Anaerobic Power Characteristics of Elite Athletes in National Level Team-Sport Games

Michael I. Kalinski, Henrick Norkowski, Matthew S. Kerner, and Wlodzimierz G. Tkaczuk

Purpose: The purpose of the study was to acquire current anthropometric and physiological profiling of elite athletes and to examine differences in the characteristics. Methods: Three hundred and sixteen male, team-sport athletes were evaluated for anaerobic performance using the Wingate anaerobic test. Results: MANOVA procedures indicated significant differences in height among players of the sports. Pearson correlations indicated strong correlations for body mass with absolute peak power (Pp) and mean power (Pm), and relative Pm. Height correlated strongly with absolute Pp and Pm, with a low correlation with relative Pp. MANOVA procedures indicated that athletes who specialized in handball, volleyball, and basketball attained the greatest relative and absolute Pp, and the greatest relative Pm. Relative and absolute Pp of the soccer athletes were lowest of all other elite athletes. Conclusion: This study introduces normative values for elite male athletes, empowering coaches in the evaluation of anaerobic abilities and in the objective selection of athletes for competition.

Key Words: Wingate anaerobic test, anaerobic capacity

Key Points:
1. This study introduces anthropometric and physiological profiling of elite male athletes from five different team sports in Poland.
2. Members of elite league teams in Poland, including soccer, European-style handball, rugby, basketball, and volleyball, were evaluated for performance in the Wingate anaerobic test.
3. Athletes specializing in European-style handball, volleyball, and basketball attained the greatest relative and absolute peak anaerobic power, and the greatest relative mean anaerobic power.
4. Height correlated strongly with absolute peak anaerobic power and mean anaerobic power, with a low correlation for height with relative peak anaerobic power.

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Introduction

Many sports can be described as interval sports, with the demands at high levels requiring intermittent bouts of high-intensity play interspersed with periods of submaximal effort, utilizing both aerobic and anaerobic energy systems. Sport activities such as volleyball, rugby, handball, basketball, and soccer are comprised of varying explosive movement patterns (e.g., forward, side-to-side, backward shuffles), runs at different intensities (e.g., jog, sprint), kicking, tackling, turning, jumps, and sustained forceful contractions to control the ball against defensive pressure. It has been suggested that success in many sport games appears to include high anaerobic capacity, not aerobic power alone (1, 13, 14, 16, 18, 20).

The assessment of physical work capacity is a major consideration in preparing athletes for high-level competition. Current information regarding physiological profiles is necessary to provide a quantifiable basis for the development and maintenance of conditioning and training programs (2, 7, 16, 18, 21). The assessment of anaerobic performance is relevant to athletes and coaches because anaerobic performance can be altered through anaerobic conditioning.

The importance of anaerobic capacity measurement in sport games is in the development of sport-specific physiological profiling, the assessment of conditioning and training programs, and the evaluation of the sport’s physiological demands.

Numerous studies have been reported to document the physiological profiles of competitors in a variety of sport games (1, 4, 6, 9, 12, 17, 20, 24). However, there is a paucity of scientific literature readily available pointing to similarities and differences among competitors of different sport games and different nations. The purpose of this study was threefold: (a) to acquire current physiological profiling of elite athletes from five different team sports of the Polish elite league to serve as a quantifiable basis for the development and maintenance of conditioning and training programs; (b) to examine the differences in the anthropometric and physiological characteristics among basketball, volleyball, handball, rugby, and soccer athletes; and (c) to compare such values with those reported for similar elite athletes from other nations.

Methods

Subjects

The 316 male subjects (age, mean = 23.7, SD = 2.9 years), having consented to participate in this investigation, were all members of first league sports teams in Poland during the 2000–2001 seasons (for basketball, n = 54; for volleyball, n = 48; for handball, n = 76; for rugby, n = 64; for soccer, n = 74). The teams were comprised of players who were chosen from different cities nationwide. Training experience averaged 8.4 years and ranged from 3.7 to 16.4 years. Subject treatment was consistent with the policies of the Academy of Physical Education Institutional Review Board.

