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PROSPECTIVE STUDY OF SOME PHYSICAL PERFORMANCE MEASURES IN YOUNG ATHLETES

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ABSTRACT

Performance measures are used to identify sports-specific profiles in athletes. Combining positional play skill sets with tailored training routines allows coaches to maximize athletic potential of junior athletes while reducing risk of injury or developmental delay. Methodologies have included assessing a range of generic anthropometric and biomotor variables and discriminant analysis of a non-sport-specific generic testing batteries. Recent focus has centered on the use of computerized posturography (CP) to measure postural stability and analyze lower limb power during explosive motor actions in athletes. Correlations have been made between both injury prediction and performance levels and postural stability using force platform technology. Maximum Vertical Jump (MVJ) is considered a highly significant performance indicator in most elite sports testing protocols and is recognized as a physical indicator of whole-body power efficiency across elite junior and adult levels. In this prospective study, MVJ efficiency measured using computerized posturography was obtained in two groups of athletes (male adolescents and female adults) and their athletic career followed over the years to determine if it could be utilized as an indicator of future performance. Results indicate that it might be worth further investigating the use of CP technology in sports performance testing and screening of young athletes when considering sports-specific skills assessment and training injury prevention.

Keywords: posturography, balance, Maximum Vertical Jump, efficiency, physical performance, force platform, beep test

INTRODUCTION

Physical performance measures are widely used in a variety of adult and junior team and individual sports to assess athletes for physical, physiological and sport skill-specific attributes [1]. They are also used to screen for injury risk and monitor post-injury rehabilitation [2]. Furthermore, physical performance testing is used in schools to detect sensorimotor delays at younger ages that may impact academic development: normative age-relative physical performance ranges are well established through early childhood years to mid-adolescence [3]. Links between sensorimotor development, cognitive development and academic performance have been recognized by educationalists [4].

Over the past two decades, computerized posturographic (CP) studies have assessed postural stability in young, normal and abnormally developed children, as well as elite athletes [5]. Force plate technology has been utilized to assess power efficiency and predict injury risk during ballistic movements used in sporting performance in young, elite level athletes [6]. Technology-based sports-specific power and balance efficiency assessment has also assisted trainers and coaches to determine whether an athlete has the potential to play a particular sport at an elite level, or play a particular field position at an elite team-sport level. Subsequent improvements in screening for attributes such as dynamic range of postural control and power efficiency during match-simulation tasks in a range of sports have emerged from this research [7].

State and national junior age-range sports squads are established to guide young athletes from junior elite sports programs to “draft” level. These prepubescent and adolescent athletes are identified as “elite potential” at a community level. Sports recruiters and performance experts use a battery of physical performance measures to identify adult athletic potential from elite junior sports squads. Specific performance markers such as Maximum Vertical Jump (MVJ), agility and stroke power assessment are measured [8]. In particular, the MVJ is considered a highly significant performance indicator in most elite sports testing protocols and is recognized as a physical indicator of whole-body power efficiency across elite junior and adult levels [9]. MVJ is tested by measuring how high an athlete can jump from a standing position. Common assessment methods are jump mats and attached graded wall brackets. Graded MVJ performance outcomes have been established for MVJ [10].

However, due to developmental variability in early to mid-adolescence, it is often difficult for group physical performance testing to accurately assess central integration in sensorimotor performance efficiency such as MVJ across an early adolescent, narrowly defined age group. Due to the limitations of standard testing equipment, MVJ is assessed as a desirable performance outcome (i.e., vertical height attained), rather than a measure of sensorimotor efficiency. The use of computerized force platforms and software has provided the opportunity for a more sensitive measure of MVJ efficiency [11]. In this prospective study, MVJ efficiency measured using computerized posturography was obtained in two groups of athletes (male adolescents and female adults) and their athletic career followed over the years to determine if it could be utilized as an indicator of future performance.

