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Original Article

Relationship between anaerobic power, vertical jump and aerobic performance in adolescent track and field athletes

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Abstract:
The purpose of this study was to investigate the relationship between anaerobic power and vertical jump performance in adolescent athletes. Twenty four track and field athletes participated in this study (mean age: 15.79±0.83 years; height: 166.78±9.77 cm; weight: 57.44±13.42 kg; BMI: 20.45±3.01 kg/m2; body fat percentage (%): 18.80±5.55). The 12 minute Cooper test was performed to estimate VO2max (41.73±6.92 ml/kg.min). After 3-7 days the subjects applied counter movement jump (CMJ) and squat jump (SJ) for the following parameters: (1) the maximum jumping height [SJh and CMJh], (2) the total work produced by the body in each jumping condition [SJw and CMJw: weight (kg) x jump height (m)] and (3) the anaerobic performance [CMJpower and SJpower (kg.m/s): P= √4.9 x weight (kg) x √jump height (m)]. The Wingate anaerobic test was applied to determine peak power, average power and fatigue index. The jumping performance variables (height, total work and anaerobic power) and VO2max did not relate significantly to the fatigue index ($p>0.05$). All jump performance variables had a significant relationship with peak power and mean power ($p<0.05$ and $p<0.01$). Although both the absolute and relative Wingate test variables were significantly correlated with all jump performance variables, the r values for the relative variables were lower than their absolute counterparts. The results of the present study indicated that in field conditions the trainers may predict anaerobic performance using the jumping properties and when the subjects' body weight was incorporated, this led to a more representative indicator of the subjects jumping abilities.
Key words: track and field athletes, adolescents, anaerobic power, anaerobic capacity, squat jump, counter movement jump

Introduction

Track and field is a sport performed indoors or outdoors and made up of various competitive athletic contests based on running, hurdling, jumping (*the high jump, the long jump, the triple jump*), vaulting (*the pole vault*), walking events and throwing varied weights and objects (*shot put, hammer throw, discus throw and javelin throw*). Additionally, there are composite events as decathlon, heptathlon or pentathlon. Therefore the strength and anaerobic power are the basic motoric abilities that determine the sports performance. The ability of generating significant amounts of power is considered to be a strong predictor of athletic success (Bompa, 1993).

In shorter activities the patterns like jumping, throwing or striking the muscle strength, and particularly the ability to produce it fast plays a major role (Bencke et al., 2002). One of the most important matters in modern sports is evaluation of the athletes' physical capacities; for this reason many tests are used for selection procedures, for screening candidates, or to monitor the efficacy of training systems (Norkowski, 2002). The most common field tests used to evaluate the anaerobic power and performance in athletes are the vertical jump tests (Brooks et al., 2000). The vertical jump tests are used as a laboratory or field functional tests to measure power output of the legs (Malliou et al., 2003) and it is considered to be a component of performance because of its involvement in the activities of various explosive sports (track and field events, volleyball and weight lifting) (Tsiokanos et al., 2002).

Anaerobic performance is composed of anaerobic power and capacity. The Wingate anaerobic power test (WAnT) is a common dynamic test used to evaluate an athlete's anaerobic performance. As a laboratory measure, the WAnT is considered to be the most valid and reliable instrument to assess peak power (PP) and anaerobic capacity (Inbar et al., 1996; Powers and Howley, 1996). It has been reported that there was a significant correlation between PP and vertical jump height in athletes ($r = 0.86$) and in a group of mixed athletes and non-athletes ($r = 0.82$) (Kasabalis et al., 2005).

Sports performance professionals and sports scientists have been focused on performance assessment; however there are lacks of research examining the relationships between various motor skills (Vescovi and

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McGuigan, 2008). While some studies have investigated the relationship between different physical performance variables (*anaerobic performance, vertical jump performance, sprinting ability etc.*) an insufficient number of studies have been conducted on track and field adolescent athletes. However the participation of children and adolescents in competitive sports has increased recently. Knowledge of the power outputs and jumping height would, therefore, be useful in terms of coaching, and it would be very vital in controlling the outcomes from the training programs (Shalfawi et al., 2011). Thus, the purpose of this study was to investigate the relationship between Wingate anaerobic test performance, vertical jump and aerobic performance in adolescent track and field athletes.

