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ORIGINAL SCIENTIFIC PAPER

Predicting Maximal Aerobic Capacity based on Self-Reported Physical Activity Levels among Adolescents

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Abstract

Growing evidence has indicated a positive association between physical activity and cardiorespiratory fitness (i.e., maximal aerobic capacity or VO_2 max). Limited evidence, however, is available among adolescents. This research aimed to predict VO_2 max based on the physical activity level and estimate the discriminant capacity of the physical activity levels on the VO_2 max status among adolescents. This research was a cross-sectional study in 141 adolescents (age 19±1 year old, 83% male). The VO_2 max was assessed using the 1-mile run test. Physical activity was measured using the International Physical activity Questionnaire-Long Form. Multiple linear regression was conducted to predict the VO_2 max using physical activity level data (in metabolic equivalent of tasks (Mets/week), sex, and body mass index (BMI). The discriminant capacity of the total and domain-specific physical activity in discriminating high and low VO_2 max was estimated with the area under the curve (AUC). The Youden Index determined cut-off points, sensitivity, and specificity. Multiple regression analysis revealed a significant predicting equation of VO_2 based on total physical activities, BMI, and sex. The equation explained a significant proportion of VO_2 max variances. The total and domain-specific physical activity significantly discriminated low and high VO_2 max status, while the highest AUC was based on total physical activity, followed by other physical activity domains. A cut-off of total physical activity levels for predicting the VO_2 max was successfully generated, with high sensitivity and specificity. Adequate evidence, thus, supports the prediction of VO_2 max based on self-reported physical activity levels among adolescents..

Keywords: *physical activity, cardiorespiratory fitness, equation*

Introduction

Physical activity levels and cardiovascular fitness are useful diagnostic and prognostic health indicators in clinical settings (Arovah & Heesch, 2021; Myers et al., 2021), including adolescents (Raghuveer et al., 2020). Cardiorespiratory fitness is also a significant predictor of aerobic performance; thus, it is important in talent scouting, athletic training programming, and evaluation (Manari et al., 2016). Therefore, routine physical activity and cardiorespiratory fitness assessments among adolescents are recommended in clinical and population settings.

The standard assessments of cardiorespiratory fitness, usually measured as maximal oxygen capacity (VO2 max), involve direct and indirect measurements. However, both maximal and submaximal tests require in-person assessment and are relatively time-consuming, cost-prohibitive, and impractical in many settings (Schembre & Riebe, 2011). Therefore, non-exercise regression equations were developed. The non-exercise-based equation for VO_2 max estimation also includes variables such as physical activity levels because most of the variability in cardiorespiratory fitness is determined by genetics

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and environmental factors; it is largely influenced by physical activity levels (Ottevaere et al., 2011; Schembre & Riebe, 2011; Taylor et al., 2018).

The gold standard for measuring physical activity level is using objective physical activity assessment involving instruments which include motion sensors and calorimetry. However, self-rated physical activity reports are increasingly used because it is more practical and inexpensive. Thus, it is often more feasible in a large-scale population. The self-report physical activity assessment can be carried out using various instruments, including the International Physical Activity Questionnaire (IPAQ), which measures sedentary times (Lee et al., 2011; Lepp et al., 2013).

The IPAQ-Short Form (IPAQ-SF) has been used to predict VO_2 max among adults with a range of fitness levels (Schembre & Riebe, 2011). The regression equation based on the IPAQ-SF explained 43% of the variance in measured VO_2 max. Based on a 20% standard error, the estimated VO_2 max based on the submaximal test fell within acceptable error limits for 87% of individuals (Schembre & Riebe, 2011). However, research shows that it is more difficult to predict the relationship between physical activities and cardiorespiratory fitness among children and adolescents because their physical activity tends to be less systematic and consistent (Morrow Jr et al., 2013). The use of diverse methods of evaluating physical activity and cardiorespiratory fitness might also contribute to inconsistency in these estimates. More research, therefore, is required to develop regression estimation equations of physical activity levels to predict cardiovascular fitness in a specific population, including adolescents, using well-established physical activity assessments.