METHODS

Two groups of subjects were investigated: 17 male adolescents (age 13.0± 0.4 years, height 1.65±0.07 m, weight 51.6±8.6 kg, BMI 18.9±1.5 kg/m^2), members of a junior (Under 14) football team (16 subjects), an elite level junior diver; and 14 female adults (age 22.4± 5.3 years, height 1.74±0.06 m, weight 69.9±12.4 kg, BMI 32.1±3.1 kg/m2), all national level volleyball players (6 of whom were international representatives). As part of their pre-season physical evaluation, the football team underwent seven different physical performance tests: 20 m multistage fitness test (MSTF) [12]; 500 m rowing (timed in s), pushups (number to fatigue); chinups (number to fatigue); wall-sit (sitting against the wall in a “chair-like” position – timed to fatigue in s); plank (or abdominal bridge – timed to fatigue in s); one MVJ. The diver performed one MVJ. The women testing protocol was part of their physical evaluation mid-season, and consisted of three MVJs. Four of the adolescents also performed three MVJs at 21 years of age. When three MVJs were recorded, the higher jump was considered in the analysis. The other two were screened for fatigue (decreased jump height over time), learning (increased jump height), consistency (similar jump height), or inconsistency (uneven jump height).

For all the subjects, the MVJ was performed as followed: each subject was instructed to stand on the force platform in a relaxed stance, feet slightly apart, with hands by his/her side. Following an auditory

9781945541193/2017

signal, the subject was required to jump as high as he/she could off the plate to a marked landing point on the floor in front of the plate (the landing point was approximately 0.2 m in front of the leading edge of the force plate). The subject was instructed not to flex the knees, or move the arms substantially from the side of his/her body during the pre-jump phase, but were free to use any motion to execute the jump. Each subject was given two practice jumps on the floor prior to the testing jump(s), to ensure compliance with the instructions.

MVJ data were recorded and analyzed using a medical device (CAPS® Professional force platform and BalanceTRAK® software v. 4.3 – Vestibular Technologies, LLC, Cheyenne WY, U.S.A.) The MVJ was acquired at 500 Hz for the adolescents and 21 years old, and 100 Hz for the women. The maximum values of the force, power, energy, acceleration, velocity and displacement, and the Performance Efficiency Grade (PEG – patent pending – the lower the better) were considered. They were normalized by either the weight or the height of the subject. Pearson's correlations between the PEG and the different MVJ measures as well as the different adolescent physical performance tests were calculated (SPSS Version 20.0, IBM Corporation, Armonk, NY, US).

RESULTS

Table 1 contains the Pearson's correlation coefficients and their significance between the PEG and other VMJ results across all the jump tests recorded, as well as between the PEG and the other physical performance measures obtained for the adolescents. Tables 2 and 3 respectively contain some of the normalized results obtained for the MVJ for the adolescents and the women, and their current athletic standing. Table 4 shows the ranks of each adolescent in the seven evaluations as well as their current athletic standing. Table 5 contains some of the results for the MVJ of the adolescents that were also tested when they were 21 years old. The results are color coded to highlight the first (green), second (cyan) and third (orange) best value/rank for each parameter considered. The current standing of the subject was assigned as follow: 2 = professional elite, international, or Olympic level; 1 = national level; 0 = amateur or not playing anymore.

DISCUSSION

Subjects were prevented from landing on the device used for acquiring MVJ data, as it was designed for posturographic analysis. However, the protocol was designed to minimize the amount of forward displacement allowing the jump to be considered vertical for the study purposes, while taking advantage of the high sensitivity and resolution of a posturographic instrument that has been proven to satisfy the metrological standards set by the International Society for Posture and Gait Research [13].

The numerical results obtained from the MVJ analysis pertain to specific aspects involved in the movement that may be related but not equivalent. For example, a higher force does not necessarily correspond to a higher jump: the ability of the subject to generate high forces needs to be translated into enough momentum to propel the body vertically. Therefore, some type of efficiency (such as the PEG) might be better suited to evaluate the performance of a subject, since it relates to how well the body is able to reach the maximum height using the least amount of propulsion. In fact, considering the

Pearson's correlation coefficients and their significance (Table 1), it is evident that the PEG correlates very well with all MVJ measures except the maximum power. This could be expected since high power does not necessarily translate into high efficiency. Therefore, only the maximum power, the maximum displacement, and the PEG were reported as results in Tables 2, 3 and 5. When comparing the PEG with the other measures of physical performance for the adolescents, the Pearson's correlation coefficient is significant only for the pushups. This is not surprising as they are all measures of different aspects of physical performance. Therefore, depending on the performance of interest, some measures might be more appropriate than others.

