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Maximal Aerobic Power Using the Modified Heck Protocol: Prediction Models

Journal:	*International Journal of Sports Medicine*
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Key word:	VO2max, soccer, Basketball, Futsal
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Maximal Aerobic Power Using the Modified Heck Protocol: Prediction Models

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ABSTRACT

The purpose of this study was to develop prediction models based on an incremental treadmill test to volitional exhaustion utilizing the m~~M~~odified Heck protocol. A total of 598 professional and youth athletes participating in different sports were recruited for this study. Specifically, the study enrolled professional male soccer players (n=380), professional male futsal players (n=24), elite male basketball players (n=27), professional male soccer referees (n=50), elite female soccer players (n=19), youth male basketball players (13-14yrs n=15, 15-17yrs n=20) and youth male soccer players (15yrs n=28, 16-17yrs n=35). Anthropometric measurements included stature, body mass, and body fat. Furthermore, all participants performed incremental cardiopulmonary exercise testing on a treadmill using the modified Heck protocol. Through multiple regression analysis, a separate prediction model was developed for each of the athletic populations. Results demonstrated that a significant (p=0.001) proportion of the variation observed in VO2max was explained by the variation in running time. The generated VO2max regression equations would allow athletes and coaches to predict VO2max ~~at~~ in a relatively short time without the need for expensive and sophisticated equipment. To our knowledge, this is the first study that provides regression models for different athletic populations using the modified Heck protocol.

Keywords: VO2max, soccer, futsal, basketball

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Introduction

Maximal aerobic power (VO2max) is a valid and accurate limit of the cardiorespiratory system's ability to transport oxygen to various tissues and utilize it [1-2]. The VO2max values reported vary greatly among athletes of different sports and are proportional to the contribution of the aerobic system [3]. Additionally, variations in values have been observed among elite athletes that compete in the same sport [4]. Moreover, improvement in VO2max is commonly used to demonstrate the training effect in running sports [5,6]. Although the VO2max effect and running performance relationship is well established, other submaximal physiological values [7] such as high anaerobic threshold (AT), running velocity at VO2max (VVO2max) [8], and running economy (RE) [9] contribute to athletic success in individuals with similar VO2max values. Nevertheless, in sports that heavily depend on an aerobic component such as soccer, VO2max correlated with distance covered during matches [6], quality of play, and competitive ranking [10,11].

Accurate attainment of VO2max is possible in laboratory settings, using various ergometers combined with graded exercise testing (GXT) [12]. The various GXT protocols require a systematic and linear increase in intensity over time until the workload is intolerable. During GXT the VO2 is gradually increasing as a function of the work rate after which it plateaus despite further increases in workload [13]. In sports, especially those that heavily or partly depend on an aerobic component, spiroergometric data combined with GXT protocols provide important information for specific metabolic capabilities [14]. These measurements allow for the designing of precise training programs, monitoring progress, and aiding athletes to understand the rationale for the training plan [15]. The various GXT protocols are individualized based on a wide range of physical or clinical capabilities [16]. Treadmill ramp protocols have a

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common characteristic of a gradual increase in workload but vary considerably in terms of levels of increments and stage durations. Consequently, these variations may hinder the ability to make meaningful interpretations, as well as comparisons, and limit their practical application [12,-16].

Several well-established protocols exist in clinical settings such as the Bruce [17], Åstrand [18], Naughton [19], and Balke [20] protocols, with the Bruce protocol and its variations leading in popularity [16]. Furthermore, the modified Heck protocol was used previously [21, 22] for professional football players testing as it was found to be valid and reliable. GXT in laboratory settings can be costly, time-consuming, and necessitate the use of advanced equipment [23-25]. Therefore, teams during congested fixture periods avoid regular laboratory fitness assessments and rely solely on field-testing that predicts VO2max values. There are numerous prediction models reported in the literature most of them limited to various sporting and normal populations [26]. Therefore, this study aimed to add to this knowledge and develop prediction models based on an incremental treadmill test to volitional exhaustion utilizing the m~~M~~odified Heck protocol.

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Materials and ~~Methods~~ methods

Participants

A total of 598 professional and youth athletes participated in this study. Specifically, the study enrolled professional male soccer players (n=380), professional male futsal players (n=24), elite male basketball players (n=27), professional male soccer referees (n=50), elite female soccer players (n=19), youth male basketball players (13-14yrs n=15, 15-17yrs n=20) and youth male soccer players (15yrs n=28, 16-17yrs n=35). The testing was performed at the beginning of pre-seasonal training for all the athletic populations. Their physical activities during the transition period were not recorded, supervised, or organized, but most of the participants engaged in a post-season training regimen prescribed by their physical fitness coaches.

