Factors of success in advanced level wrestling; reliability and validity of several diagnostic methods

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Summary

Introduction. There is an evident lack of studies which examined factors which discriminate high-level wrestlers in pursuit of small differences in their quality. The aim of this study was to determine the applicability of several fitness parameters in order to discriminate between high-level and top-level wrestlers (n = 22; all males).

Material and methods. The sample was divided into two groups: a top-level-group (selected for national-team; N = 6) and a high-level-group (national-team-sparing partners; N = 16). The variables included body height, body mass, BMI, sport-experience, bench-press, pull-ups, wrestling-modified-specific-judo fitness-test, VO2max, arm-cranking-test achievement (WATTmax); and physiological variables collected throughout a maximal progressive arm-cranking test: HRmax, and O2 decrease (pO2d; difference between maximum, and O2 concentration at exhaustion; all measured by transcutaneous oximetry).

Results. The model (Y = 4.083 + 0.837 x pO2d) successfully classified 83% top level and 94% high-level wrestlers, indicating that among the top-level the transcutaneous oxygen partial pressure decrease (left + right) is more evidenced (OR 0.84; 95%CI: 0.72 – 0.97).

Conclusions. The top-level-group was more experienced, had higher WATTmax and pO2. Forward conditional logistic regression revealed pO2d as a single significant predictor of the dichotomous criterion (top-level vs. high-level group).

Introduction

Achievement in contemporary Olympic wrestling depends largely on upper body strength, endurance and anaerobic power [1-3]. Studies have found that elite wrestlers possess a higher fat free mass, vertical jump height, anaerobic Wingate power, dynamic and isokinetic strength, in comparison to their less successful peers [1,4,5].

Due to biomechanical and anatomical similarity to sport of wrestling, different arm-cranking test protocols were applied in testing the physical capacities of the wrestlers [6-9]. This test was applied in wrestling as a common arm Wingate, or modified arm Wingate or variable intensity arm crank test designed to be similar to wrestling match conditions [1,3,4,10].

Transcutaneous monitoring is a noninvasive method to estimate the partial pressure of oxygen (tcpO2) on the skin surface by employing noninvasive heated electrodes [11,12]. It has been shown that arterial and transcutaneous blood gas values are highly correlated [13]. The tcp O2 is a known diagnostic tool in several medical treatments (wound evaluation, hyperbaric therapy, amputation level determination, plastic surgery, and peripheral vascular disease assessment), but it's usage is suggested for assessment of the intramuscular oxygen partial pressure among healthy subjects during exercise [14,15].

The aim of this study was to determine the differences between high-level and top-level wrestling athletes in several fitness parameters including tcpO2 measures. This included the validation of the applied tests in defining the differences between top-level and high-level wrestlers, apart from the fact that very few studies investigated fitness factors which contribute to success in competitive wrestling, we have found no study which investigated differences between high-level wrestlers in pursuit of small gains performance (i.e. high-level and top-level athletes). Apart from standard and known sport-specific measuring protocols, in this study the arm-cranking test is modified in order to design the measuring procedure of similar physiological demands as they appear throughout a wrestling match.

Methods

Subjects

The subjects consisted of 22 male wrestlers who had all finished in the top three places of the national championships.
They were divided into two qualitative-level groups: a top-level-group (N = 6) and a high-level-group (N = 16). Top-level group consisted of those wrestlers who were selected for national-team, all medalists at top-level international competitions (European- and World-level contests). High-level group consisted of who were at the moment of testing second-and/or third-best athletes in each weight category (non-selected for national team; national-team-sparing partners). Each official weight category was represented by two or three wrestlers, of whom one was top-level athlete. Subjects participated voluntarily with a written informed consent to participate in the study. The Institutional ethics committee approved the study protocol.

### Measures

Apart from age, and experience in wrestling (in years) the sample of variables consisted of anthropometrics (body height – BH, body mass – BM and calculated body mass index – BMI), standard and sport-specific fitness tests, and variables collected during the arm cranking test.

#### Standard fitness tests

Those tests were: 1-repetitum maximum of bench press (BPRESS), maximal number of pull-ups (PULLUPS).

