Original Research

Accuracy of the Omron HBF-500 Body Composition Monitor in Male and Female College Students

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ABSTRACT

Int J Exerc Sci 4(1) : 93-101, 2011. The Omron HBF-500 is an inexpensive body composition monitor that incorporates both hand-to-hand and foot-to-foot electrical impedance technology. At this time, studies examining the accuracy of the HBF-500 when estimating percent body fat (%BF) are scarce and if this instrument gains popularity due to its claimed precision, comparisons against validated techniques should be conducted. The purpose of this study was to assess the accuracy of the Omron HBF-500 body composition monitor using the BOD POD as a criterion. Forty-eight men and 33 women participated in the study (24.3±6.9 years, 171.0±10.0 cm, 78.4±18.0 kg, 26.6±5.1 kg/m^2). Participants were asked to refrain from exercise and caffeine on the day of testing, not eat a heavy meal three hours prior to measurement (a meal that would typically constitute breakfast, lunch or dinner), and to remain normally hydrated. Participants removed all jewelry and garments down to skintight clothing such as swimsuits or cycling shorts and were assessed on the BOD POD and Omron according to manufacturer's guidelines. The Omron significantly overestimated %BF compared to the BOD POD in males (24.4±8.0 % and 22.9±9.1 %, respectively), and females (35.5±7.7 % and 30.1±7.9 %), p = .001. The Omron was significantly correlated with the BOD POD when assessing body fat, r= .95. The estimates of %BF produced by the BOD POD and HBF-500 differ considerably. Consequently, caution should be taken when using the Omron HBF-500 as a measure of body fat. However, given the difference of only 1.5% BF between the two methods, perhaps males could use the HBF-500 to gain a general idea of body composition status. For females, the degree of overestimation is too high to be suitable for this purpose and incorrect categorization of %BF status could result. In cases where an accurate estimate of %BF is crucial, using a more established method than the Omron is recommended.

KEY WORDS: Body fat, validity, BOD POD

INTRODUCTION

Body composition is a vital element of human health. Maintaining a relatively low percentage of body fat is essential in minimizing the occurrence of a variety of negative conditions like cardiovascular disease and type 2 diabetes (12, 27). Favorable body composition also helps in managing existing conditions, including diabetes, hypertension and various orthopedic problems (12, 27). Using bodyweight as the sole measure of body composition can be misleading; an ordinary body weight scale does not distinguish between fat mass and lean mass. Body mass index (BMI), when used with athletic populations, can give a similarly inaccurate impression of body composition status (22, 27). Fortunately, instruments are available that produce a more comprehensive and accurate picture of an individual's body composition.

A variety of accepted methods are available for estimating percent body fat (%BF), including hydrostatic weighing (HW), skinfold calipers, Dual X-ray absorptiometry (DXA) scans and air displacement plethysmography (ADP) (22, 27). Air displacement plethysmography in particular offers relative ease of operation, takes little time to estimate subjects' %BF, and a number of studies have shown this method to be accurate (1, 19, 21).

The aforementioned methods of estimating %BF are generally costly and/or require professional expertise for effective and safe use, placing them beyond the reach of the general public. Skinfold calipers are relatively inexpensive, but still require a trained technician to produce accurate estimates of %BF. However, a variety of consumer-grade devices targeted at the public purportedly estimate %BF, usually through bioelectrical impedance (BIA). Such products come in many forms, including attachable electrodes, handheld devices, scales, and products that are a combination of these.

Studies have been conducted to validate consumer-grade BIA instruments. For example, Pateyjohns et al. (24) compared two BIA devices, the ImpediMed SFB7 and the Tanita UltimateScale, using DXA as a criterion. Forty-three healthy overweight or obese males between the ages of 25 and 60 were assessed with each device and in the case of the ImpediMed SFB7, using both single frequency (SF) and multifrequency (MF) currents. When compared to DXA, the SFB7 significantly underestimated %BF with both MF and SF currents by 7.0±1.3 % and 1.7±1.8 %, respectively. While the absolute and relative agreement between the Tanita UltimateScale and DXA was strong, the limits of agreement between the two methods were wide and the UltimateScale overestimated %BF by 1.2±1.7% when compared to DXA

The Omron HBF-500, a bodyweight scale and BIA body fat estimating device, estimates %BF by sending electrical currents through the hands via handheld electrodes and the feet via electrodes on the scale's surface. The combination of handheld and scale electrodes take into account both the upper and lower body when %BF is estimated. A cost below 100 U.S. dollars puts it well within the reach of the general public. Studies examining the accuracy of the HBF-500 when estimating %BF are scarce and if this instrument gains popularity due to its claimed precision, comparisons against validated techniques should be conducted.