The development of the equation for predicting VO_2 max based on self-reported physical activity is expected to reduce the need for VO_2 max assessments that generally requires more resources. While, IPAQ-SF has been used to predict VO_2 max, no attempt has been made to develop the estimation equations using the IPAQ long format (IPAQ-LF), which is one of the most highly validated and utilized physical activity questionnaires (Kim et al., 2013). Moreover, IPAQ-LF provides domain-specific physical activity (i.e., work-related, recreational-based, transport-related, or household-related), which is not available in IPAQ-SF. Therefore, the development of the estimation equation using the IPAQ-LF allows exploration of the capacity of each domain-specific physical activity level to predict VO_2 max and estimate the cut-off of the levels for discriminating between low and high VO_2. This study, therefore, aimed to develop a regression equation for predicting VO_2 max based on the self-reported physical activity level using the IPAQ-LF and to estimate the discriminant capacity of the physical activity levels in differentiating VO_2 max status among adolescents. The successful demonstration of the validity and accuracy of the equation is expected to justify its use in large population-based studies involving adolescents for assessing cardiorespiratory fitness for health evaluation, talent scouting, or athletic training programming and evaluation purposes.

Method

Research Design, Subject, and Setting

This research was a cross-sectional observational study on 141 students enrolling in a sports science faculty in Indonesia in September 2019. The researcher conducted all the measurements at the faculty site with a team of experienced faculty officers. All participants were provided with informed consent, and the study protocol was approved by the Human Ethics Committee of Gadjah Mada University (Approval No. KE/0142/02/2019).

Instruments and Scoring

The maximum oxygen capacity (VO_2 max) was measured using a 1-mile run test. The test was conducted on a 1.6 km flat running course (4x400 m track). A group of participants (up to 10 participants) was asked to complete the 1.6-km course in the shortest possible time. At the start, they were asked to line up behind the starting line and started to run on the command while the tester started the stopwatch. The testers recorded the total time to complete the course for each participant in minutes and seconds. The testers also recorded participants' weight, height, and age prior to the test. The VO_2 max was calculated based on the regression equation from Cureton et al. (1995). VO_2 max in boys was (0.21xage) - (0.84xbody mass index) - (8.41xrunning time) + (0.34x(running time)2) + 108.94, while for girls, it was (0.34x(running time)2) + 08.94 - (0.84xBMI) - (8.41xrunning time). The VO_2 max score was subsequently classified into high or low according to the median of the data because the data were not normally distributed, referring to the technique suggested by Manikandan (2011).

Physical activity was measured using an online International Physical Activity Questionnaire-Long Form (IPAQ-LF) questionnaire comprising 25 items. The questionnaire asks time that participants spent for walking and moderate to vigorous physical activity in the last seven days. Moderate physical activity was defined to participants as an activity that causes shortness of breath but does not disturb their ability to make a conversation. On the other hand, vigorous physical activity was defined to participants as any physical activity that creates difficulties in making conversation due to shortness of breath. All physical activities were conducted within the four domains of physical activity, which included work-related, recreational-based, transport-related, or household-related physical activities. Following the scoring guideline, the total physical activity was calculated as the metabolic equivalent of tasks (METs) per week using the formula of METs derived from walking time multiplied by 3.3, added with moderate physical activity time, which was multiplied by 4.0 and vigorous physical activity time multiplied by 8.0 from all domains (Sjostrom et al., 2005). Physical activities in METs per week were also recorded for each domain, while sedentary time was recorded as time spent in sedentary activities both on weekdays and weekends in minutes per week (Sjostrom et al., 2005).

Data analysis

Descriptive analysis was conducted to describe the mean and standard deviation of age, weight, height, body mass index (BMI), 1-mile running performance, VO_2 max, and METs of total and domain-specific physical activity per week. The multiple linear regression was used to generate prediction equations for VO_2 max in 75% of randomly selected data (the derivation sample) with domain-specific physical activity or total physical activity and sedentary time as the main predictors in the initial model, while BMI and sex were assigned as covariates, using stepwise regression to obtain the final developed model. The goodness of fit and precision of the regression equations were evaluated using adjusted multiple coefficients of determination (adjusted R2) and a standard error of estimation (SEE) in the developed model. The generated prediction models were then cross-validated by comparing the goodness of fit indices and the correlation between the predicted values and the data in the remaining 25% of data (the validation sample).