Their physical fitness was assessed through a body composition analysis and a functional performance test (incremental treadmill test). It should be noted that all participants had prior experience with treadmill running. Participation in this study was voluntary and all participants were informed of the risks of this investigation before signing an institutionally approved informed consent document. For all participants under the age of 18 years, old parental consent was granted prior to any testing activities. The study meets the ethical standards of the ~~journal~~ journal [27] and was approved by the University [redacted] ethics committee board [redacted]. Athletes who reported musculoskeletal injuries the last six months before the testing were excluded from the study. Furthermore, goalkeepers were not included as they were considered outliers ~~which~~ that could lead to biased estimates of averages and standard deviations, especially in the groups with small sample sizes. All athletes were advised to abstain from heavy physical activity the day prior to testing. The measurements were obtained between 9:00 and 15:00.

Study design

Anthropometric measurements included stature, body mass, body mass index, and body fat. A wall stadiometer (The Leicester Height Measure, Tanita, Japan) was used to measure stature. Leg-to-leg bioelectrical impedance analyzer system (BC 418 MA, Tanita, Japan) was used to determine the body composition by using the athlete mode and the input variables of body height, gender, and age.

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Cardiopulmonary exercise testing

Participants performed an incremental maximal cardiopulmonary exercise testing (CPET) to volitional exhaustion on a treadmill (h/p/Cosmos Quasar med, H-P-Cosmos Sports & Medical GmbH, Nussdorf-Traunstein, Germany). During CPET and recovery phase the gas exchange measurements were collected with reusable rubber masks, turbine flow meter, two-way nonrebreathing valve, (model 7940, Hans Rudolph, Kansas City, MO), and continuously monitored on the Cosmed Quark CPET (Rome, Italy) system, using a breath-by-breath analysis. The mask size varied from small, medium, and large, and selection was determined based on a preliminary fit to the face frame.

Before each testing session, the air VO2 flowmeter (ID28 QUARK), the oxygen, and the carbon dioxide meters were calibrated with a 3-liter air syringe and gas with known oxygen (16.5%), carbon dioxide (5.3%), and nitrogen (rest of the content) concentrations, respectively, as suggested by the manufacturer. Laboratory temperature was kept constant at 20 ± 1°C and the relative humidity was 50%. The modified Heck incremental maximal protocol was used for ~~the~~ testing, as it was previously demonstrated to be valid and reliable [21,-22] (Table 1). Once the test was completed, the results were filtered, and the VO2max was detected as the highest value recorded for an average of 10 seconds. Additionally, the heart rate (COSMED wireless HR monitor, Rome, Italy), VO2, carbon dioxide production (VCO2), and expired minute volume (VE) were monitored continuously ~~monitored~~.

Statistical analyses

SPSS 26.0 for windows (SPSS Inc., Chicago) was used for the statistical analysis. Before analyzing the data, the normality assumption was tested. Shapiro-Wilk tests for normality were tested at $p<0.10$ for significance. Means and standard deviations were calculated for all

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parameters. Multiple linear regression analysis (backward selection method) was utilized for each sport individually to determine the proportion of VO2max variation that was explained by the independent variables (height, body weight, body fat, and running time on the treadmill). Pearson-product moment correlation coefficients were calculated among the independent variables and VO2max (dependent variable). For all statistical analyses, significance was accepted at ~~*p*~~ *p* ~~<~~ ≤ .05. Multicollinearity was tested and all the independent variables that exceeded variance inflation were removed. Cohen's f^2 was calculated using the $R^2/1-R^2$ formula.

