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Validation of nonexercise equation using international physical activity questionnaire to predict VO_{2max} in Indian adults

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Abstract. The addition of important covariates with known associations with cardiorespiratory fitness (CRF) and/or physical activity (PA) is common in the development of VO_{2max} estimation equations that incorporate measures of PA. The purpose of this study was to validate the nonexercise equation using International Physical Activity Questionnaire – short form (IPAQ – S) to calculate VO_{2max} in Indian adults. *Material and Methods*. Seventy participants (38 males and 32 females), aged 18 – 35yrs. successfully completed a maximal graded exercise test (GXT) to assess VO_{2max}. The nonexercise data includes the participant's age, gender, total and vigorous physical activity using (IPAQ – S). *Results*. The VO_{2max} obtained by nonexercise equation using IPAQ-S was significantly associated with recorded VO_{2max} in both males (R = 0.476, SEE = 0.5 ml.kg^{-1}.min^{-1}, $\%SEE$ = 1.08) and females (R = 0.314, SEE = 0.522 ml.kg^{-1}.min^{-1}, $\%SEE$ = 1.36). *Conclusion*. This study supports nonexercise equation using IPAQ-S scores that yields relatively accurate results and is a convenient way to predict VO_{2max} in Indian adults.
Key words: *cardio-respiratory fitness, exercise testing, nonexercise equation, VO_{2max}.*

Introduction

The ability to perform large muscle, dynamic, moderate-to-high intensity exercise for prolonged periods is related to cardio-respiratory fitness (CRF). Performance of such exercise is dependent on the functional state of the respiratory, cardiovascular, and skeletal muscle systems. The criterion measure of cardio respiratory fitness is maximal oxygen uptake (VO_{2max}) of a person (1). Hooker et al. (2008) & Sui et al. (2008) in their studies reported that low level of cardio respiratory fitness represented by poor maximal oxygen uptake, was a predictor for diseases such as hypertension, stroke, type 2 diabetes and metabolic syndrome (2,3,4). Other studies reported that mortality from cardiovascular disease and all causes of mortality was associated with cardio respiratory fitness (5,6,7).

The standard test for determining CRF is the measurement of maximal oxygen uptake (VO_{2max}) during the performance of a maximal graded exercise test is the standard test for determining CRF (8). VO_{2max} can be assessed with direct or indirect procedures (9-11). Direct measures provide the most precise assessment of CRF and are obtained by ventilatory gas analysis at maximal exertion during a graded exercise ergometry test (8-10). Indirect methods estimate VO_{2max} from maximal exercise duration, the peak workload and/or heart rate (HR) responses achieved during submaximal or maximal exercise ergometry, or the amount of time required to walk, jog, or run a specified distance (8,11). However, for assessing CRF by both direct and indirect methods, may be difficult and impractical for regular use in most settings.

However, a convenient estimate of CRF can be obtained by nonexercise regression equations without the need to perform a maximal or submaximal exercise test. For large groups this approach is inexpensive, time efficient, and realistic. Similar standards of error as compared to submaximal exercise testing have been demonstrated by estimates of VO_{2max} derived from regression equations that incorporate various measures of self-reported physical activity (12-18).

To date, nonexercise predictor variables include age, gender, body mass index (BMI), percent body fat, physical activity rating (PA-R) (16,17), perceived functional ability (PFA) (13,15), body surface area (BSA)

