Volume 53 • Number 12 • December 2021

Medicine & Science in Sports & Exercise

The Official Journal of the American College of Sports Medicine

www.acsm-msse.org

Full Text OVID

Wolters Kluwer

AMERICAN COLLEGE of SPORTS MEDICINE
www.acsm.org

ISSN: 0195-9131

Cross-validation of three jump power equations

SAYERS STEPHEN P.; HARACKIEWICZ, DAVID V.; HARMAN, EVERETT A.; FRYKMAN, PETER N.; ROSENSTEIN, MICHAEL T.

Medicine & Science in Sports & ExerciseMedicine & Science in Sports & Exercise. 31:p 572-577, April 1999.

Author Information

Department of Physical Education, Health Fitness Studies, Central Connecticut State University, New Britain, CT 06050; Military Performance Division, U. S. Army Research Institute of Environmental Medicine, Natick, MA 01760-5007; and Computer Science Department, University of Massachusetts, Amherst, MA 01003-4610

Submitted for publication July 1997.

Accepted for publication March 1998.

Address for correspondence: Stephen P. Sayers, Department of Exercise Science, room 110, Totman Building, University of Massachusetts, Amherst, MA 01003. E-mail: ssayers@excsci.umass.edu.

Abstract

Cross-validation of three jump power equations. *Med. Sci. Sports Exerc.*, Vol. 31, No. 4, pp. 572-577, 1999. The vertical jump-and-reach score is used as a component in the estimation of peak mechanical power in two equations put forth by Lewis and Harman et al.

The purpose of the present study was to: 1) cross-validate the two equations using the vertical jump-and-reach test, 2) develop a more accurate equation from a large heterogeneous population, 3) analyze gender differences and

jump protocols, and 4) assess Predicted Residual Sum of Squares (PRESS) as a cross-validation procedure.

One hundred eight college-age male and female athletes and nonathletes were tested on a force platform. They performed three maximal effort vertical jumps each of the squat jump (SJ) and countermovement jump (CMJ) while simultaneously performing the vertical jump-and-reach test. Regression analysis was used to predict peak power from body mass and vertical jump height.

SJ data yielded a better power prediction equation than did CMJ data because of the greater variability in CMJ technique. The following equation was derived from SJ data: Peak Power (W) = 60.7 × (jump height [cm]) + 45.3 × (body mass [kg]) − 2055. This equation revealed greater accuracy than either the Lewis or previous Harman et al. equations and underestimated peak power by less than 1%, with a SEE of 355.0 W using SJ protocol. The use of one equation for both males and females resulted in only a slight (5% of power output) difference between genders. Using CMJ data in the SJ-derived equation resulted in only a 2.7% overestimation of peak power. Cross-validation of regression equations using PRESS reveals accurate and reliable R^2 and SEE values.

The SJ equation is a slightly more accurate equation than that derived from CMJ data. This equation should be used in the determination of peak power in place of the formulas developed by both Harman et al. and Lewis. Separate equations for males and females are unnecessary.

Power output is an essential component of success in many sports. A useful means of determining basic athletic ability, especially in sports where jumping is critical to success, is the vertical jump test. The vertical jump has become the most widely used standard by which "explosive" athletic performance is assessed.

The ability to assess jumping power can also aid in the evaluation of an athlete's progress or in the determination of a training program's effectiveness. However, the use of a force platform to determine power is prohibitively expensive for many who would wish to estimate vertical jumping power. That is why a convenient and inexpensive, but reasonably accurate, method of assessing human power output is essential.

In 1974 the Lewis formula was devised to estimate an athlete's power from body weight and vertical jump distance (4). This formula has been widely used in exercise physiology and tests and measurements texts and in research (3,4,8,10). However, in 1991, Harman et al. (6) challenged the theoretical concept behind the Lewis formula and determined that the power calculated from the formula was that of gravity exerted on the jumper's body as it falls back to the ground from the high point of the jump, not the power exerted during the takeoff phase of the jump. Harman et al. (6) tested 17 subjects on a force platform to determine their peak and average power during the takeoff phase of the jump, then tested them to find their vertical jump-and-reach score. The researchers used the squat jump (SJ), in which subjects assumed a bent knee preparatory position, paused, then jumped vertically as high as possible. Regression equations were derived to estimate peak and average power from body weight and vertical jump distance. However, because of the small population (N = 17) and its homogeneity, the validity of the equation has yet to be determined.