The discriminant capacity of physical activity levels (total and domain-specific) on theVO_2 max status (high or low status) was then calculated based on the area under the curve (AUC) on the Receiver Operating Curve (ROC). The vertical axis of the curve reflects sensitivity that, in this case, represented the proportion of participants correctly identified as having high VO_2 max. The horizontal axis was 1-specificity. In this case, specificity was the proportion of correctly identified participants with low VO_2 max based on the physical activity level. The outcome assigned in the ROC curve for physical activity was a high VO_2 max status, while for the sedentary activity was a low VO_2 max status, as it was hypothesized that it was inversely related to the level of physical performance (Carter et al., 2016). Youden's formula (sensitivity + specificity-1) to obtain the most optimal specificity and sensitivity (Martínez-Camblor & Pardo-Fernández, 2019). All analyses were conducted using Statistical Package for Social Sciences (SPSS) v. 25.0, and a significance level of 5% was used for all data analysis.

Results

Participants' Characteristics and the Maximum Aerobic Capacity

A summary of the anthropometric profile and maximal aerobic capacity is presented in Table 1. As shown in Table 1, 83% of participants were male, while the average age of the total sample was 19±0.7 years old. As illustrated in the table, there were no differences in characteristics between Samples 1 and 2.

Table 1. Anthropometric Profiles and Maximum Aerobic Capacity

	Total (n=141)	Derivation sample (n= 116)	Validation sample (n= 25)	p*
Sex				
Men	117 (83%)	96 (83%)	21 (84%)	0.573
Women	24 (17%)	20 (17%)	4 (16%)	
Age (years)	19.5±0.7	19.6±0.7	19.4±0.9	0.329
Height (cm)	167.2±7.0	167.4±7.3	165.8±5.6	0.312
Weight (kg)	58.9±9.8	59.5±10.2	56.4±7.3	0.148
Body mass index	21.0±2.5	21.1±2.7	20.5±1.9	0.325
VO_2 max (mm/kg BW/min)	48.5±4.9	48.4±5.0	48.9±4.4	0.635
Physical activity		5506±2535	5185±2452	0.567

Note: *Height and physical activity used independent t-test. Weight, BMI, age, and VO_2 max = Mann Whitney.

Physical Activity Levels

Figure 1 illustrates the average physical activity in the four domains (i.e., work activities, transportation, domestic, and leisure), total physical activity, and sedentary time per week, participants in high and low VO_2 max groups. The overall average total physical activity was 5449±2461 METs per week. As expected, participants in the high VO_2 group significantly reported higher physical activity levels than their counterparts (6967±1701 Mets/week vs. 3276±1597 Mets/week (p<0.001). Similar trends were found in the four domain-specific physical activities. In contrast, there was no difference in sedentary time reported in both groups.

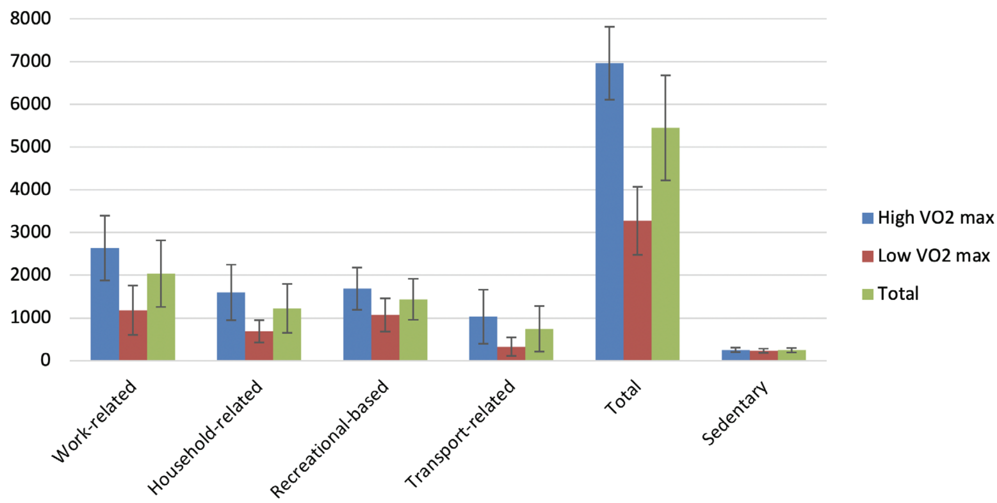

FIGURE 1. Physical Activity Levels by VO2 status in all samples (n=141)

