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Modelling anaerobic peak power assessed by the force-velocity test among late adolescents

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SUMMARY

OBJECTIVES: The aim of this study was to examine the concurrent contributions of body size, estimates of whole-body composition, and appendicular volume in addition to participation in competitive basketball to explain inter-individual variance in anaerobic peak power output during late adolescence. The study also tested non-participation versus participation in basketball as an independent predictor of peak power output.

METHODS: The sample of this cross-sectional study was composed of 63 male participants (basketball: n=32, 17.0±0.9 years; school: n=31, 17.4±1.0 years). Anthropometry included stature, body mass, circumferences, lengths, and skinfolds. Fat-free mass was estimated from skinfolds and lower limbs volume predicted from circumferences and lengths. Participants completed the force-velocity test using a cycle ergometer to determine peak power output.

RESULTS: For the total sample, optimal peak power was correlated to body size (body mass: r=0.634; fat-free mass: r=0.719, lower limbs volume: r=0.577). The best model was given by fat-free mass and explained 51% of the inter-individual variance in force-velocity test. The preceding was independent of participating in sports (i.e., the dummy variable basketball vs. school did not add significant explained variance).

CONCLUSION: Adolescent basketball players were taller and heavier than school boys. The groups also differed in fat-free mass (school: 53.8±4.8 kg; basketball: 60.4±6.7 kg), which was the most prominent predictor of inter-individual variance in peak power output. Briefly, compared to school boys, participation in basketball was not associated with optimal differential braking force. Higher values in peak power output for basketball players were explained by a larger amount of fat-free mass.

KEYWORDS: Adolescent. Sport. Physiology. Anaerobic.

INTRODUCTION

Basketball is an intermittent sport involving repeated transitions between offence and defence phases. Periods of high-intensity activity were interspersed with low- to moderate-intensity activities[1]. The preceding emphasizes the need for basketball players to perform extensive sprinting and high-intensity shuffling activities during matchplay. The maximal efforts are predominantly supported by the anaerobic re-synthesis of adenosine triphosphate from phophocreatine and glycolysis[2]. The Wingate test (WAnT) is perhaps the most popular protocol to assess anaerobic fitness[3]. It requires a 30-s maximal effort in the cycle ergometer, adopting a standardized braking force (Fb) calculated as 7.5% of body mass (BM) as recommended by the original authors[4]. Nevertheless, a recent study adopted an Fb of 10% of BM to assess 32 trained male athletes from different sports (track and field, tennis, basketball, and football) in the WAnT[5].

Youth basketball players tend to plot above the median of the US reference data for boys[6,7]. An interesting research question emerges regarding whether Fb follows a constant proportionality in relation to BM as assumed by the WAnT protocol. Alternatively, the force-velocity test (FVT) has been used to assess peak power output in both school boys[8] and youth basketball players[7]. The FVT protocol requires participants to execute 3–5 maximal intensity efforts lasting 10 s or less to allow the estimation of the optimal braking force (Fb_{opt}) and associated optimal peak power (PP_{opt}). The calculation is obtained from a parabolic function that represents the relationship between peak power and Fb[7]. In fact, among youth basketball players aged 8.4–12.3 years, PP_{opt} assessed by the FVT was determined by adopting an Fb corresponding to 0.089 kg per unit of BM[9].

Considering that youth basketball players tend to be characterized by a larger body size compared to the normal population,

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the aim of this study was to examine the independent and combined effects of sports participation status, body size, and estimates of body composition to predict inter-individual variance in PP_{opt} assessed by the FVT among late adolescents. It was hypothesized that although the traditional standardized Fb would be questionable, the principle of geometric similarity applies to both non-athlete late adolescents and athletes of the same chronological age and fat-free mass (FFM) would be confirmed as the best predictor.