(20,21) and health related physical activity by IPAQ (22-24). But the validity of the test should be established in Indian population, before applying any indirect protocol for the prediction of VO_{2max}. The above mentioned prediction equation have been developed and validated in Caucasian populations. Recent evidences have indicated that racial differences may exist in body composition and physical activity levels. Geissler & Aldouri (1985) found that the energy cost of each activity, lying, sitting and standing, was significantly higher, by 10-17%, in Europeans as compared to Asians and these differences in energy requirements do exist due to body size and activity (25). Wang et al. (1994) indicated that BMI for given weight under predicts the percentage body fat in Asian Indians (26). Elaine et al. (2004) indicated that for the same BMI, %BF for Pacific Island men was 4% points lower and for Asian Indian men was 7–8% points higher compared to Europeans (27). Compared to European men for the same %BF, BMI was 2–3 units higher for Pacific Island and 3–6 units lower for Asian Indian. Asian Indians have more abdominal fat deposition than their European and Pacific Island counterparts (27). Kanade, Gokhale and Rao (2001) found that energy costs of activities were associated with body composition, especially with absolute fat-free mass, which may vary even with the same body fat percentage (28). Considering the fact that most of the equations use either BMI , % Body fat, percieved functional ability or physical activity levels in their formation, we believe that the accuracy of these nonexercise models using anthropometric data of BMI or % Body fat and physical activity levels may be questionable in the Asian Indian population. Therefore, there is a need to validate separate prediction equations for different communities.
Thus this study was designed with the broad objective of testing VO_{2max} obtained by a selection of Non-Exercise equation given by Schembre (2011) [Estimated VO2max = 47.749 − [6.493 × Gender] + [0.140 × (Vigorous Activity)$^{1/2}$, males = 1 and females = 2] with the gold standard treadmill test. It was anticipated that this study would validate the above non exercise based equation with reference to Bruce Treadmill Test to calculate VO_{2max} in Indian adults. We further wish to evaluate how well the nonexercise predictor variables (IPAQ-S) estimate VO_{2max} in Indian adults.

Material and Method

Subjects. In accordance with University ethical Committee guidelines, seventy participants (38 males and 32 females), and aged 18 – 35yrs actively participated in this study. Participants were recruited mainly from the Amritsar, Punjab. All participants completed and signed an informed consent document. Prior to testing, all subjects completed brief Physical Activity Readiness Questionnaire (PAR-Q) to screen for cardiovascular contraindications.
Test Procedures. Subjects were weighed in minimal lightweight clothing, bare foot, using standard weighing machine. Stadiometer was used for measuring standing height, subjects were asked to stand bare foot on horizontal surface. Heel touched the ground, counter board of stadiometer was brought down till it touches the vertex .The height of subjects was recorded. Body mass index (BMI) was calculated from height and weight as follows: BMI = weight (kg)/height^2 (m^2).
Physical Activity (PA) was assessed using the IPAQ-Short Form (IPAQ-S) (29). Continuous IPAQ-S outcomes of Walking, Moderate Activity, and Vigorous Activity were calculated by the following IPAQ scoring protocol and reported in units of MET min·week-1: Walking = (3.3 × Walking minutes × Walking days); Moderate Activity = (4.0 × Moderate activity minutes × Moderate activity days); Vigorous Activity = (8.0 × Vigorous activity minutes × Vigorous activity days) (30). All participants completed a maximal GXT to determine VO_{2max}. Participants were instructed to drink plenty of water and refrain from strenuous exercise for 24h prior to testing, and not to consume food, alcohol, caffeine, or tobacco products three hours before testing. Each participant was fitted with a HR monitor (Polar Inc., NY) to measure exercise HR during the maximal GXT on a calibrated motor driven treadmill (vacuumed vista). Instructions about the maximal GXT (involving the protocol, electronic heart rate monitor, mouth piece, and rating of perceived exertion (RPE) scale (Borg, 1982) were given to all participants prior to testing (31). And we also allowed subjects to practice treadmill walking/jogging if needed before actual testing.
Protocol. Participants performed a maximal GXT using Bruce graded GXT protocol. This test consists of seven, three minute stages in which participants exercise to the point of volitional fatigue. The Bruce protocol starts with participants walking 1.7 mph at a 10% grade and imposes large increments in the metabolic cost of exercise throughout test with each 3 min stage. At every three minute intervals the inclination of the treadmill increases by 2%, and the speed increases as shown in the table below.

Walk
Stage 1 = 1.7 mph at 10% Grade
Stage 2 = 2.5 mph at 12% Grade
Jog/walk
Stage 3 = 3.4 mph at 14% Grade
Stage 4 = 4.2 mph at 16% Grade
Run
Stage 5 = 5.0 mph at 18% Grade
Stage 6 = 5.5 mph at 20% Grade
Stage 7 = 6.0 mph at 22% Grade
Recovery
00-02 min 2.5 Speed slope 12