Considering the numerical results of the MVJ (Table 2 and 3), it is evident that there is a wide range of values for the maximum power, the maximum displacement, and the PEG, even if these values are normalized for the subject. Furthermore, the values are different between the adolescents and the women, with the women on average able to exert more power, jumping higher and having lower PEG. This would be expected within elite level adult athletes, as whole body activities that do not require skills-specific precise motor control, such as the MVJ, require significantly developed neurological integration. This has been found to occur within neural networks at cortical, subcortical and brainstem levels [14]. Feed-forward and feedback mechanisms need to be integrated and trained to produce whole-body motor commands in volleyball players that require maximum efficiency whole-body motor output.

When attempting to predict physical performance outcomes in the adolescent group, with the exception of rowing, all the other measures considered are promising (Table 4): K_08, scored at the top for the PEG, the MSTF, pushups, wall-sit and plank and third for the chinups. Chinups are a measure of upper body rather than of whole body strength, whereas all the other measures pertain to either the lower extremities or the whole body. The PEG may have potential as a possible predictor for athletic performance (Tables 2, 3, and 5): K_08 (currently a professional footballer) and K_17 (currently an Olympic diver) have very low PEG as compared to the other adolescents and most of the women. The adult professional sports training K_08 has received may have maintained an initial high adolescent MVJ efficiency (Table 5), but the explosive nature of his jump requirements may possibly contribute to significant neural network demand and the progressive fatigue noted throughout his three adult jumps. The PEG deteriorated over the years for K_17. However, his PEGs are highly consistent throughout his three adult jumps. This may be due to the different neural network training requirements: divers repeat their dives in an exact choreographed manner ensuring their center of mass consistently reaches a desired height from a platform launch, enabling complex whole body movements to be performed in a short time frame. The other two adolescents re-tested as adults improved their PEGs, achieving similar values to the adult female volleyballers. This may suggest that motor control of whole body movements is still developing from 13 to 21 years of age in some athletes.

The results of the women are worth consideration. First, they could be affected by the fact that subject testing occurred at different times during an intense training session, resulting in possible significant pre-testing fatigue in some of the subjects reducing their capacity to achieve a maximum MVJ. It is also noted that the women with the lowest PEG are no longer playing at the top level or stopped playing altogether. A high MVJ is a desirable attribute for certain field positions in this team sport. Two of the

9781945541193/2017

women with the lowest PEG were of below average height, assigning them to a position where high MVJ efficiency is not essential. Three of the volleyballers still playing international level achieved varied PEG scores. It may be that the PEG can be considered as a reliable indicator of developed efficiency within early adolescents, but sports skills performance is equally as desirable in adult athletes.

Table 1 – Pearson's Correlation Coefficients between the PEG and the other measures, and their significance.

	Pearson's Corr. Coeff.	Sig. (2-tailed)
Norm_FzMax	0.441	0.000
Norm_PzMax	-0.178	0.138
Norm_WzMax	-0.737	0.000
Norm_AzMax	0.435	0.000
Norm_VzMax	-0.458	0.000
Norm_Dzmax	-0.750	0.000
MSFT	0.026	0.922
Rowing	-0.334	0.206
pushups	-0.576	0.020
chinups	0.073	0.787
wall-sit	-0.343	0.193
plank	-0.368	0.160

Table 2 - Normalized results obtained for the MVJ for the adolescents and their current athletic standing.