METHODS

Procedures

This cross-sectional study was approved by the Ethical Committee of the University of Coimbra [CE/FCDEF-UC/00122014] and followed the recommendations by the World Medical Association for research with humans[10]. Parents or legal guardians signed an informed consent. All measurements were completed by the same observers at the same hours of the day, that is, during the mornings of non-school days, under the same conditions as previously reported elsewhere[7]. Participants were advised to avoid eating food at least 3 h before the functional protocol and not to drink caffeine-containing beverages for at least 8 h before the laboratory assessment. All tests occurred at the Coimbra University Stadium.

Participants

The sample included 31 non-athlete adolescent boys (aged 17.4±1.0 years) recruited in secondary schools with which the University of Coimbra had agreements to carry out research projects. Inclusion criteria were as follows: (1) not participating in organized sports and (2) any physical limitations to perform maximal tests such as asthma. In parallel, 32 male adolescent basketball players (aged 17.0±0.9 years) were assessed as an independent group. The basketball players were recruited in four clubs registered in Portuguese Basketball Federations who already completed at least two seasons at the time of the observations. They regularly train three to four sessions per week of 90–120 min each under the supervision of a certified coach and in official basketball competitions (usually on weekend days).

Body size and body composition

Anthropometry was completed by a single observer following standardized procedures[11]. Stature was measured to the nearest 0.1 cm using a stadiometer (Harpenden model 98.603, Holtain LTD, Crosswell, UK). A portable balance (SECA model 770, Hanover, MD, USA) was used to measure BM to the nearest 0.1 kg. Skinfold thickness was measured at two sites (triceps and subscapular) to the nearest 1 mm using a Lange calliper (Beta Technology Incorporate Cambridge, MD, USA). A non-invasive equation recommended for male adolescents[12] was used to determine body fat expressed as a percentage of BM (%FM). Subsequently, fat mass (FM) and FFM in kg were derived.

Lower limbs volume

Estimates of lower limbs volume (LLV) were determined as previously detailed[7]. The lower limb was fractionated using geometric truncated cones. It requires circumferences and partial lengths between consecutive transverse plans. Lengths and circumferences were measured to the nearest 0.1 cm. The protocol partitioned the lower limb into truncated cones. The circumferences were measured as follows: at the most proximal gluteal furrow; at the level of the largest mid-thigh circumference; at the minimum circumference above the knee; at the maximum circumference around the knee, that is, at the patella level; at the minimum circumference below the knee; at the maximum calf circumference; and at the minimum ankle circumference. The lengths between consecutive transverse plans corresponding to each circumference (from the gluteal furrow to the minimum ankle circumference) were measured. To calculate the volume of a truncated cone, the following equation was used: $V = [A_1 + A_2 + (A_1 \times A_2)^{0.5}] \times h \div 3$, where A_1 (e.g., area at the proximal circumference level) and A_2 (e.g., area at the distal circumference level) are the areas at the sections that define the truncated cone, and h is the length between the two transverse plans. The areas (A_1, A_2) were derived from leg circumferences (C) as follows: $A = C^2/4\pi$. LLV (in L) was calculated as the sum of the volumes of the truncated cones.

Force-velocity test

Participants completed the FVT on a cycle ergometer interfaced to a computer (Monark 824E; Monark AB, Vargerg, Sweden). The standardized warm-up consisted of pedalling for 5 min at 60 revolutions per minute (rpm) against the basket (resistance: 1 kg) interspersed with a 3-s "all-out" sprint at the second, third, and fourth minutes. The FVT involved a set of three to six "all-out" sprints against random breaking forces. The initial resistance was set at 0.74 N kg^{-1} with subsequent Fbs randomly above and below the initial load. Flywheel velocity was measured using an optical sensor (Opto Sensor 2000; Sports Medicine Industries Inc., St. Cloud, MN, USA). The test was automatically interrupted when the optical sensor detected that rpm declined for three consecutive revolutions. Each sprint was interspaced by a 5-min active recovery (pedalling at 60 rpm with minimal resistance, i.e., the 1 kg the basket of the ergometer). PP_{opt} and Fb_{opt} were individually calculated[3,7,13].

