Validity of maximal oxygen consumption prediction equations in young Saudi females

Marwah M. Almakhaita, MBBS, MSc, Lubna I. Al Asoom, MBBS, PhD, Nazish Rafique, MBBS, FCPS, Rabia Latif, MBBS, PhD, Anas M. Alduhishy, BSc PT, PhD.

ABSTRACT

لأهداف: مقارنة الحد الأقصى لاستهلاك الأكسجين المقاس فعليا باستخدام اختبار الجهد البدني العالي لدى الطالبات السعوديات ومقارنة القيم بما تنتجه المعادلات التالية: جونز و هانسن و واسرمان .

الطريقة: أجريت هذه الدراسة المستعرضة في جامعة الإمام عبد الرحمن بن فيصل خلال الفتره من مارس إلى مايو لعام 2017م. حيث تم قياس القيمة الفعلية للحد الأقصى لاستهلاك الأكسجين مباشرة من خلال جهاز (COSMED) لإجراء التمارين القلبية التنفسية القصوى، وشارك في الدراسة مائه طالبة واثنتين ذوات مؤشر كتلة جسم طبيعي وتتراوح أعمارهن بين ١٩–٢٥عام. كما تم حساب القيم المتوقعة للحد الأقصى لاستهلاك الأكسجين باستخدام ثلاث معادلات مستخدمه دوليا (جونزو هانسن، وواسرمان). ثم قورنت القيم الفعلية والمتوقعة من المعادلات باستخدام الاختبارات الإحصائية التالية: ((Paired t–test)، (Pearson correlation)، (Bland–Altman plot)) للمقارنه وتحليل الارتباط والاتفاق.

النتائج: جدنا أن الفرق بين متوسط القيمة الفعلية للحد الأقصى لاستهلاك الأكسجين (27.39±4.06 ملم/كجم/دقيقه) ومتوسط القيم المتوقعة الناتجه من استخدام معادلات الجهد البدني: جونز وهانسن وواسرمان (35.19±2.12، 33.64±0.24، ملم/كجم/دقيقه على التوالي) كان ذا دلاله إحصائية فارقة (p>0.001). كما بين تحليل (Bland–Altman plot) عدم وجود اتفاق بين القيمة الفعلية للحد الأقصى لاستهلاك الأكسجين وأي من معادلات التنبؤ. بالإضافة إلى فشل ارتباط بيرسون في الكشف عن أي ارتباط بين القيمة الفعلية للحد الأقصى لاستهلاك الأكسجين والقيم المتوقعة المحسوبة بواسطة أي من المعادلات الثلاث.

الخاتمة: أثبتت هذه الدراسة أن استخدام معادلات التنبؤ العالمية جونز وهانسن وواسرمان التي تم اختبارها قد تغالي في تقدير اللياقة القلبية التنفسية لدى الشابات السعوديات. لذلك نوصي بتطوير معادلات جديده خاصه بمختلف فئات المجتمع السعودي للتنبؤ الصحيح بهذه القيمة الحيوية المهمة.

Objectives: To determine the applicability of Jones, Hansen, and Wasserman predictive equations for maximal oxygen consumption (VO_{2max}) in Saudi females.

Methods: This cross-sectional study was conducted at Imam Abdulrahman Bin Faisal University, Dammam, Kingdom of Saudi Arabia, between March and May 2017. Maximal oxygen consumption was measured directly through the COSMED system for cardiopulmonary exercise testing in 102 girls with normal body mass index (19-25 years old). Maximal oxygen consumption was indirectly predicted by Jones, Hansen, and Wasserman equations. Paired t-test, Pearson correlation, and Bland-Altman plot were used for comparison, correlation, and agreement analysis.

Results: The difference between the mean and standard deviation (±SD) VO_{2max} values of the direct measurement (27.39±4.06 ml/kg^{-1}/min^{-1}), and the Jones (35.19±2.12 ml/kg^{-1}/min^{-1}), Hansen (33.64±0.24 ml/kg^{-1}/min^{-1}), and Wasserman (35.20±0.17 ml/kg^{-1}/min^{-1}) equations, was statistically significant (p<0.001). Bland-Altman plot analysis suggested a lack of agreement between direct and predicted VO_{2max}. Pearson correlation failed to reveal any correlation between direct VO_{2max} and VO_{2max} calculated with any of the 3 equations.

Conclusion: Jones, Hansen, and Wasserman equations for prediction of VO_{2max} cannot be justified in the studied population. For the better prediction of VO_{2max}, either these equations should be modified, or a new equation should be developed for the Saudi population.