Method

Participants

Twenty four amateur track and field young athletes (n= 13 males, age: 15.92 ± 0.64 years; n=11 females; age: 15.63 ± 1.02 years; runners, jumpers and throwers) of boarding sports high school volunteered to participate in this study. All participants were the member of the same team competing in the national league and trained at least ninety minutes in a day for six days per week. Nobody of the participants had a history of major lower limb injury and disease. At the beginning of the study all participants were informed about possible risks and benefits of the study and written consents were obtained from them and from their parents or legal guardian. The study was approved by the local ethical committee and was conducted in accordance with the Helsinki Declaration.

Procedures

The study was conducted in two parts over a week period. Anthropometric data collection and evolution of maximal oxygen uptake (VO_2max) were performed at the same day. After 3-7 days, vertical jump and Wingate anaerobic power test (WAnT) were performed giving sufficient recovery time between tests. All participants were instructed to avoid from strenuous exercise for the 48h period before the tests (Bloomer et al., 2005).

Measurements

Participants' heights were measured using a stadiometer (Holtain, Britain) to the nearest 0.1 cm, additionally participants' weights, BMI (kg/m^2) and percent body fat (%) were estimated by bioelectrical impedance analyzer (Tanita MC-180-MA, Japan). All measurements were performed in duplicate with the average value used as the criterion. After collecting the anthropometric data, a 12 minute walk/run test (Cooper) was used as an indirect method to predict VO_2max. The results were determined by multiplying the number of tours and the distance of each tour (400 m) and adding the distance of the completed tour (meter). The VO_2max values were determined using the Balke formula (1961).

VO_2 ml/kg.min = 33.3 + (distance covered/12 – 150) x 0.178 ml/kg.min

Three to seven days following the VO_2max evaluation the participants came to the laboratory in the morning (10.00 am) for the second part of the study. After 10-15 min (Bloomer et al., 2005) of rest in sitting position systolic blood pressure (SBP), diastolic blood pressure (DBP) and resting heart rate (HR) were measured on the upper arm according to the manuscript, using sphygmomanometer (Microlife BP A100, Switzerland).

First of all participants started with a standardized warm-up of 5-7 minute of cycling at 55-60 rpm against no load (894 Ea, Peak Bike by Monark AB, Sweden) and 5-7 minute of stretching. Following the warm-up, participants rested for 5-min. All jumps were performed using a dedicated force platform (Sport Expert TM, MPS-501, Tumer Electronic LDT, Turkey). After a familiarization session (*learning the proper techniques of the two jump conditions*) each subject performed three maximal voluntary vertical jumps at each of two testing conditions - Squat Jump (SJ) and Counter Movement Jump (CMJ); and the best value of the three trials were used for further analyses.

The SJ was performed from a starting position with the subjects' knees flexed to 90^0, hands fixed on the hips and with no allowance for preparatory counter-movement. The CMJ was performed from an upright standing position, with the hands fixed on the hips and with a counter movement preparatory phase ended at a position corresponded to the starting position in SJ. Sufficient recovery time was given among trials (more than 2 minutes). For the SJ and CMJ, three parameters were estimated (Çakır-Atabek et al., 2009): (1) the maximum jumping height (SJh and CMJh), (2) the total work produced by the body in each jumping condition (SJw and CMJw) which was calculated according to Genuario and Dolgener formula (1980) and (3) the power output (SJpower and CMJpower) value which was determined using the following formula (Roger, 1990).

SJ_{power} and CMJ_{power} (kg.m/s) = √4.9 x body weight (kg) x √jump height (m)

The WAnT was conducted using a mechanically braked cycle ergometer (894 Ea, Peak Bike by Monark AB, Sweden). Participants were seated on the ergometer and adjustments to the ergometer were made to ensure an optimal cycling position. Seat height was adjusted to each participant's satisfaction, and toe clips with straps were used to prevent the feet from slipping of the pedals. The WAnT was conducted according to widely accepted recommendations for standardization (Inbar et al., 1996). The WAnT was administered for 30 seconds and the resistance was set at 7.5% of body mass. Participants were encouraged to pedal as fast as they could prior to the application of resistance. Following application of resistance the participants continued pedaling at maximum speed throughout the remaining 30s. Verbal encouragement was provided by the investigator. Absolute peak power (APP), relative peak power (RPP), absolute mean power (AMP), relative mean power (RMP) and minimum power were calculated automatically by the WAnT program via computer (Monark Exercise AB, Sweden) and were recorded for further analysis. A fatigue index (FI) was calculated by using the following equation (Inbar et al., 1996).