Results

The demographic characteristics, as well as running times and VO2max of the participants, are presented in Tables 2 and 3, respectively. Pearson product-moment correlation coefficients for the independent variables (height, body weight, body fat, running time) and the dependent variable (VO2max) are presented in Tables 4 and 5. Parameter estimates are presented in ~~Table~~ Table 6. Predictors that were correlated were removed from the models, as the inclusion of one variable was enough to capture the impact of both. The principle of parsimony was applied especially in the groups with a small sample size. Through multiple regression analysis, nine separate formulas (~~Table~~ Table 7) were developed for each of the athletic populations tested. Based on the results, 49.3% of the variation in VO2max was explained by the variation in running time for male professional soccer players, and ~~while~~ for male futsal players, 74% of the variation in VO2max was explained by the variation in running time. In addition, the proportions of variance for VO2max that ~~was~~ were explained by running time ~~was~~ were 57.2% and 59.6% for male soccer referees and elite female soccer players, respectively. Professional basketball players demonstrated greater R^2 values, which indicated that 74.3% and 71.3% of the variation in VO2max was explained by the variation in running time for youth basketball players between

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the ages of 15-17 and 13-14 years, respectively. Finally, the proportions of variance for VO2max that ~~was~~ were explained by running time ~~was~~ were 52.5% and 50.6% for male youth soccer players between the ages of 16-17 and at 15 years, respectively.

Discussion

This study aimed to develop VO2max prediction models for various athletic populations using the modified Heck protocol. Direct measurements of VO2max in laboratory settings can be costly, time-consuming, and necessitate the use of advanced equipment. Consequently, there are instances when teams avoid regular laboratory fitness assessments and rely solely on the field or non-laboratory testing that predicts VO2max.

Several well-established protocols exist in clinical settings such as the Bruce [17] Å~~A~~strand [18] Naughton [19] and Balke [20] protocols, with the Bruce protocol and its variations leading in popularity [16]. Furthermore, the modified Heck protocol was used previously [21,~~-~~22] for professional football player~~s~~ testing, as it was found to be valid and reliable.

~~Throughout~~ Over the years~~'~~, many studies ~~were~~ have been conducted to develop VO2max prediction equations [28] that are comparable to this study. One of the first protocols introduced was the Balke protocol in which the pace was kept constant at 3.3 miles per hour with the initial grade ~~of~~ of 0%. Following the ~~1st~~ first minute, the grade was increased to 2% with an additional increase of 1% each minute thereafter until exhaustion. The predictive formulas for both males and females, that were developed utilizing the Balke protocol relied solely on running time for the estimation of VO2max and did not consider any anthropometric measurements [29,~~-~~30]. A large body of research indicated that age results in an overall decrease in maximal heart rate, stroke volume, and maximal arteriovenous O2 difference, which lead to lower oxygen delivery

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to the muscles and subsequently in lower VO2max [31-33]. It is widely accepted that age is an essential variable when predicting VO2max [34]. Research demonstrated that age was more effective than gender and BMI at predicting VO2max in adults between the ages of 18 and 65 years old. Alternatively, even though age was considered more effective than gender and BMI at predicting VO2max ~~than gender and BMI~~, it was not as effective as treadmill grade and speed [34]. Our fitted models did not consider age as a predictor, as they included mostly homogenous age groups. Additionally, even in the groups where the age range was greater, the age parameter was not a significant predictor of VO2max, and it was excluded from the prediction models. When considering the Balke protocol, the low pace of the test made it possible to be used not only by healthy individuals but also cardiac patients. It is, however, questionable whether elite athletes can attain maximal conditions and produce true VO2max values at a speed of 3.3 mph. Research indicated that when physiological variables such as VO2max were measured (under submaximal and maximal conditions), the total variation was smallest when obtained under the maximal conditions [35]. It is therefore essential to use a testing protocol ~~by which~~ capable of detecting small changes in a given variable ~~are detected~~, which implies the use of maximal rather than submaximal testing protocols [35].

Another widely used protocol that was developed for a different target population was the Åstrand protocol. The test included higher running speeds, and therefore was more appropriate for athletes involved in sports in which aerobic endurance is a component such as distance running, triathlon, and cycling. The predictive formula for VO2max relied only on the time that was needed to complete the test, which is in line with the results of this study, as well as the formulas created by the Balke protocol. The Åstrand protocol maintained a constant running speed of ~~5~~ 5 mph and the grade of the treadmill was increased by 2.5% every two minutes after

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~~stage~~ stage 1. The athletes ought to continue until exhaustion, and upon ~~the~~ termination of the test, the recorded time was used to estimate VO2max. The results were then compared to normative data formulated for males and females, which separated data into age ranges ~~that corresponded~~corresponding to VO2max levels (from very poor to superior). The normative data provided came to eliminate the age issue, yet the actual calculation was not affected by these data [36].