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From the Department of Physiology (Almakhaita, Al Asoom, Rafique, Latif), College of Medicine and from the Department of Physiotherapy (Alduhishy), College of Applied Medical Sciences, Imam Abdulrahman Bin Faisal University, Dammam, Kingdom of Saudi Arabia.

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Address correspondence and reprint request to: Dr. Rabia Latif, Department of Physiology, College of Medicine, Imam Abdulrahman Bin Faisal University, Dammam, Kingdom of Saudi Arabia. E-mail: rlhussain@iau.edu.sa
ORCID ID: orcid.org/0000-0001-6489-5809

Exercise is prescribed as the first line of treatment for several medical problems in the modern world. Cardiorespiratory fitness/maximal oxygen consumption (VO_{2max}) testing plays a pivotal role in exercise physiology.[1] It helps in developing exercise programs and monitoring the progress of participants in such programs. It apprises people of their current fitness status while comparing it to norms and identifies high-risk individuals. Maximal oxygen consumption is an important physiological variable that is strongly associated with decreasing the risk of developing cardiovascular diseases (CVD).[2] According to an international meta-analysis by Kodama et al,[3] 13% reductions in all-cause mortality and 15% reductions in coronary heart/vascular disease morbidity, can be achieved by just a 12% improvement in VO_{2max}. Given that cardiovascular disease accounts for 37% of all deaths in Kingdom of Saudi Arabia, a readily available measure of VO_{2max} would be very useful in clinical settings.

The gold standard method of measuring VO_{2max} is expired gas analysis during an incremental exercise test to exhaustion using a treadmill or cycle ergometer.[4,5] However, despite the reliability and accuracy of the gas analysis, its use is limited because it requires expensive high-tech equipment and the assistance of trained personnel. This makes it infeasible for use in most clinical/research settings.[6] Moreover, accurately measuring VO_{2max} involves an intense physical effort which certain older or higher-risk individuals may not be able to perform. To address these issues, researchers have generated several non-exercise-based equations using variables for predicting VO_{2max}, such as age, weight, height, body mass index (BMI), body fat percentage, gender, and so forth.[1]

A majority of the VO_{2max} prediction equations have been derived from studies of Western populations.[7-9] Race or ethnicity is a persistent determinant of VO_{2max} due to inter-racial variations in genetically determined race-specific skeletal muscle properties and hemoglobin concentration.[10,11] In addition to race, other variables that may affect VO_{2max} are body composition, nutrition, physical activity, and socioeconomic factors.[12] Owing to this, prediction equations derived from one population may not accurately measure VO_{2max} in other populations. Multiple studies have reported such interracial differences.[13-16] Because of these facts, prediction equations for estimating VO_{2max} derived from the Western population might not accurately reflect the results among Asian Arabs. The objective of the current study was to measure VO_{2max} directly and cross-validate the 3 Caucasian-based internationally published VO_{2max} prediction equations (Jones, Hansen, and Wasserman) in the Saudi female population.[17,18] The female version of these equations was selected.

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Methods. This cross-sectional study was conducted in the Department of Physiology, College of Medicine, Imam Abdulrahman Bin Faisal University, Dammam, Kingdom of Saudi Arabia, between March and May 2017. The sample size was calculated using G*power 3.1 statistical power analysis software version 19 based on the calculation of the effect size to give a power of 95%. The effect size 0.39 was calculated using the mean VO_{2max} value of the null hypothesis (H0: 33.7), the standard deviation (SD: 10.97) (mean VO_{2max} and SD values were taken from the local study).[20] Meanwhile, the mean VO_{2max} value of the alternative hypothesis was (H1: 40). The participants (n=102; age 19-25 years) composed of Saudi young females recruited from various health colleges in Imam Abdulrahman Bin Faisal University in Dammam, Kingdom of Saudi Arabia. Simple random selection was performed using a Microsoft excel sheet. Each student in these colleges was allotted a random value. Later, the values were sorted in ascending order and the required sample was chosen from the top of the list.

The recruitment was carried out via phone. Criteria for inclusion in the study were apparently healthy females, having a normal body mass index (BMI) of 18.50-24.99 (kg/m^{-2}), and sedentary as defined by the international physical activity questionnaire.[21,22] Students with prior history of cardiovascular diseases, respiratory diseases, orthopedic or musculoskeletal lesions, taking any regular medication, lactating, pregnant or smokers were excluded. Prior to testing, written informed consent was obtained from all eligible participants. The research was approved by the Institutional Review Board of the university (IRB approval number: IRB-PGS-2017-01-219). All procedures were performed according to the principles of the Helsinki Declaration.