Assessment of Body Mass

Body mass and stature were measured according to Gordon et al. (11). Body mass was measured using a leveled platform scale, with a beam and moveable weights.
The subjects were weighed wearing shorts and a tee shirt, and without shoes. Body mass was recorded to the nearest 100 g. Stature was measured using a portable stadiometer. The subjects were measured wearing thin socks, with bodyweight evenly distributed to both feet and head positioned in the Frankfurt Horizontal Plane. Stature was recorded to the nearest .25 cm.

**Wingate Anaerobic Test**

Metabolic criteria were assessed using the Wingate protocol (15) on a Monark 824E cycle ergometer (Monark, Varberg, Sweden) interfaced with a computer. Data were collected with the OptoSensor testing software package (Sports Medicine Industries, Inc., St. Cloud, MN, U.S.). Each subject was asked to cycle at maximum effort against a predetermined workload. The subjects were instructed to begin seated pedaling as fast as possible throughout the test. Subjects were instructed to complete a 4–5-min intermittent warm-up at an intensity sufficient to elicit heart rate increases to 150–160 b · min$^{-1}$. The warm-up was interspersed with three “all-out sprints” at maximum rpm, lasting 4–8 s, to get a feel for the actual test. The subjects then rested for about 5 min to eliminate any fatigue associated with the warm-up.

The data collection phase was initiated by a 3–4-s period, whereby subjects pedaled at a submaximal resistance to allow them to overcome the inertial and frictional resistance of the flywheel and to shorten the acceleration phase. This was immediately followed by application of the full workload, corresponding to 0.075 kp · kg$^{-1}$ of bodyweight, which signaled the beginning of the 30-s test. The subjects were instructed to pedal as fast as possible for the entire length of the test and to maintain that maximal effort throughout the 30-s test period. Verbal encouragement was given throughout the test. The test was followed by a 2–3-min active recovery period on the cycle ergometer, consisting of pedaling against a light resistance that allowed the heart rate to return to within 10 b · min$^{-1}$ of resting value in all cases.

Performance was expressed by two indices commonly used in this test: peak power (Pp) or maximal power output attained during the test, and mean power (Pm) performed during the entire 30 s. Peak power output was taken as the highest power output attained over a 5-s interval, and mean power output was the average of all values obtained during the test. Peak anaerobic power and Pm were expressed in relative and absolute terms.

**Statistical Procedures**

Means and standard deviations were calculated individually for each sport and for the five sports combined. Pearson correlations were executed between the anthropometric data and the metabolic criteria. Multiple analysis of variance procedures were used to determine possible significant differences among the elite players of the Polish elite league sports teams. This was followed by post hoc Tukey multiple-comparison procedures in order to identify pair-wise differences among the groups. Significance levels for all statistical analyses were set at $\alpha = .05$.

**Results**

Table 1 provides the anthropometric and descriptive data for variables according to each team sport, and probability values for MANOVA and post hoc Tukey tests.
Table 1  Anthropometric and Descriptive Characteristics of the Subjects By Sport Including Probability Values for MANOVA and Post Hoc Tukey Tests Between the Sports (N = 316)

<table>
<thead>
<tr>
<th>Sport/variables</th>
<th>n</th>
<th>Longevity of training (year)</th>
<th>Age (year)</th>
<th>Body mass (kg)</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basketball</td>
<td>54</td>
<td>9.4 (3.3)</td>
<td>24.2 (3.3)</td>
<td>91.0 (10.5)</td>
<td>196.9 (7.5)</td>
</tr>
<tr>
<td>2. Volleyball</td>
<td>48</td>
<td>8.1 (3.1)</td>
<td>23.7 (3.3)</td>
<td>85.1 (5.4)</td>
<td>195.4 (5.2)</td>
</tr>
<tr>
<td>3. Handball</td>
<td>76</td>
<td>8.0 (2.9)</td>
<td>23.5 (3.1)</td>
<td>88.3 (6.2)</td>
<td>190.2 (4.9)</td>
</tr>
<tr>
<td>4. Rugby</td>
<td>64</td>
<td>7.4 (2.6)</td>
<td>24.3 (2.8)</td>
<td>93.3 (11.5)</td>
<td>184.8 (6.4)</td>
</tr>
<tr>
<td>5. Soccer</td>
<td>74</td>
<td>8.9 (2.1)</td>
<td>23.0 (2.2)</td>
<td>75.8 (6.0)</td>
<td>178.3 (6.3)</td>
</tr>
<tr>
<td>Mean</td>
<td>316</td>
<td>8.4 (3.3)</td>
<td>23.7 (2.9)</td>
<td>86.3 (10.4)</td>
<td>188.2 (9.2)</td>
</tr>
</tbody>
</table>