~~Further~~ In addition to the aforementioned protocols, Bruce developed a multistage test with progressive workloads ~~which~~ that was utilized for the prediction of VO2max. The initial protocol was used to detect cardiac conditions, as well as early signs of coronary heart disease, and therefore a 12-lead electrocardiograph machine was necessary during the test. The running speed and grade were both altered during the test to increase the workload. In addition to the high cost of the equipmen~~t, which was~~ t ~~required~~ needed to carry out the test, the protocol was criticized for its uneven increments in speed as well as the high initial grade of 10~~%~~ % [37]. Furthermore, given the low starting speed of 1.7 mph, it took around 15 minutes for the individual to start running, which by then the elevation was already 18%. When considering the speed and elevation of the protocol, young or less trained individuals could find it difficult to execute the test without holding onto the handrails while elite athletes would need to carry out the test for prolonged periods. Besides, the high elevation may result in premature muscular fatigue in individuals who are not accustomed to this kind of training.

Research indicated that the ACSM~~’~~'s running equation was not capable of accurately predicting VO_2max in athletes aged 18-37 years utilizing the Bruce protocol. Even though the ACSM~~’~~'s formula was developed using highly fit males, it has been indicated that it overestimated VO2max in the athletic population while the regression-based equations were

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significantly correlated with the measured VO2max [38]. ~~In agreement with T~~The previously mentioned research was also in agreement with the work done ~~for~~ to ~~producing~~ produce predicting values for heart rate reserve (HRR) and oxygen uptake reserve (VO2R), which also indicated that the ACSM~~'~~'s metabolic equation overestimated both HRR and VO2R [39]. It ~~shall~~ should be noted, however, that the ~~ACSM's~~ ACSM's equation was intended for estimation of VO2max during steady-state exercise and not graded exercise testing~~,~~. As a result,~~thus the~~ utilization of the Bruce protocol might have been inappropriate.

In the present study, ~~through~~ multiple regression analysis were used to develop~~,~~ nine separate formulas ~~were developed~~, one for each of the athletic populations tested. These formulas allow athletes of the specific sports to predict VO2max by recording the time taken to complete the protocol on the treadmill. Furthermore, the modified Heck protocol is valid, reliable, and easy to apply. At the same time, the velocity is gradually increasing while the incline remains at 3% without causing premature muscular fatigue to the athletes at the initial stages of the testing. Finally, the duration of the test is appropriate for the evaluation of professional athletes, ~~especially~~ particularly soccer players. Research suggested that tests of about 10.5 minutes or longer may be more appropriate to evaluate soccer performance rather than tests of a shorter duration ~~tests~~ [40]. Taking into consideration how effective treadmill grade and speed is at predicting VO2max [34], it is suggested that the modified Heck protocol could be used as an alternative testing protocol.

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Conclusion

The utilization of the modified Heck protocol along with the generated VO2max regression equations would allow athletes and coaches to predict VO2max ~~at~~ in a relatively short time without the need for expensive and sophisticated equipment. It would have been advantageous, if the present study had evaluated the recreation equations by testing how accurately they predict directly measured VO2max values in the various athletic populations. Despite this limitation, ~~to our knowledge,~~ this is the first study to our knowledge that provides regression models for participants of different athletic populations using the modified Heck protocol. Further studies are encouraged to examine the external validity of these regression models using the modified Heck protocol, which is a valid, reliable, and easily applicable alternative protocol.

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Table 1: The modified Heck protocol

Velocity (km/h)	Velocity (m/s)	Inclination (%)	Stage duration (min)	Accumulated time (min)
		Warm up		
4.8	80	3	1	1
6	100	3	1	2
7.2	120	3	1	3
		Exercise		
8.4	140	3	2	2
9.6	160	3	2	4
10.8	180	3	2	6
12	200	3	2	8
13.2	220	3	2	10
14.4	240	3	2	12
15.6	260	3	2	14
16.8	280	3	2	16
18	300	3	2	18
19.2	320	3	2	20
20.4	340	3	2	22
21.6	360	3	2	24
22.8	380	3	2	26
24	400	3	2	28

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Table 2: Demographic characteristics