The present study was an attempt to cross-validate the two equations from the literature by assessing them on a subject pool of 108 college-age male and female athletes and nonathletes, a more heterogeneous population than in the previous studies, and to develop an improved equation. The study examined two jump protocols, the aforementioned SJ and the countermovement jump (CMJ). In the CMJ, subjects dropped into a crouch from the standing position and, without pausing, jumped vertically as high as possible. This was done to assess the effects of countermovement on estimates of power. In contrast to the SJ, the CMJ allows greater joint moments to be achieved at push-off and during initial joint extension, allowing more work to be produced (1). This greater work contributes to greater jump heights. The CMJ may also use the stretch reflex to increase muscle stimulation and to contribute to a greater muscular force necessary to achieve greater vertical jump height (1). It has been reported that vertical jump height can be 10-23% higher using the CMJ than without it (11). Thus, a secondary purpose of the experiment was to determine whether a strict jumping protocol must be adhered to in an assessment of jumping power based on vertical jump distance. Because there might be circumstances under which CMJ data may inadvertently be used to estimate jump power by employing an equation developed with SJ data, or *vice versa*, it is important to know the resulting degree of error in power output estimation. The study also attempts to determine whether the same equations are appropriate for both males and females and whether separate equations are needed. Although both peak and average power equations are determined in the present study, the emphasis in this article is on the peak power equation and its accuracy. This is because of the superior correlations seen between peak power and the variables of body weight and jump height (2,5).

Back to Top

METHODS

A force platform was used to record the vertical ground reaction forces exerted by 108 college-age male and female athletes and physical education students at Central Connecticut State University during three maximal effort vertical SJ and three maximal effort CMJ. Informed consent was obtained in accordance with Central Connecticut State University's guidelines for human subject research. Table 1 describes the test subjects in the study. Each participant placed a Velcro (Velcro USA, Inc., Manchester, NH) ring around the middle finger of his or her right hand, at the very tip. Then the subject stood with the right shoulder adjacent to the wall and, while keeping the feet flat on the floor, reached up as high as possible, touching the Velcro ring to the vertical jump measurement device mounted on the wall. This established the subject's standing reach height. The subject was then asked to perform a maximal height SJ, starting with the knees at roughly a 90° angle and the arms back, to be subsequently thrust forward and upward to contribute to the height of the jump. Three trials of this jump were performed. The Velcro ring marked the height of the vertical jump and standing reach height was subtracted to establish actual vertical distance jumped. Then the subject was asked to perform a countermovement jump in which the subject began in the standing position, dropped into the squat position, and immediately jumped as high as possible. Again, three trials were performed. The best jump from each of the protocols was used for analysis. There was time between trials to take the measurements, write down the information in the subjects' individual files, and run the program that analyzed the force versus time data to determine power output. This provided enough intertrial rest to allow all jumps to be performed without fatigue. Following the jumping trials, the body weight and four to five skinfold sites of each subject were measured. Body weight was taken on an upright balance scale, while skinfolds were assessed using Lange skinfold calipers.

Variable	Mean	SD
Male (*N* = 59)		
Age	21.3	3.4
Body mass (kg)	78.3	15.4
Fat free mass (kg)	69.3	10.2
% Body fat	12.1	5.8
Female (*N* = 49)		
Age	20.4	2.2
Body mass (kg)	64.7	9.8
Fat free mass (kg)	48.6	5.9
% Body fat	22.5	6.6

Anthropometric measures of the test subjects.

The force platform was connected to an amplifier which passed signals proportional to the force of the feet on the plate to a computer and display device. The force platform was a model LG611 0.6 by 1.2 m force platform connected to a model SGA6-3 amplifier system, both from AMTI (Newton, MA). The continuous voltage signal was digitized at 500 Hz by an APAS analog data collection system (Ariel Dynamics, Vista, CA). The ground reaction force recorded from each jump trial was stored in a file on magnetic tape for later analysis and a custom program processed the files to calculate power output (6).