During the maximal GXT, metabolic gases were collected using the VACUUMED VISTA MX metabolic measurement system (USA). The VO_{2max} and respiratory exchange ratio (RER) were computed, averaged, and printed by an online computer system every 15 seconds.
The participants' exercise heart rate (HR) and RPE score was recorded at the end of each stage. VO_{2max} was considered valid when at least two of the following three criteria were met (33-36): maximal heart rate within 15 beats of age predicted maximal heart rate, respiratory exchange ratio equal to or greater than 1.10, plateau in VO2 despite an increase in work load, RPE equal to or greater than 17, the subject has reached volitional fatigue (the subject terminates the test). Participants who failed to meet at least two of these criteria were dropped from the study.
Statistical Analysis. The statistical calculations were carried out by using Statistical Package for the Social Sciences 16™ (SPSS, USA), Microsoft Excel™ for Windows 7™ (USA) (75). Descriptive statistics was used with mean ± standard deviation (*SD*). We conducted a correlation analysis in which we examined the associations between the equation-predicted VO_{2max} and the VO_{2max} obatined by maximal graded exercise testing. Also, the associations between parameters of the International Physical Activity Questionnaire and recorded VO_{2max} was examined using correlation analysis and scatter plot. The predictive accuracy of the equation-predicted VO_2max was evaluated by computing correlation coefficients (R values), significance level (p), standard error of estimation (*SEE*) and % of standard error of estimation (%*SEE*).

Results

A total of 70 healthy adult males (n=38) and females (n =32) volunteered and completed this study. Descriptive statistics for the total sample and specific age groups are presented in Table I.

Table 1. Descriptive statistics and physiological parameters of total participants in the study

	N	Minimum	Maximum	Mean	Std. Deviation
Age(years)	70	18	35	25.6	3.861
Ht.(cm)	70	150	185	165.285	8.061
Wt.(kg)	70	43	82.6	64.725	8.843
BMI(kg/m2)	70	16.49	26.73	23.165	2.119
Vigorous Activity	70	0	2880	1044	604.520
Total physical Activity (METS/week)	70	2184	6088	3464.507	744.256

N = number of subjects

The age of the sample ranged from 18 to 35yrs (mean 25.6 ± 3.86yrs). Participant's height, weight and BMI ranged from 150 to 185cm, 43 to 82.6kg and 16.49 to 26.73$kg.m^{-2}$, respectively.
Participant's vigorous activity scores ranged from 0 to 2880 $MET.mins.week^{-1}$. This indicated that participants with a wide range of physical activity were included in the study. The study was comprised of participants ranging in there fitness level from moderate to high with mean total physical activity of 3464.50 (± 744.25) $METS.mins.week^{-1}$.
Table II shows that all subjects achieved a valid VO_{2max} during the maximal GXT with the mean (± *SD*) of 42.45(±5.75) $ml.kg^{-1}.min^{-1}$. The VO_{2max} obtained by using IPAQ scores is most closely correlated with the recorded VO_{2max} and significantly associated ($p < 0.0001$).

Table 2. Mean and Standard Deviation of recorded VO_{2max} and that obtained by using Non-Ex prediction equation in total Subjects

N = 70	**Recorded VO_{2max}**	**IPAQ**
Mean	42.452	42.42
Standard Deviation	5.575	3.781
Correlation coefficient	*R*	0.736
Significance level	*P*	<0.001
Standard Error of Estimation (SEE)	*SEE* ($ml^{-1}.kg^{-1}.min^{-1)}$)	0.032
% Standard Error of Estimation	*%SEE*	0.08

N = number of subjects

Table III shows that in males, the VO_{2max} obtained by using IPAQ scores, is significantly correlated with Recorded VO_{2max} ($p < 0.01$). In females, the VO_{2max} obtained by using IPAQ scores is significantly correlated with Recorded VO_{2max} ($p < 0.05$) but less significant as compared to that in males.

Table 3. Mean and Standard Deviation of recorded VO_{2max} and that obtained by using Non-Ex Prediction equation in males and females

N = 38 *N* = 32	M F	Recorded VO_{2max}	IPAQ
Mean	M F	45.955 38.293	45.455 38.815
Standard Deviation	M F	3.656 4.511	1.685 1.933
Correlation coefficient	M F	*R*	0.476 0.314
Significance level	M F	*p*	<0.01* <0.05*
Standard Error of Estimation	M F	*SEE* ($ml^{-1}.kg^{-1}.min^{-1)}$)	0.5* 0.522*
% Standard Error of Estimation	M F	*%SEE*	1.08* 1.36*

N - number of subjects, Males – M, Females – F, * shows significant values.