Analyses

Descriptive statistics were calculated for school-aged adolescents and basketball players. The mean differences between school-aged adolescents and basketball participants were examined with the t-test for independent samples. The magnitude of differences was interpreted as follows[14]: <0.20 (trivial), 0.20–0.59 (small), 0.60–1.19 (moderate), 1.20–1.99 (large), 2.0–3.9 (very large), and ≥4.0 (nearly perfect). The linear relationship among body size descriptors and PP_{opt} was examined using Pearson product-moment correlation, and the magnitude of correlations was interpreted as follows[14]: trivial (r<0.1), small (0.1≤r<0.3), moderate (0.3≤r<0.5), large (0.5≤r<0.7), very large (0.7≤r<0.9), and nearly perfect (r≥0.9).

An initial model[15] was obtained using multiple linear regression analysis and the log-transformed values of BM, FFM, and LLV. In addition, sports participation status was encoded as a dummy variable (school=0; basketball=1). From an initial model including all predictors, it was tested whether it was possible to extract a more economical solution of predictors without a significant decline in explained variance (backward method of multiple regression analysis). For the final model, it was summarized as follows: coefficient R (multiple regression coefficient), standard error of estimate (SEE), squared R (explained variance), and significance value. For each predictor, an unstandardized coefficient was presented. The significance level was set at 5%. Statistical analyses were performed using the IBM SPSS version 19.0 software (IBM Corp., Armonk, NY, USA) and GraphPad Prism version 5.03 software (GraphPad Software, Inc., La Jolla, CA, USA).

RESULTS

Table 1 summarizes descriptive statistics separately for school-aged adolescents and basketball players, who were, on average, +8.5 cm taller and +8.2 kg heavier compared to non-athletes. Basketball players produced +123 W in the cycle ergometer test protocol compared to their school peers. The Fb_{opt} was 11.7% of BM (specific values were 11.3 and 12.2% of BM, respectively, for non-athlete adolescents and basketball players). For the total sample, the gradient of the correlation coefficients between PP_{opt} and each body size descriptor were as follows: LLV ($r_{PPopt, LLV}$=0.577; 95%CI 0.384–0.722; large), BM ($r_{PPopt, BM}$=0.634; 95%CI 0.458–0.762; large), and FFM ($r_{PPopt, FFM}$=0.719; 95%CI 0.573–0.821; very large). Table 2 summarizes the initial solution that considered log-transformed values for the three anthropometric variables in addition to sports participation as a dummy variable (school boys vs. basketball players). It explained 52.3% of the variance. Nevertheless, another significant model was obtained after excluding the dummy variables, suggesting that the sports status was not essential to explain the performance variable. In fact, the explained variance was reduced to 51.9%. Afterwards, it was also possible to exclude LLV with a minimal impact on explained variance (R^2=0.509). Finally, by excluding BM from the set of predictors, a model exclusively including FFM as a predictor was significant (R=0.712, SEE=0.130, p<0.001; 50.6% explained variance). The obtained equation is presented in Figure 1. The anti-log function corresponds to $PP_{opt}=2.106+FFM^{1.150}$. It is generalized to both non-athletes and basketball participants.

Table 1. Descriptive statistics by sports status (non-athletes vs. basketball players) for chronological age, body size, body composition, and force-velocity test outputs among male post-pubertal adolescents.

