EFFECTS OF GENDER AND THE LEWIS FORMULA IN MECHANICAL POWER ESTIMATES

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INTRODUCTION

The vertical jump test is one of the most popular means of assessing power output. Unfortunately, to accurately determine power output, force platforms and/or high speed film analysis are required. One of the most popular power prediction equations used with the vertical jump is the Lewis formula published by Mathews and Fox (1976):

$$P = \sqrt{4.9} \cdot BM \cdot \sqrt{h_j} \qquad (1)$$

where BM was the body mass (kg) and hj the vertical jump height (VJH) (m). The Lewis formula is a relatively simple test to administer and requires very little equipment. However, Harman et al. (1991) discovered that the Lewis formula has several flaws: 1) it did not use standard units of power, 2) it did not take gravity into consideration, and 3) it did not state whether it measured peak or average power. In their analysis, Harman et al. (1991) found that the Lewis formula only predicted the average power of a jumper as it falls back to the ground. Harman et al. (1991) and Garhammer and Stone (1990) stated that the Lewis formula was inaccurate but the Lewis formula was still widely used.

There has not been a simple formula developed using the results from a countermovement jump and reach test from a force platform. Also, although there are gender differences in power output, gender has never been used as a variable to predict power. The purposes of this study were to devise simple mechanical power formulas for peak and average power using the countermovement jump and reach test in college male and female athletes and to test the validity of the Lewis formula.

METHODS

Sixty nine male and 49 female university athletes participated in the study. The anthropometric measurements taken were body mass (BM), body height (BH), thigh skinfold, thigh circumference, thigh length, and foreleg length. All leg measurements were taken from the subject's right leg.

The vertical jump test was performed from a Kistler force platform (sampling rate 500 Hz) interfaced with a Zenith microcomputer which used the FADAP (Fadap, Inc., Indianapolis, IN) computer program to collect force platform data. The vertical jump height was measured with a Vertec jump training apparatus. Reach height was determined using the subject's dominant arm, the subject was instructed to perform a vertical countermovement jump with an arm swing and to touch the highest lever possible with the dominant arm. The subject's arm movements and depth of knee flexion (counter-movement) were self-determined. No jab step or preparatory run was permitted. The height of the vertical jump was the difference between the highest point touched during the jump and the reach height.

Subjects were allowed 10 minutes to warm up and stretch prior to testing. Three practice jumps were performed, followed by three test jumps. The jumps were measured to the nearest half inch on the Vertec and then converted to centimeters. The height of the best vertical jump test was used for the power regression equation.

Vertical velocity, (Vz), and vertical jump power output (VJP) were determined from the parameters obtained from the Kistler force platform. The change in vertical velocity (ΔVz), was calculated using Equation (2):

$$\Delta Vz = Fnz \cdot \Delta t/m \qquad (2)$$

where Fnz, was equal to the force Fz obtained from the force platform minus the subject's body weight, t was the time interval, and m was the body mass. This equation gave the net vertical force that created the change in Vz. The net Vz was determined by adding ΔVz to the Vz at the start of each time interval. Vz was calculated from the first positive force value equal to body weight following the countermovement jump to takeoff.

A FORTRAN computer program was used to calculate mechanical power from the force platform data. VJP was the product of the vertical force Fz times the vertical velocity Vz, $VJP = Fz \cdot Vz$. Peak VJP and average VJP were calculated over a period from the beginning of the jump to the takeoff. Peak VJP was the highest positive instantaneous power output value achieved during the jump. Average VJP was calculated by computing the area under the positive instantaneous power output curve achieved during the jump.

STATISTICAL PROCEDURES

Peak and average mechanical power prediction equations were calculated using the force platform results (peak and average power output) as the dependent variables. Multiple regression analysis was performed using gender, BH, VHJ, BM, thigh girth, thigh skinfold measurement, thigh girth/skinfold ratio, thigh length, foreleg length, and thigh/foreleg length ratio as independent variables. Thirty of the subjects were randomly chosen to be withheld from the development of the regression equation to be used as a cross-validation group (CVG) to determine prediction accuracy. The remaining 88 subjects were used to develop a stepwise multiple regression equation with no forced variables for both peak and average mechanical power.