Height was measured in centimeters (cm) by a stadiometer (Seca, Hamburg, Germany; Model 217) and the body mass was measured in kilograms (kg) by a digital weight scale (Seca, Hamburg, Germany; Model 8813306100327), while the participant wore lightweight clothing and no shoes. Participants were instructed to drink plenty of water and avoid vigorous physical activity one day before testing and to not consume heavy meals or caffeine for 3 hours prior to testing. Maximal oxygen consumption was measured using the COSMED system for cardiopulmonary exercise testing (Quark CPET, COSMED, Rome, Italy; Model C02900-01-04). The system was calibrated in accordance with the manufacturer's instructions. Participants were asked to rest quietly for 5 minutes before resting heart rate (HRrest) was measured using the 3 bipolar leads of electrocardiogram. During the test, all subjects performed a maximal exercise test on a stationary bicycle ergometer using a one-minute incremental test. The height of the seat was adjusted to keep the subject's legs at near full extension during each pedal revolution.[23] The selection of the work rate increment was calculated using the previously published formula.[24] Briefly, the formula were: oxygen uptake (VO_2) unloaded in milliliters per minute= (150+6* body mass in kilograms); peak VO_2 in milliliters per minute (height in centimeters - age in years) *14 for sedentary women; work rate increment per minute in watts equals (peak VO_2 in milliliters per minute-VO_2 unloaded in milliliters per minute)/100.

After a period of rest, the incremental protocol allowed the subject initially to cycle for 3 minutes of unloaded pedaling as a warm-up period. Then, the power output started at 20 Watts and was increasingly incremented by 15 Watts every minute by computer control until the subject was limited by debilitating symptoms despite verbal encouragement. The cycling frequency was maintained at 50 revolutions per minute (rpm) throughout the exercise. Finally, the subjects were asked to continue cycling for 3 minutes without resistance in the recovery period. Time until exhaustion (TTE) was recorded to exclude the subjects who took longer than optimum time (6-12 minutes) for recording VO_{2max}. Subjects were asked about the reason of stopping the exercise test.

The subjects wore a nose clip and breathed through a mouthpiece. Metabolic gases were collected using breath by breath gas analysis system. The participants' heart rate (HR) and blood pressure were monitored every 2 minutes. Ratings of perceived exertion (RPE) score was recorded at the end of each stage. The Borg rating of perceived exertion scale was specifically used. It rates the intensity of the exercise from 6 to 2025 and duration. Respiratory exchange ratio and VO_{2max} was considered valid when at least 2 of the following criteria were met: plateau of oxygen consumption despite an increase in workload; respiratory exchange ratio of ≥1.1; age-predicted maximal heart rate (220- age); and RPE of ≥17.[25]

The plateau of oxygen consumption was determined by the maximum value of VO_2 achieved by the subject as a clear plateau of VO_2 max in the graph of VO_2 versus time was difficult to be obtained from all subjects.

The American College of Sports Medicine (ACSM) Guidelines of indications for terminating exercise testing were followed.[26] Subjects were excluded from the study as they did not reach VO_{2max}. For indirect VO_{2max} calculation, following 3 prediction equations were used: Jones et al,[17] (Jones 2 equations): VO_2 (l/min^{-1})= -2.26+0.025 *height+0.01 *body mass-0.018 *age. Hansen et al,[17] (Hansen/Wasserman equations): VO_2 (l/min^{-1}) = 0.001 *height *(14.783-0.11 *age) + 0.006 *body mass (actual-ideal), age of 30 years was put for adults younger than 30 years; ideal body mass = 0.65 *height-42.8). Wasserman et al,[18] equation: VO_2 (l/min^{-1}) = (body mass + 42.8) *(22.78-0.17 *age)/1000.

In all the aforementioned equations, height was in cm, body mass was in kg and age was in years. The results of the predicted VO_{2max} from these equations were converted from (l/min^{-1}) to (ml/min^{-1}) for comparison with the actual VO_{2max} values.

The Statistical Package for Social Sciences, version 22 (IBM Corp., Armonk, NY, USA) was used to perform the statistical analyses. Testing for normality of distribution was performed by using Shapiro-Wilk test. Mean±SD, minimum and maximum were obtained by descriptive statistics. Paired t-test was used to compare direct VO_{2max} with predicted VO_{2max} obtained by 3 different equations. Pearson correlation test was run to find out the possible correlation between direct VO_{2max} and predicted VO_{2max}. Bland-Altman plots were used to analyze the agreement. For Bland-Altman plots, mean difference between the 2 methods of measurement, namely, the actual and predicted VO_{2max} values and mean of the 2 methods of measurement were calculated.[27]

Results. The selection of study participants as shown in **Figure 1**. **Table 1** provides the baseline characteristics, direct and predicted VO_{2max} values. Approximately 21.6% of the participants were having "very poor" VO_{2max}, whereas 53.92% of participants had "poor" VO_{2max} as per the fitness categories of Heyward (**Table 2**).[28] Differences between VO_{2max} values measured by direct method (27.39±4.06 ml/kg/minute) and each one of the predicted equations, Jones (35.19±2.12 ml/kg/minute), Hansen (33.64±0.24 ml/kg/minute) and Wasserman (35.20±0.17 ml/kg/minute) were statistically significant (**Table 3**). In fact, all 3 predictive equation significantly overestimated the VO_{2max} compared to direct method measured value (**Table 1**).