Variable	Unit	Comparisons between non-sports participants and basketball players					
		Non-athletes (n=31)	Basketball players (n=32)	t	p	Magnitude effect	
						d	(Qualitative)
Chronological age	years	17.4±1.0	17.0±0.9	1.461	0.149	0.43	(Small)
Stature	cm	171.8±4.5	180.3±7.8	5.225	<0.001	1.35	(Large)
Body mass	kg	64.9±8.6	73.1±10.3	3.398	0.001	0.88	(Moderate)
Fat mass	%	16.4±6.9	16.9±4.7	0.309	0.758	0.09	(Trivial)
	kg	11.1±6.0	12.7±5.0	1.120	0.267	0.29	(Small)
Fat-free mass	kg	53.8±4.8	60.4±6.7	4.484	<0.001	1.15	(Moderate)
Lower limbs volume	L	12.9±2.1	15.5±3.1	3.904	<0.001	1.08	(Moderate)
Optimal braking force	kg	7.3±1.4	8.8±1.8	3.562	0.001	0.94	(Moderate)
	$kg.kg^{-1}$	0.113±0.016	0.120±0.028	1.484	0.143	0.40	(Small)
	$N.kg^{-1}$	1.11±0.16	1.18±0.28	1.477	0.145	0.40	(Small)
PP_{opt}	W	806±140	929±157	3.267	0.002	0.84	(Moderate)

PP_{opt}, optimal peak power; d, Cohen's d-value.

Table 2. Modelling of peak power output among male adolescents (n=63).

Step	Variables in the model	Excluded in the model	Model summary						Coefficients				
									Scaling			Constant	
			R	SEE	R^2	R^2 adjusted	F	p	k	(95%CI)	p	a	p
1[a]	ln BM												
	ln FFM												
	ln LLV												
	School vs BB		0.723	0.131	0.523	0.490	15.887	<0.001					
2[b]	ln BM												
	ln FFM												
	ln LLV	School vs. BB	0.720	0.131	0.519	0.494	21.195	<0.001					
3[c]	ln BM												
	ln FFM	ln LLV	0.713	0.131	0.509	0.493	31.105	<0.001					
4[d]	ln FFM	ln BM	0.712	0.130	0.506	0.498	62.547	<0.001	1.150	(0.859–1.440)	<0.001	2.106	<0.001

ln BM, log-transformed body mass; ln FFM, log-transformed fat-free mass; ln LLV, log-transformed lower limbs volume; school vs. BB, dummy variable: school=0 and basketball=1; R, multiple correlation coefficient; R^2, explained variance; SEE, standard error of estimation; 95%CI, 95% confidence interval. [a]Model 1: $\ln(PP_{opt})=k_1{*}\ln(BM)+k_2{*}\ln(FFM)+k_3{*}\ln(LLV)+a+b{*}\text{dummy variable}+\ln(\varepsilon)$. [b]Model 2: $\ln(PP_{opt})=k_1{*}\ln(BM)+k_2{*}\ln(FFM)+k_3{*}\ln(LLV)+a+\ln(\varepsilon)$. [c]Model 3: $\ln(PP_{opt})=k_1{*}\ln(BM)+k_2{*}\ln(FFM)+a+\ln(\varepsilon)$. [d]Model 4: $\ln(PP_{opt})=k_1{*}\ln(FFM)+a+\ln(\varepsilon)$.

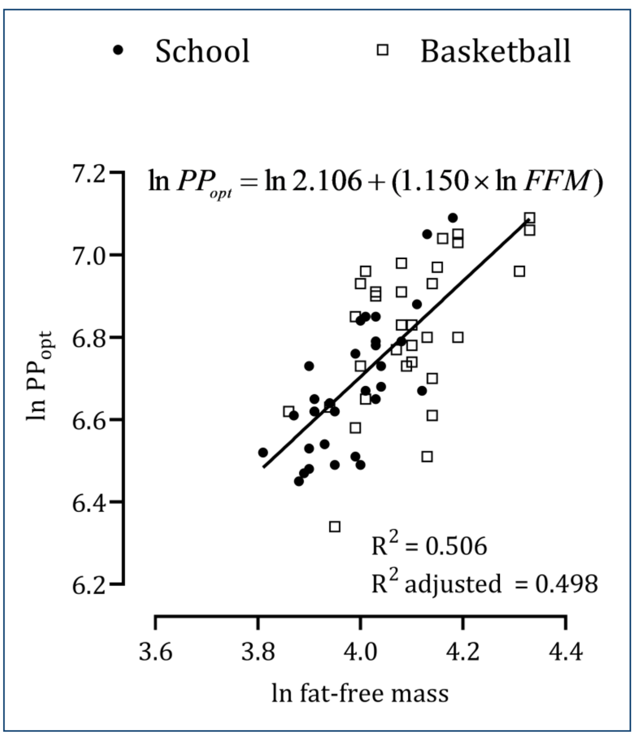

Figure 1. Linear regression of the ln transformed optimal peak output with the ln transformed fat-free mass.