Cross-validation was performed by entering the variables of jump height and body weight of the 108 subjects into the two equations of Lewis (4) and Harman et al.(6)(Table 2) and comparing the estimates of peak and average power from the respective equations to actual peak and average power determined from the force platform. Next, to evaluate the accuracy of the cross-validated equations, a new set of regression equations was developed from the subjects in the present study and cross-validated using a 2/3 split of the data, with 72 subjects randomly assigned to the fitting sample and 36 to the validation sample (equations 1a and 1b for SJ and CMJ, respectively, in Table 3). These latter peak power equations were then compared with the equations of Lewis and Harman et al. (6). The success of these new equations prompted the derivation of a final set of equations from all 108 subjects in the present study (equations 2a and 2b for SJ and CMJ, respectively, in Table 3). The latter equations were cross-validated using Predicted Residual Sum of Squares (PRESS).

Lewis formula (1974) (4)
Power ($kg \cdot m \cdot s^{-1}$) $= \sqrt{4.9} \times$ body mass (kg) $\times \sqrt{\text{jump-and-reach score (m)}}$
Harman et al. formula (1991) (6)
Peak Power (W) $= 61.9 \times$ jump height (cm) $+ 36.0 \times$ body mass (kg) $- 1822$

Note. Lewis power must be multiplied by 9.81 to obtain watts.

References: 4. Fox, E. L. and D. K. Mathews. *The Interval Training: Conditioning for Sports and General Fitness.* Philadelphia: W. B. Saunders, 1974, pp. 257–258; 6. Harman, E. A., M. T. Rosenstein, P. N. Frykman, R. M. Rosenstein, and W. J. Kraemer. Estimation of human power output from vertical jump. *J. Appl. Sports Sci. Res.* 5:116–120, 1991.

Previous jump power equations in the literature.

Equation 1a: Squat jump (72 subjects)

$$\text{Peak Power (W)} = 61.2 \times \text{SJ height (cm)} + 47.2 \times \text{body mass (kg)} - 2223$$

$R^2 = 0.89$

SEE = 379.2

Equation 1b: Countermovement jump (72 subjects)

$$\text{Peak Power (W)} = 48.3 \times \text{CMJ height (cm)} + 50.1 \times \text{body mass (kg)} - 1890$$

$R^2 = 0.74$

SEE = 631.9

Equation 2a: Squat jump (108 subjects)

$$\text{Peak Power (W)} = 60.7 \times \text{SJ height (cm)} + 45.3 \times \text{body mass (kg)} - 2055$$

$R^2 = 0.88$

SEE = 372.9

Equation 2b: Countermovement jump (108 subjects)

$$\text{Peak Power (W)} = 51.9 \times \text{CMJ height (cm)} + 48.9 \times \text{body mass (kg)} - 2007$$

$R^2 = 0.78$

SEE = 561.5

Equation 1a and 1b were developed on 72 subjects and cross-validated on the remaining 36 subjects.
Equation 2a and 2b were developed on the entire population of 108 subjects and cross-validated using PRESS.

Peak power equations developed in present study.

Back to Top

RESULTS

Correlations between actual peak power scores from the force platform and peak power scores from the equations of Lewis (4) and of Harman et al. (6) showed strong associations (Table 4). Correlations were greatest between actual power scores and estimates from the formulas of Lewis and of Harman et al. when the SJ protocol was used and SJ data was put into the equations. SJ data were also preferable when both males (*N* = 59) and females (*N* = 49) were assessed individually; the correlations were smaller, but followed the same pattern.

	Actual Power (W)		Predicted Power (W)					
	M	SD		M	SD	% Diff	r	SEE
SJ	3861.2	1076.4	Lewis	1034.1	264.0	−73.2	0.92	421.9
CMJ	3964.6	1183.6	Lewis	1075.9	287.2	−72.8	0.87	583.6
SJ	3861.2	1076.4	Harman	3477.1	899.8	−9.9	0.94	372.9
CMJ	3964.6	1183.6	Harman	3688.8	977.2	−6.9	0.87	579.9
SJ	3654.8	965.7	Eq. 1a	3628.2	973.9	−0.7	0.93	355.0
CMJ	3655.4	1034.7	Eq. 1b	3753.0	1031.0	2.7	0.91	429.0

% Diff, 100 (predicted power − actual power)/actual power; r, correlation between actual peak power from force platform and predicted peak power.
Equation 1a and 1b were developed on 72 subjects and cross-validated on the remaining 36 subjects.
Equation 2a and 2b were developed on the entire population of 108 subjects and cross-validated using PRESS.

