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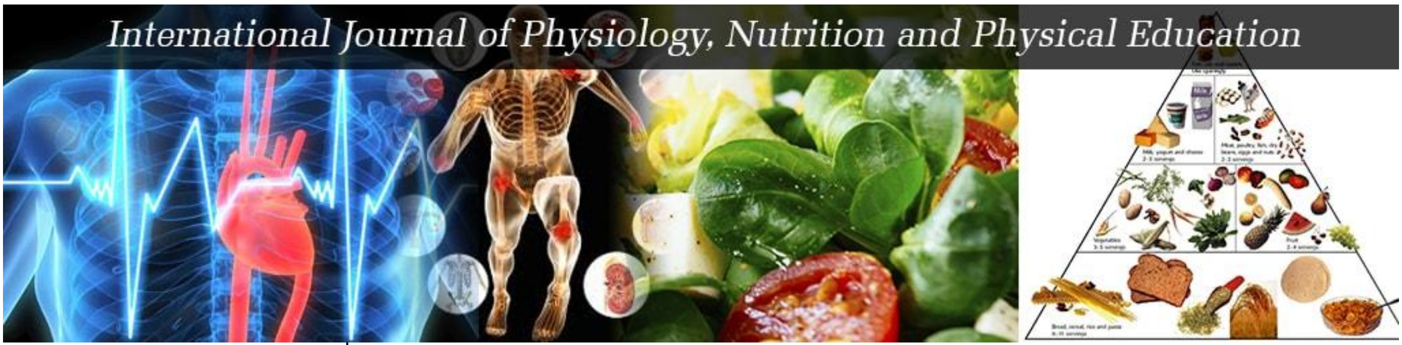

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Development of regression models for estimating maximal oxygen uptake (VO_2 max.) of male youth of Kashmir (Habitat of high altitude)

Sajjadh Ahmad Bhat and Dhananjoy Shaw

Abstract
The aim of the study was to develop regression models for estimating Maximal Oxygen Uptake (VO2 Max.) of male youth habitat of Kashmir valley. The study was conducted on two hundred forty two healthy male youth of Kashmir (altitude: 6070 feet/1850 meters). The age of the subjects ranged from 18 to 23 years. The youth were administered with submaximal bench step test (American College of Sports Medicine Protocol) to determine the VO2max. by plotting HR-workload combinations calculated by Karvonen heart rate reserve method. Data was collected using Cardio-Sport heart rate monitor and step test protocol. The selected variables were Age in years, Body weight in kilograms (B.Wt.), Height in centimeters (Ht.), Resting Heart Rate (HRrest), Target Heart Rate (THR), Maximal Heart Rate (HRmax.), Heart Rate at Two minutes of step testing with cadence 15 steps/min (ExHR2), Heart Rate at Four minutes of step testing with cadence 20 steps/min (ExHR4), Heart Rate at Six minutes of step testing with cadence 30 steps/min (ExHR6), recovery heart rate at one minutes of rest (RcvHR1), recovery heart rate at two minutes of rest (RcvHR2) and recovery heart rate at third minute of rest (RcvHR3); (As per the formula advocated by American College of Sports Medicine). The collected data was computed with mean, standard deviation, correlation matrix, ANOVA and stepwise multiple correlations for deriving regression models using SPSS. The study concluded with the development of regression models for Kashmiri youth (habitat of high altitude) for estimating their VO2 max. (Aerobic fitness) with high degree of power of prediction. Among the eight regression models for estimating VO2 max. for Kashmiri youth (habitat of high altitude),the best model was model eight (-.458 × ExHR4 + .041 × ExHR6 - .314 × Age + 131.147 constant) followed by model seven (.018 × B.Wt - .458 X ExHR4 + .042 × ExHR6 - .328 × Age + 129.955 constant).

Keywords: Maximal oxygen consumption, heart rate, step testing, high altitude, aerobic fitness, correlation matrix, multiple regression analysis

Introduction

The Kashmir Valley being at high altitude (6070 feet/1850 meters) with mountains around demands a great deal of physical efficiency to survive and to live a graceful and healthy life. Kashmiri has to perform best in different changing altitudes, time and again, with or without any acclimatization for the life and social requirements, because of the very nature of its geographical, political, social, administrative and vocational requirement/s. It has been observed that Kashmiri youth is a habitat of high altitude, but they interact with rest of India (low or variable altitude), whether it is games/sports (nationals, inter-university, senior nationals, junior nationals, rural nationals etc.) or cultural exchange programs, education and others. Hence, VO2 max. regression models for estimating and evaluating aerobic fitness suitable to them becomes imperative.