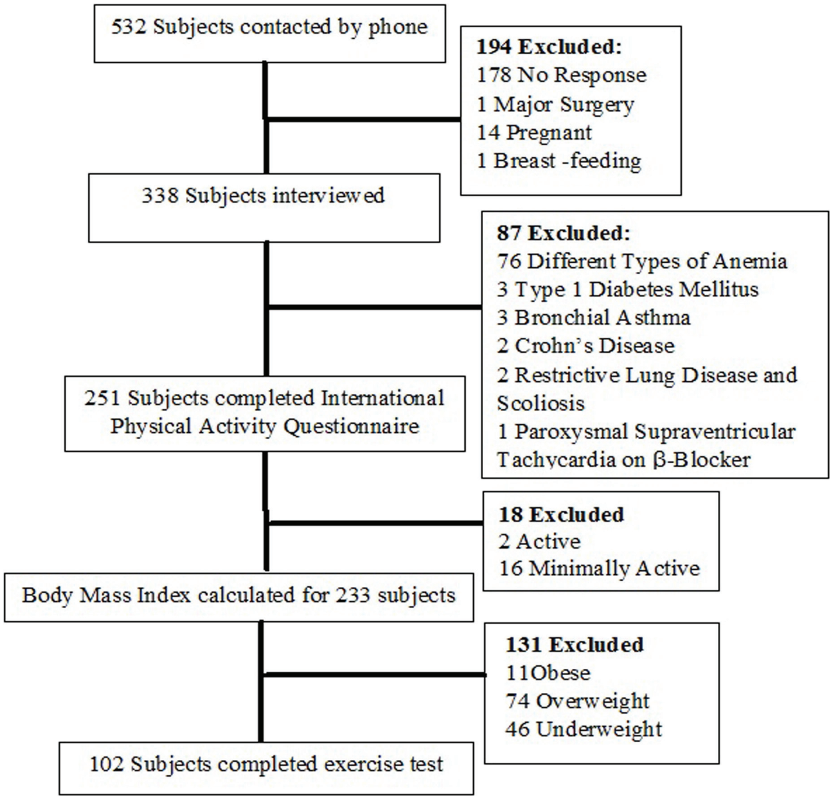

Figure 1 - Selection of 102 participants.

Table 1 - Physical parameters and predicted and measured VO_{2max} values of the 102 participant.

Characteristics	Minimum	Maximum	Mean ± SD
Age (years)	19	25	19.89±1.15
Height (cm)	145.80	172.60	158.03±5.36
Body mass (kg)	41.50	66.20	53.12±5.56
Body mass index (kg.m^{-2})	18.59	24.98	21.24±1.63
Resting heart rate (bpm)	64	126	95.28±13.21
Maximal heart rate (bpm)	157	196	181.45±7.73
Predicted VO_{2max} Jones equation (ml/min/kg)	30.78	39.31	35.19±2.12
Predicted VO_{2max} Hansen equation (ml/min/kg)	28.95	39.49	33.64±0.24
Predicted VO_{2max} Wasserman equation (ml/min/kg)	30.71	39.71	35.20±0.17
Direct VO_{2max} (ml/min/kg)	19.63	38.77	27.39±4.06

bpm - beats per minute, min - minute, VO_{2max} - maximal oxygen consumption

Table 3 shows the *p*-value obtained by paired t-test, mean difference and 95% limits of agreement of all 3 predicted equations.

A lack of correlation between direct VO_{2max} and VO_{2max} calculated by Jones (r=0.006, p>0.05), Hansen (r = 0.164, p>0.05) and Wasserman (r = 0.133, p>0.05) equations as shown in **Table 4**.

Analysis of the data using the Bland and Altman method for limits of agreement between direct VO_{2max} and VO_{2max} predicted by Jones equation revealed that the limits of agreement were 16.73 to -1.15. With Hansen and Wasserman equations, limits of agreement were 14.81 to -2.33 with Hansen equation and 16.01 to -0.41 with Wasserman equation (**Figure 2**).