Fatigue Index (FI) = [(Peak Power Output - Minimum Power Output) / Peak Power Output] x 100

Statistical analysis

All values were presented as mean ± standard deviation. Before parametric analyses were done, the normality of distribution of the data was assessed with Kolmogorov–Smirnov test. Then, the correlations between Wingate anaerobic test variables (APP, RPP, AMP, RMP, and FI), jump performance variables (SJh, CMJh, SJw, CMJw, SJpower and CMJpower) and VO_2max was evaluated using the Pearson Product Moment Correlation analysis. All analyses were executed using the SPSS for windows version 16.0 and statistical significance was set at $p < 0.05$.

Results

Participants' descriptive data are presented in Table 1. The squat jump (SJh, SJw and SJpower) and the counter movement jump (CMJh, CMJw and CMJpower) values of the subjects are presented in Table 2, moreover, the values of WAnT performance (APP, RPP, AMP, RMP, and FI (%)) of the subjects are presented in Table 3.

Table 1: Participants' descriptive data

	Females (n=11)	Males (n=13)	Total (n=24)
Age (years)	15.63 ± 1.02	15.92 ± 0.64	15.79 ± 0.83
Height (cm)	159.30 ± 6.51	173.12 ± 7.28	166.79 ± 9.78
Weight (kg)	49.81 ± 4.32	63.90 ± 15.22	57.45 ± 13.43
Percent Body Fat (%)	22.92 ± 3.42	15.33 ± 4.56	18.81 ± 5.55
Body Mass Index (kg/m^2)	19.63 ± 1.23	21.15 ± 3.87	20.45 ± 3.01
Resting SBP (mmHg)	112.91 ± 11.88	119.46 ± 12.59	116.46 ± 12.46
Resting DBP (mmHg)	69.18 ± 8.07	71.84 ± 5.83	70.63 ± 6.92
Resting HR (pulse/min)	83.82 ± 11.52	69.69 ± 12.13	76.17 ± 13.65
VO_2max ($ml.kg^{-1}.min^{-1}$)	36.96 ± 5.09	45.77 ± 5.65	41.73 ± 6.93

Note: SBP: Systolic blood pressure, DBP: Diastolic blood pressure, HR: Heart rate, VO_2max: Maximal oxygen uptake

Table 2: The maximum jump height, the total work and the anaerobic power values of the subjects, produced by the body in each jumping condition

	Females (n=11)	Males (n=13)	Total (n=24)
SJh (cm)	24.09 ± 3.11	31.23 ± 3.70	27.96 ± 4.96
CMJh (cm)	28.18 ± 3.89	35.69 ± 4.59	32.25 ± 5.67
SJw (kg.m)	11.98 ± 1.69	20.07 ± 5.53	16.36 ± 5.84
CMJw (kg.m)	13.98± 1.84	23.00 ± 6.81	18.87 ± 6.84
SJpower (kg.m/s)	53.97 ± 5.15	79.15 ± 19.99	67.61 ± 19.60
CMJpower (kg.m/s)	58.30 ± 5.12	84.72 ± 22.15	72.61 ± 21.17

Note: SJh: Squat jump height, CMJh: Counter movement jump height, SJw: Squat jump total work, CMJw: Counter movement jump total work, SJpower: Squat jump anaerobic power, CMJpower: Counter movement jump anaerobic power

Table 3: Wingate anaerobic test peak power, mean power and fatigue index values of the subjects

	Females (n=11)	Males (n=13)	Total (n=24)
Peak Power (w)	481.18 ± 55.67	854.91 ± 205.12	683.62 ± 243.89
Peak Power (w/kg)	9.68 ± 0.78	13.43 ± 1.79	11.71 ± 2.36
Mean Power (w)	272.52 ± 33.28	450.30 ± 97.58	368.82 ± 116.78
Mean Power (w/kg)	5.48 ± 0.54	7.08 ± 0.57	6.35 ± 0.98
Fatigue Index (%)	74.90 ± 3.91	79.78 ± 12.89	77.55 ± 9.97
Load (kg)	3.20 ± 0.27	4.22 ± 1.07	3.75 ± 0.95

Table 4 presents the correlation coefficients among measured variables. For all examined variables, it appears that the jump performance variables (height, total work and anaerobic power) and VO_2max did not have a significant relationship with the FI (%) ($p > 0.05$). Furthermore, the VO_2max did not have a significant relationship with load (kg), peak power and mean power expressed in watt (w: absolute values) ($p>0.05$), but it had a significant relationship with peak power and mean power expressed in watt/weight (w/kg: relative values) ($p<0.05$). In addition, all jump performance variables (height, total work and anaerobic power) had a significant relationship with load (kg), peak power and mean power ($p<0.05$ and $p<0.01$). Although both the absolute and relative WAnT variables (w and w/kg) were significantly correlated with SJw, CMJw, SJpower and CMJpower performance variables the r values for the relative variables were lower than their absolute counterparts (Table 4).