Discussion

Cardio respiratory fitness (CRF) testing is costly, time consuming and can necessitate some risk. These factors are prohibitive to routine clinical assessments of CRF and preclude use in larger population samples, in spite of the importance of CRF to numerous health outcomes (1). The purpose of this study was to evaluate and validate prediction equation to estimate CRF using IPAQ-S as the measure of physical activity in young men and women with varied fitness levels in Indian population. The prediction equation used was age and gender generalized. The equation is not validated in Indian population hence there was a need to validate this equation to predict VO_{2max} in Indian Adults.

The most compelling finding in this study was the statistically significant contribution of the IPAQ scores in predicting VO_{2max} (*%SEE* = 0.08).The measure of physical activity calculated by using IPAQ-S has been most consistently associated with VO_{2max} (24). Associations between CRF and PA assessed by the IPAQ-S in multiple populations have been reported in several studies (22,24,38-42) (Table II).

The addition of important covariates with known associations with CRF and/or PA is common in the development of VO_{2max} estimation equations that incorporate measures of PA. Most often variables such as gender, age, height, weight, BSA and/or BMI are added to the model to improve the accuracy of the equation. When there is a significant amount of variation in the population characteristics it is most appropriate to include such variables. This study included a relatively homogeneous subsample of healthy males and females; therefore, fewer covariates were anticipated to contribute to the explanation of VO_{2max}. As expected, the most significant covariate, namely gender, had a strong independent association with measured VO_{2max} ($R = 0.603$).

The results of this study indicated that men had higher values for VO_{2max} obtained by maximal graded exercise testing than women. Studies have suggested that, along with the body composition differences (muscle mass), the smaller stroke volume and lower post pubertal hemoglobin concentration of females contribute to lower maximal aerobic power (43,44). It is also likely that females are less active than their male counterparts, resulting in lower peak VO_{2max} (45-47). The VO_{2max} obtained by nonexercise estimation equation used in this study also showed similar results (Table III).

The VO_{2max} obtained by using equation derived by IPAQ-S had $\%SEE = 1.08$ in males and had $\%SEE = 1.36$ in females. There are however, limitations involved in the self reporting of physical activity. Generally individuals tend to overestimate their physical activity level. (Table III).

Therefore, the VO_{2max} acquired by using IPAQ–S was considerably significant method of predicting VO_{2max} in both male and female Indian adults. As good as other established self-reported physical activity levels, the IPAQ instruments have acceptable measurement properties. IPAQ has reasonable measurement properties for monitoring levels of physical activity among population of 18 to 65yrs old adults in diverse settings. The short IPAQ form "last 7 day recall" is recommended for national monitoring (22). It represented that people with moderate physical activity i.e. ranging from 600 to 1500 METS/week are fit with VO_{2max} ranging between 40 – 50 ml/kg/min. The non-exercise equation derived by Schembre (2011) is strengthened by use of the IPAQ, which is the most widely used and well validated measure of physical activity to be used at the level of population.

On the grounds of this reason, physical activity on daily basis should be considered as components linked with maximal oxygen uptake, and be comprehended in the non-exercise equation for estimating VO_{2max}. The accession of nonexercise questionnaires added on the accuracy of VO_{2max} measurement and was an informative instrument used to shape participants' physical activity and exercise intensity levels. Also, Hirai et al. (2006) suggested that the physical workload might contribute to the increase in maximal oxygen uptake and Park et al. (2001) reported that physical activities such as walking and ascending stairs were significantly associated with maximal oxygen uptake (48,49). Also, leisure time physical activity such as exercise is well known to be associated with maximal oxygen uptake (50,51). This study was done in moderately active adults with age group of 18 to 35 yrs. Down the line further validation of the nonexercise equation using the IPAQ in comparable populations and further advancement of alternative population characteristics in VO_{2max} prediction equations are warranted.

Conclusion

The present study concluded that non-exercise regression equation using gender and scores of IPAQ-S can estimate VO_{2max} of an individual with approximate precision in comparison with other exercise models in Indian adults. This research validates that use of nonexercise equation comprising IPAQ scores can be used to evaluate VO_{2max} in sample of Indian adults.

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