VO_2 max. also known as maximal oxygen consumption/maximal oxygen uptake/peak oxygen uptake or maximal aerobic capacity is the maximum rate of oxygen consumption as measured during incremental exercise, most typically on a motorized treadmill or on a bench step test (Dlugosz 2013) [5]. Maximal oxygen consumption reflects the aerobic physical fitness of the individual and is an important determinant of their endurance capacity. The name is derived from V = volume, O_2 = oxygen and max. = maximum.

VO_2 max is expressed either as an absolute rate in (for example) liters of oxygen per minute (L/min) or as a relative rate in (for example) millilitres of oxygen per kilogram of body mass per minute (e.g., ml/kg/min). The latter expression is often used to compare the performance of endurance sports athletes. However, VO_2 max generally does not vary linearly with body mass. (Wikipedia, July 2017) [14].

VO_2max. is the very important determinant of cardio-respiratory fitness and aerobic performance.VO_2 max (ml/min/kg) is a measure of the maximum amount of oxygen that one use during intense physical activity. This measurement determines fitness level by calculating how efficiently cells use oxygen for energy (Tipton, 1977) [4]. There are several methods one can use to measure VO_2 max. but many require sophisticated equipment such as a treadmill or a specially calibrated exercise cycle with calorimetry/ spirometry /gas analyzer. The step test with heart rate recordings is quickest, easiest and safest as well as feasible way to measure ones VO_2 max for basic calculation after taking in consideration the Karvonen formula for a step testing protocol and sub maximal exercise heart rate (Practical Math for Health Fitness Professionals, 1996). It is postulated that appropriate regression models will be a step advance for estimating VO2 max. for Kashmiri youth in forms of feasibility.

Heart rate is arguably a very easy cardiovascular measurement, especially in comparison to the invasive or noninvasive procedures used to estimate stroke volume and cardiac output. Consequently, measurement of heart rate is routinely used to assess the response of the heart to exercise, or the recovery from exercise, as well as to prescribe exercise intensities (Froeliche, 2000) [6]. Given that the increase in heart rate during incremental exercise mirrors the increase in cardiac output, maximal heart rate is often interpreted as the upper ceiling for an increase in central cardiovascular function. Indeed, research for the last 100 years has demonstrated that heart rate does in fact have a maximal value; one that cannot be surpassed despite continued increases in exercise intensity or training adaptations (Robert 2008) [9].

The regular exercise leads to adoptive changes in cardiac, physical performance and oxygen uptake capacity. Physically trained individuals are found to have maximum oxygen uptake capacity than physically untrained ones (Heyward, 1997) [10]. The requirement or adaptation of VO2max. for different games and sports or physical activity are different. The developed regression models will be of great help for above requirements.

Recent research revealed that the Queens College step test provides a valid estimate of VO2max. Step test performance at 3800 meters was reduced by 11% compared to sea level, whereas no change was observed at 2040 meters. These data corroborate previous findings that indicate a threshold at which altitude adversely affects aerobic capacity (Tiaira Bates, 2015) [12].

Healthy high altitude dwellers show excellent adaptation to their environment. These adaptations are likely to be associated with altered gene expression as the expression of genes associated with vascular control and reactions to hypoxia have been found to be high in altitude dwellers (Appenzeller 2006) [1]. Blood volumes are larger in high altitude dwellers. This is due to a large packed cell volume whereas at sea levels plasma volume was found to be large. Probably as the result of the large blood volumes, tolerance to orthostatic stress was greater than that in sea-level residents (Claydon, 2005) [3].

It is summarized that at altitudes over 5000 feet (1524 meters), the ability to perform physical work is decreased due to hypoxia (lowered PO_2). However, physical performance at moderate altitude may sometimes be improved with continued stay at altitude due to the acclimatization process. This involves: (1) increased pulmonary ventilation (hyper ventilation); (2) increased red blood cells and hemoglobin concentrations; (3) elimination of bicarbonate (HCO_3) in the urine; and (4) in those chronically exposed to altitude, tissue level changes. Increased physical fitness does not alone acclimatize the individual to altitude (Houmard, 1991) [8].