Sport		Age (Years)	Height (cm)	Body Weight (Kg)	Body Mass Index	Body Fat (%)
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Male Professional Soccer Players	*n*= 380	25.46±4.60	178.67±6.01	76.31±7.27	23.86±1.51	11.36±3.04
Male Professional Futsal Players	*n*=24	27.33±4.57	174.31±5.78	80.05±12.94	26.33±3.29	16.30±4.83
Male Professional Basketball Players	*n*= 27	27.30±4.31	192.63±8.00	92.94±10.24	25.00±1.68	12.86±3.29
Male Soccer Referees	*n*= 50	30.92±5.74	176.82±6.33	77.12±7.95	24.45±2.40	13.92±3.23
Female Professional Soccer Players	*n*= 19	23.58±4.30	165.16±6.63	60.17±7.58	21.83±1.61	20.14±3.33
Male Youth Basketball Players 15-17yrs	*n*= 20	15.80±0.83	181.65±6.98	75.96±5.95	22.69±1.77	17.94±4.24
Male Youth Basketball Players 13-14yrs	*n*= 15	13.53±0.52	171.87±9.92	62.67±9.41	21.19±2.47	18.34±3.42
Male Youth Soccer Players 15yrs	*n*= 28	15.00±.00	174.10±6.01	64.46±6.65	21.23±1.33	15.41±2.53
Male Youth Soccer Players 16-17yrs	*n*= 35	16.79±0.41	173.54±7.15	66.54±8.25	22.22±1.84	11.81±3.33

Table 3. Running times and VO2max for each sport

Sport		Running Time (min)	95% CI	VO2max (ml/kg/min)	95% CI
		Mean ± SD		Mean ± SD	
Male Professional Soccer Players	*n*= 380	15.57±1.98	15.37-15.77	54.89±6.42	54.25-55.54
Male Professional Futsal Players	*n*= 24	12.72±2.51	11.66-13.78	48.94±5.83	46.48-51.40
Male Professional Basketball Players	*n*= 27	13.50±2.10	12.68-14.33	49.54±5.60	47.32-51.75
Male Soccer Referees	*n*= 50	13.52±2.14	12.91-14.13	47.84±4.95	46.08-48.89
Female Professional Soccer Players	*n*= 19	12.55±1.97	11.60-13.50	51.03±6.53	47.89-54.18
Male Youth Basketball 15-17yrs	*n*= 20	13.51±2.71	12.24-14.78	56.51±6.03	53.69-59.33
Male Youth Basketball 13-14yrs	*n*= 15	13.33±1.91	12.28-14.39	59.02±4.31	56.23-61.40
Male Youth Soccer Players 15yrs	*n*= 28	15.74±1.95	14.98-16.50	55.91±7.06	53.17-58.64
Male Youth Soccer Players 16-17yrs	*n*= 35	16.41±1.78	15.80-17.03	57.73±6.38	55.54-59.92

Table 4: Intercorrelations among independent variables and VO2max for the different sports

	Variables	VO2max (ml/kg/min)	RT (min)~~2~~	Height (cm)~~3~~	4BW (kg)	BF %~~5~~
Male Soccer Players	VO2max (ml/kg/min)	1.00				
	RT (min)	0.702**	1.00			
	Height (cm)	-0.197**	-0.031	1.00		
	BW (kg)	-0.206**	-0.069	0.721**	1.00	
	BF %	-0.209**	-0.142**	0.021	0.398**	1.00
Male Futsal Players	VO2max(ml/kg/min)	1.00				
	RT (min)	0.860**	1.00			
	Height (cm)	-0.376	-0.308	1.00		
	BW (kg)	-0.633**	-0.572**	0.635**	1.00	
	BF %	-0.511**	-0.532**	0.128	0.764**	1.00
Male Basketball Players	VO2max (ml/kg/min)	1.00				
	RT (min)	0.828**	1.00			
	Height (cm)	-0.137	-0.005	1.00		
	BW (kg)	-0.066	0.002	0.759**	1.00	
	BF %	-0.263	-0.148	0.097	0.399*	1.00
Male Soccer Referees	VO2max (ml/kg/min)	1.00				
	RT (min)	0.756**	1.00			
	Height (cm)	-0.261	-0.176	1.00		
	BW (kg)	-0.146	0.019	0.713**	1.00	
	BF %	-0.297*	-0.151	-0.186	0.258	1.00
Female Soccer Players	VO2max (ml/kg/min)	1.00				
	RT (min)	0.772**	1.00			
	Height (cm)	-0.321	0.00	1.00		
	BW (kg)	-0.385	-0.009	0.807**	1.00	
	BF %	-0.378	-0.186	0.023	0.483*	1.00