Comparisons of actual peak power to equation-predicted peak power (N = 108).

Peak power was underestimated by 6.9% when using CMJ data in the equation of Harman et al. (6) and underestimated by 9.9% when using SJ data (Table 4). Underestimations of peak power were similar for the individual genders, although slightly greater for males, and slightly smaller for females.

The Lewis formula revealed that peak power was underestimated by 72.8% when using CMJ data in the equation, and by 73.2% when using SJ. Results were similar for the individual genders. Although not shown, average power was underestimated by 42.6% when using CMJ data in the equation and by 42.5% when using SJ data. In the description of the Lewis formula, whether the power score obtained was peak or mean power was never specified.

The split data formula from the validation sample of subjects in the present study showed very good accuracy (see Table 4). Peak power was underestimated by 0.7% when using SJ equation 1a and overestimated by 2.7% when using CMJ equation 1b. Results for males showed even smaller differences between estimated and actual peak power scores, while females showed a 7.2% overestimation when using the CMJ equation, but only a 1.8% underestimation when using the SJ equation.

In the present study, SEE was the primary determinant of the accuracy of a regression equation. When assessing the SEE of peak power equations using the CMJ data versus the SJ data in the equation, it can be seen in Table 4 that the SEE was smaller using SJ data than by using CMJ data in the formulas of Lewis and of Harman et al. (6), as well as in equation 1a. This resulted from smaller standard deviations for SJ data and stronger correlations between predicted peak power and actual peak power. The same was true for the smaller populations of males and females.

The new regression equations for peak power derived from the entire population of 108 subjects in the present study (Equations 2a and 2b) were cross-validated using the PRESS statistic (7). PRESS allows for use of all the available data and avoids equation instability because of the reduced sample size characteristic of data splitting. The PRESS method also provides unbiased estimates of the prediction equation's future performance, similar to data splitting. The PRESS statistic replaces the ordinary ANOVA residual sum of squares with PRESS residuals resulting in a modified R^2 and SEE. It can be seen that differences did exist between the actual regression equations derived from data splitting and regression equations derived from the total population of 108 (Table 3). Because of the success and accuracy of the equations derived from data splitting, the accuracy of an equation based on the whole population of 108 (equations 2a and 2b) should have been better than one derived on only 72 subjects (equations 1). Table 5 reveals that when compared with the R^2 and SEE of the original non-cross-validated regression equations based on 108 subjects using the SJ protocol, the R^2 and SEE from the cross-validated sample using PRESS revealed an accurate and usable equation for both peak and mean power. The R^2 of 0.87 and the SEE of 382.4 W for the SJ peak power formula cross-validated by PRESS were similar to the R^2 of 0.88 and the SEE of 372.9 W of the original non-cross-validated SJ peak power equation. It can be seen that the CMJ protocol produced a poorer R^2 and SEE than did the SJ protocol when using the non-cross-validated equation and both the data-split and PRESS validated equations. Thus, in this study the CMJ protocol provided a less accurate estimate of peak power than did the SJ protocol.

Sample	R^2	SEE	R^2_s	SEE_s	R^2_p	SEE_p
Equation 2a	0.88	372.9	0.89	379.2	0.87	382.4
Equation 2b	0.78	561.5	0.74	631.9	0.76	579.4

R^2 and SEE refer to regression-related statistics of 108 subjects.
R^2_s and SEE_s refer to regression-related statistics of 72 subjects in data-splitting sample.
R^2_p and SEE_p refer to regression-related statistics of 108 subjects cross-validated using PRESS.

Cross-validation results of new equations (2a and 2b) using PRESS and data-splitting techniques.

To assess the robustness of the new equations derived from the entire 108 subjects (equations 2a and 2b), two things were done. First, peak power was estimated by substituting CMJ data into the SJ equation and *vice versa*, to reveal the magnitude of error resulting from inadvertently using the wrong equation. Second, male and female scores were inserted separately into the equations to support or refute the notion that separate equations for the genders are necessary.

