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# IDENTIFICATION OF SPECIFIC SELECTION CRITERIA IN YOUNG BALL SPORT PLAYERS

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***Abstract***

*Background: Our study aimed to analyze body composition and spiroergometric data of young (14-15 years) elite level ball sport players. We suggested three-ball sports (handball, soccer, and basketball) share common performance indicators, as rapid intermittent movements primarily characterize each ball sport.*
*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. Seventy-nine males and thirty-one females participated in our study; their average age was 14.51 and 14.56, respectively.*
*They participated in laboratory testing; 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 Bruce protocol limitations 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/$VO_2$ (ml/min), peak/$VCO_2$ (ml/min), and peak/ $O_2$ pulse (ml) data is a reliable indicator of the sport-specific performance. We may also suggest that in our male basketball and handball players' population, peak/Vtex (l) is the only variable, which is significantly different. Between groups of male handball and soccer players, peak/$VO_2$/kg (ml/min) may be a valid performance indicator. Among female basketball and handball players, we found a significant difference in three performance variables: peak/Vtex (l), peak/$VO_2$ (ml/min), and peak/ $O_2$ pulse (ml).*

***Keywords:*** *Sport physiology, performance analysis, ball-sports, talent identification*

## THEORETICAL 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. Sports performance is a complex phenomenon (KISS-BALOGH, 2019; PUCSOK et al., 2018);

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 cardiorespiratory fitness (RIVERA BROWN-FRONTERA, 1998). Excellent endurance capacity is one of the most critical performance indicators for a ball-sport player (BANGSBO-LINDQUIST, 1992; EKBLOM, 1986; REILLY et al., 2000). 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 motion direction and pace (EKBLOM, 1986; REILLY et al., 2000; REILLY et al., 2008). A treadmill choice as an analyzing device is obvious because ball-sports are predominantly characterized by a running type of movement. 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, are prevalent 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. (RIVERA BROWN et al., 1994).

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

It is practical to administer field-based tests to measure sports performance in ball sport athletes. A 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 a commonly applied field test by sports professionals in ball sports (GRANTHAM et al., 2007; HARLEY et al., 2007; SMITH et al., 2007). Researchers such as Tomkinson and Olds (2007), Voss and Sandercock (2009) investigated the predictive power of the viral 20-meter shuttle run test in the assessment of aerobic fitness (VO2 max). They provided an in-depth review of recent investigations (15 studies), assessing the 20-m shuttle run test's validity and reliability. They found only moderate criterion validity ($r = 0.51$) predicting peak VO2 in physically inactive adolescents. In soccer, sport-specific tests such as the modified version of the Hoff test and Bangsbo endurance test are controversial in the 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 eight 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" (CHAMARI et al., 2005). 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 (BANGSBO et al., 2006; CHAMARI et al., 2004). However, Bangsbo test results indicated no significant relationship with peak VO2 measurements in a laboratory setting (BANGSBO et al., 2006). We may conclude that despite the advantages of sports-specific field tests, laboratory-based tests are more accurate in determining maximal or peak aerobic capacity. One of the limitations of specific testing methods involving a ball is the high skill proficiency required to perform successfully. 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 monitoring aerobic performance option.

### Assessment of VO2 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 the laboratory (treadmill) testing protocols, or they do not have enough motivation, mental stamina to maintain the exercise test's pace. Some researchers suggested that the choice of exercise protocol may influence the measurement of the so-called VO2 plateau. However, there is a substantial 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 the term peak VO2 reflects the person's actual VO2 max in the young population (RIVERA BROWN et al., 1992).

## 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 three-ball sports (handball, soccer, and basketball) share common performance indicators, as rapid intermittent movements primarily characterize each ball sport. A high level of both aerobic and anaerobic performance is necessary to achieve success in these sports.

We hypothesized that due to the participants' young age, they would find it difficult to perform at their plateau during laboratory-based treadmill testing. We priorly expected that there would be only a limited number of significant differences in spiroergometric variables. However, training adaptations induced by prolonged intensive exercise may occur even among adolescent athletes, facilitating the identification of specific performance (physiological) variables that specifically characterize 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 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, 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 |
|---|---|---|---|
| **Handball** | 14 | 15 | 29 |
| **Basketball** | 25 | 16 | 41 |
| **Soccer** | 40 | 0 | 40 |
| **Total** | 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 investigation time.