RT=Running Time; BW=Body Weight, BF= Body Fat

**Correlation is significant at $p < 0.01$; * Correlation is significant at $p < 0.05$

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Table 5: Intercorrelations among independent variables and VO2max for the different sports

	Variables	VO2max (ml/kg/min)	RT (min)	Height (cm)	BW (kg)	BF %
Male Youth Basketball Players 15-17yrs	VO2max (ml/kg/min)	1.00				
	RT (min)	0.862**	1.00			
	Height (cm)	-0.182	-0.063	1.00		
	BW (kg)	-0.359	-0.449	0.454	1.00	
	BF %	-0.325	-0.458*	-0.401	-0.053	1.00
Male Youth Basketball Players 13-14yrs	VO2max (ml/kg/min)	1.00				
	RT (min)	0.845**	1.00			
	Height (cm)	-0.038	0.331	1.00		
	BW (kg)	-0.335	0.026	0.672**	1.00	
	BF %	-0.583*	-0.418	-0.038	0.639*	1.00
Male Youth Soccer Players 16-17yrs	VO2max (ml/kg/min)	1.00				
	RT (min)	0.724**	1.00			
	Height (cm)	-0.389*	-0.047	1.00		
	BW (kg)	-0.415*	-0.200	0.788**	1.00	
	BF %	0.363*	-0.020	-0.392*	-0.288	1.00
Male Youth Soccer Players 15yrs	VO2max (ml/kg/min)	1.00				
	RT (min)	0.711**	1.00			
	Height (cm)	-0.399*	-0.228	1.00		
	BW (kg)	-0.580**	-0.322	0.809**	1.00	
	BF %	-0.211	-0.153	-0.023	0.274	1.00

RT=Running Time; BW=Body Weight, BF= Body Fat

**Correlation is significant at $p < 0.01$; * Correlation is significant at $p < 0.05$

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Table 6: Parameter ~~Estimates~~ estimates

	Beta weights	*t* value	Variance inflation
Male Professional Soccer Players			
Intercept	19.51	10.49**	
RT	2.27	19.17**	1.00
Male Professional Futsal Players			
Intercept	23.57	7.20**	
RT	1.994	7.90**	1.00
Male Professional Basketball Players			
Intercept	19.628	4.79**	
RT	2.215	7.39**	1.00
Male Soccer Referees			
Intercept	28.772	7.65**	
RT	1.680	7.87**	1.023
Female Professional Soccer Players			
Intercept	18.92	2.92**	
RT	2.558	5.01**	1.00
Male Youth Basketball Players 15-17yrs			
Intercept	31.17	8.58**	
RT	1.86	7.01**	1.00
Male Youth Basketball Players 13-14yrs			
Intercept	33.547	7.42**	
RT	1.91	5.69**	1.00
Male Youth Soccer Players 16-17yrs			
Intercept	15.108	2.13*	
RT	2.596	6.04**	1.00
Male Youth Soccer Players 15yrs			
Intercept	15.477	1.96*	
RT	2.569	5.16**	1.00

**P<0.01; *P<0.05

RT: Running Time~~, BF: Body Fat %; BW: Body Weight~~

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Table 7: Equations for the fitted model

Sport	Equation	R^2	Cohen's f^2
Male Professional Soccer Players	VO2max= 19.51 + (2.27 x RT)	**49.3%**	**0.97**
Male Professional Futsal Players	VO2max= 23.57 + (1.994 x RT)	**74%**	**2.85**
Male Professional Basketball Players	VO2max= 19.628 + (2.215 x RT)	**68.6%**	**2.18**
Male soccer referees	VO2max= 23.886 + (1.746 x RT)	**57.2%**	**1.33**
Female Professional Soccer Players	VO2max= 38.679 + (2.548 x RT)	**59.6%**	**1.48**
Male Youth Basketball Players 15-17yrs	VO2max= 31.17 + (1.86 x RT)	**74.3%**	**2.89**
Male Youth Basketball Players 13-14yrs	VO2max= 33.547 + (1.97 x RT)	**71.3%**	**2.48**
Male Youth Soccer Players 16-17yrs	VO2max= 15.108 + (2.596 x RT)	**52.5%**	**1.11**
Male Youth Soccer Players 15yrs	VO2max = 15.477 + (2.569 x RT)	**50.6%**	**1.02**

RT: Running Time

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