The Purpose of the study was to develop regression models for estimating maximal oxygen uptake (VO2max.) of high altitude Kashmiri male youth, which will be useful for evaluation, grading, grouping and monitoring the aerobic fitness of Kashmiri male youth.

Methodology

The study was conducted on two hundred and forty two healthy male subjects of Kashmir valley (altitude: 6070 feet/1850 meters). The age of the subjects ranged from 17 to 23 years. The youth were administered submaximal bench step test to determine the VO2 max. by plotting HR-workload combinations calculated by Karvonen heart rate reserve method. The selected variables were Age in years, Body weight in kilograms (B.Wt), Height in centimeters (Ht.), Resting Heart Rate (HRrest), Target Heart Rate (THR), Maximal Heart Rate (HRmax.), Heart Rate at Two minutes of step testing with cadence 15 steps/min (ExHR2), Heart Rate at Four minutes of step testing with cadence 20 steps/min (ExHR4), Heart Rate at Six minutes of step testing with cadence 30 steps/min (ExHR6), recovery heart rate at one minutes of rest (RcvHR1), recovery heart rate at two minutes of rest (RcvHR2) and recovery heart rate at third minute of rest (RcvHR3),(As per the method advocated by American College of Sports Medicine).

Submaximal exercise testing can be used for estimating VO2max. by taking advantage of linear relationship between heart rate responses and workload VO2 values. This linear relationship was taken in consideration by plotting HR-workload combinations calculated by Karvonen heart rate reserve method. (Practical Math for Health Fitness Professionals, 1996).

The statistical analysis was mean, standard deviation, correlation matrix, ANOVA and stepwise multiple regression for deriving regression models using SPSS.

Findings

Table 1: Descriptive Statistics of the Selected Variables of the Subjects (High Altitude Kashmiri Male Youth)

S.N0	Variable Name	Symbol	Mean	S.D
1	Age (Years)	AGE	18.75	1.01
2	Body weight (Kgs)	B wt.	54.53	6.88
3	Height (cms)	Ht.	171.97	6.02
4	Maximal Oxygen Uptake(ml/kg/min)	VO2max.	53.20	5.11
5	Resting Heart rate (bts/min)	HRrest	63.26	10.10
6	Heart rate at 2 mins of exercise (bts/min)	ExHR2	144.95	9.22
7	Heart rate at 4 mins of exercise(bts/min)	ExHR4	174.68	10.86
8	Heart rate at 6 mins of exercise(bts/min)	ExHR6	197.47	9.22
9	Recovery heart rate at 1 min (bts/min)	RcvHR1	156.16	10.85
10	Recovery heart rate at 2 min (bts/min)	RcvHR2	135.14	10.13
11	Recovery heart rate at 3 min (bts/min)	RcvHR3	117.70	10.42

N=242

Table 2: Pearson Correlation among Selected Variables of Habitat of High Altitude Kashmiri Male Youth

	VO2max	Bwt	Ht.	HRrest	ExHR2	Ex.HR4	Ex.HR	RcvHR1	RcvHR2	RcvHR3	Age
VO2max	1	.090	.018	-.700*	-.475*	-.965*	-.092	-.023	-.210	-.380*	-.057
B.wt.		1	.460*	-.116	-.080	-.084	-.122	-.018	-.085	-.123	-.131
Ht.			1	-.017	-.125	-.040	-.171	.056	-.007	-.002	.028
HR rest				1	.305*	.692*	-.176	.004	.260	.485*	.021
Ex.HR2					1	.501*	.290	.206	.209	.234	-.017
Ex.HR4						1	.157	.013	.198	.367*	-.013
Ex.HR6							1	.077	.017	-.097	-.137
RcvHR1								1	.787*	.586*	-.059
RcvHR2									1	.830*	-.077
RcvHR3										1	-.053
AGE											1

*Significant at 0.05 level

According to table-2, the VO2 max. highly correlated to HRrest (r = -.700), ExHR2 (r = -.475), ExHR4 (r = -.965) and RcvHR3 (r = -.380). The body weight significantly correlated to Ht. (r = .460). Heart Rate Rest (HRrest) significantly correlated to ExHR2 (r = .305), ExHR4 (r = .692) and RcvHR3 (r = .485). ExRH2 highly correlated to ExHR4 (r = .501). ExHR4 significantly correlated to RcvHR3 (r = .367).RcvHR1 highly correlated with RcvHR2 (r = .787) and RcvHR3 (r =.586).RcvHR2 highly correlated with RcvHR3 (r = .830).