Note. Values expressed as mean (SD).
*p < .001; **p = .001; †p < .03; ‡p < .02; *p < .05; **p < .01.

between the sports (N = 316). The age of the athletes ranged from 19 to 34 years (mean = 23.7, SD = 2.9). Results of MANOVA procedures indicate no significant differences in age between the elite athletes by sport.

Length of training ranged from 3.7 to 16.4 years (mean = 8.4, SD = 3.3). MANOVA procedures indicated that the length of training was significantly highest for the basketball athletes and lowest for both handball and rugby athletes.

Player height ranged from 165 to 212 cm, while body mass ranged from 64 to 122 kg. Descriptive analyses and MANOVA procedures indicated that rugby and basketball athletes had the greatest body mass, and soccer athletes the least. Results of MANOVA procedures indicate that significant differences in body mass exist between players of; volleyball and soccer, rugby and basketball; soccer and volleyball, rugby, handball and basketball; rugby and volleyball, soccer, and handball; handball and soccer and rugby; and basketball and volleyball and soccer.

Results of descriptive analyses point out that basketball and volleyball athletes had the greatest body height, and soccer, the least. Results of MANOVA procedures indicated that significant differences in body height exist between players of: volleyball and soccer, rugby and handball; soccer and volleyball, rugby, handball and basketball; rugby and volleyball, soccer, handball, and basketball; handball and volleyball, soccer, rugby and basketball; and basketball and soccer, rugby and handball.

A significant large correlation was found for body mass with height (r = .83, p < .001) among the basketball players. Significant (p < .001) moderate correlations were found for body mass with height for handball (r = .62), soccer (r = .54), rugby (r = .52), and volleyball (r = .48). Overall, a significant moderate correlation was
found for body mass with height \((r = .60, p < .001)\). Height and body mass ranges for the basketball players were very large, from 178 cm to 212 cm and 65 kg to 111 kg, respectively. Figure 1 illustrates that body mass of the soccer players tended to cluster at the low end of the range of height scores, with body mass scores of the volleyball and handball players clustering about the midrange of height scores, and the body mass scores of the rugby players having slightly greater variability about the mid to high range of height scores.

Significant large correlations were found for body mass with absolute \(P_p\) \((r = .87, p < .001; \text{Figure 2})\) and absolute \(P_m\) \((r = .86, p < .001; \text{Figure 3})\). A low but significant correlation was found for body mass with relative \(P_m\) \((r = .12, p < .03; \text{Figure 4})\). No correlation was observed between body mass and relative \(P_p\) (Figure

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**Figure 1** — Relationship between body mass and height among sports \((N = 316)\).

**Figure 2** — Relationship between body mass and absolute peak anaerobic power among sports \((N = 316)\).
Height correlated strongly with absolute $P_p$ ($r = .59$, $p < .001$; Figure 6) and absolute $P_m$ ($r = .47$, $p < .001$; Figure 7). A low but significant correlation was found for height with relative $P_p$ ($r = .15$, $p < .01$; Figure 8), while no correlation was observed between body mass and relative $P_m$ (Figure 9).