Table 4 Correlation between Wingate anaerobic test variables and vertical jump tests variables and maximal oxygen uptake

	Load (kg)	APP (w)	RPP(w/kg)	AMP (w)	RMP (w/kg)	FI (%)
SJh (cm)	0.501*	0.709**	0.738**	0.699**	0.761**	NS
CMJh (cm)	0.478*	0.693**	0.697**	0.669**	0.691**	NS
SJw (kg.m)	0.906**	0.915**	0.598**	0.938**	0.577**	NS
CMJw (kg.m)	0.893**	0.898**	0.562**	0.917**	0.530**	NS
SJpower (kg.m/s)	0.955**	0.912**	0.528**	0.945**	0.502*	NS
CMJpower (kg.m/s)	0.945**	0.904**	0.513**	0.934**	0.479*	NS
VO_2max ($ml.kg^{-1}.min^{-1}$)	NS	NS	0.535**	NS	0.635**	NS

*Note: * $p < 0.05$; ** $p \leq 0.01$; NS: No Significant*

SJh: Squat Jump Height, CMJh: Counter Movement Jump Height, SJw: Squat Jump Total Work, CMJw: Counter Movement Jump Total Work, SJpower: Squat Jump anaerobic power, CMJpower: Counter Movement Jump anaerobic power, VO_2max: Maximal Oxygen Uptake, APP: Absolute Peak Power, RPP: Relative Peak Power, AMP: Absolute Mean Power, RMP: Relative Mean Power, FI (%): Fatigue Index

Discussion

The relationship between vertical jump performance and WAnT performance was investigated in amateur adolescent track and field athletes. The main findings of the current study show that there is a high correlation between WAnT performance variables (APP, RPP, AMP, RMP) and all jump performance variables, however, the r values for the relative variables were lower than their absolute counterparts.

Anaerobic performance is important for every type of sport activities. As it is known the sudden and high intensity power production is required in times of sudden attack and press defense during the team games, during the sprinting, during the throwing and jumping events and also in many other sports activities. Anaerobic performance is composed of anaerobic power and capacity. Anaerobic power reflects the ability to use the phosphagenic system and anaerobic capacity, reflects the ability to derive energy from a combination of anaerobic glycolysis and the phosphagen system. Anaerobic performance depends on many factors, such as body composition, age, sex, muscle fiber composition, muscle cross sectional area, strength and training (Kin-İşler et al., 2008). The dynamic and static contraction power of legs are closely related to anaerobic power performance where it is an important criterion for the sport performance in sports involving explosive efforts (Fox et al., 1993). In addition The Wingate anaerobic power test is a reliable and the most popular method for calculating the anaerobic peak power of lower limb muscles (Inbar et al., 1996).

The relationships between various performance variables and fatigue index have been examined by few studies (Alemdaroğlu, 2012; Saç and Taşmektepligil, 2011; Arslan, 2005). Fatigue index is one of the criteria that assess an athlete's ability to sustain high power outputs during exercise. It has been reported that in first division basketball players there was no significant relationship between VO_2max and FI; also, there was no significant relationship between CMJh, SJh and FI (Alemdaroğlu, 2012). In another study it has been shown that in well trained male athletes there was not significant relationship between anaerobic power, measured with the vertical jump, and FI (Saç and Taşmektepligil, 2011). Additionally, in a group of trained and sedentary men and women no correlation was seen between vertical jump values and FI (Arslan, 2005). In consistent with these results, the findings of the current study indicated that the jump performance variables (height, total work and anaerobic power) and VO_2max did not significantly correlate with the FI in adolescent track and field athletes ($p>0.05$). In a recent study by Alemdaroğlu (2012) it was shown that there was no significant relationship between RPP, RMP and VO_2max. Although, the results of the present study indicated that the VO_2max did not correlate with load (kg), APP and AMP ($p>0.05$), the VO_2max significantly correlated with RPP and RMP ($r=0.54$; $r=0.64$, respectively; $p<0.01$). Lack of findings regarding the relationship between WAnT performance and VO_2max limits our discussion.

