

# Identification of Specific Selection Criteria in Young Ball Sport Players

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## Research article

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## Abstract

**Background:** The purpose of our study was to analyze body composition and spiroergometric data of young (14-15 years) elite level ball sport players. We suggested that three-ball sports (handball, soccer, and basketball) share common performance indicators, as each ball sport is primarily characterized by rapid intermittent movements.

**Methods:** We selected one-hundred and ten, handball (n=30), basketball (n=40) and soccer (n=40) players male and female from local clubs in Hungary. To measure their performance to develop high-quality training programs adequately age was differing from 14 to 15, they represented the elite level of their sports. They participated in performance analysis, the protocol included a body composition analysis and spiroergometric tests. We measured body composition and physiological parameters utilizing an In Body 720 device, and a standard Bruce treadmill protocol. Although we were aware of the limitations of the Bruce protocol in elite athletes, we choose this protocol as a safer alternative for younger inexperienced athletes.

**Results and conclusions:** We concluded that in young male soccer and basketball players mean peak /load (W), peak/VE (l), peak/Vtex (l), peak/VO<sub>2</sub> (ml/min), peak/VCO<sub>2</sub> (ml/min), and peak/ O<sub>2</sub> pulse (ml) data is a reliable indicator of the sport-specific performance. We may also suggest, that in our population of male basketball and handball players peak/Vtex (l) is the only variable, which is significantly different. Between groups of male handball and soccer players, peak/VO<sub>2</sub>/kg (ml/min) may be a valid performance indicator too. Among female basketball and handball players we found a significant difference in three performance variables: peak/Vtex (l), peak/VO<sub>2</sub> (ml/min) and peak/ O<sub>2</sub> pulse (ml). Although we must be careful when interpreting results, prior experiences with exercise testing, biological maturation differences must be considered.

**Trial registration:** All examinations involving human subjects were approved by the Hungarian Ethical Committee ETT TUKEB:15117-4/2018/EÜIG.

## Background

In today's sport, it is essential to have objective measurements to assess physical performance. In general, anthropometric, body composition, spiroergometric analyses are performed, to monitor general and sport-specific performance. Laboratory testing methods provide a direct way of measuring aerobic and anaerobic endurance capacity. Body composition analysis coupled with spiroergometric data enables sport professionals to diagnose sports performance in a more complex way. Sports performance is a complex phenomenon [1], analyzing performance capacity using a treadmill protocol, is a safe and reliable way of assessing physical capacity. Treadmill, arm, or bicycle ergometers are used to measure performance variables. Excellent endurance capacity is one of the most important performance indicators for a ball-sport player [2, 3, 4]. However, ball sports such as handball, basketball or soccer are primarily characterized by a rapid change of movements and intermittent high-speed, explosive movements such as forward, backward, side to side shuffles and sprints, jumps and hops. The three different kinds of ball sports (basketball, handball, soccer) share one common characteristic, the constant change in the direction and pace of motion. [3, 4, 5]. The specificity of training is the key factor in implementing a type of instrumentation and protocol. There is a strong relationship between training background and method of sub-maximal testing [6]. The choice of a treadmill as an analyzing device is obvious because ball-sports are predominantly characterized by a running type of movement [7]. In ball sports, the most effective way of analyzing spiroergometric parameters is via a motorized treadmill.

Cardio-respiratory endurance, aerobic and anaerobic endurance capacity has been widely monitored via various laboratory or field tests in sport. Ball sports especially soccer is extremely popular among recreational or competitive athletes. The target group of these examinations were primarily adults or juniors, we found a relatively lower number of studies concerning youth athletes participating in ball sports.

## Assessment of performance via field-based versus laboratory testing

It is found to be practical to administer field-based tests, to measure sports performance in ball sport athletes. In case of monitoring aerobic performance, Sport-specific test is preferred, general field tests have limited criterion validity for predicting maximal or peak aerobic capacity. The 20-meter shuttle run test is commonly applied field test by sports professionals in ball sports [8, 9, 10]. Researchers such as Tomkinson and Olds [11], Voss and Sandercock [12] investigated the predictive power of the highly popular 20-meter shuttle run test in the assessment of aerobic fitness (VO<sub>2</sub> max). They provided an in-depth review of recent investigations (15 studies), assessing the validity and reliability of the 20-m shuttle run test. They found only moderate criterion validity (r = 0.51) predicting peak VO<sub>2</sub> in physically inactive adolescents. In soccer, results of sport-specific tests such as the modified version of the Hoff test and Bangsbo endurance test are