The Development and Cross-validation of the Regression Equation for Predicting VO_2 Max Status

Table 2 summarises the intercepts, coefficients, standardized coefficients (β), the adjusted R2, and standard error of estimate (SEE) of the multiple regression equation of the model development and cross-validation. The main predictors for model A were all four domain-specific physical activity and sedentary time. In contrast, the main predictors for model B were total physical activity and sedentary time. Sedentary time was removed in the model as it did not reach a significant level, in contrast to sex and BMI. However, the final model A was not cross-validated in the validation sample, as opposed to the final model B.

Table 2. The Development and Cross-validation of the Regression Equation for Predicting VO_2 max

	Initial Model (n=116)			Final Model (n=116)			Cross-validation (n=25)		
	Coefficient	β	p	Coefficient	β	p	Coefficient	β	p
Model A									
Intercept	40.1	-	<0.001	55.6	-	<0.001	52.15	-	<0.001
Work	0.001	0.47	<0.001	0.001	0.25	<0.001	0.000	0.09	0.519
Transport	0.002	0.39	<0.001	0.001	0.27	<0.001	0.000	0.10	0.481
Household	0.002	0.40	<0.001	0.001	0.23	<0.001	0.001	0.16	0.209
Recretional	0.001	0.23	<0.001	0.001	0.12	0.007	0.001	0.18	0.201
Male	-	-	-	6.59	0.51	<0.001	6.09	0.57	<0.001
BMI	-	-	-	-0.80	-0.42	<0.001	-0.84	-0.26	0.069
Adjusted R2	0.57	-	-	0.80	-	-	0.71	-	-
SEE	3.34	-	-	2.35	-	-	2.23	-	-
Model B									
Intercept	39.9	-	<0.001	55.1	-	<0.001	53.4	-	<0.001
Physical activity	0.002	0.75	<0.001	0.001	0.44	<0.001	0.001	0.32	0.020
Male	-	-	-	6.07	0.46	<0.001	6.56	0.52	0.018
BMI	-	-	-	-0.79	-0.41	<0.001	-0.63	-0.29	<0.001
Adjusted R2	0.57	-	-	0.79	-	-	0.75	0.75	
SEE	3.32	-	-	2.25	-	-	2.20	2.20	

Note: Model A= domain-specific physical activity as the main predictors, Model B = total physical activity as the main predictor, BMI= Body Mass Index, SEE= standard estimating equation

As seen in Table 2, the final model for predicting VO_2 max was VO_2 max= 55.1 + (0.002*total physical activity) - (0.41*body mass index) + (6.07*gender (male =1, female=0)). The adjusted R2 for that model indicated that 79% variances for the VO_2 max were explained by physical activity levels, sex, and body mass index with the standard error estimates of 2.25 ml O2/kg/minutes.

Physical Activity Discrimination Capacity on the VO_2 max Status

Based on the median VO_2 max, 83 (59%) participants had high VO_2 max, while the remaining 58 (41%) had a low VO_2 max. Figure 2 and Table 3 further describe the discriminatory capacity of the four physical activity domains, the total physical activity, and sedentary time on discriminating the VO_2 max status (i.e., high/low).