Mechanical power is an essential variable for the performance in sport and in the daily activities, and has been studied by researches for a long time. SJ and CMJ are commonly used tests to measure athlete-jumping ability. SJ is used as a measure of lower-body concentric strength/power, while CMJ as a measure of lower-body reactive strength/power (Newton et al., 2006). The mentioned studies suggest the two tests, SJ and CMJ, are valid and relevant measurement tools of athletic lower-body force and power ability (Riggs and Sheppard, 2009). When performing different types of jumps, the central nervous system uses different motor programs to execute the neuromuscular coordination necessary for the specific jumps. The SJ can be used as the most basic functional expression of explosive muscle strength as it requires only concentric activation. The CMJ requires moderate eccentric activation followed by high concentric activation, and therefore requires a more complex timing and graduation of the motor units. Thus the SJ can serve as a baseline for the potential of explosive muscle strength and CMJ may indicate development of this potential (Bencke et al., 2002).

The results of the present study indicated that all jump performance variables (height, total work and anaerobic power) had a significant relationship with load (kg), PP and MP ($p<0.05$ and $p<0.01$; Table 4). Stauffer et al. (2010) observed strong significant relationship ($r=0.85$) between peak power measured with the vertical jump and the WAnT in the group of 13 females basketball players (age: 19.7±1.1 years). In a similar study conducted by Farlinger et al. (2007) the r value of correlation between the vertical jump (height) and the modified Wingate performance (APP, AMP, RPP and RMP) was reported to be between 0.63 and 0.69 in a group of male competitive hockey players between the ages of 15 and 22 years (mean age: 16.3±1.7 years). Besides this, it has been reported that the correlation between the peak power measured with the vertical jump and the absolute Wingate performance (APP, AMP) were 0.88 and 0.89 respectively. On the other hand the correlation between the peak power measured with the vertical jump and the relative Wingate performance (RPP, RMP) were 0.46 and 0.33 respectively (Farlinger et al., 2007). In another study conducted by Arslan (2005) it was reported that in the regular exercise group, which included men and women, there was a positive correlation between APP, RPP, AMP, RMP and vertical jump performance ($r=0.60$, $r=0.49$, $r=0.63$, $r=59$, respectively). In addition it has been indicated that there was significant relationship between APP, AMP and vertical jump performance ($r=0.68$, $r=0.65$, respectively) in the sedentary group (Arslan, 2005). Moreover, it has been determined that the WAnT-APP was significantly correlated to vertical jump height ($r=0.56$) in soccer players aged of 19.6±0.8 years (Miller et al., 2011).

In another study conducted by Bencke et al. (2002) it has been observed that there was a weak relationship between PP development and SJ and CMJ performance ($r=0.41$ and $r=0.46$, respectively) in a group of children (boys and girls) aged between 10 – 13 years old, which were active in swimming, tennis, gymnastics or handball. Similar to these results, it has been reported that in a group of male athletes competing at the national and international level (volleyball, basketball, wrestling) there was a weak relationship between vertical jump and PP ($r=0.36$) (Saç and Taşmektepligil, 2011). Moreover, it has been shown that there was a weak relationship between AMP, RMP and vertical jump ($r=0.35$, $r=0.43$) (Almuzaini and Fleck, 2008).

In contrast to the mentioned studies above, it has been indicated that there was no relationship between APP, RPP and vertical jump performance in a group of physical education student (age: 21.66±1.66 years) (Almuzaini and Fleck, 2008). Besides this, no relationship was observed between CMJh and APP in adolescent skiers (age: 14.6 ± 1.1 years for boys and 14.9 ± 1.0 years for girls) (Emeterio and González-Badillo, 2010). Additionally, no significant relationship was observed between RPP, RMP and CMJh, no significant relationship was observed between RPP and SJh in American football players (age: 23.07±3.45 years), only the SJh was observed to be significantly related to RMP ($r=0.536$) (Eyuboğlu et al., 2009). Moreover, although it has been determined that the relationship between CMJh, SJh and PP were significant, the relationship between CMJh and MP was not significant (Alemdaroğlu, 2012).

Conclusion

In conclusion, there are two purposes for assessing athletic performance. First and most common is to determine quantitative improvements made after a training cycle. This allows the athlete and sport performance professional to examine if a training stimulus was sufficient to cause a positive adaptation. This method does not however lead the professionals in the direction that they should focus the training on. Therefore a second purpose of athletic assessment is to point out specific weaknesses in performance using various splits (Shalfawi et al., 2011). It is known that the SJ and CMJ are typically used as indicators of lower body power and the results indicated that vertical jump may predict the maximal anaerobic power and could be used by coaches as a practical and easy-to-apply field screening test (Kasabalis et al., 2005). However, it has been suggested that when the subjects' body weight was incorporated, this led to a more representative indicator of the subjects jumping abilities. It means that, with same jumping height a heavier subject will need greater extension strength to overcome the higher external resistance during jumping (Çakır–Atabek et al., 2009).

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