A Partial Regression Plot of dependent variable: VO2max. with ExHR4 (heart rate at four minutes of exercise) has been graphically represented in the figure below:

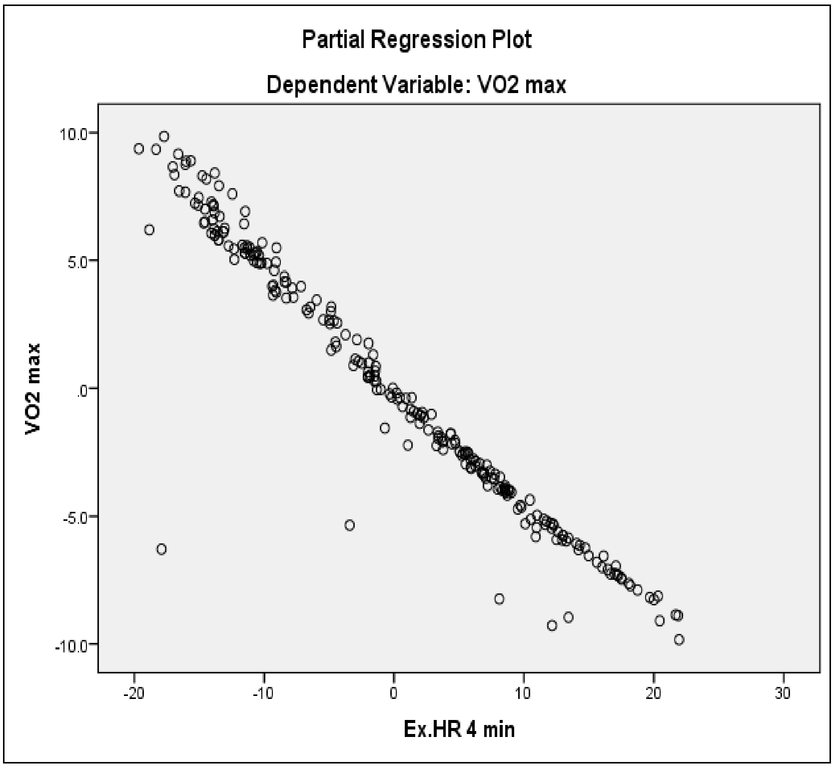

Fig 1: Partial Regression Plot Between Dependent Variable (VO2 max.) and Independent Variable (ExHR4min.) as Best Predictor.

Table 3: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig.F
1	.970[a]	.941	.938	1.2710	.941	366.692	10	231	.000
2	.970[b]	.941	.938	1.2683	.000	.002	1	231	.967
3	.970[c]	.941	.939	1.2656	.000	.002	1	232	.963
4	.970[d]	.941	.939	1.2629	.000	.012	1	233	.914
5	.970[e]	.940	.939	1.2628	.000	.983	1	234	.322
6	.970[f]	.940	.939	1.2650	.000	1.822	1	235	.178
7	.969[g]	.939	.938	1.2681	-.001	2.154	1	236	.144
8	.969[h]	.939	.938	1.2713	-.001	2.206	1	237	.139

Table 4: Analysis of Variance among Selected Independent Variables and Dependent Variable (VO2 Max.) of Habitat of High Altitude Kashmiri Male Youth