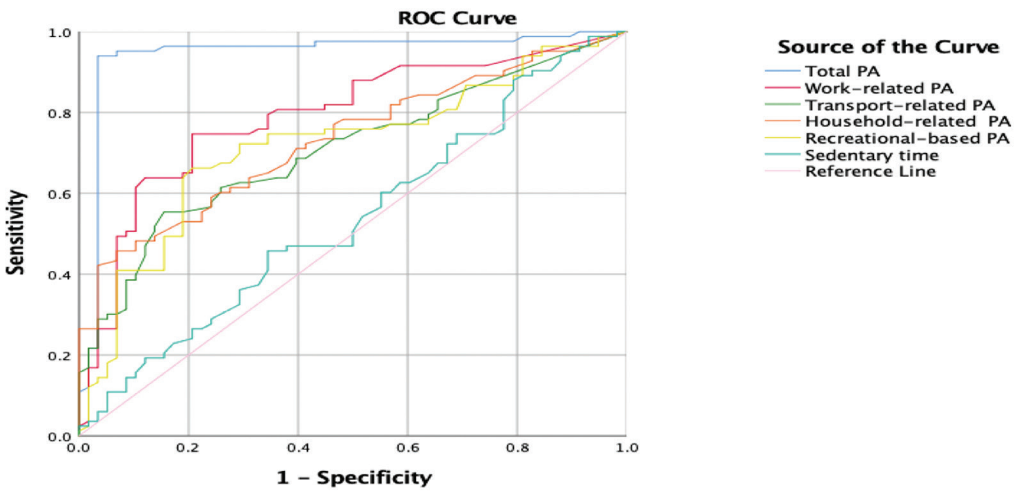

FIGURE 2. Physical Activity Capacity in Discriminating VO2 max status

Figure 2 suggested that the total physical activity had the highest discriminatory capacity, with 0.95 [95% CI 0.90-0.99], p<0.001, while sedentary time did not discriminate VO_2 max capacity, with the AUC of 0.54 [95% CI 0.44-0.64], p=0.437. The cut-off values for discriminating the VO_2 max status based on the Youden index are further illustrated in Table 3.

Consistent with the AUC, total physical activity has the highest sensitivity and specificity with a 5088 Mets/week cut-

Table 3. Cut off, sensitivity, and specificity of physical activity level to discriminate on VO_2 max status

Domain	Cut off	Sensitivity	Specificity
Work-related (Mets/week)	1824	75%	79%
Transport-related (Mets/week)	625	55%	85%
Household-related (Mets/week)	1320	48%	90%
Recreational-based (Mets/week)	1068	75%	66%
Total physical activity (Mets/week)	5088	94%	97%

off point with a sensitivity of 94% and specificity of 97%. The specificity for the four physical activity domains was relatively high (>66%), but the sensitivity for transports and household-related was low (<60%), thus, having the lowest diagnostic values.

Discussion

This is the first study to develop a prediction equation of cardiorespiratory fitness (i.e., maximum oxygen capacity/VO_2 max) based on the physical activity levels, which were assessed using the IPAQ-LF, a validated self-reported physical activity assessment, and to estimate the discriminant capacity of physical activity in differentiating high and low VO_2 max among late adolescents. We found that the total physical activity with sex and body mass index adequately predict VO_2 max, while both total and domain-specific physical activity have the capacity to discriminate high and low VO_2 max.

Our prediction equation for VO_2 max differs from Schembre and Riebe (2011), as they used different physical activity predictors: physical activity intensity. They reported vigorous physical activity and gender as significant prediction covariates while reporting that walking and moderate-intensity physical activity did not. However, a full comparison could not be made as they did not assign total physical activity as an alternative predictor in their model. However, their reported adjusted R2 was much lower than ours (0.47 vs. 0.79), suggesting that total physical activity derived from IPAQ-LF is potentially a better predictor than vigorous physical activity derived from the IPAQ-SF.

To some extent, our findings are also in discrepancy with some findings from previous studies. For instance, a study in the middle-aged population using a direct maximal exercise test reported that total physical activity was not a significant VO_2 max predictor (Aadahl et al., 2007). Another prediction equation from a study using an objective physical activity measure indicated that VO_2 max was positively associated with leisure-based physical activity but not with occupational-based physical activity on workdays (Mundwiler et al., 2017), emphasizing the inadequate level of intensity during the occupational time to improve VO_2 max. This finding to some extent is in discrepancy with our finding that suggests that domain-specific physical activity did not predict VO_2 max. The discrepancy is possibly due to the difference in the physical activity assessment methods. Their method incorporated an accelerometer, an objective physical activity measure, which is more likely to accurately differentiate physical activity intensity levels in each domain. Based on the diversed findings, it appears that prediction equations may be population-specific and specific for different assessment methods.