Table 2 - Classification of the participants' VO_{2max} values based on physical fitness specialist certification manual (Heyward, 1997).[28]

VO_{2max} category (ml/kg^{-1}/min^{-1})	Age (13-19 years)	Age (20-29 years)	n (%)
Very poor	<25.0	<23.6	22 (21.57)
Poor	25.0-30.9	23.6-28.9	55 (53.92)
Fair	31.0-34.9	29.0-32.9	14 (13.73)
Good	35.0-38.9	33.0-36.9	8 (7.84)
Excellent	39.0-41.9	37.0-41.0	3 (2.94)
Superior	>41.9	>41.0	0

VO_{2max} (ml/kg^{-1}/min^{-1}) - maximum oxygen consumption relative to body weight

Table 3 - Comparison between direct VO_{2max} and predicted VO_{2max}.

VO_{2max} values (ml/min/kg)	*P*-value	Mean difference (Mean±SD)	95% limits of agreement
Direct VO_{2max} vs predicted VO_{2max} Jones equation	0.00	7.79±6.90	16.73--1.15
Direct VO_{2max} vs predicted VO_{2max} Hansen equation	0.00	6.24±4.37	14.81--2.33
Direct VO_{2max} vs predicted VO_{2max} Wasserman equation	0.00	7.80±4.19	16.01--0.41

VO_{2max} - maximal oxygen consumption

Table 4 - Pearson coefficient correlation.

VO_{2max} categories (ml/min/kg)	Pearson correlation (r)	*P*-value
Direct VO_{2max} vs predicted VO_{2max} Jones equation	0.006	0.95
Direct VO_{2max} vs predicted VO_{2max} Hansen equation	0.164	1
Direct VO_{2max} vs predicted VO_{2max} Wasserman equation	0.133	0.18

VO_{2max} - maximal oxygen consumption

Discussion. The objective of the current study was to determine reference values for VO_{2max} by direct method and to cross-validate equations by Jones, Hansen, and Wasserman for prediction of VO_{2max} in the young Saudi female population. The VO_{2max} values of our study participants, obtained by the direct method, are comparatively lower than those of other populations. In a study involving young, healthy, British females, VO_{2max} was 39.8±7.2 ml/kg^{-1}/min^{-1}, much higher than our values.[29] In another study, involving Spanish sedentary nursing college students, VO_{2max} was higher than ours (33.3±7.1 ml/kg^{-1}/min^{-1}).[30] The Fitness Registry and the Importance of Exercise National Database (FRIEND) registry reference data of VO_{2max} for a healthy young US female population revealed VO_{2max} values of 30.8±9.4 ml/kg^{-1}/min^{-1}.[24] Souza e Silva et al,[31] measured VO_{2max} in 101 females with a mean age of 28.5± 5 years and a normal mean BMI. The value of their VO_{2max} was 29.9±7.3 ml/kg^{-1}/min^{-1}. Neder et al,[32] studied the VO_{2max} of 20 sedentary female subjects and found it to be 1679±228 ml/min^{-1} in contrast to 1449.10±233.92 ml/min^{-1} in our study. The higher values of VO_{2max} in these populations could be justified by the genetic variations or due to higher levels of physical fitness.

As evident from **Table 3**, compared to directly measured V_{O2max}; the 3 predicted equations overestimated VO_{2max}, with a mean difference of 7.79 (Jones), 6.24 (Hansen), and 7.80 (Wasserman) (ml/min/kg). Hence, our study demonstrated that none of the predicted equations can be applied for use with the studied population (young Arab females). In addition, there is a lack of correlation between the direct VO_{2max} and the VO_{2max} that these equations predict. Limits of agreement analysis suggested no agreement of actual VO_{2max} with any of the predicted equations. Hence, we suggest caution in indirect measurement of VO_{2max} by the Jones, Hansen, and Wasserman equations in the Arab population. Our results are in accordance with Ahmadian et al,[33] who reported significantly increased predicted VO_{2max} values derived from these 3 equations (Wasserman, Jones, and Hansen) as compared to direct VO_{2max} in symptomatic patients who underwent cardiopulmonary exercise testing. Likewise, Almedia et al,[34] demonstrated a significantly increased (p=0.001) predicted VO_{2max} in a Brazilian population by the Jones equation and the Wasserman algorithm compared to direct VO_{2max}. Although Almedia et al,[34] linked this overestimation to variations in the experimental protocol, namely, the use of a cycle ergometer while deriving the equations versus the use of a treadmill while performing the comparison, this justification is less likely in our study, as we used a cycle ergometer for our research.