The results from Table 6 show that when CMJ data were inserted into equations derived from SJ data (equation 2a) and compared with actual CMJ power, peak power was overestimated in the total population by 2.7%. Similarly, when SJ data were inserted into equations derived from CMJ data (equation 2b) and compared with actual SJ power, peak power was underestimated in the total population by 1.9%.

	Actual Power (W)		Equation Used	Predicted Power (W)		% Diff	r	SEE
	M	SD		M	SD			
CMJ	3964.1	1183.6	2a	4070.3	1074.6	2.7	0.89	539.7
SJ	3861.2	1076.4	2b	3786.1	978.44	−1.9	0.91	446.3
Male ($N = 59$)								
CMJ	4708.4	888.9	2a	4768.9	872.7	1.3	0.84	482.3
SJ	4620.2	822.5	2b	4424.4	761.9	−4.2	0.80	493.5
Female ($N = 49$)								
CMJ	3069.1	818.2	2a	3228.9	575.63	5.2	0.72	567.8
SJ	2993.7	542.9	2b	3017.1	978.4	−0.8	0.85	285.9

% Diff, 100 (predicted power − actual power)/actual power; r, correlation between actual peak power from force platform and predicted peak power.

Comparisons of Interchanged SJ and CMJ data in Equations 2a and 2b (N = 108).

Another important aspect of the present research was to see whether a single equation could provide good estimates of both male and female jumping power rather than using separate equations for each. Table 7 shows that for males the equations derived from all 108 male and female subjects underestimated peak power by 1.8% using equations 2a and 2b. For females, peak power was overestimated by 2% and 3.2% for equations 2a and 2b, respectively (Table 7). Thus, the equations had the effect of slightly underestimating the difference between males and females in peak power. The SEE showed no aberrations, remaining higher for the CMJ protocol than for the SJ protocol.

	Actual Power (W)		Equation Used	Predicted Power (W)		% Diff	r	SEE
	M	SD		M	SD			
Male (*N* = 59)								
SJ	4620.2	822.48	2a	4535.6	731.2	−1.8	.87	405.5
CMJ	4708.4	888.9	2b	4623.9	877.3	−1.8	.82	508.8
Female (*N* = 49)								
SJ	2993.7	542.9	2a	3052.2	587.6	2.0	.85	286.0
CMJ	3069.1	818.24	2b	3168.7	567.31	3.2	.82	468.3

% Diff, 100 (predicted power − actual power)/actual power; r, correlation between actual peak power from force platform and predicted peak power.

Comparisons of males and females predicted power from equations 2a and 2b (N = 108).