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5923.793	10	592.379	366.692	.000[b]
	Residual	373.173	231	1.615		
	Total	6296.967	241			
2	Regression	5923.791	9	658.199	409.196	.000[c]
	Residual	373.176	232	1.609		
	Total	6296.967	241			
3	Regression	5923.787	8	740.473	462.325	.000[d]
	Residual	373.179	233	1.602		
	Total	6296.967	241			
4	Regression	5923.769	7	846.253	530.612	.000[e]
	Residual	373.198	234	1.595		
	Total	6296.967	241			
5	Regression	5922.201	6	987.033	618.927	.000[f]
	Residual	374.766	235	1.595		
	Total	6296.967	241			
6	Regression	5919.294	5	1183.859	739.770	.000[g]
	Residual	377.672	236	1.600		
	Total	6296.967	241			
7	Regression	5915.847	4	1478.962	919.696	.000[h]
	Residual	381.119	237	1.608		
	Total	6296.967	241			
8	Regression	5912.300	3	1970.767	1219.348	.000[i]
	Residual	384.667	238	1.616		
	Total	6296.967	241			

N=242, Dependent Variable = VO2max. According to table-4, all 'F' ratio found to be statistically significant and supported the developed models.

Table 5: Predictors in the Models for Estimating Dependent Variable (VO2 Max.) of Habitat of High Altitude Kashmiri Male Youth

Model	Predictors	V.R*	F
1	B.Wt,Ht,HRrest,ExHR2 ExHR4,ExHR6, RcvHR1,RcvHR2,RcvHR3,AGE +C	Nil	.000
2	B.Wt, Ht, HRrest, ExHR2 ExHR4,ExHR6, RcvHR1,RcvHR2,AGE +C	RcvHR3	.967
3	B.Wt, Ht, HRrest, ExHR2, ExHR4,ExHR6,RcvHR2,AGE +C	RcvHR1	.963
4	B.Wt, Ht, HRrest ExHR4,ExHR6,RcvHR2,AGE +C	ExHR2	.914
5	B.Wt,Ht, ExHR4,ExHR6,RcvHR2,AGE +C	HRrest	.322
6	B.Wt,Ht, ExHR4,ExHR6,AGE + C	RcvHR2	.178
7	B.Wt, ExHR4,ExHR6,AGE + C	Ht.	.144
8	ExHR4,ExHR6,AGE +C	B.Wt	.139

C = Constant, VR* = Variables Removed

The above table (table-5), shows the models with predictors among selected variables with dependent variable (VO2 max.)

Table 6: Regression Models Developed for Estimating Dependent Variable (VO2 Max.) for Habitat of High Altitude Kashmiri Male Youth

Model	Equation
1	= (.024 x B.Wt) - (.022 x Ht.) - (.013 x HRrest) - (.001x ExHR2) - (.447x ExHR4) + (.034 x ExHR6) - (.001 x Rcv. HR1) - (.010 x Rcv. HR2)- (.001 x Rcv. HR3) - (.340 x AGE) + (135.639 Constant)
2	= (.024 x B.Wt) - (.022 x Ht.) - (.012 x HRrest) - (.001x ExHR2) - (.447x ExHR4) + (.034 x ExHR6) - (.001 x Rcv. HR1) - (.009 x Rcv. HR2) -(.341 x AGE) + (135.647 Constant)
3	= (.024 x B.Wt) - (.022 x Ht.) - (.012 x HRrest) - (.001x ExHR2) - (.447x ExHR4) + (.034 x ExHR6) - (.010 x Rcv. HR2) - (.341 x AGE) + (135.641 Constant)
4	= (.024 x B.Wt) - (.022 x Ht.) - (.012 x HRrest) - (.447x ExHR4) + (.034 x ExHR6) - (.010 x Rcv. HR2) - (.341 x AGE) + (135.616 Constant)
5	= (.026 x B.Wt)-(.022 x Ht.)-(.455x ExHR4)+(.039 x ExHR6)- (.011 x Rcv. HR2)-(.342 x AGE) + (135.281 Constant)
6	= (.027 x B.Wt) - (.023 x Ht.) - (.457x ExHR4) + (.040 x ExHR6) - (.334 x AGE) + (133.938 Constant)
7	= (.018 x B.Wt) - (.458 x ExHR4) + (.042 x ExHR6) - (.328 x AGE) + (129.955 Constant)
8	= (-.458 x ExHR4) + (.041 x ExHR6) - (.314 x AGE) + (131.147 Constant)

Table 7: Casewise Diagnostics with Dependent Variable VO2 Max. for Habitat of High Altitude Kashmiri Male Youth