controversial in youth (14–17 years old) athlete population. In the modified Hoff test „the player has to conduct the ball in a forward run through the track. The track width is 35 m, the length is 55 m on the right and only 51.5 m on the other side. The distance from cone 7 to gate 8 is performed with backward dribbling. There are three hurdles (30–35 cm height), 22 cones (two cones for the backward run gate and two for the starting line). Total distance per lap: 290 m" [13]. The Bangsbo endurance test designed to mimic the intermittent performance characteristics of soccer consists of 40 bouts of various high-intensity runs and low-intensity recovery sessions for a total of 16.5 minutes. Hoff test demonstrated a significant correlation ( $r = 0.68$ ;  $p < 0.05$ ), with laboratory-based measurements of peak oxygen uptake [14, 15]. However, Bangsbo test results indicated no significant relationship with peak VO<sub>2</sub> measurements in a laboratory setting [14]. We may conclude despite the advantages of sports-specific field tests, laboratory-based tests are more accurate in the determination of maximal or peak aerobic capacity. One of the limitations of specific testing methods involving a ball is the high skill proficiency required to successfully perform. In adolescent athletes, lack of experience or inadequate skill level may distract the results. In ball sports, exercise testing such as the Bruce protocol treadmill stress test is a reliable option for monitoring aerobic performance.

## Assessment of VO<sub>2</sub> plateau in young athletes

Young athletes may be unable to perform their maximal aerobic capacity during a laboratory-based exercise test. Either they do not have enough experience in laboratory (treadmill) testing protocols, or they do not have enough motivation, mental stamina to maintain the pace of the exercise test. Some researchers suggested that the choice of exercise protocol may influence the measurement of the so-called VO<sub>2</sub> plateau. However, there is a strong body of evidence indicating that maximal aerobic capacity may be more effectively monitored using a discontinuous compared to a continuous exercise protocol. Relevant literature indicated that in the young population the term peak VO<sub>2</sub> is reflective of the person's true VO<sub>2</sub> max. [16].

## Methods

### Purpose

The purpose of our study was to analyze body composition and spiroergometric data of young (14–15 years) elite level ball sport players. We suggested that three-ball sports (handball, soccer, and basketball) share common performance indicators, as each ball sport is primarily characterized by rapid intermittent movements. A high level of both aerobic and anaerobic performance is necessary to achieve success in these sports.

We hypothesized, that due to the young age of the participants, they will find difficult to perform at their plateau, during laboratory-based treadmill testing. We priorly expected, that there will be only a limited number of significant differences in spiroergometric variables. However, training adaptations induced by prolonged intensive exercise may occur even among the adolescent athletes, which may facilitate the identification of certain performance (physiological) variables, that specifically characterizes each sport (handball, basketball, and soccer). This way more sport-specific, individualized selection programs may be developed by sports professionals. We suggested that focusing on certain performance variables may help coaches to predict future talents in a more advanced way.

## Participants

One-hundred and ten, handball ( $n = 29$ ), basketball ( $n = 41$ ) and soccer ( $n = 40$ ) players male and female from local clubs in North-Eastern Hungary, they represented the elite level of their sports. Among the participants 79 were males, 31 were females (Table 1).

Table 1  
Participants of the study

	Male	Female	Total
<b>Handball</b>	14	15	29
<b>Basketball</b>	25	16	41
<b>Soccer</b>	40	0	40
<b>Total</b>	79	31	110

We defined elite athletes as a registered member of academies participating in regular practices (5d/week), competing at the highest national level. The athletes were selected according to the above-mentioned objective standards by head coaching personnel; therefore, selection bias was minimized. The average age of the male and female participants was 14.52 and 14.43, respectively. The average training age of the handball, basketball, and soccer players was 5.00, 5.38, 5.20 respectively at the time of the investigation.

