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RESEARCH STUDY

Comparison of Two Methods for Calculating Percent Body Weight on a Tilt Table

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Physical therapists commonly treat patients when knowledge of percent weight bearing is desirable during functional lower extremity exercise. The purpose of this study was to compare two methods for calculating percent body weight at different angles of inclination on a tilt table. Twenty healthy subjects were weighed on a spring scale in standing and on a tilt table at 5° increments between 0 and 90° of tilt. Percent body weight at each angle was compared to a value predicted from a trigonometric equation. Predicted values were significantly greater than measured values at all angles greater than 10° of tilt. Predicted overestimation ranged from 2.8 to 14.2%. Compared to the trigonometric method, physical therapists can more easily and accurately determine percent body weight on a tilt table using a scale if total body weight is known. Partial weight-bearing rehabilitation could be performed on the tilt table by varying the degree of inclination, allowing functional lower extremity exercise for patients with weight-bearing restrictions. Guidelines could be established following a variety of injuries and orthopaedic procedures incorporating functional lower extremity exercises at varying percentages of body weight.

Key Words: *percent body weight, tilt table*

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Physical therapists commonly encounter patients with weight-bearing restrictions following surgical procedures or injuries to the lower extremity. Assistive devices such as crutches and canes are typically prescribed to allow safe progression to full weight bearing. Therapeutic exercise performed during the period of restricted weight bearing should be closely monitored. Therapists are increasingly incorporating closed kinetic chain exercises with the feet fixed into rehabilitation programs, even before full weight bearing is allowed. For example, closed kinetic chain exercises have been advocated following anterior cruciate ligament reconstruction during the protected weight-bearing phase secondary to the decreased stress on the ligament compared to open chain exercises where the leg is free to move through space (7). The principle of closed kinetic chain rehabilitation at varying percentages of body weight has been incorporated into therapeutic programs by changing the patients' angle of inclination from horizontal (6). However, percent weight bearing when performing closed kinetic chain exercise during the protected weight-bearing phase of rehabilitation has not been documented. Therapists should know what percentage of body weight is exerted during this critical stage of recovery.

The importance of determining percent weight bearing in the development of standing programs for pediatric patients with cerebral palsy has also been noted (4,9,12). Standing programs may be used with different types of standing devices to stimulate bone development (9,12).

Tilt tables have been traditionally used in the clinic to gradually acclimate debilitated patients to the upright position. The use of tilt tables in patient rehabilitation has been noted to help prevent the adverse effects of prolonged immobilization, including disuse osteoporosis (10).

Suggestions have been made to determine percent body weight exerted at different angles of inclination from the horizontal position. Elam (5) suggested a trigonometric method. He considered the effects of friction and safety belts to be minimal in the calculation and, therefore, did not factor these into the equation. Criticism was later raised regarding the failure to account for the effects of friction and safety belts in this method, thereby grossly overestimating percent body weight at various angles of tilt (2). Andrew (1) supported the overestimation of percent body weight as calculated by the formula. Percent body weight lifted at different angles of tilt has been calculated by trigonometric formulas and tensiometer measurement for the Totalgym (Engineering Fitness International/Medical Systems, San Diego, CA), which allows partial weight-bearing exercise by varying the patient's angle of inclination (8). Standard scales and force plates have also been used to determine percent weight bearing at different angles of tilt on prone and supine standers for pediatric patients with cerebral palsy (4,9).

The purpose of this study was to compare the percent body weight predicted by the trigonometric method (5) to measured percent body weight derived from standard scale measurement at various angles of tilt on a tilt table. It was hypothesized that the percent body weight predicted by the trigonometric method would be significantly greater than percent body weight derived from scale measurement at every angle of tilt.

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METHOD

Subjects

Twelve healthy female and eight healthy male subjects between the ages of 20 and 40 ($\bar{X}$ = 24.9 years) consented to participate in the study, which was approved by the Institutional Research Board at The University of New England. Body weight ranged from 49.1 to 95.5 kg with a mean of 66.4 kg.