T-tests for dependent means were used to examine the differences between predicted and actual mechanical power in the 30 subjects of the cross-validation group. Also, t-tests for independent means were used to examine the differences between gender. If no significant differences were found between the actual and predicted mechanical power values, the validation and cross-validation groups' results were combined to develop a more accurate stepwise regression equations for peak and average mechanical power (Pedhazur, 1986).

Once a stepwise regression equation was created for average mechanical power, an ANOVA between estimated average power values, the Lewis formula power values, and the actual average power values was performed using the cross-validation group. Also, if gender would be a significant variable, separate regression equations would be developed and compared.

RESULTS AND DISCUSSION

There were significant differences between gender in all the variables except the foreleg length. There were no significant differences between the CVG and the validation group.

Table 1. Gender descriptive characteristics (Mean and SD)

Variables	Men N=69	Women N=49	M/F Ratio
Height (cm)	185.54 (8.27)	169.65 (8.12)	109.4*
Mass (kg)	80.11 (9.26)	63.06 (8.87)	127.0*
Thigh Girth (cm)	56.38 (3.92)	52.61 (4.18)	107.0*
Thigh Skinfold (mm)	12.74 (3.48)	21.61 (5.66)	59.0*
Thigh girth/skinfold	4.77 (1.39)	2.56 (0.55)	186.3*
Thigh length (cm)	41.46 (2.74)	41.87 (2.79)	99.0
Foreleg length (cm)	43.58 (2.99)	40.39 (3.15)	107.9*
Thigh/foreleg ratio	1.05 (0.08)	0.97 (0.07)	108.2*
Vertical jump (cm)	64.70 (8.34)	43.02 (6.11)	150.4*
Peak Power (W)	5,782.00 (1,123)	3,285.00 (563)	176.0*
Average Power (W)	3.037.00 (638)	1,828.00 (351)	166.0*

* Significant differences between men and women ($p<.05$)

When the gender variable was forced in first in the stepwise multiple regression procedure, it produced adjusted R^2 values of .64 and .55 for peak and average power, respectively. However, the gender effect was practically eliminated by the effects of VJH, BM, and BH. When no forced variables were used, the gender variable was not significant and was not loaded in the mechanical power prediction equations. VJH, BM, and BH were the three significant variables selected by the multiple regression equation. These variables accounted for 91 and 82 % of the variance in peak and average power output, respectively. Equation 3 and 4 were our best model equations using the combined validation and CVG groups (N=118).

$$\text{Ppeak (W)} = 78.5 \text{ (VJH (cm)} + 60.6 \text{ (BM (kg)} - 15.3 \text{ (BH (cm)} - 1{,}308 \quad (3)$$

$$\text{Pave (W)} = 41.4 \text{ (VJH (cm)} + 31.2 \text{ (BM (kg)} - 13.9 \text{ (BH (cm)} + 431 \quad (4)$$

The results of the ANOVA showed that significant differences ($p<.05$) between the values derived from the Lewis formula, and the estimated values obtained in this study and the actual values. The Lewis formula underestimated the average power values by 258 W, while the derived values from this study overestimated the actual values by only 84 W.

VHJ, BM and BH were the significant variables selected by the stepwise multiple regression procedures that best predicted both peak and average mechanical power. VHJ is good predictor of mechanical power because it is dependent upon the vertical ground reaction force and the takeoff velocity generated by the subject. The amount of force needed in a VJ is dependent upon the subject's mass. The greater the force-output-to-body mass ratio the greater the VJH. Although height was a significant variable, it accounted for less than 2% of the variance and only reduced the S.E.E. by ± 11 and 12 (W) for peak and average power output, respectively.

CONCLUSIONS

Because VJH, BM, and BH are easy to measure, these prediction equations can be of value to physical education, coaches, athletic trainers, and other fitness professionals for monitoring athletic performance, aid in team selection, and analyze injury rehabilitation. Differences in gender in power production were the result of size and strength and not a male-female quality, therefore there is not need for separate prediction equations. Finally, the Lewis formula is not a valid tool to calculate average power values using a countermovement jump.

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