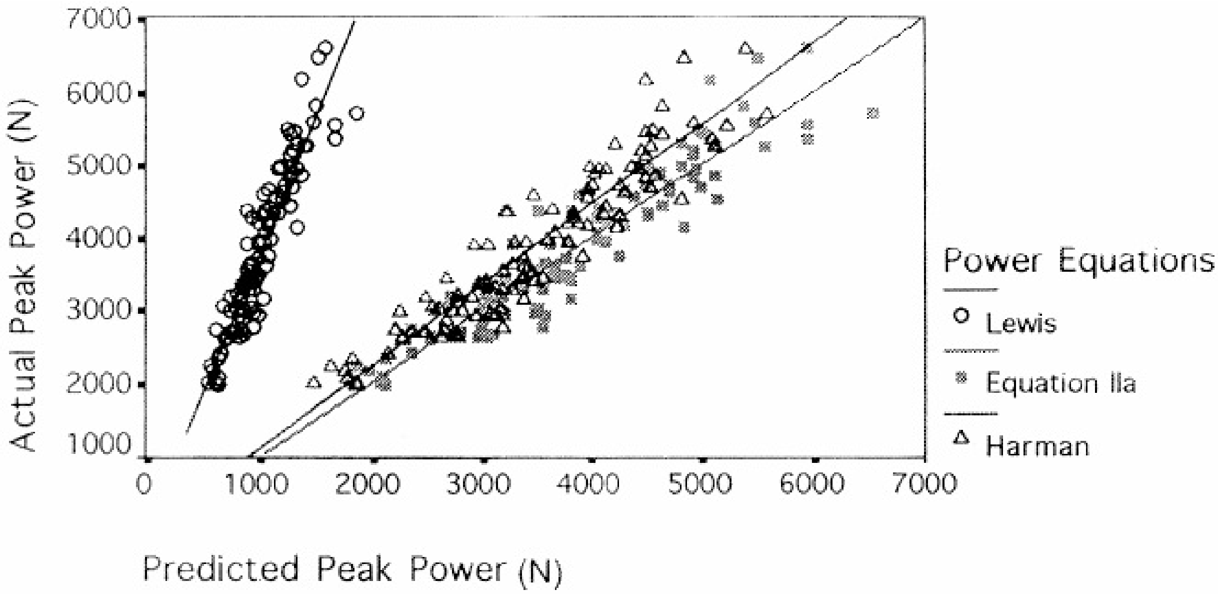
Back to Top

DISCUSSION

The present study has resulted in the development of a new equation for estimation of peak power from vertical squat jump distance and body mass. The new equation is considerably more accurate than the traditional one of Lewis and can be considered more valid than the equation of Harman et al. (6) since it is based on the data of a larger and more diverse population.

Several things can be inferred from the results of the study. First, the SJ protocol is preferable to the CMJ protocol for testing peak jumping power. It is essential to have a standard type of jump, without too much variation. When testing different athletes on the CMJ it becomes apparent that there are a variety of CMJ techniques, some with a large countermovement, others with a small countermovement. Some perform the movement quickly, others slowly. Some pause slightly at the bottom of the CMJ, which can turn the CMJ into more of a SJ. Since both the magnitude and rapidity of the countermovement contribute to vertical jump performance, variation in these factors will contribute to error in peak power prediction. Theoretically, if all jumps were able to be initiated at the 90° knee angle, the only timing differences would reflect the subjects' height and ability to provide thrust. With the CMJ, timing varies according to how large the countermovement is, how quickly it is performed, or whether there is a pause at the bottom. The SJ protocol thus minimizes variability. A protocol that has subjects begin with the knee angle at approximately 90°, with arms back, ready to be swung forward and upward during the thrust phase of the jump seems to be an acceptable way to guarantee that form is controlled within and across jumping groups. An argument can be made for specificity, i.e., that different athletes should be tested using the type of jump predominant in their sport. However, to provide a fair comparison of the power produced by jumpers using a countermovement, all the jumpers would have to be trained to do the CMJ very similarly. Specificity is important to training, but consistency is more important for testing.

The SJ protocol is more acceptable than the CMJ protocol with regard to accuracy of prediction. Using the SJ in the power formula of Lewis (4), Harman et al. (6), and the present study produced a smaller SEE than when the CMJ protocol was used. This resulted from lower standard deviations with the SJ than the CMJ, probably because of the more uniform nature of the SJ discussed earlier. The smaller SEE also reflected a higher correlation between peak power derived from regression equations using the SJ protocol and actual peak power scores (Table 4). These trends held true for both male and female populations. Although correlations between equation-derived peak power scores and actual peak power scores were lower for females than males, the SEE was lower for the SJ protocol than the CMJ protocol. Although the Lewis formula exhibited strong correlations between predicted and actual power and a small SEE, it greatly underestimated both peak and average power. This formula, therefore, cannot be considered an accurate or valid estimate of peak or average power. Explaining this anomaly, Holiday et al. (7) stated "... statistical correlatedness does not necessarily imply equality in regression" (p. 614). The good correlations between the Lewis formula and force platform observed peak power resulted because the actual and predicted values differ by some fairly constant amount, which was quite large. This view is reinforced by Kline et al. (9) who support "... the preferred use of SEE over correlation coefficients when comparing equations which have been derived on different samples" (p. 257). Yet, the SEE may be low when correlations are high and standard deviations are unrealistically low, as occured in the Lewis formula. Since $SEE = Sy \sqrt{1 - r^2}$, small standard deviations and/or high correlation coefficients can produce a small SEE despite large but consistent errors in estimation. This is what seemed to occur with the low SEE and good correlations observed with the inaccurate Lewis formula. Figure 1 reveals the extent of the inaccuracy of the Lewis formula in comparison with the formulas of Harman et al. (6) and of present study's equation 2a. Although correlations between Lewis and actual power were quite good, the deviation of the regression line from the line of identity shows that large differences existed between predicted and actual scores.