#### Sport-specific fitness tests

The SJFT (16) consists of three periods: (I) 15 sec, (II) 30 sec, and (III) 30 sec with 10 s intervals among them. During each active period the evaluated wrestler throws two partners of similar weight (6 m distance between partners) as many times as possible using the arm throw technique. The heart rate is taken immediately from the monitor following the last throw (HRfinal) and one-minute later (HR1min). The index of performance is calculated according to following formula: Index = (HRfinal + HR1min) / number of throws

For the VO2max, participants performed a graded exercise test on the treadmill, according to the protocol described in recent literature for the sample of wrestlers [17]. Velocity on the treadmill started at 6 and 8 km/h and was increased every 3 minutes by 2 km/h at 0 degrees inclination. Running velocity was increased until the athlete reached volitional exhaustion. Maximal oxygen uptake was analyzed by a computerized respiratory gas analyzer. The gas analysis system was calibrated according to the manufacturer’s recommendation before each test using gases of known concentration. Criteria according to Howley et al were applied to verify that each athlete attained VO2max [18].

#### Arm – cranking test variables

Throughout arm-cranking tests we measured maximal power (WATTmax), O2 value at maximal power (PO2max), and O2 at exhaustion (PO2exhaustion). Additionally we have calculated the difference between PO2max and PO2exhaustion (PO2d). The duration of the arm-cranking test was adjusted to 6-10 minutes in order to mimic the duration of the standard wrestling match. Throughout the pretesting the initial workload of 30W was found to be appropriate, while the crank rate was set on previously recommended 30 km/h [19]. To avoid significant influence of leg power and trunk movement subjects were tested in the prone position [20]. The subject lies down on a bench, reaches for the pedals (adopted for arm-cranking) and starts pedaling. After a warm-up of 5 minutes, the workload was set on 30 Watts and test begins when subject achieve crank rate of 30 km/h test. The work load was increased by 5 W every 15 seconds up to exhaustion. The moment of exhaustion was defined as a moment when the arm crank rate decreased to lower than 20 km/h for more than 10 seconds. WATTmax was established as the maximal power achieved. Transcutaneous PO2 was monitored during the arm crank test. Before the arm crank test blood gas PO2 sensors and heart rate monitor were fixed on subject. The blood gas PO2 sensors were set above the left and right brachial triceps. This technique uses a sensor containing Clark polarographic electrodes that are placed on the skin at the area of interest, avoiding calloused areas, oedema and bony prominences [21]. The manufacturer’s calibration protocol was: sensor calibration, skin was cleaned of all oils, soaps, and dead skin, sensor fixation ring was placed, 1–2 drops of contact gel was placed inside the ring and sensor was placed into the ring. The sensor warms the surrounding skin, it takes about 10-15 minutes localised hyperaemia to take place and transcutaneous reading becomes meaningful. The measured PO2 in the dermis is displayed in millimetres of mercury (mmHg). Following this procedure, the arm crank test begins. Every 15 seconds TpcO2 left, TpcO2 right and heart rate were recorded. Although measured continuously throughout the arm-cranking test, the PO2 values were recorded in three occasions; at the beginning of the test (PO2initial), at the moment of the maximal test-achievement (PO2max), and at exhaustion (PO2exhaustion). The PO2d was calculated as the mean difference between PO2max and PO2exhaustion, for the left and right arm.