## Procedures

They participated in performance analysis, the protocol included body composition and a standard spiroergometric test. The measurements were taken place at the 2018-19 season during the preparatory phase, in February. The training cycle and competition schedule of the athletes were fully considered, the timing of the measurements made it possible to adopt appropriate alterations in the training regimen, if necessary. We measured body composition and physiological parameters utilizing an In Body 720 Body Composition Analyzer device (In Body Co, Cerritos, USA) and a standard Bruce treadmill protocol. Spiroergometric parameters were monitored utilizing Ergo Stress, TSE-01 telemetric cardiovascular analyzing system (MDE GmbH, Walldorf, Germany), and an Ergo-Fit Cardio Line 400 Trac treadmill (Ergo-Fit GmbH, Pirmasens, Germany). Although we were aware of the limitations of the Bruce protocol in elite sport, we chose this protocol as a safer alternative for younger, inexperienced athletes. The termination of the test was set either at the point of volitional fatigue when VO<sub>2</sub> plateau or certain RER (1.15) values were reached [17].

## Statistical analysis

We chose a cross-sectional design, to analyze the results of various measurements. Out of numerous anthropometric and body composition variables, we further selected seven: Body Weight, Body Mass Index (BMI), Percent Body Fat (PBF), Fat-Free Mass (FFM), Body Fat Mass (BFM), Skeletal Muscle Mass (SMM), and Growth Score (Table 2.).

Table 2  
Body composition data of all participants

Gender	Age	Body Weight (kg)	Body Mass Index (BMI)	Percent Body Fat (PBF)	Fat-Free Mass (FFM, kg)	Body Fat Mass (BFM, kg)	Skeletal Muscle Mass (SMM, kg)	Growth Score
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
F	14.52	59.80	20.23	15.81*	50.96	7.76	28.42	105.00
M	14.43	62.72	20.37	12.12*	52.40	7.55	29.26	100.00
* p < 0.05								

We suggested that these variables realistically represent the overall physical fitness and maturation status of the athletes [18]. Ten dependent spiroergometric variables: peak/Load (W), peak/HR (1/min), peak/VE (l/min), peak/BF (1/min), peak/V<sub>t</sub> (l), peak/VO<sub>2</sub> (ml/min), peak/VCO<sub>2</sub> (ml/min), peak/VO<sub>2</sub>/kg (ml/min), peak/RER, peak/O<sub>2</sub> pulse (ml) were selected to test our hypothesis. First, a standard t-test was conducted to analyze differences in the above-mentioned ten dependent variables between two groups of male and female athletes. To conduct an in-depth analysis a Levene test was applied to test the homogeneity of variances, to assess the equality of **variances** for a given variable calculated for three (soccer, handball and basketball players) groups. Analysis of Variances (ANOVA) and the Welch test was used for calculating differences among group means if any. Finally, the Tukey and the Tamhane Post Hoc tests were applied to conduct multiple comparisons of group means.

## Results

As we priorly expected, selected body composition data (Table 3.) of ball sports especially basketball and handball players indicated a taller stature and leaner physique for all participants compared to their athlete counterparts participating in other sports [19].

Table 3  
Body composition data of male participants

		N	Mean	Std. Deviation	Sig.
<b>BMI (Body Mass Index)</b>	Handball	14	21.90	3.43	0.07
	Basketball	25	20.47	1.83	
	Soccer	40	19.77	2.08	
<b>PBF (Percent Body Fat)</b>	Handball	14	13.94	10.18	0.03*
	Basketball	25	14.08	6.25	
	Soccer	40	10.27	4.44	
<b>Growth Score</b>	Handball	14	10.93	18.04	0.16
	Basketball	25	109.72	11.39	
	Soccer	40	103.68	10.90	
<b>BFM</b>	Handball	14	9.04	6.42	0.22
	Basketball	25	8.10	4.63	
	Soccer	40	6.69	4.08	
<b>FFM</b>	Handball	14	48.11	9.65	0.12
	Basketball	25	55.19	10.49	
	Soccer	40	52.17	10.47	
<b>SMM</b>	Handball	14	26.66	5.81	0.13
	Basketball	25	30.88	6.25	
	Soccer	40	29.16	6.32	
* p < 0.05					

Growth Score of 100 and over, indicated, greater body height and healthier (lower PBF, higher SMM) body composition data especially the Growth Score suggested, that both males and females were rather early maturing [20]. After analyzing selected spiroergometric data (Table 4.), we found significant difference ( $p < 0.05$ ) in the following parameters: peak/load, peak/VE, peak/Vtex, peak/VO<sub>2</sub>, peak/VCO<sub>2</sub>, peak/VO<sub>2</sub>/kg, peak/O<sub>2</sub> pulse between male and female athletes, all the participants of the study.