### Evaluation of Metabolic Criteria

Results of the anaerobic assessments expressed by team sport participation and probability values for MANOVA and post hoc Tukey tests between the sports ($N = 316$) are shown in Table 2.
Description of the images:

**Figure 5** — Relationship between body mass and relative peak anaerobic power among sports ($N = 316$).

**Figure 6** — Relationship between height and absolute peak anaerobic power among sports ($N = 316$).

**Relative Peak Anaerobic Power ($W \cdot kg^{-1}$).** Descriptive analyses indicated that the athletes who specialized in handball, volleyball, and basketball attained the greatest relative Pp, with the lowest relative Pp attained by soccer players. Significant differences in relative Pp were found between volleyball and soccer ($p < .001$); soccer and volleyball ($p < .001$); handball ($p < .001$); and basketball ($p < .05$). Handball and soccer ($p < .05$) and basketball and soccer ($p < .05$). No significant differences in relative Pp were observed between rugby and the other team sports.
Absolute Peak Anaerobic Power (W). Descriptive analyses indicated that the athletes who specialized in rugby, basketball, and handball attained the greatest absolute Pp, with the lowest Pp attained by volleyball and soccer players. Significant differences in absolute Pp were found between volleyball and soccer (p < .001) and rugby (p < .02); soccer and volleyball (p < .001), rugby (p < .001), handball (p < .001), and basketball (p < .001); rugby and volleyball (p < .02) and soccer (p < .001); handball and soccer (p < .001); and basketball and soccer (p < .001).
Relative Mean Anaerobic Power (W · kg⁻¹). Descriptive analyses indicated that the athletes who specialized in handball, rugby, and basketball attained the greatest relative Pm, with the lowest relative Pm attained by volleyball and soccer players. Significant differences in relative Pm were found between volleyball and soccer (p < .03), rugby (p < .001), handball (p < .001), and basketball (p < .001); soccer and volleyball (p < .03), rugby (p < .001), handball (p < .001) and basketball (p < .001); rugby and volleyball (p < .001) and soccer (p < .001); handball and volleyball (p < .001) and soccer (p < .001); and basketball and volleyball (p < .001) and soccer (p < .001).

Absolute Mean Anaerobic Power (W). Descriptive analyses indicated that the athletes who specialized in rugby, basketball, and handball attained the greatest absolute Pm, with the lowest absolute Pm attained by volleyball and soccer players. Significant differences in absolute Pm were found between volleyball and soccer (p < .01), rugby (p < .001), handball (p < .001), and basketball (p < .001); soccer and volleyball (p < .01), rugby (p < .001), handball (p < .001), and basketball (p < .001); rugby and volleyball (p < .001) and soccer (p < .001); handball and volleyball (p < .001) and soccer (p < .001); and basketball and volleyball (p < .001) and soccer (p < .001).

Discussion

In sport games such as volleyball, soccer, rugby, handball, and basketball, athletes perform intermittent exercise (3). Bangsbo states that aerobic metabolism contributes to sport games during both exercise and recovery phases, whereas anaerobic metabolism provides energy during the exercise bout (3). The results of this study describe the anthropometric, and relative and absolute anaerobic characteristics of elite athletes from different team sports of a national elite league. To the best of our
### Table 2  Anaerobic Potentials of the Subjects Including Probability Values for MANOVA and Post Hoc Tukey Tests Between the Sports (N = 316)

<table>
<thead>
<tr>
<th>Sport/variables</th>
<th>Relative peak anaerobic power (W·kg⁻¹)</th>
<th>Absolute peak anaerobic power (W)</th>
<th>Relative mean anaerobic power (W·kg⁻¹)</th>
<th>Absolute mean anaerobic power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basketball</td>
<td>11.05 (0.81)</td>
<td>1002.73 (114.09)</td>
<td>8.70 (0.63)</td>
<td>789.92 (93.88)</td>
</tr>
<tr>
<td>2. Volleyball</td>
<td>11.24 (0.64)</td>
<td>956.01 (78.69)</td>
<td>7.95 (0.46)</td>
<td>676.27 (57.85)</td>
</tr>
<tr>
<td>3. Handball</td>
<td>11.27 (0.80)</td>
<td>994.79 (101.13)</td>
<td>8.93 (0.66)</td>
<td>788.02 (77.37)</td>
</tr>
<tr>
<td>4. Rugby</td>
<td>10.94 (0.59)</td>
<td>1016.84 (124.22)</td>
<td>8.79 (0.49)</td>
<td>816.1 (101.08)</td>
</tr>
<tr>
<td>5. Soccer</td>
<td>10.69 (0.68)</td>
<td>809.84 (79.56)</td>
<td>8.26 (0.57)</td>
<td>626.34 (67.50)</td>
</tr>
<tr>
<td>Mean</td>
<td>11.03 (0.74)</td>
<td>951.41 (128.80)</td>
<td>8.56 (0.67)</td>
<td>739.2 (111.00)</td>
</tr>
</tbody>
</table>