### Measuring equipment

The BH and BM were measured by SECA stadiometer and scale (SECA Instruments Ltd. Hamburg, Germany). A Cosmed cycle ergometer E100P/K (Cosmed, Rome, Italy,) was modified for arm cranking. A Polar PE3000 Heart Rate monitor (Polar Electro Oy, Kempele, Finland) was used for heart rate monitoring. A Radiometer TCM400 (Radiometer Medical ApS, Denmark) blood gas analyzer, valid for exercise tests [22] was used for transcutaneous oximetry. Maximal oxygen uptake was analysed by computerized respiratory gas analyzer Cosmed PFT4ergo (Cosmed, Rome, Italy) on a Quinton ST55 Treadmill (Quinton USA). The BPRESS test was performed with a competition standard Olympic style bar and weights (T-100G; Eleiko, Halmstad, Sweden). The BPRESS and WATTmax were expressed as absolute values, as well as relative-to-body-mass values (BPRESSkg; WATTmaxkg).
up protocol consisted of: light running (5 min), general preparatory exercises (5 min), and specific wrestling preparatory exercises (5 min). Multiple warm-up trials were given prior to actual 1 repetition maximum BPRESS. These consisted of: 10 repetitions at 30% followed by 2 min rest, 7 repetitions at 50% followed by 2 min rest, 4 repetitions at 70% followed by 3 min rest, 1 repetition at 90% followed by 3 min rest at 16:00, following a standardized warm-up, subjects performed the arm crank test. Afternoon warm-up protocol 5 min consisted of cranking with no load. The 11 randomly selected subjects repeated the arm-cranking test five days later.

Statistical analyses

For the variables collected during arm-cranking test (WATTmax, pO2max and pO2exhaustion) the ICC (test-retest correlation) was used to determine test reliability [23]. Additionally, for those variables where ICC was found to be appropriate, Bland–Altman plot was used to visually present the errors against the true values by plotting the differences between the test and retest according to the variable scores [24]. These analyses were done for the 11 subjects who performed test and retest. The differences between two qualitative groups of wrestlers (top-level vs. high-level) were established using the Kruskal-Wallis ANOVA test.

Finally, forward conditional logistic regression was calculated to determine the independent impact of the morphological and physical fitness variables on the dichotomous criterion variable (top-level vs. high-level wrestlers).

Results

The ICCs and Bland Altman plots showed appropriate reliability for the variables obtained from arm cranking test. The ICC was 0.97; 0.80 and 0.62 for WATTmax, pO2max and pO2exhaustion respectively (all significant at p < 0.05). According to Bland Altman plots (Figures 1-3), the test-retest mean differences were -0.36; -0.27, and 0.53, with the limits of agreement (LOA) ranging from 3.66 to -4.39; 1.64 to -2.20.

<table>
<thead>
<tr>
<th>Variable</th>
<th>High level (non-selected for national team)</th>
<th>Top level (National team)</th>
<th>Mann-Whitney U test</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH (cm)</td>
<td>172.93</td>
<td>178.83</td>
<td>-1.37</td>
</tr>
<tr>
<td>BM (kg)</td>
<td>74.37</td>
<td>84.33</td>
<td>-1.70</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.78</td>
<td>26.31</td>
<td>-1.51</td>
</tr>
<tr>
<td>Experience (years)</td>
<td>8.00</td>
<td>11.00</td>
<td>-2.46</td>
</tr>
<tr>
<td>WATTmax</td>
<td>166.30</td>
<td>205.00</td>
<td>-2.52</td>
</tr>
<tr>
<td>WATTmax/kg·kg bwt⁻¹</td>
<td>2.30</td>
<td>2.40</td>
<td>-1.18</td>
</tr>
<tr>
<td>BPRESS (kg)</td>
<td>92.60</td>
<td>109.00</td>
<td>-1.44</td>
</tr>
<tr>
<td>BPRESS/kg·kg bwt⁻¹</td>
<td>1.20</td>
<td>1.30</td>
<td>-0.48</td>
</tr>
<tr>
<td>PULLUPS (repetitions)</td>
<td>19.20</td>
<td>16.50</td>
<td>1.00</td>
</tr>
<tr>
<td>pO2initial (mm/hg)</td>
<td>62.00</td>
<td>42.90</td>
<td>1.37</td>
</tr>
<tr>
<td>pO2max (mm/hg)</td>
<td>66.10</td>
<td>57.30</td>
<td>-0.78</td>
</tr>
<tr>
<td>pO2exhaustion (mm/hg)</td>
<td>62.10</td>
<td>42.90</td>
<td>3.36</td>
</tr>
<tr>
<td>pO2d (mm/hg)</td>
<td>8.10</td>
<td>31.00</td>
<td>-3.06</td>
</tr>
<tr>
<td>VO2max (ml/kg/min)</td>
<td>181.80</td>
<td>188.30</td>
<td>2.34</td>
</tr>
<tr>
<td>HRmax (bpm)</td>
<td>53.00</td>
<td>49.00</td>
<td>-0.92</td>
</tr>
</tbody>
</table>