In 2008, Barnes, Pujol and Williams (5) compared the %BF estimates of five different BIA scales: the Tanita BF-350, Tanita BF-522, Omron HBF-300, Omron HBF-306 and Omron HBF-500. Eleven college-aged females were assessed with DXA, which was used as a criterion. The Tanita BF-350, Tanita BF-522, Omron HBF-300 and Omron HBF-306 produced results significantly lower from DXA scans, each underestimating %BF by 5.4±2.0 %, 5.4±2.0 %, 10.7±1.9 % and 10.5±2.4 %, respectively. The HBF-500 was the only device used that provided results not significantly different from DXA scans, with a difference of only -0.83±0.8 %.
A later study by Barnes et al. (4) assessed the %BF of 35 collegiate baseball players with the five BIA scales mentioned in the

preceding study and DXA scans also served as the criterion. In this population, the DXA results were found to be significantly different from those provided by the other instruments. The Tanita BF-350, Tanita BF-522, Omron HBF-300, Omron HBF-306 underestimated %BF by 5.6±3.5 %, 5.4±3.4 %, 4.6±3.0 % and 5.4±4.0 %, respectively, while the Omron HBF-500 overestimated %BF by 2.16±2.7 %.

Since current studies of the HBF-500 have only examined a very limited segment of the population and produced varied reports on the device's accuracy, the accuracy of this instrument needs further examination. The purpose of this study was to assess the accuracy of the Omron HBF-500 body composition analyzer in male and female college students. It was hypothesized that no significant difference would exist between estimated percent body fat between ADP and the Omron HBF-500 body composition analyzer in males or in females. ADP was chosen as a criterion due to accessibility and its established accuracy.

METHODS

Participants

Subjects were a convenience sample of 48 male and 33 female college students who volunteered from kinesiology classes at a southwest Texas university. This study was accepted by the university's institutional review board and, prior to measurement, participants signed an informed consent and were given an opportunity to ask any questions. Exclusion criteria included being pregnant, under 18 years of age, and being over 136.3 kg (the weight limit of the HBF-500). Participant characteristics can be seen in Table 1.

Data Collection - Procedures

On the day of assessment, participants were asked to refrain from exercise and to have not eaten a heavy meal (a meal that would typically constitute breakfast, lunch or dinner) 3 hours prior to measurement. Participants were first asked to relieve themselves and to change into skintight clothing such as swimsuits or cycling shorts, which were provided in case participants did not have any. All other clothing and items, such as shoes, jewelry, and glasses were also removed. Participants then had their height measured using a Seca 214 portable height rod (Hamburg, Germany) after which waist circumference was assessed with a flexible measuring tape to the nearest tenth of a centimeter around the waist at the smallest circumference between the iliac crest and the lower ribs. They were then fitted with a swim cap to compress their hair.

Participants were then assessed on the Omron HBF-500 scale, which involved entry of the participant's age, height, and gender. Still wearing the skintight clothing,

Table 1. Means and standard deviations of participant characteristics

	Total (*N*= 81)	Male (*n*= 48)	Female (*n*= 33)
Age	24.3±6.9	25.8±8.5	22.2±2.3
Height (cm)	171.0±10.0	176.6±7.9	162.8±6.4
Weight (kg)	78.4±18.0	86.7±15.6	66.2±14.0
BMI (kg/m^2)	26.6±5.1	27.8±4.7	24.9±5.2
Waist Circumference (cm)	82.9±12.0	88.1±10.8	75.5±9.6

Table 2. Percent body fat (%BF) measurements from two body composition analyzers

	All (N = 81)	Males (n = 48)	Female (n= 33)
Air Displacement Plethysmography (%BF)	25.9±9.3	22.9±9.1 [a] [b]	30.1±7.9 [b]
Omron HBF-500 (%BF)	28.9±9.6	24.4±8.0 [a]	35.5±7.7

[a] significant difference between gender with the same instrument, $p < .01$

[b] significant difference between instrument within the same gender, $p < .01$

participants stood on the scale barefoot and grasped the handle electrodes for approximately 10 seconds until the process was complete. Assessment using the ADP system immediately followed.