## 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 athletes' training cycle and competition schedule 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 Bruce protocol limitations in elite sport, we chose this protocol as a safer alternative for younger, inexperienced athletes. The test's termination was set either at the point of volitional fatigue when VO2 plateau or certain RER (1.15) values were reached (EDVARDSEN et al., 2014).

## 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.).

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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 athletes' overall physical fitness and maturation status [18]. Ten dependent spiroergometric variables: peak/Load (W), peak/HR (1/min), peak/VE (l/min), peak/BF (1/min), peak/Vtex (l), peak/VO2 (ml/min), peak/VCO2 (ml/min), peak/VO2/kg (ml/min), peak/RER, peak/O2 pulse (ml) were selected to test our hypothesis. First, a standard t-test was conducted to analyze differences in 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 to calculate 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 (PÁPAI, 2003).

Table 3. Body composition data of male participants

| | | N | Mean | Std. Deviation | Sig. |
|---|---|---|---|---|---|
| **BMI (Body Mass Index)** | Handball | 14 | 21.90 | 3.43 | 0.07 |
| | Basketball | 25 | 20.47 | 1.83 | |
| | Soccer | 40 | 19.77 | 2.08 | |
| **PBF (Percent Body Fat)** | Handball | 14 | 13.94 | 10.18 | 0.03* |
| | Basketball | 25 | 14.08 | 6.25 | |
| | Soccer | 40 | 10.27 | 4.44 | |
| **Growth Score** | Handball | 14 | 10.,93 | 18.04 | 0.16 |
| | Basketball | 25 | 109.72 | 11.39 | |
| | Soccer | 40 | 103.68 | 10.90 | |
| **BFM** | Handball | 14 | 9.04 | 6.42 | 0.22 |
| | Basketball | 25 | 8.10 | 4.63 | |
| | Soccer | 40 | 6.69 | 4.08 | |
| **FFM** | Handball | 14 | 48.11 | 9.65 | 0.12 |
| | Basketball | 25 | 55.19 | 10.49 | |
| | Soccer | 40 | 52.17 | 10.47 | |
| **SMM** | Handball | 14 | 26.66 | 5.81 | 0.13 |
| | Basketball | 25 | 30.88 | 6.25 | |
| | Soccer | 40 | 29.16 | 6.32 | |

* p<0.05

A growth score of 100 and over indicated greater body height and healthier (lower PBF, higher SMM) body composition data, especially the Growth Score. This suggested that both males and females were relatively early maturing (HARSÁNYI, 2003). After analyzing selected spiroergometric data (Table 4.), we found a significant difference ($p<0.05$) in the following parameters: peak/load, peak/VE, peak/Vtex, peak/VO2, peak/VCO2, peak/VO2/kg, peak/O2 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/$VO_2$ (mL/min)** | **PEAK/$VCO_2$ (ml/min)** | **PEAK/ $VO_2$ /kg (ml/min)** | **PEAK/ RER** | **PEAK/ $O_2$ pulse (mL)** |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Mean | Mean | Mean | Mean | Mean | Mean | Mean | Mean | Mean |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **F** | 205.97* | 195.78 | 86.74* | 50.40 | 1.75* | 2718.13* | 2657.81* | 45.69* | 1.03 | 13.53* |
| **M** | 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/VO2, peak/O2 pulse between female basketball and handball players.