DISCUSSION

This study examined the contribution of concurrent size descriptors to explain inter-individual variation on PP_{opt} obtained from the FVT protocol among a sample of late adolescent males combining non-athletes and basketball players. Compared to school boys, current basketball players presented larger amounts of LLV and FFM. The differences between sports participants and non-athletes do not necessarily follow the principles of geometric similarity. The final solution to explain PP_{opt} suggested that, among post-pubertal males, FFM was the best single predictor. The previous studies highlighted the importance of metabolically active tissues and appendicular volume to interpret inter-individual performance in the anaerobic performance output under discussion.

Few studies have examined anaerobic power among male adolescent basketball players combining WAnT and FVT. The preceding protocols were used in youth and adult basketball[16], and peak power derived from WAnT were 864, 700, and 1,039 W, respectively, for under-15 (n=35), under-18 (n=35), and elite adult players (n=31). The corresponding mean values obtained from the FVT protocol were 868, 1,086, and 1,255 W. The authors found that both WAnT and FVT protocols consistently detected variation of the mean performance values by playing position. Guards and forwards scored better than centers, more pronounced at senior level[16].

In this study, Fb_{opt} was 11.3% of BM (1.11 $N.kg^{-1}$) among school-aged adolescents and 12.0% (1.18 $N.kg^{-1}$) for basketball players. The above values were different from 7.5% of BM (0.74 $N.kg^{-1}$) as recommended in the WAnT protocol. Finally, pre-pubertal basketball players aged 10.8 years assessed using the FVT showed an estimated Fb_{opt} of

8.9% of BM. These results confirm that PP_{opt} is not associated to a standardized Fb as proposed by WAnT and, additionally, the size descriptor having largest shared variance to anaerobic performance is FFM. Consequently, body composition should be part of batteries aimed at assessing basketball players. In fact, body composition is a discriminant characteristic between non-athletes and basketball players. Finally, strength training designed to gain muscle mass may be a valid goal to increase anaerobic performance.

Despite the limitations of using the ratio standard[17,18], maximal short-term power output derived from FVT and WAnT protocols is often expressed per unit of BM (watt/kg). Previous study[6] suggested allometric scaling as the recommended option to obtain a size-free understanding of inter-individual variance which is believed to be relevant in sports such as basketball characterized by selection based on body size. Briefly, the simple ratio tends to penalize heavier individuals and rarely represents an appropriated approach to examine variability among participants[17,19,20]. The current study illustrated a linear relationship among FFM and anaerobic peak power derived from the FVT; nevertheless, it should be recognized that future studies need to use a better methodology in the assessment of body composition.

CONCLUSION

This study suggested that Fb_{opt} to assess anaerobic peak power should not be standardized at 0.075 kg per unit of BM. It has also been demonstrated that inter-individual variability in PP_{opt} in post-pubertal male school boys and adolescent basketball players is largely related to differences in the amount of FFM. Regardless of participation in basketball, among post-pubertal adolescents, FFM was confirmed as the most relevant body size descriptor to explain maximal intensity short-term output given by FVT.

AUTHORS' CONTRIBUTIONS

RB: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Validation. **MJCS:** Conceptualization, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft. **ACS:** Conceptualization, Data curation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft. **DVM:** Formal Analysis, Investigation, Methodology, Software, Validation, Writing – review & editing. **JVS:** Investigation, Software, Validation. **TO:** Formal Analysis, Resources, Software, Validation. **AST:** Software, Validation.

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