The ADP system used was the BOD POD® (Life Measurement, Inc, Concord, CA). Warm-up procedures and calibration of the system and its bodyweight scale were performed according to manufacturer's guidelines. Information regarding participant height, gender, age and race was input into the ADP software. The procedures for assessing body composition with ADP were as follows: Participants were asked to step onto the BOD POD® scale for weighing. After weighing was completed, participants were seated inside the BOD POD® and given instructions to breathe normally and remain still during measurement. Upon successful completion of the %BF measurement, participants were instructed to exit the BOD POD®. Predicted lung volumes produced by the ADP software, which have been shown to be as accurate as measuring lung volume (8, 10), were used for this study. At this point, the testing was complete and participants were given the opportunity to discuss their test results with the researchers.

Statistical Analysis

Statistical analyses were performed with SPSS 15 for Windows (SPSS Inc, Chicago, Illinois, USA). A 2 X 2 (instrument x gender) factorial ANOVA was used to determine differences in %BF estimated from ADP and the Omron HBF-500 body composition analyzer between genders. In the case of a significant interaction with alpha set at .05, Bonferroni-adjusted form of the least significant difference (LSD) was used for pairwise comparisons among each condition. Alpha for these comparisons was set at .05/4. A Pearson's Product Moment correlation was used to examine the relationship between the %BF estimates from the two instruments. Since a high correlation does not necessarily imply agreement, Bland-Altman plots of ADP and HBF-500 registered by the instruments were used to provide an indication of over/under representation of %BF and agreement between the measures (7). Scores below zero indicate an overestimation by the HBF-500 and scores above zero indicate an underestimation by the HBF-500. These plots show the variability in %BF scores while allowing for the mean difference score and the 95% limits of agreement to be shown. Error scores of zero indicate that there was no difference between the actual %BF measured by ADP and those registered by the HBF-500. Percent error was calculated as [(%BF detected by HBF-500 – ADP) / ADP] x 100.

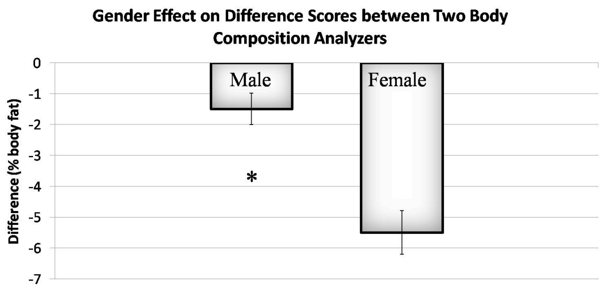

Figure 1. The difference in percent body fat between air displacement plethysmography and the Omron HBF-500 after assessing males was significantly less than the difference between instruments after assessing

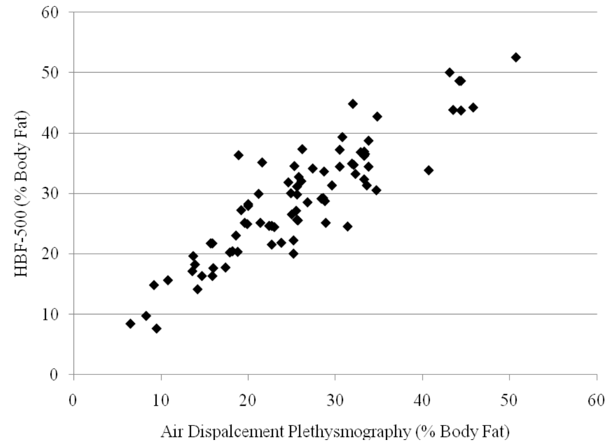

Figure 2. Correlation between body fat percent measured by the ADP and HBF-500 (r = .95, p = .001) in 81 males and females.