ID	PzMax [kW/kg]	DzMax [m/m]	PEG	Standing
K_08	0.052	0.544	22.606	2
K_15	0.048	0.447	28.379	0
K_07	0.051	0.437	28.791	0
K_17	0.043	0.296	32.476	2
K_14	0.050	0.272	52.700	0
K_12	0.053	0.270	60.535	0
K_05	0.042	0.243	53.069	0
K_13	0.048	0.239	55.685	0
K_16	0.048	0.234	45.793	0
K_01	0.044	0.229	62.212	1
K_04	0.043	0.227	64.012	0
K_03	0.050	0.226	54.329	0
K_10	0.040	0.225	51.103	0
K_09	0.043	0.222	60.774	1
K_02	0.040	0.216	46.404	0
K_11	0.043	0.207	67.775	1
K_06	0.036	0.204	51.436	0
Average	0.046	0.279	49.299	
Stdev	0.005	0.099	13.594	

Table 3 - Normalized results obtained for the MVJ for the women and their current athletic standing.

ID	PzMax [kW/kg]	DzMax [m/m]	PEG	Repetitions	standing
W_14	0.0719	0.7948	17.5208	inconsistent	1
W_10	0.0578	0.6720	17.3669	inconsistent	1
W_08	0.0446	0.4701	21.3525	inconsistent	0
W_06	0.0621	0.3820	35.7034	learning	2
W_02	0.0522	0.3782	37.2995	inconsistent	1
W_01	0.0704	0.3196	75.3935	learning	0
W_04	0.0581	0.3195	41.4394	consistent	1
W_12	0.0498	0.2834	40.1089	consisitent	0
W_11	0.0454	0.2816	35.7552	inconsisitent	0
W_09	0.0513	0.2739	45.1575	consistent	2
W_13	0.0461	0.2686	38.8612	consisitent	1
W_05	0.0515	0.2390	59.4509	learning	0
W_07	0.0460	0.2372	49.5653	consistent	0
W_03	0.0474	0.2321	55.4795	fatigue	2
Average	0.0539	0.3680	40.7468		
StDev	0.0090	0.1700	16.1564		

Table 4 - Ranks of each adolescent in the seven evaluations as well as their current athletic standing.

ID	PEG	MSFT	Rowing	pushups	chinups	wall-sit	plank	Standing
K_08	1	1	5	1	3	1	1	2
K_09	13	4	11	5	6	7	4	1
K_01	14	5	3	7	4	10	8	1
K_11	16	2	13	9	4	8	10	1
K_15	2	10	8	2	5	4	5	0
K_07	3	6	10	8	6	6	7	0
K_16	4	12	1	5	3	1	8	0
K_02	5	11	5	4	1	1	9	0
K_10	6	7	12	5	6	1	1	0
K_06	7	15	6	3	5	1	3	0
K_14	8	14	7	8	6	5	2	0
K_05	9	11	7	10	6	1	8	0
K_03	10	3	6	6	3	10	1	0
K_13	11	13	2	9	2	9	10	0
K_12	12	9	9	7	3	2	6	0
K_04	15	8	4	4	3	3	8	0

Table 5 - Normalized results obtained for the MVJ for the adolescents that were tested at 13 and 21 years old.

ID	K_04		K_08		K_12		K_17	
Age	13	21	13	21	13	21	13	21
PzMax [kW/kg]	0.043	0.057	0.052	0.077	0.053	0.055	0.043	0.071
DzMax [m/m]	0.227	0.301	0.544	0.710	0.270	0.285	0.296	0.363
PEG	64.012	51.369	22.606	21.868	60.535	44.283	32.476	46.686
Repetitions		Fatigue		Fatigue		Learning		Consistent

9781945541193/2017

CONCLUSIONS

It seems that posturographic measures obtained from MVJs are potential indicators of how adolescent athletes could perform when they reach adulthood. This study suggests that measures of efficiency in particular could be used to better determine adolescent potential in a specific sport, especially if a sport requires the ability to translate power into performance. Further studies on a larger number of subjects are needed to investigating the use of CP technology in sports performance testing and screening of young athletes when considering sports-specific skills assessment and training injury prevention.

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