Procedure

Subjects' body weights were initially recorded in standing with a standard spring scale (Counselor Company, Rockford, IL). To ensure accuracy of scale measurement from 0 to 90° of tilt on the tilt table, the scale was tested with three repetitions at 15° increments throughout the range by exerting 50 lbs of force through a digital force gauge (Chatillon Model DFI 200, Chatillon Force Measurement, Greensboro, NC) and comparing scale and force gauge measurements. The author noted discrepancies of 0 to 4 lbs throughout the tested range, with the force gauge consistently recording slightly higher values (2–3 lbs). The author feels that the scale maintained its accuracy throughout the range as manual testing and comparison of digital to dial readouts created sources of error. Even with the maximum discrepancy of 4 lbs noted, this only translates to a maximum 3.34% error in a 120-lb person.

Subjects were positioned supine on the manual tilt table (Midland Manufacturing Company, Inc., Columbia, SC) with a bed sheet between themselves and the tilt table. Because different articles of clothing have different coefficients of friction, the sheet was used to standardize this factor. Bed sheets are also commonly used on tilt tables in the clinic. Subjects were positioned with both feet flat against the scale (Figure). Safety straps were secured across the chest and lower extremities with enough tension to prevent the subjects from falling, yet tight strap support was avoided to minimize interference with weight bearing on the scale. Subjects were instructed not to move during the elevation of the table to minimize differences between subjects in overcoming the effects of friction. Subjects were raised from 0 to 90°, and body weight was recorded at each 5° increment. The angle of tilt was measured using a goniometer with the stationary arm aligned along the metal horizontal base of the table, the moving arm aligned along the metal horizontal stripping of the table, and the fulcrum placed at the axis of rotation of the table from the base. Measured percent body weight at a specific angle of tilt was calculated by dividing the subject's body weight recorded at that angle by his or her standing body weight (Figure). Standing body weight is defined as the body weight measured in standing with the scale flat on the floor. Percent body weight predicted from the trigonometric method (5) = sin θ × 100% (Figure).

Data Analysis

The percent body weight from the scale measurements was compared to the predicted values generated by the trigonometric method (5) at each angle using a one-sample

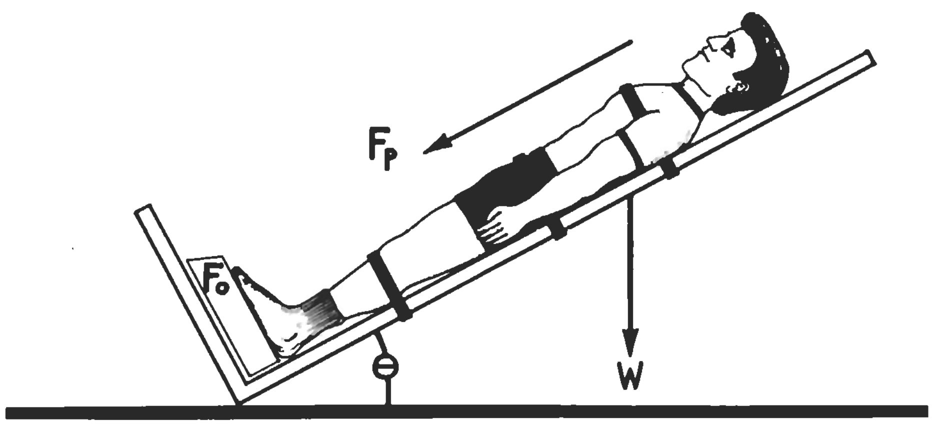

FIGURE. *Subject is standing on the scale at the base of the tilt table. The predicted force down the incline is $F_p = W \times \sin\theta$, where W is the standing body weight of the subject. Predicted percent body weight = $F_p/W \times 100\% = \sin\theta \times 100\%$ and is independent of standing body weight. The observed force down the incline, F_o, is the weight of the subject measured on the scale. The measured percent body weight = $F_o/W \times 100\%$. (Adapted from Elam (5); reprinted from* Physical Therapy *with the permission of the American Physical Therapy Association).*

t-test. This test is recommended when the comparison mean is a specified value (3). The Bonferoni correction for multiple comparisons was used (11).