RESULTS

A significant interaction between instrument and gender emerged, $F(1, 79) = 21.08$, $p = .001$, with pairwise comparisons indicating a significant difference between instrument readings in males, $t(47) = -2.9$, $p = .006$, as well as females $t(32) = -7.4$, $p = .001$ (Table 2). As would be expected, males were estimated with significantly less body fat than females when measured on ADP, $t(79) = -3.6$, $p = .001$, and the HBF-500, $t(79) = -6.2$, $p = .001$. An additional independent t-test of the difference scores between the instruments revealed the HBF-500 significantly overestimated %BF to a greater degree in females compared to males $t(79) = 4.6$, $p = .001$, Figure 1.The Pearson Product moment correlation (Figure 2) between the two measures was very strong $r(243) = .95$, $p = .001$. This indicated that participants with a high %BF measured on ADP were also measured with a high %BF on the HBF-500. This relationship was stronger in males $r(48) = .92$, $p = .001$, than in females $r(33) = .85$, $p = .001$.

Bland-Altman plots suggest greater agreement between the instruments in the males compared to the females. While the mean difference between the instruments when measuring the males was only -1.49 %BF (indicated by the solid black line in figure 3), this was still significant. The limit of agreement was tighter in the males, which is indicated by two standard deviations above and below the mean difference and represented by the upper and lower dashed lines (5.63 %BF and -8.62 %BF, respectively) in figure 3. The limit of agreement was not as tight in females, with 2.98 %BF representing two standard deviations above the mean difference (-5.49 %BF) and -13.97 %BF indicating two standards deviations below the mean difference (Figure 3). Note that only two scores from the males and one score from the females fell outside this interval. Error of the HBF-500 with genders combined was 12.1%, and was less in males (6.5%) compared to females (18.3%).

DISCUSSION

This study examined the accuracy of the Omron HBF-500 as an instrument for estimating %BF. In both genders, it appears the HBF-500 significantly overestimates %BF, though the effect is far more pronounced with females. In males, the mean difference between %BF estimates was relatively small at -1.49% compared to

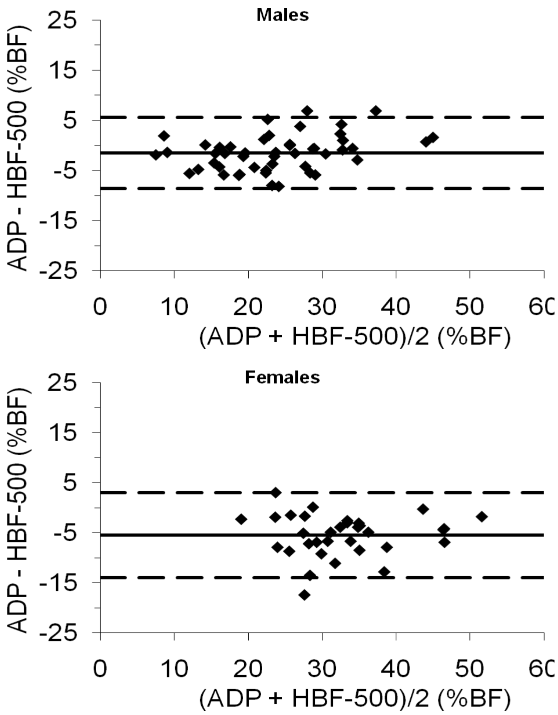

Figure 3. Bland-Altman plots depicting error scores for air displacement plethysmography and the Omron HBF-500. Error was greater for females than males. Solid line represents mean difference, dashed line represents 95% prediction interval.

the females, whose mean difference was -5.49%. Additionally, the Bland Altman plots above show tighter agreement between the BOD POD® and HBF-500 for males than females.

It is possible these differences are related to the menstrual cycle (22), for which the current study did not control. Additionally, we did not control for facial and body hair when using the BOD POD®, which have been shown to cause overestimation of %BF by roughly 1.0% (17). While we requested participants remain normally hydrated and refrain from exercise prior to testing, we were unable to monitor compliance, which may have been an additional source of error. Our findings for male participants are consistent with those of Barnes et al.'s 2009 study (4), where the HBF-500 overestimated %BF by an average of 2.4%.

The BOD POD® was chosen as a criterion measure due to its established accuracy, and availability to the researchers. A standard criterion for estimating %BF does not presently exist, and it could be argued that using the BOD POD® in this role is not ideal. The BOD POD® uses a two component model for estimating %BF, which consists of fat and fat-free mass (22). Hydrostatic weighing, formerly referred to as the "gold standard" for body composition assessment, also relies on the two component model (22).