Consistent with the findings from the multiple linear regression, the total physical activity demonstrates the highest prediction capacity. The cut-off for the total physical activity was 5088 Mets, which was much higher than the criteria set by the IPAQ-LF scoring for classification for a high level of physical activity (>3000 METs/week) (Sjostrom et al., 2005), suggesting that the majority of our participants were highly physically active. Although the possibility of overreporting, which is inherent in the self-reported physical activity assessment, could not be overruled, our findings support previous research stating that a high level of physical activity is required for achieving a high VO_2 level (Black et al., 2016; Corazza et al., 2019; Nevill et al., 2020).

The main strength of this study was the involvement of both development and validation stages in the improvement of the VO_2 max prediction equation, thus ensuring the external validity of the equation. We demonstrated that both domain-specific and total physical activity have the capacity to discriminate VO_2 max status. The equation could be used for discriminating cardiorespiratory status based on physical activity data for health evaluation, talent scouting, or athletic training programming and evaluation purposes. However, several limitations need to be acknowledged. First, the age range of our samples was limited and with a small representation of women (12.5%). Therefore, it limits the generalisability of the findings of this study to other age groups and women. Secondly, our samples were relatively physically active individuals. Further studies, thus, are required to develop prediction and discrimination capacity with adolescents with wider age ranges, more balanced sex distribution, and varied physical activity levels.

Conclusion

This study indicates that the total physical activity derived from the IPAQ-LF, a validated physical activity instrument, significantly predicts VO_2 max. Both domain-specific and total physical activity levels can discriminate VO_2 max status with sufficient sensitivity and specificity, justifying its use to estimate VO_2 status among late adolescents, particularly those with similar characteristics to this study's participants.

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Declaration of competing interest
No competing interest is declared.

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References

Aadahl, M., Kjær, M., Kristensen, J.H., Mollerup, B., & Jørgensen, T. (2007).

Self-reported physical activity compared with maximal oxygen uptake in adults. *European Journal of Preventive Cardiology, 14*(3), 422-428. doi:10.1097/HJR.0b013e3280128d00

Arovah, N.I., & Heesch, K. (2021). The association between cardiorespiratory fitness and metabolic syndrome diagnosis: A cross-sectional study in Indonesian middle-aged and older adults. *Physical Activity Review, 9*(2), 101-110. doi:10.16926/par.2021.09.26

Black, N.E., Vehrs, P.R., Fellingham, G.W., George, J.D., & Hager, R. (2016). Prediction of VO2max in Children and Adolescents Using Exercise Testing and Physical Activity Questionnaire Data. *Research Quarterly for Exercise and Sport, 87*(1), 89-100. doi:10.1080/02701367.2015.1124969

Carter, J.V., Pan, J., Rai, S.N., & Galandiuk, S. (2016). ROC-ing along: Evaluation and interpretation of receiver operating characteristic curves. *Surgery, 159*(6), 1638-1645. doi:10.1016/j.surg.2015.12.029

Corazza, P.R., Tadiotto, M.C., Junior, F.J.M., Czoczuk, M., Biscouto, T.A., Lopes, M.F., . . . Leite, N. (2019). Cardiorespiratory Fitness and Metabolic Profile in Adolescents with High Sedentary Behavior and Low Level of Physical Activity. *Journal of Professional Exercise Physiology, 16*(3). Retrieved from https://link.gale.com/apps/doc/A623251989/AONE?u=anon~c8f0ab0c&sid=googleScholar&xid=9696bd7b

Cureton, K.J., Sloniger, M.A., O'Bannon, J.P., Black, D.M., & McCormack, W.P. (1995). A generalized equation for prediction of VO2peak from 1-mile run/walk performance. *Medicine & Science in Sports & Exercise, 27*(3), 445-451. Retrieved from https://journals.lww.com/acsm-msse/Abstract/1995/03000/A_generalized_equation_for_prediction_of_V_O2peak.23.aspx

Kim, Y., Park, I., & Kang, M. (2013). Convergent validity of the international physical activity questionnaire (IPAQ): meta-analysis. *Public Health Nutrition, 16*(3), 440-452. doi:10.1016/j.pcad.2019.01.002

Lee, P.H., Macfarlane, D.J., Lam, T.H., & Stewart, S.M. (2011). Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 8*(1), 115. doi:10.1186/1479-5868-8-115