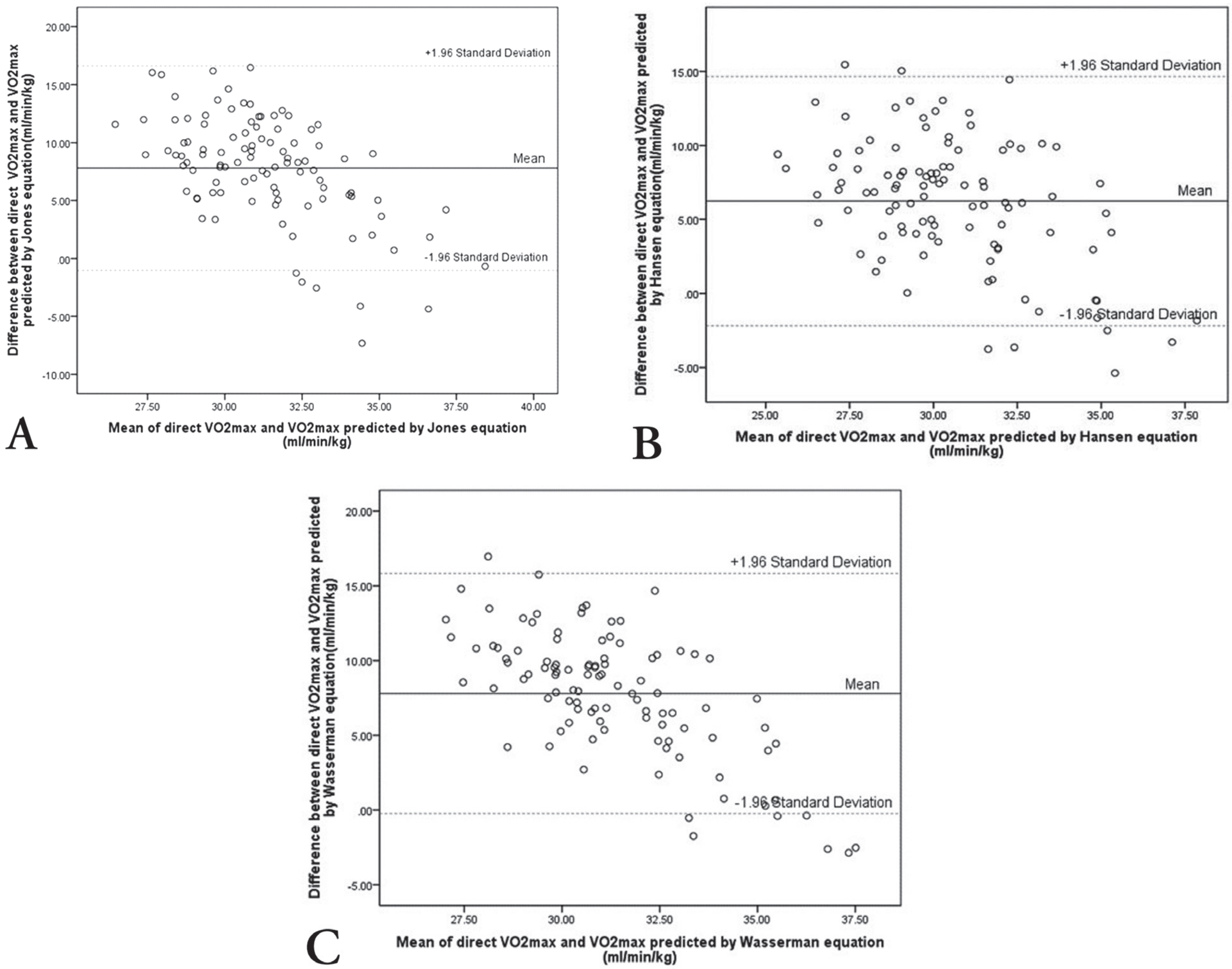

Figure 2 - Bland-altman plot showing the difference between actual VO_{2max} and VO_{2max} predicted by **A**) Jones, **B**) Hansen, and **C**) Wasserman equations.

Our results agree to Debeaumont et al,[16] who found predicted VO_{2max} through Wasserman et al,[18] equation as valid and correlated to actual VO_{2max} in French obese women with metabolic syndrome; however, the accuracy was low on Bland-Altman analysis. That led them to develop a new prediction equation adapted specifically for their studied population. Likewise, Racil et al,[35] compared predicted VO_{2max} obtained through Wasserman et al's,[18] and Debeaumont et al's,[16] equations to actual VO_{2max} in obese women and found predicted VO_{2max} by Wasserman equation significantly differed from actual VO_{2max}. Similarly, Scott et al,[36] compared 3 prediction equations (Scott et al,[36] and 2 commonly used FitnessGramTM equations) with actual VO_{2max} in children and reported that both FitnessGram^{TM} equations significantly underestimated the VO_{2max}.