The BOD POD® has been compared to HW in numerous studies (6, 9, 11, 13, 14, 18, 20, 23, 26). In studies by Biaggi et al. (6), Fields et al. (14), Levenhagen et al. (18), and Nuñez et al. (23), no significant difference was found between estimates of %BF produced by HW and the BOD POD®. Other studies, such as those by Collins et al. (9), Dewit et al. (11), Millard-Stafford et al. (20), and Wagner et al. (26) have shown a significant difference in %BF estimates between HW and the BOD POD®. However, there are factors that may be responsible for these disparities that are unrelated to the BOD POD® itself. One of these factors is the variation of equipment between laboratories (13). Presently, the variation in readings between individual BOD POD® units is unknown (13), but it has been conjectured that less difference exists between BOD POD® units than HW units because there are a number of possible HW designs, compared to only one type of BOD POD® unit (13). Other factors that may create a disparity between HW and BOD POD® tests include participant wetness from HW, size, gender, postprandial conditions, deviation from manufacturer clothing guidelines and error in residual lung volume measurements (13).

A primary assumption underlying the two-component model is the constancy of constituents that make up the body's lean mass between individuals (3). This assumption is disputable, particularly with age, gender, fatness, ethnicity and physical activity levels affecting the composition of fat-free mass (22). Methods that use the three-component model (bone, fat and soft lean mass) and the four-component model (water, fat, bone mineral and protein) should theoretically provide more accurate estimates of %BF because they consider more elements of lean mass (3). Nonetheless, in some studies, the BOD POD® has underestimated %BF compared to the DXA, but the correlation between the two methods is high (3, 16, 25). In other studies, the BOD POD® has compared favorably to DXA scans (2, 15).

Future studies of the Omron HBF-500 should control for the menstrual cycle and take measures to ensure that participants follow pre-test procedures. Additionally, studies are needed to determine accuracy in populations like children and seniors, which appear to be completely unrepresented in the current literature. In light of disparity between the readings for females in our study and the females in Barnes, Pujol and Williams' 2008 study (5), more research to determine accuracy in female populations is also necessary.

The estimates of %BF produced by the BOD POD® and HBF-500 differ considerably. However, given the lower difference scores between the two methods, perhaps males could use the HBF-500 to gain a general idea of body composition status. For females, the degree of overestimation is too high to be suitable for this purpose and incorrect categorization of %BF status could result. In cases where an accurate estimate of %BF is crucial, using a more established method than the Omron is recommended.

REFERENCES

1. Alemán-Mateo H, Huerta RH, Esparza-Romero J, Méndez RO, Urquidez R, Valencia RM. Body composition by the four-compartment model: validity of the BOD POD for assessing body fat in Mexican elderly. Eur J Clin Nutr 61: 830-836, 2007.

2. Ballard T, Fafara L, Vukovich M. Comparison of BOD POD and DXA in female collegiate athletes. Med Sci Sports Exerc 30: 731-735, 2004.

3. Ball SE, Altena TS. Comparison of the BOD POD and dual energy x-ray absorptiometry in men. J Am Diet Assoc 102: 1677-1679, 2002.

4. Barnes JT, Elder CL, Nelm MN, Pujol TJ, Kearney ML, Loennke JP, Williams RD. Accuracy of bioelectrical impedance analysis instruments for the measurement of body composition in collegiate baseball players. Med Sci Sports Exerc 41 suppl: 159, 2009.

5. Barnes JT, Pujol TJ, Williams D Jr. Accuracy of five bioelectrical impedance analysis instruments for the measurement of body composition in college females. Med Sci Sports Exerc 40 suppl: 271, 2008.

6. Biaggi RR, Vollman MW, Nies MA, Brener CE, Flakoll PJ, Levenhagen DK, Sun M, Karabulut Z, Chen KY. Comparison of air displacement plethysmography with hydrostatic weighing and bioelectrical impedance analysis for the assessment of body composition in healthy adults. Am J Clin Nutr 69: 898-903, 1999.

7. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet, 1: 301-310, 1986.

8. Collins AL, McCarthy HD. Evaluation of factors determining the precision of body composition

measurements by air displacement plethysmography. Eur J Clin Nutr 57: 770-776, 2003.