Lepp, A., Barkley, J.E., Sanders, G.J., Rebold, M., & Gates, P. (2013). The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of US college students. *International Journal of Behavioral Nutrition and Physical Activity, 10*(1), 79. Retrieved from http://www.ijbnpa.org/content/10/1/79

Manari, D., Manara, M., Zurini, A., Tortorella, G., Vaccarezza, M., Prandelli, N., . . . Galli, D. (2016). VO2Max and VO2AT: athletic performance and field role of elite soccer players. *Sport Sciences for Health, 12*(2), 221-226. Retrieved from https://www.springermedizin.de/vo2max-and-vo2at-athletic-performance-and-field-role-of-elite-so/10106294

Manikandan, S. (2011). Measures of central tendency: Median and mode. *Journal of Pharmacology and Pharmacotherapeutics, 2*(3), 214. doi:10.4103/0976-500X.83300

Martínez-Camblor, P., & Pardo-Fernández, J. C. (2019). The Youden index in the generalized receiver operating characteristic curve context. *The International Journal of Biostatistics, 15*(1). doi:10.1515/ijb-2018-0060

Morrow Jr, J.R., Tucker, J.S., Jackson, A.W., Martin, S.B., Greenleaf, C.A., & Petrie, T.A. (2013). Meeting physical activity guidelines and health-related fitness in youth. *American Journal of Preventive Medicine, 44*(5), 439-444. doi:10.1016/j.amepre.2013.01.008

Mundwiler, J., Schüpbach, U., Dieterle, T., Leuppi, J.D., Schmidt-Trucksäss, A., Wolfer, D.P., . . . Brighenti-Zogg, S. (2017). Association of occupational and leisure-time physical activity with aerobic capacity in a working population. *PLoS One, 12*(1), e0168683. doi:10.1371/journal.pone.0168683

Myers, J., Vainshelboim, B., Kamil-Rosenberg, S., Chan, K., & Kokkinos, P. (2021). Physical activity, cardiorespiratory fitness, and population-attributable risk. *In Mayo Clinic Proceedings (Vol. 96, No. 2, pp. 342-349).* Amsterdam, Netherlands: Elsevier.

Nevill, A.M., Duncan, M.J., & Sandercock, G. (2020). Modeling the dose–response rate/associations between VO2max and self-reported Physical Activity Questionnaire in children and adolescents. *Journal of Sport and Health Science, 9*(1), 90-95. doi:10.1016/j.jshs.2019.05.001

Ottevaere, C., Huybrechts, I., De Bourdeaudhuij, I., Sjöström, M., Ruiz, J.R., Ortega, F.B., . . . Moreno, L. A. (2011). Comparison of the IPAQ-A and actigraph in relation to VO2max among European adolescents: the HELENA study. *Journal of Science and Medicine in Sport, 14*(4), 317-324. doi:10.1016/j.jsams.2011.02.008

Raghuveer, G., Hartz, J., Lubans, D.R., Takken, T., Wiltz, J.L., Mietus-Snyder, M., . . . Edwards, N.M. (2020). Cardiorespiratory fitness in youth: an important marker of health: a scientific statement from the American Heart Association. *Circulation, 142*(7), e101-e118. Retrieved from https://www.ahajournals.org/doi/pdf/10.1161/CIR.0000000000000866?download=true

Schembre, S.M., & Riebe, D.A. (2011). Non-exercise estimation of VO2max using the international physical activity questionnaire. *Measurement in Physical Education and Exercise Science, 15*(3), 168-181. doi:10.1080/1091367X.2011.568369

Sjostrom M, Ainsworth B, Bauman A, Bull F, Hamilton-Craig C, & Sallis J. (2005). *Guidelines for data processing analysis of the International Physical Activity Questionnaire (IPAQ)-short and long forms.* Retrieved from http://www.IPAQ.ki.se

Taylor, R.J., Sanders, D., Myers, T., Abt, G., Taylor, C.A., & Akubat, I. (2018). The dose-response relationship between training load and aerobic fitness in academy rugby union players. *International journal of sports physiology and performance, 13*(2), 163-169. doi:10.1123/ijspp.2017-0121