Several factors, such as ethnicity, genetics, habits, body composition, and physical activity, vary from population to population. Predicted equations derived from one population and cross-validated in the same may not provide an accurate VO_{2max} in another population.[1,8] Hence, either these equations should be modified, or new equations should be derived in other ethnic populations. Thus, our study supports the development and validation of population-specific prediction equations for the estimation of VO_{2max} in the Saudi population.

Study limitations. The present study has some strengths. A key strength was that the VO_{2max} was measured directly, which is the gold standard test for cardiopulmonary fitness. Also, the study has cross-validated prediction equations in the Saudi population.

Because VO_{2max} changes with gender, increasing age, and degree of physical activity, we limited our study to females who were sedentary and aged 18-25 years, thereby eliminating these confounding variables. However, one limitation was that all our subjects were females, and recruited from a single university. Therefore, our findings cannot be generalized.

In conclusion, our results indicate that young Saudi females may have poor cardiorespiratory fitness. Probably, there is a need to develop a new equation or to modify the previous equations for the prediction of VO_{2max} in the Saudi population so that accurate measurements of VO_{2max} can be obtained, resulting in a reduced mean bias, a narrower limit of agreement, and a significant correlation with direct VO_{2max}. We suggest further research to be undertaken with a greater number of participants and wider age ranges.

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References

1. American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th ed. Philadelphia (PA): Lippincott Williams & Wilkins; 2010.
2. Gupta S, Rohatgi A, Ayers CR, Willis BL, Haskell WL, Khera A, et al. Cardiorespiratory fitness and classification of risk of cardiovascular disease mortality. ***Circulation*** 2011; 123: 1377-1383.
3. World Health Organization. Saudi Arabia [Internet]. WHO; 2016 [Accessed 04 January 2019]. Available from: https://www.who.int/nmh/countries/sau_en.pdf
4. Fletcher GF, Ades PA, Kligfield P, Arena R, Balady GJ, Bittner VA, et al. Exercise standards for testing and training: a scientific statement from the American Heart Association. ***Circulation*** 2013; 128: 873-934.
5. Aguilaniu B, Wallaert B. [From interpretation of cardiopulmonary exercise testing to medical decision]. ***Rev Mal Respir*** 2013; 30: 498-515. French
6. Coquart J, Tabben M, Farooq A, Tourny C, Eston R. Submaximal, perceptually regulated exercise testing predicts maximal oxygen uptake: A meta-analysis study. ***Sports Med*** 2016; 46: 885-897.
7. Jones NL, Makrides L, Hitchcock C, Chypchar T, McCartney N. Normal standards for an incremental progressive cycle ergometer test. ***Am Rev Respir Dis*** 1985; 131: 700-708.
8. Wasserman K, Hansen JE, Sue DY, Stringer WW, Whipp BJ. Principles exercise testing and interpretation. 4th ed. Philadelphia (PA): Lippincott Williams & Wilkins; 2005. p. 80-81, 160-167.
9. Hansen JE, Sue DY, Wasserman K. Predicted values for clinical exercise testing. ***Am Rev Respir Dis*** 1984; 129: S49-S55.
10. Suminski RR, Mattern CO, Devor ST. Influence of racial origin and skeletal muscle properties on disease prevalence and physical performance. ***Sports Med*** 2002; 32: 667-673.
11. Pivarnik JM, Bray MS, Hergenroeder AC, Hill RB, Wong WW. Ethnicity affects aerobic fitness in US adolescent girls. ***Med Sci Sports Exerc*** 1995; 27: 1635-1638.
12. McArdle WD, Frank IK, editors. Essentials of Exercise Physiology. Vol 1. 3rd ed. Philadelphia (PA): Lippincott Williams & Wilkins; 2005.
13. Fulambarker A, Copur AS, Javeri A, Jere S, Cohen ME. Reference values for pulmonary function in Asian Indians living in the United States. ***Chest*** 2004; 126: 1225-1233.
14. Ernesto C, Martins da Silva FM, Pereira LA, de Melo GF. Cross validation of different equations to predict aerobic fitness by the shuttle run 20 meters test in Brazilian students. ***Journal of Exercise Physiology Online*** 2015; 18: 46-55.
15. John N, Thangakunam B, Devasahayam AJ, Peravali V, Christopher DJ. Maximal oxygen uptake is lower for a healthy Indian population compared to white populations. ***J Cardiopulm Rehabil Prev*** 2011; 31: 322-327.
16. Debeaumont D, Tardif C, Folope V, Castres I, Lemaitre F, Tourny C, et al. A specific prediction equation is necessary to estimate peak oxygen uptake in obese patients with metabolic syndrome. ***J Endocrinol Invest*** 2016; 39: 635-642.
17. Wasserman K, Hansen JE, Sue DY, Stringer WW, Sietsema KE, Sun XG, et al. Principles of Exercise Testing and Interpretation: Including Pathophysiology and Clinical Applications. 5th ed. Wolters Kluwer/Lippincott Williams & Wilkins Health; 2011. p. 592.
18. Wasserman K, Hansen JE, Sue DY, Casaburi R, Whipp BJ. Principles of Exercise Testing and Interpretation: Including Pathophysiology and Clinical Applications. 3rd ed. Philadelphia (PA): Lippincott Williams & Wilkins; 1999.
19. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. ***Behav Res Methods*** 2009; 41: 1149-1160.
20. Al-Asoom LI. Is cardiopulmonary fitness level a risk factor in young Saudi females? [Internet]. [Updated 2015; Accessed 04 January 2019]. Available from: http://webcache.googleusercontent.com/search?q=cache:ajsRYzuVsdIJ:www.jkaumedsci.org.sa/index.php/jkaumedsci/article/download/447/449+&cd=1&hl=ar&ct=clnk&gl=sa&client=firefox-b-d
21. World Health Organization. WHO Technical Report Series 894. Obesity: preventing and managing the global epidemic. Geneva (CH): WHO. Available from: https://www.who.int/nutrition/publications/obesity/WHO_TRS_894/en/
22. International physical activity questionnaire [Internet]. IPAQ; 2002 [Accessed 2019 January 4]. Available from: https://sites.google.com/site/theipaq/home
23. Balady GJ, Arena R, Sietsema K, Myers J, Coke L, Fletcher GF, et al. Clinician's guide to cardiopulmonary exercise testing in adults: a scientific statement from the American Heart Association. ***Circulation*** 2010; 122: 191-225.
24. Kaminsky LA, Imboden MT, Arena R, Myers J. Reference standards for cardiorespiratory fitness measured with cardiopulmonary exercise testing using cycle ergometry: Data from the fitness registry and the importance of exercise national database (FRIEND) registry. ***Mayo Clin Proc*** 2017; 92: 228-233.
25. Sharma M, Kamal RB, Chawla K. Correlation of body composition to aerobic capacity. A cross sectional study. ***Indian Journal of Applied Research*** 2016; 2: 38-42.