Table 4  
Spiroergometric data of all participants

Gender	PEAK Load (W)	PEAK/HR(1/min)	PEAK/VE(L/min)	PEAK/BF(1/min)	PEAK/Vtex(L)	PEAK/VO <sub>2</sub> (mL/min)	PEAK/VCO <sub>2</sub> (ml/min)	PEAK/VO <sub>2</sub> /kg (ml/min)	PEAK/RER	PEAK/O <sub>2</sub> pulse (mL)
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
<b>F</b>	205.97*	195.78	86.74*	50.40	1.75*	2718.13*	2657.81*	45.69*	1.03	13.53*
<b>M</b>	259.75*	193.63	107.48*	51.97	2.07*	3421.91*	3368.66*	54.80*	1.00	17.33*
* p < 0.05										

When analyzing gender-specific performance (Table 5.) we found a significant difference ( $p < 0.05$ ) in peak/Vtex, peak/VO<sub>2</sub>, peak/O<sub>2</sub> pulse between female basketball and handball players.

Table 5  
Spiroergometric data of male participants

		N	Mean	Std. Deviation	Sig.
<b>PEAK/LOAD (W)</b>	Handball	14	250.71	38.82	0.004**
	Basketball	25	286.20	50.48	
	Soccer	40	246.38	46.69	
<b>PEAK/HR (1/min)</b>	Handball	14	195.00	7.04	0.90
	Basketball	25	194.68	5.03	
	Soccer	40	194.05	9.24	
<b>PEAK/V'E (L/min)</b>	Handball	14	102.07	14.16	0.01*
	Basketball	25	117.84	22.83	
	Soccer	40	102.90	21.16	
<b>PEAK/BF (1/min)</b>	Handball	14	51.26	4.39	0.02
	Basketball	25	51.25	7.59	
	Soccer	40	53.80	8.47	
<b>PEAK/Vtex (L)</b>	Handball	14	1.99	0.20	0.0003**
	Basketball	25	2.32	0.45	
	Soccer	40	1.95	0.39	
<b>PEAK/VO<sub>2</sub> (mL/min)</b>	Handball	14	3210.79	413.93	0.0003**
	Basketball	25	3706.44	532.61	
	Soccer	40	3257.70	582.28	
<b>PEAK/VCO<sub>2</sub> (mL/min)</b>	Handball	14	3286.36	442.21	0.003**
	Basketball	25	3762.28	610.20	
	Soccer	40	3256.63	593.22	
<b>PEAK/VO<sub>2</sub>/kg (mL/...)</b>	Handball	14	50.14	8.24	0.006*
	Basketball	25	55.34	4.86	
	Soccer	40	56.10	5.55	
<b>PEAK/RER</b>	Handball	14	1.02	0.01	0.08
	Basketball	25	1.01	0.05	
	Soccer	40	1.00	0.05	
<b>PEAK/O<sub>2</sub> pulse (mL)</b>	Handball	14	16.46	2.17	0.006*
	Basketball	25	19.06	2.86	
	Soccer	40	16.83	3.18	
* p < 0,05, ** p < 0,005					

We may also suggest, that in our population of male basketball and handball players peak/Vtex is the only variable, which is significantly different. Between groups of male handball and soccer players, peak/VO<sub>2</sub>/kg may be also a valid performance indicator.

An in-depth analysis resulted in significant differences (p < 0.05) between the groups of male soccer and basketball players in mean peak /load, peak/VE, peak/Vtex, peak/VO<sub>2</sub>, peak/VCO<sub>2</sub>, and peak/ O<sub>2</sub> pulse. We may conclude that peak/Vtex is the only variable, which was

significantly different between the groups of male basketball and handball players.