Case Number	Std. Residual	VO2 max	Predicted Value	Residual
199	-5.441	48.1	55.017	-6.9170
201	-11.403	48.0	62.497	-14.4967
233	-3.555	44.8	49.319	-4.5190
235	-2.206	44.2	47.004	-2.8040
238	-2.913	43.8	47.503	-3.7029

According to table-7, in regard to case number 199, the actual VO2 max. was 48.1 and the predicted VO2max. was 55.017 where residual value was -6.9170. In regard to case number 201, the actual VO2 max. was 48.0 and the predicted VO2max. was 62.497 where residual value was -14.4967. In regard to case number 233, the actual VO2 max. was 44.8 and the predicted VO2 max. was 49.319 where residual value was -4.5190. In regard to case number 235, the actual VO2 max. was 44.2 and the predicted VO2max. was 47.004 where residual value was -2.8040. In regard to case number 238, the actual VO2 max. was 43.8 and the predicted VO2max. was 47.503 where residual value was -3.7029.

Discussion of Findings

Table 8: Estimation of VO2 Max. using Developed Eight Models for Habitat of High Altitude Kashmiri Male Youth

Case No	Actual VO2 max.	VO2max.from Developed Models							
		M1	M2	M3	M4	M5	M6	M7	M8
14	60.8	59.61	59.91	59.92	60.03	60.05	60.15	59.96	60.34
36	59	58.40	58.69	58.70	58.82	58.82	58.88	58.70	58.95
95	55	54.72	55.06	55.07	55.18	55.18	55.40	54.96	54.92
174	49.6	49.64	49.96	49.97	50.09	50.03	50.06	49.86	50.16
237	43.8	42.26	42.60	42.61	42.75	42.72	42.84	42.66	42.82

According to the table-8, in regard to the case number14, the actual VO2max. was 60.8, M1 estimated 59.62, M2 estimated 59.91, M3 estimated 59.92, M4 estimated 60.03, M5 estimated 60.05, M6 estimated 60.15, M7 estimated 59.96 and M8 estimated VO2 max value of 60.34. Likewise in case number 36, the actual VO2max. was 59, M1 estimated 58.40, M2 estimated 58,69, M3 estimated 58.70, M4 estimated 58.82, M5 estimated 58.82, M6 estimated 58.88,M7 estimated 58.70 and M8 estimated VO2 max value of 58.95. Likewise in regard to the case number 95, the actual VO2max. was 55, M1 estimated 54.72, M2 estimated 55.06, M3 estimated 55.07,M4 estimated 55.18, M5 estimated 55.18,M6 estimated 55.40, M7 estimated 54.96 and M8 estimated VO2 max value of 54.92. Likewise in case number 174, the actual VO2 max. was 49.6, M1 estimated 49.64, M2 estimated 49.96, M3 estimated 49.97, M4 estimated 50.09, M5 estimated 50.03, M6 estimated 50.06, M7 estimated 49.86 and M8 estimated VO2 max value of 50.16. Likewise in case number 237,the actual VO2 max. was 43.8, M1 estimated 42.26, M2 estimated 42.60, M3 estimated 42.61, M4 estimated 42.75, M5 estimated 42.72, M6 estimated 42.84, M7 estimated 42.66 and M8 estimated VO2 max value of 42.82.

All the developed regression models predicted very close score of the actual VO2 max. where M7 and M8 documented best prediction. Out of the five case study M7 appeared best for three cases (case numbers 14, 36 and 174) and M8 appeared best for four cases (case numbers 14, 36, 95 and 237) hence were proved best among the eight developed models for estimating the VO2max. value of Kashmiri male youth (habitat of high altitude).

Conclusions

1. The developed regression models are appropriate for estimating VO2 max. for habitat of high altitude Kashmiri youth for aerobic fitness evaluation, found to have high power of prediction and validity hence are recommended for future research.
2. Among the eight regression models for estimating VO2 max. for habitat of Kashmiri youth (habitat of high altitude),the best model was model eight (-.458 × ExHR4 + .041 × ExHR6 - .314 × Age + 131.147 constant) followed by model seven (.018 × B. Wt - .458 × ExHR4 + .042 × ExHR6 - .328 × Age + 129.955 constant).

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