Table 5. Spiroergometric data of male participants

| | | N | Mean | Std. Deviation | Sig. |
|---|---|---|---|---|---|
| **PEAK/LOAD (W)** | Handball | 14 | 250.71 | 38.82 | 0.004** |
| | Basketball | 25 | 286.20 | 50.48 | |
| | Soccer | 40 | 246.38 | 46.69 | |
| **PEAK/HR (1/min)** | Handball | 14 | 195.00 | 7.04 | 0.90 |
| | Basketball | 25 | 194.68 | 5.03 | |
| | Soccer | 40 | 194.05 | 9.24 | |
| **PEAK/V'E (L/min)** | Handball | 14 | 102.07 | 14.16 | 0.01* |
| | Basketball | 25 | 117.84 | 22.83 | |
| | Soccer | 40 | 102.90 | 21.16 | |
| **PEAK/BF (1/min)** | Handball | 14 | 51.26 | 4.39 | 0.02 |
| | Basketball | 25 | 51.25 | 7.59 | |
| | Soccer | 40 | 53.80 | 8.47 | |
| **PEAK/Vtex (L)** | Handball | 14 | 1.99 | 0.20 | 0.0003** |
| | Basketball | 25 | 2.32 | 0.45 | |
| | Soccer | 40 | 1.95 | 0.39 | |
| **PEAK/$VO_2$ (mL/min)** | Handball | 14 | 3210.79 | 413.93 | 0.0003** |
| | Basketball | 25 | 3706.44 | 532.61 | |
| | Soccer | 40 | 3257.70 | 582.28 | |
| **PEAK/$VCO_2$ (ml/min)** | Handball | 14 | 3286.36 | 442.21 | 0.003** |
| | Basketball | 25 | 3762.28 | 610.20 | |
| | Soccer | 40 | 3256.63 | 593.22 | |
| **PEAK/$VO_2$/kg (mL/...)** | Handball | 14 | 50.14 | 8.24 | 0.006* |
| | Basketball | 25 | 55.34 | 4.86 | |
| | Soccer | 40 | 56.10 | 5.55 | |
| **PEAK/RER** | Handball | 14 | 1.02 | 0.01 | 0.08 |
| | Basketball | 25 | 1.01 | 0.05 | |
| | Soccer | 40 | 1.00 | 0.05 | |
| **PEAK/$O_2$ pulse (mL)** | 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 male basketball and handball players' population, peak/Vtex is the only variable, which is significantly different. Between groups of male handball and soccer players, peak/VO2/kg may also be 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/VO2, peak/VCO2, and peak/ O2 pulse. We may conclude that peak/Vtex is the only variable, which was significantly different between 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 aerobic performance. It seems that in this population of male soccer and basketball players, mean peak /load, peak/VE, peak/Vtex, peak/VO2, peak/VCO2, peak/VO2/kg, and peak/ O2 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 in male soccer-basketball and basketball-handball groups. It seems that peak/Vtex may be an overall indicator of sport-specific performance among young male soccer, basketball, and handball players. Previously expected male soccer players demonstrated significantly higher peak oxygen consumption (peak/VO2/kg) than handball players. We measured no significant difference between handball and basketball players. Out of ten spiroergometric variables in young female basketball and handball players, three (peak/Vtex, peak/VO2, peak/O2 pulse) may serve as selection criteria for young athletes. In young male basketball, handball, and soccer and 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 also be necessary for sports professionals to focus more on developing 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 (ARMSTRONG et al., 2008; LEGER, 1996; RIVERA BROWN-FRONTERA, 1998).

The athletes failed to reach their true VO2 plateau; thus, a 1.15 RER value as a cut-off point was set. None of the participants achieved the end-criterion value of 1.15 RER, so we could not determine the point of aerobic-anaerobic turnover realistically.

### 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. During prolonged, exhaustive exercise, lower running economy, and fatigue resistance may also distract the results to some extent, even in trained adolescents.

We must be careful when interpreting results, prior experiences with exercise testing, and biological maturation differences. 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 actual VO2 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/VO2 (mL/min) – Peak Oxygen Uptake

PEAK/VCO2 (ml/min) – Peak Exhaled Carbon Dioxide

PEAK/VO2/kg (mL/...) – Peak Oxygen Consumption

PEAK/RER – Peak Respiratory Exchange Ratio

PEAK/O2 pulse (mL) – Peak Oxygen Pulse

VO2 max – Maximal Oxygen Consumption

VO2 plateau – Highest Rate of Oxygen Consumption

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