Regression lines for three peak power equations used in this study using SJ data vs actual peak power scores as recorded by the force platform. The Harman et al. (6) equation (61.9 × SJ height [cm] + 36.0 × body mass [kg] − 1822) and equation IIa (60.7 × SJ height [cm] + 45.3 X body mass [kg] − 2055) reveal accurate regression equations. The Lewis formula (4) (√4.9 × body mass [kg] × √SJ height (m) greatly underestimates peak power.

This leads to a second conclusion: the Lewis formula is not an accurate assessment of either peak or average power and its use should be discontinued based on the findings from the present investigation. Its underestimation of peak power by over 70% and average power by over 40% reveals its inappropriateness as a prediction equation. This supports a previous finding from Harman et al (6).

Gender influence. Gender does not seem to interfere with the accuracy of estimates of peak and mean power scores. Interestingly, the formula of Harman et al. (6) revealed peak power scores that were more accurate using female subjects than male subjects, even though the original equation was developed on males. For the total population or for a male or a female population, the formula of Harman et al. (6) is acceptable to use on a more disparate, heterogeneous group despite its development on a small homogeneous population. This suggests that both the male and female populations can be included when predicting peak power from the Harman et al. formula.

The power estimation equations derived from the entire population of 108 males and females produced only minor errors when applied separately to the individual male and female populations. The same was true for the formula of Harman et al. (6) developed from 17 male military personnel but tested on females in this study. In fact, the accuracy was greater in the female population than in the male population. Both male and female populations can be confident using these equations despite the different populations on which they were tested.

Preference of jump protocol. Although in the present study different formulas resulted from SJ and CMJ data, the lower accuracy of the CMJ equation makes it a less desirable equation. The study did reveal a larger peak power score for the CMJ (3964.64 W) than for the SJ (3861.18 W) (Table 4), yet the difference between them was only 2.6%. In addition, vertical jump height using the CMJ was only 7% greater than when using the SJ, smaller than has been seen in other studies (11). Moreover, when comparing differences between regression derived power scores and actual peak power scores, one should note that differences do not discriminate in favor of either jump protocol. The equation from the Harman et al. (6) study revealed greater accuracy when using the CMJ data for the total male and female population when cross-validated to the present study's population, despite having originally been developed using the SJ protocol. It would seem that if each of the different jump protocols were that influential on the outcome of the jump, then these aforementioned anomalies would probably not be present. However, there was evidence of overestimations of power using CMJ data in equations derived from the SJ protocol and slight underestimations of power using SJ data in equations derived from the CMJ protocol in the present study. It is interesting how well the equations estimate actual peak power scores even when different protocols are used. The power scores from the present study equations were more accurate than the power scores using interchanged CMJ and SJ data from the formula of

Harman et al. (6). Using the SJ and CMJ protocols interchangeably in the formulas of Harman et al. or present study allowed a somewhat acceptable range of between 91% and 103% of the actual peak power score for the total population. A standard protocol, however, would alleviate the inconsistencies that are seen in the CMJ protocol. In addition, the excellent R^2 and SEE seen in the newly developed regression equation from the present study for the SJ protocol, as well as the good correlations and SEE found in the cross-validated equations put forth by Harman et al. for the SJ protocol, support preferential use of the SJ protocol. (Table 8)

Source	*dF*	Sums of Squares	Mean-Square	*F*	*P*
Regression	2	106312681.21237	53156340.60618	382.37	0.0000
Residual	102	14179789.16725	139017.54086		
Total	104	120492470.37962			

Dependent variable	Peak power
Independent variables	Body weight, jump height
Multiple R	0.93932
R square	0.88232
Adjusted R square	0.88001
Standard error	372.85

Variable	B	SE B	Beta	T	*P*
Constant	−2055.063387	217.103566	−9.466		0.0000
Body weight	45.285906	2.529706	0.626757	17.902	0.0000
Jump height	60.666886	3.765922	0.564009	16.109	0.0000

Analysis of variance.