| [1] p           | *5                       | *5                       | *5                       | *5                       |
| [2] p           | *5                       | *5; *4                   | *1,3,4; **5             | *1,3,4; **5             |
| [3] p           | *5                       | *5                       | *2,5                    | *2,5                    |
| [4] p           | n.s.                     | *2; *5                   | *2,5                    | *2,5                    |
| [5] p           | *2.3; *1                 | *1,2,3,4                 | *1,3,4; **2             | *1,3,4; **2             |

**Note.** Values expressed as mean (SD).

*‘p < .001; **‘p < .03; ‘p < .02; ‘p < .05; ‘p < .01.

knowledge, data presented in Tables 1 and 2 represent the first profiling of anaerobic characteristics of such athletes as in Poland’s elite league. A limited number of comparisons to similar elite athletes can be made with respect to anaerobic power. The current investigation complements previous studies in which comparisons between metabolic criteria and anthropometric data were limited to a single sport game, devoid of comparison to different games. Data were absent for comparison between metabolic criteria and anthropometric data measured in this study and other studies of elite athletes from the sports of volleyball, soccer, rugby, handball, and basketball.

**Physical Characteristics**

In this investigation, subjects indicated a considerable number of years in specific conditioning and training for their sport games, averaging 8.4 years (SD = 3.3), with basketball players averaging the greatest at 9.4 years (SD = 3.3).
Basketball and volleyball players were significantly taller than the athletes of the other sports. Success in both basketball and volleyball depends upon characteristics of blocking, spiking, and shooting, all combined with high technical skill. It has been suggested that player height may be a very important criterion when selecting players (22). A comparison of body heights among international basketball and volleyball teams reveals that mean heights ranged from 192 to 195 cm (12, 19, 22–24). However, success in sport is also dependent in large part upon explosive power, skill, training, and tactic. Driss, Vanderwalle, and Monod (9) have reported a mean height of 180 cm ($SD = 7.0$) for volleyball players, with Maud (17) reporting body heights as low as 160 cm (mean = 180.7 cm, $SD = 8.7$) for rugby players.

In this investigation, rugby and basketball players had the greatest body mass and soccer players, the least. Results of MANOVA procedures indicate that significant differences in body mass exist between players of: volleyball and soccer, rugby and basketball; soccer and volleyball, rugby, handball and basketball; rugby and volleyball, soccer, and handball; handball and soccer and rugby; and basketball and volleyball and soccer. A comparison of body mass among American, Canadian, English, Finish, French, Saudi, and Soviet national basketball, rugby, soccer, and volleyball teams reveals that mean body mass ranged widely, from 69 to 90.1 kg (1, 9, 17, 19, 20, 22, 23). The broad body mass range indicates that body mass is likely a result of sport selection yet also points toward heterogeneity of body mass, even within the same sport.

**Anaerobic Characteristics**

We observed for both relative and absolute $P_p$ that values achieved for elite athletes of basketball, handball, rugby, and volleyball were similar. Whereas the rugby and basketball players attained the largest absolute $P_p$ values, their absolute $P_p$ values displayed an inverse relationship to body mass. This is in agreement with a previous study (5) and supports the argument that dimensional scaling should be incorporated when comparing athletes with different body mass. A limited comparison could only be made with regard to elite athletes in similar sports due to a paucity of published data in the sports of rugby and handball, in particular.

Our findings for relative $P_p$ of volleyball players are 15.5% lower than those found of Canadian national volleyball players (mean = 13.3 W · kg$^{-1}$, $SD = 0.9$; 20). Our findings for relative $P_p$ of basketball players are 21.6% lower than those found for Israeli national basketball players (mean = 14.1 W · kg$^{-1}$, $SD = 1.4$; 12). The absolute $P_p$ of the Israeli national team (mean = 1199.91 W) was 19.7% higher than the absolute $P_p$ reached by the basketball players in this study. We observed that both relative and absolute $P_p$ of the basketball, volleyball, handball, and rugby athletes in this study were exceedingly higher (for relative $P_p$, as high as 23%; for absolute $P_p$, as high as 64%) than for those anaerobic potentials reported for apparently healthy, untrained males (15).