RESULTS

Predicted values generated by the trigonometric method significantly overestimated values determined by scale measurement at all angles of tilt greater than 10° (Table). Percent overestimation was greater than 10% for angles of tilt between 25 and 75°. The difference between predicted and observed values was not as great at the extremes of the measured angles of tilt (Table). Percent body weight as determined by scale measurement exceeded predicted percent body weight at 0 and 5°.

DISCUSSION

Accurate knowledge of percent body weight exerted at angles of tilt

Percent overestimation was greater than 10% for angles of tilt between 25 and 75°.

is needed if patients have weight-bearing restrictions. This study demonstrates the overestimation of determining percent body weight by trigonometry alone. Factors that can affect percent body weight include friction (1,2,5), tightness of the supporting straps (2,5), movement of subjects during the tilt procedure, overcoming friction to varying degrees, and initial positioning of subjects on the tilt table. For example, subjects in this study were originally positioned with feet flat against the scale with the ankle joints in approximately 0° dorsiflexion. However, the normal resting position of the ankle joints in supine is plantarflexion. It was noted that scale-measured values exceeded predicted values at 0 and 5° of tilt. This was attributed to the initial positioning of the subjects, which resulted in some force being exerted on the scale secondary to the plantarflexion moment at the ankle joints. It should be noted that although the trigonometric method (5) overestimated percent body weight as determined by scale measurement at any angle greater than 10° of tilt, from a patient safety point of view, the trigonometric method erred on the conservative side.

Because it is difficult to account for all of the factors involved in predicting percent body weight in the clinic, this author recommends using a calibrated spring scale on the base of the tilt table. Percent body weight can be quickly and safely determined at any angle if the total body weight is known, regardless of patient movement on the tilt table, tightness of the supporting straps, etc. The use of a scale has also been suggested in checking the vertical loading by children on prone and supine standers (12). Research protocols using standard spring scales could be developed to investigate percent weight bearing needed to stimulate bone formation and to develop formal guidelines in protected closed kinetic chain rehabilitation. A calibrated spring scale maintains good accuracy at varied degrees of inclination and is also more practical and economical for general clinic use compared to a force plate.

Angle of Tilt θ (degrees)	Predicted % Body Weight*	Measured % Body Weight†‡	Difference
0	0	8 (3.4)	−8
5	8.7	10.1 (3.4)	−1.4
10	17.4	14.6 (3.5)	+2.8
15	25.9	19.1 (3.5)	+6.8
20	34.2	24.5 (3.5)	+9.7
25	42.3	30.4 (3.8)	+11.9
30	50.0	36.9 (3.4)	+13.1
35	57.4	43.3 (3.3)	+14.1
40	64.3	50.1 (3.2)	+14.2
45	70.7	56.5 (3.4)	+14.2
50	76.6	62.7 (3.3)	+13.9
55	81.9	68.4 (3.5)	+13.5
60	86.6	73.4 (3.2)	+13.2
65	90.6	78.3 (3.0)	+12.3
70	94.0	82.5 (3.0)	+11.5
75	96.6	85.9 (2.4)	+10.7
80	98.5	89.2 (2.7)	+9.3
85	99.6	91.4 (2.8)	+8.2
90	100	92.7 (2.6)	+7.3

* *Predicted % body weight (B.W.) = sin θ × 100, adapted from Elam (5).*

† *Measured % body weight =* $\dfrac{\text{scale measured B.W. at } \measuredangle\, \theta}{\text{standing B.W.}} \times 100.$

‡ *Mean of 20 subjects, (SD).*

TABLE. *Percent body weight as determined by the trigonometric method* and based on measured body weight†. (Adapted from Elam (5); reprinted from* Physical Therapy *with the permission of the American Physical Therapy Association).*

SUMMARY

The results of this study demonstrate that percent body weight predicted by trigonometric method significantly overestimated percent body weight determined by scale measurement at all angles of tilt greater than 10° in this study. Physical therapists should realize that many factors impact on the actual percent body weight on a tilt table and that these factors are difficult to account for in the clinic. Therefore, it is recommended that physical therapists use a calibrated spring scale on the base of a tilt table or other inclination device to determine percent of body weight when treating patients with weight-bearing restrictions. JOSPT

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