26. ACSM. ACSM's Guidelines for Exercise Testing and Prescription. 9th ed. Philadelphia (PA): Wolters Kluwer/ Lippincott Williams & Wilkins Health; 2014. p. 480.
27. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. ***Lancet*** 1986; 1: 307-310.
28. Heyward VH. Advanced Fitness Assessment & Exercise Prescription. 3rd ed. Human Kinetics Pub; 1997. p. 322.
29. Orr JL, Williamson P, Anderson W, Ross R, McCafferty S, Fettes P. Cardiopulmonary exercise testing: arm crank vs cycle ergometry. ***Anaesthesia*** 2013; 68: 497-501.
30. Irazusta A, Gil S, Ruiz F, Gondra J, Jauregi A, Irazusta J, et al. Exercise, physical fitness, and dietary habits of first-year female nursing students. ***Biol Res Nurs*** 2006; 7: 175-186.
31. Souza e Silva CG, Araújo CG. Sex-specific equations to estimate maximum oxygen uptake in cycle ergometry. ***Arq Bras Cardiol*** 2015; 105: 381-389.
32. Neder JA, Nery LE, Peres C, Whipp BJ. Reference values for dynamic responses to incremental cycle ergometry in males and females aged 20 to 80. ***Am J Respir Crit Care Med*** 2001; 164: 1481-1486.
33. Ahmadian HR, Sclafani JJ, Emmons EE, Morris MJ, Leclerc KM, Slim AM. Comparison of predicted exercise capacity equations and the effect of actual versus ideal body weight among subjects undergoing cardiopulmonary exercise testing. ***Cardiol Res Pract*** 2013; 2013: 940170.
34. Almeida AE, Stefani Cde M, Nascimento JA, Almeida NM, Santos Ada C, Ribeiro JP, et al. An equation for the prediction of oxygen consumption in a Brazilian population. ***Arq Bras Cardiol*** 2014; 103: 299-307.
35. Racil G, Lemaire C, Dubart AE, Debeaumont D, Castres I, Coquart JB. Comparison of specific prediction equations to estimate peak oxygen uptake in obese women. ***Int J Sports Med*** 2017; 38: 541-545.
36. Scott SN, Springer CM, Oody JF, McClanahan MS, Wiseman BD, Kybartas TJ, et al. Development and validation of a PACER prediction equation for VO_2peak in 10- to 15-year-old youth. ***Pediatr Exerc Sci*** 2019; 31: 223-228.