We observed for both relative and absolute $P_m$ that values achieved for elite athletes of basketball, handball, and rugby were similar. Mean anaerobic power of the volleyball and soccer players was unremarkably different. Herein, again, only limited comparisons could be made with regard to elite athletes in these sports due to a paucity of published data in the sports of rugby, handball, and volleyball, in particular.
Our findings for relative Pm of volleyball players in this study is 16.3% lower than that found of Israeli National basketball players (mean = 9.5 W · kg⁻¹; 14). The absolute Pm of the Israeli national team (mean = 808.45 W) was only 2.3% higher than the absolute Pm reached by the basketball players in this study.

In this study, we observed that both relative and absolute Pm of the basketball (for relative Pp, 16.0%; for absolute Pp, 127.3%), volleyball (for relative Pp, 6.0%; for absolute Pp, 94.8%), handball (for relative Pp, 19.1%; for absolute Pp, 127.1%), and rugby (for relative Pp, 17.2%; for absolute Pp, 235.2%) athletes were exceedingly higher than for those “good” anaerobic potentials reported for apparently healthy, untrained males (15). The relative and absolute Pm of the aforementioned sport games in this investigation were 8.59 W · kg⁻¹ and 767.5 W, respectively. A comparison of these relative and absolute Pm values to those of the untrained Israeli males indicates that the average relative and absolute Pm values of the athletes from these four sports are greater by 48.4% and 93.1%, respectively. In this study, we observed mean relative and absolute Pp for basketball, volleyball, handball, and rugby of 11.13 W · kg⁻¹ and 922.6 W, respectively. A comparison of these relative and absolute Pp values to those of the untrained Israeli males indicates that the average relative and absolute Pm values of the athletes from these four sports are greater by 21.6% and 59.6%, respectively.

In this study, we observed that both relative and absolute Pp and Pm of the soccer athletes were higher than the apparently healthy, untrained males previously reported by Inbar, Bar-Or, and Skinner (15). While the soccer players in the current study reached a relative Pp of 10.7 W · kg⁻¹ and an absolute Pp of 810 W, these values are 16.9% and 30.0% higher than the “good” normalized scores reported in the Inbar, Bar-Or, and Skinner study (for relative Pp, as high as 23%; for absolute Pp, as high as 64%). The relative and absolute Pm of the soccer athletes in the current investigation were 10.1% and 80.2% greater than the “good” normalized scores reported in the Inbar, Bar-Or, and Skinner study. These findings are in agreement with data reported by Kirkendall (16), who concluded that when comparing soccer players to the general population, the athletes’ physiological profiles are above the norm. The relative and absolute Pp values in this study were similar to those recently reported for elite soccer players (for relative Pp, mean = 11.88, SD = 1.3; for absolute Pp, mean = 873.6, SD = 141.8; 1). Our findings are also in agreement with the relative and absolute Pm values reported in that same study by Al-Hazzaa et al. (for relative Pm, mean = 8.02, SD = 0.53; for absolute Pp, mean = 587.7, SD = 55.4; 1). In contrast, the mean values for both peak power and mean power, expressed relative to body mass, were lower than values reported for elite Swedish (10) and English soccer players (8).

In comparison, however, we found the relative and absolute Pp of the soccer athletes to be lowest of all other elite athletes in this study (for handball, 5.1% and 18.8%, respectively; for volleyball, 4.9% and 15.3%, respectively; and for basketball, 3.3% and 19.2%, respectively). In addition, we found the absolute Pp of the soccer athletes to be 20.4% lower than the handball athletes, with no significant difference in absolute Pp between them.

Conclusions

The present study introduces normative values for male athletes at the elite level of the team sports of basketball, volleyball, handball, rugby, and soccer. These data
should benefit coaches and athletes alike in the evaluation of anaerobic abilities and assist in the selection of athletes for competition. The physiological profile of a sport describes the physical characteristics of an athlete, which can then be used to identify talent and develop sport-specific training programs.

References


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