## Conclusions

After reviewing the relevant literature, we may conclude that for younger 14–15 years old players direct, laboratory-based examinations of maximal aerobic capacity provide a more accurate measurement of the aerobic performance. It seems, that in this population of male soccer and basketball players mean peak /load, peak/VE, peak/Vtex, peak/VO<sub>2</sub>, peak/VCO<sub>2</sub>, peak/VO<sub>2</sub>/kg and peak/ O<sub>2</sub> pulse is a reliable indicator of the sport-specific performance. Surprisingly, peak expiratory tidal volume (peak/Vtex) is the only performance variable indicating significant differences not only in male soccer-basketball but in basketball-handball groups too. It seems that peak/Vtex may be an overall indicator of sport-specific performance among young male soccer, basketball, and handball players. As we previously expected male soccer players demonstrated significantly higher peak oxygen consumption (peak/VO<sub>2</sub>/kg), than handball players. We measured no significant difference between handball and basketball players. In young female basketball and handball players out of ten spirometric variables, three (peak/Vtex, peak/VO<sub>2</sub>, peak/O<sub>2</sub> pulse) may serve as selection criteria for young athletes. In young male basketball, handball, and soccer as well as female basketball and handball players, peak/Vtex seems to be a universal indicator of sport-specific performance. It would be beneficial to identify peak/Vtex as a possible selection criterion for coaches. It would be also necessary for sports professionals to focus more on the development of expiratory volumes in young ball sport athletes. The mean peak Respiratory Exchange Ratio (RER) values demonstrated a moderately high anaerobic effort, however, all participants fulfilled the plateau criterion (85–95% of age-predicted maximum: 220-age) of mean peak heart rate [21, 22, 23].

The athletes failed to reach their true VO<sub>2</sub> plateau, thus 1.15 RER value as a cut-off point was set. None of the participants were able to achieve the end-criterion value of 1.15 RER, so we could not able to realistically determine the point of aerobic-anaerobic turnover.

## Strength and Limitations

The main strengths of the current study were its large sample size. All participants were tested directly in the same laboratory, by the same technicians, inaccuracies in the measurement process were minimized.

Although we were carefully ensuring validity and reliability, certain limitations may apply in this study. The young athlete population, participants of our study had no or limited amount of prior experience in treadmill testing. Most of them were unaccustomed to the laboratory-based testing environment. Lower running economy and fatigue resistance during prolonged, exhaustive exercise may also distract the results to some extent even in trained adolescents.

We must be careful when interpreting results, prior experiences with exercise testing, biological maturation differences must be considered. In the future, we are planning to retest the sample population with a more sport-specific treadmill test, which integrates the various characteristics of these three sports. This subsequent, follow-up test would ensure a more reliable assessment of the true VO<sub>2</sub> max. We developed a ball-sport specific intermittent treadmill protocol based on our prior knowledge and notational analysis of match-play. We hypothesized that a more specific exercise test might provide more accurate data to analyze sports performance.

## Abbreviations

BMI - Body Mass Index

PBF - Percent Body Fat

BFM – Body Fat Mass

FFM – Fat Free Mass

SMM – Skeletal Muscle Mass

PEAK/LOAD (W) – Peak Workload in Watts

PEAK/HR (1/min) – Peak Heart Rate

PEAK/V'E (L/min) – Peak Minute Ventilation

PEAK/BF (1/min) – Peak Breathing Frequency

PEAK/Vtex (L) – Peak Expiratory Tidal Volume

PEAK/VO<sub>2</sub> (mL/min) – Peak Oxygen Uptake

PEAK/VC0<sub>2</sub> (mL/min) – Peak Exhaled Carbon Dioxide

PEAK/VO<sub>2</sub>/kg (mL/...) – Peak Oxygen Consumption

PEAK/RER – Peak Respiratory Exchange Ratio

PEAK/O<sub>2</sub> pulse (mL) – Peak Oxygen Pulse

VO<sub>2</sub> max – Maximal Oxygen Consumption

VO<sub>2</sub> plateau – Highest Rate of Oxygen Consumption

## Declarations

## Ethics approval and consent to participate:

Written informed consent was obtained from the parents of the participants.

All examinations involving human subjects were approved by the Hungarian Ethical Committee “Országos Tisztifőorvos Feladatokért Felelős Helyettes Államtitkárság, Egészségügyi Igazgatási Főosztály” (Office of the Surgeon General, Department of General Health Issues, approval number: 15117-4/2018/EÜIG).

## Consent for publication

Not applicable

## Availability of data and materials

Our research contains data of human subjects, which is not public. However, we may provide any data, by securing anonymity of the subjects upon request.

## Competing interests:

not applicable

## Funding:

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## Authors contributions:

PJM - primary author, responsible for preparing the manuscript, organize data, secondary creator of study design

RG - responsible for statistical analysis, helps creating and designing figures and tables

VK - responsible for contacting basketball head coaches, recruiting and coordinating subjects for examination

PG - responsible for contacting handball head coaches, recruiting and coordinating subjects for examination

LPA - responsible for contacting soccer head coaches, recruiting and coordinating subjects for examination

BZ - responsible for statistical design, additional help in analyzing results

BL - creator of the original study design, selection of subjects, supervising all tasks related to our research

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