilize clinical techniques, such as tactile feedback, as well as several devices, such as scales, biofeedback systems, and force plates, to train patients who require partial weight bearing^{10–13}). However, it is difficult to stand independently in the early stages of an injury or after surgery, and the cost of equipment may limit clinical application of partial weight bearing. Early weight bearing in patients with the lower limb injury would diminish the risk of post-operative complications, such as deep venous thrombosis and stiffness, and provide safer recovery to a pre-fracture ambulation level¹⁴). Thus, the tilt table can help efficiently in early partial weight bearing training, and it can maintain a constant the identical amount of weight bearing according to different angles of inclination.

Our results indicated that the contact and peak contact pressures of each side during tilt table standing at 60° were lower by 7–9% of total body weight than the pressures during tilt table standing at 90°, and they were lower by 18–20% of total body weight than the pressures during tilt table standing at 90°. If the plantar pressures of the dominant or non-dominant sides during tilt table standing at 90° are interpreted to a full weight bearing, the weight bearing of each side during tilt table standing at 60° would be 80% of full weight bearing and that at 30° would be a 60% of full weight bearing. Our findings are supported by the previous study of Kim et al.¹⁵), who reported that the larger the tilting degree of the tilt table, the greater the electromyographic activity exerted on the lower limb. Yuk's study¹⁶), which observed changes in pressure on the sacrum and buttock according to different angles of inclination of a tilt table, also indicated that as the inclination angle continues to increase, body weight is gradually transferred to the lower limbs.

Our study suggested that use of a tilt table for partial weight bearing can enable accurate loading of a prescribed target body weight and that a tilt table can be used stably and efficiently for orthopedic patients, which necessary for partial weight bearing in early rehabilitation. Several limitations could be raised and should be taken into account when interpreting the data. Our study only measured the longitudinal pressure of the lower limb according to different angles of inclination during tilt table standing. Thus, it is difficult to generalize and directly apply the present study

to the clinical field. However, our study has meaningful significance in that it suggests quantitative value for weight bearing of the lower limb according to different angles of inclination on the tilt table. If in-depth studies of these issues are performed in the future, the tilt table could become an efficient tool for partial weight training of orthopedic patients, who needs partial weight bearing during early rehabilitation.

REFERENCES

- 1) Chang AT, Boots RJ, Brown MG, et al.: Ventilatory changes following head-up tilt and standing in healthy subjects. *Eur J Appl Physiol*, 2005, 95: 409–417. [Medline] [CrossRef]
- 2) Duffus A, Wood J: Standing and walking for the T6 paraplegic. *Physiotherapy*, 1983, 69: 45–46. [Medline]
- 3) Newman M, Barker K: The effect of supported standing in adults with upper motor neurone disorders: a systematic review. *Clin Rehabil*, 2012, 26: 1059–1077. [Medline] [CrossRef]
- 4) Aranzulla PJ, Muckle DS, Cunningham JL: A portable monitoring system for measuring weight-bearing during tibial fracture healing. *Med Eng Phys*, 1998, 20: 543–548. [Medline] [CrossRef]
- 5) Karlsson M, Nilsson JA, Sernbo I, et al.: Changes of bone mineral mass and soft tissue composition after hip fracture. *Bone*, 1996, 18: 19–22. [Medline] [CrossRef]
- 6) Lachiewicz PF, Suh PB, Gilbert JA: In vitro initial fixation of porous-coated acetabular total hip components. A biomechanical comparative study. *J Arthroplasty*, 1989, 4: 201–205. [Medline] [CrossRef]
- 7) Phillips TW, Nguyen LT, Munro SD: Loosening of cementless femoral stems: a biomechanical analysis of immediate fixation with loading vertical, femur horizontal. *J Biomech*, 1991, 24: 37–48. [Medline] [CrossRef]
- 8) Hershko E, Tauber C, Carmeli E: Biofeedback versus physiotherapy in patients with partial weight-bearing. *Am J Orthop*, 2008, 37: E92–E96. [Medline]
- 9) Hurkmans HL, Bussmann JB, Selles RW, et al.: The difference between actual and prescribed weight bearing of total hip patients with a trochanteric osteotomy: long-term vertical force measurements inside and outside the hospital. *Arch Phys Med Rehabil*, 2007, 88: 200–206. [Medline] [CrossRef]
- 10) Chow DH, Cheng CT: Quantitative analysis of the effects of audio biofeedback on weight-bearing characteristics of persons with transtibial amputation during early prosthetic ambulation. *J Rehabil Res Dev*, 2000, 37: 255–260. [Medline]
- 11) Cobb J, Claremont DJ: Transducers for foot pressure measurement: survey of recent developments. *Med Biol Eng Comput*, 1995, 33: 525–532. [Medline] [CrossRef]
- 12) Wolf SL, Binder-Macleod SA: Use of the Krusen Limb Load Monitor to quantify temporal and loading measurements of gait. *Phys Ther*, 1982, 62: 976–984. [Medline]
- 13) Woodburn J, Helliwell PS: Observations on the F-Scan in-shoe pressure measuring system. *Clin Biomech (Bristol, Avon)*, 1996, 11: 301–304. [Medline] [CrossRef]
- 14) Haak KT, Palm H, Holck K, et al.: Immediate weight-bearing after osteosynthesis of proximal tibial fractures may be allowed. *Danish Medical Journal*, 2012, 59: A4515.
- 15) Kim K, Kim SH, Jeong SH, et al.: Characteristics of the Lower Limbs Muscular Force on the Angle Variation of Tilting Bed. *Korean Soc Precis Eng*, 2004, 4: 944–947.
- 16) Yuk GC: Pressure on Sacrum and Bottock according to tilt table inclination. *J Korean Soc Ther*, 2013, 25: 71–75.