It is also important to look at the trends of the average R^2 and SEE seen in Table 5. According to Holiday et al. (7), either data splitting or PRESS can be more or less optimistic in any given sample, yet the averages of R^2 and SEE are expected to follow the trend of adjusting downward, exhibiting less optimistic values than for the equation from the entire population. Both data splitting and PRESS exhibited this trend for SEE in both equations 2a and 2b, not for R^2. R^2 values were more optimistic for PRESS in equation 2a and for data splitting and PRESS in equation 2b. The PRESS statistic followed its expected trends, but more importantly, revealed a successful cross-validation technique that supports the implementation of the utilization of new peak and mean power equations using the SJ protocol.

It can be concluded that: 1) the Lewis formula (4) is not accurate for determining either mean or peak power. Thus, it can be stated with confidence that the Lewis formula should be discontinued for estimating the power of an athlete. 2) Although the accuracy of the formula of Harman et al. (6) is somewhat acceptable for peak power, equation 2a from the present study exhibits a more accurate equation that has been cross-validated using PRESS, revealing a good R^2 and SEE. 3) The SJ protocol is recommended for predicting jump power, using the following equation: Peak Power (W) = (60.7) × (jump height [cm]) + 45.3 × (body mass [kg]) − 2055. However, inadvertent use of the CMJ protocol in the equation derived from SJ data will not greatly affect the results. 4) Both males and females are able to use the same equations with good accuracy. The following regression equation for peak power should be implemented for an accurate assessment of an athlete's power: Peak Power (W) = (60.7) × (jump height [cm]) + 45.3 × (body mass [kg]) − 2055.

Back to Top

REFERENCES

1. Bobbert, M. F., K. G. M. Gerritsen, M. C. A. Litjens, and A. J. Van Soest. Why is countermovement jump height greater than squat jump height? *Med. Sci. Sports Exerc.* 28:1402-1412, 1996.
Cited Here...
2. Dowling, J. J. and L. Vamos. Identification of kinetic and temporal factors related to vertical jump performance. *J. Appl. Biomech.* 9:95-110, 1993.
Cited Here...
3. Fox, E. L. and D. K. Mathews. *The Physiological Basis of Physical Education and Athletics*, 3rd Ed. Philadelphia: Saunders College, 1981, pp. 619-621.
Cited Here...
4. Fox, E. L. and D. K. Mathews. *The Interval Training: Conditioning for Sports and General Fitness.* Philadelphia: W.B. Saunders, 1974, pp. 257-

258.
Cited Here...
5. Harman, E. A., M. T. Rosenstein, P. N. Frykman, and R. M. Rosenstein. The effects of arms and countermovement on vertical jumping. *Med. Sci. Sports Exerc.* 22:825-833, 1990.
Cited Here...
6. Harman, E. A., M. T. Rosenstein, P. N. Frykman, R. M. Rosenstein, and W. J. Kraemer. Estimation of human power output from vertical jump. *J. Appl. Sports Sci. Res.* 5:116-120, 1991.
Cited Here...
7. Holiday, D. B., J. E. Ballard, and B. C. McKeown. PRESS-related statistics: regression tools for cross-validation and case diagnostics. *Med. Sci. Sports Exerc.* 27:612-622, 1995.
Cited Here...
8. Kirkendall, D. R., J. J. Gruber, and R. E. Johnson. *Measurement and Evaluation for Physical Education*, 2nd Ed. Champagne: Human Kinetics, 1987, pp. 118-120.
Cited Here...
9. Kline, G. M., J. P. Porcari, and R. Hintermeister. Estimation of $\dot{V}O_{2max}$ from a one-mile track walk, gender, age, and body weight. *Med. Sci. Sports Exerc.* 19:253-259, 1987.
Cited Here...
10. Mathews, D. K. and E. L. Fox. *The Physiological Basis of Physical Education and Athletics*, 2nd Ed. Philadelphia: W.B. Saunders, 1976, pp. 584-586.
Cited Here...
11. Vandewalle, H., G. Peres, and H. Monod. Standard anaerobic exercise tests. *Sports Med.* 4:268-289, 1987.
Cited Here...
Keywords:

JUMP-AND-REACH TEST; PEAK POWER; LEWIS FORMULA; PRESS STATISTIC

© 1999 Lippincott Williams & Wilkins, Inc.