9. Collins MA, Millard-Stafford ML, Sparling PB, Snow TK, Rosskopf LB, Webb SA, Omer J. Evaluation of the BOD POD for assessing body fat in collegiate football players. Med Sci Sports Exerc 31: 1350-1356, 1999.

10. Demerath EW, Guo SS, Chumlea WC, Towne B, Roche AF, Siervogel RM. Comparison of percent body fat estimates using air displacement plethysmography and hydrodensitometry in adults and children. Int J Obes Rel Metab Dis 26: 389-397, 2002.

11. Dewit O, Fuller NJ, Fewtrell MS, Elia M, Wells JC. Whole body air displacement plethysmography compared with hydrodensitometry for body composition analysis. Archives of Disease in Childhood, 82: 159-164, 2000.

12. Durstine JL, Moore EM, Painter PL, Roberts SO. ACSM's exercise management for persons with chronic diseases and disabilities (3rd ed.). U.S.: Human Kinetics, 2009.

13. Fields DA, Goran MI, McCrory MA. Body-composition assessment via air-displacement plethysmography in adults and children: a review. Am J Clin Nutr 75: 453-467, 2002.

14. Fields DA, Wilson GD, Gladden LB, Hunter GR, Pascoe DD, Goran MI. Comparison of the BOD POD with the four-compartment model in adult females. Med Sci Sports Exerc 33: 1605-1610, 2001.

15. Harris GK, Stote KS, Clevidence BA, Paul DR, Kramer MH, Baer DJ. BOD POD approximates corrected DEXA values more closely than BIA in overweight and obese adults [abstract]. Federation of American Societies for Experimental Biology, 21: 679, 2007.

16. Heden T, Shepard S, Smith J, Covington K, LeCheminant J. Resulting shifts in percentile and standard placements after comparison of the BOD POD and DXA. Int J Exerc Sci 1: 113-124, 2008.

17. Higgins PB, Fields DA, Hunter GR, Gower BA. Effect of scalp and facial hair on air displacement plethysmography estimates of percentage body fat. Obesity, 9: 326-330, 2001.

18. Levenhagen DK, Borel MJ, Welch DC, Piasecki JH, Piasecki DP, Chen KY, Flakoll PJ. A comparison of air displacement plethysmography with three other techniques to determine body fat in healthy adults. Journal Parenteral Enteral Nutr 23: 293-299, 1999.

19. Maddalozzo GF, Cardinal BJ, Snow CA. Concurrent validity of the BOD POD and dual energy x-ray absorptiometry techniques for assessing body composition in young women. J Am Diet Assoc 102: 1677-1679, 2002.

20. Millard-Stafford ML, Collins MA, Evans EM, Snow TK, Cureton KJ, Rosskopf LB. Use of air displacement plethysmography for estimating body fat in a four-component model. Med Sci Sports Exerc 33: 1311-1317, 2001.

21. Miyatake N, Nonaka K, Fujii M. A new air displacement plethysmograph for the determination of Japanese body composition. Diabetes Obes Metab 1: 347-351, 1999.

22. Nieman DC. Exercise testing and prescription: a health-related approach (6th ed.). U.S.: McGraw-Hill, 2007.

23. Nuñez C, Kovera AJ, Pietrobelli A, Heshka S, Horlick M, Kehayias JJ, Wang Z, Heymsfield SB. Body composition in children and adults by air displacement plethysmography. Eur J Clin Nutr 53: 382-387, 1999.

24. Pateyjohns IR, Brinkworth GD, Buckley JD, Noakes M, Clifton PM. Comparison of three bioelectrical impedance methods with DXA in overweight and obese men. Obesity, 14: 2064-2070, 2006.

25. Radley D, Gately PJ, Cooke CB, Carroll S, Oldroyd B, Truscott JG. Percentage fat in overweight and obese children: comparison of DXA and air displacement plethysmography. Physiol Meas 25: 671-678, 2001.

26. Wagner DR, Heyward VH, Gibson AL. Validation of air displacement plethysmography

for assessing body composition. Med Sci Sports Exerc 32: 1339-1344, 2000.

27. Wilmore JH, Costill DL, Kenney WL. Physiology of sport and exercise (4th ed.). U.S.: Human Kinetics, 2008.