LEGEND: BH – body height, BM – body mass, BMI – body mass index, Experience – years of wrestling experience, WATTmax – maximal power on arm-cranking test, WATTmax/kg·kg bwt⁻¹ – maximal power on arm-cranking test / body mass, BPRESS – 1 repetition maximum of bench press, BPRESS/kg·kg bwt⁻¹ – 1 repetition maximum of bench press / body mass, pO2initial – O2 value at beginning of arm-cranking test, pO2max – O2 maximal value, pO2exhaustion – O2 value at moment of exhaustion, HRmax – heart rate maximum value, VO2max – maximal oxygen uptake
and 2.46 to -1.40 for WATTmax, pO2max and pO2exhaustion respectively.

The reliability of the SJFT was not appropriate, with test-retest correlation of 0.37 (p > 0.05). Consequently, the SJFT was not used in the further analyses.

There were no significant differences between groups in BH, BM, BMI, BPRESS and PULLUPS. The significant differences between groups are found for experience (top-level group had more experience in wrestling), and WATTmax (top-level group achieved higher results). The high-level group had significantly higher VO2max, pO2max and pO2exhaustion than the top-level group. For the top-level group we have found larger difference between pO2max and pO2exhaustion (pO2d) (Table 1).

A logistic regression analysis revealed that pO2d is the single significant predictor of the qualitative level, and this single-variable model is the only significant logistic model built (p < 0.05). The model (Y = 4.083 + 0.837 x pO2d) successfully classified 83% top level and 94% high-level wrestlers, indicating that among the top-level the transcutaneous oxygen partial pressure decrease (left + right) is more evidenced (OR 0.84; 95%CI: 0.72 – 0.97). The inclusion of any other variable from this study did not contribute to the significance logistic model.

**Discussion**

We can highlight several most important findings of this study. First, most of the physical fitness measures observed in this study are found to be reliable in testing the fitness capacities in high-level wrestlers. Next, some of the tests are found to be applicable in defining the differences between the two studied groups (top-level and high-level athletes). Finally, pO2d during the wrestling specific arm-cranking ergometry is found to be the strongest predictor of the qualitative level in wrestling.

**Reliability**

In a recent study, Dutch authors applied the submaximal arm-cranking procedure in testing the aerobic fitness for healthy non-athletes and found appropriate test-retest reliability (R = 0.76), while Australian investigators reported similar values (R = 0.69) when they examined the reliability of the arm-ergometry protocol during peak aerobic power determination in healthy females [25,26]. Therefore, we may highlight the high reliability of the applied arm-cranking test in the evaluation of the fitness capacities of the wrestlers (Figures 1-3).

The SJFT is previously found to be a reliable and applicable judo-specific test, and it is also recommended for wrestling [16,27]. To the best of our knowledge, this is the first study where the SJFT was applied in top-level wrestling, and the reliability was found to be inappropriate. Most probably the main cause of the poor reliability in this study should be found in the small variance of tested subjects. Mainly, we tested highly homogenous group of subjects where reliability is relatively harder to be achieved [28].

**Validity**

The finding that the high-level group achieved better results in VO2max is not surprising. Briefly, the primary energy systems utilized in wrestling are the ATP-CP and lactic acid system, and therefore, similar to other anaerobic sports, the wrestlers' physical performance (i.e. competitive achievement) depends on anaerobic- and not aerobic-fitness capacities [1,29]. However, it must be stressed that we studied differences between high-level and top-level wrestlers. For that reason, aerobic endurance should not be judged as “non-important” in wrestling, but rather that this fitness capacity should be developed up to some basic level (i.e. approximately 50 ml/kg/min) while further improvements would probably not contribute to wrestling performance.
The similar discussion implies for BPRESS and PULLUPS also, where no significant differences between groups are found. In short, although both tests are known to be important in determining the fitness capacities of wrestlers, it seems that performance in strength and power variables should be considered as a factor which efficiently discriminates lower-level from high-level wrestlers (i.e. amateurs vs. elite) [1,4], while discriminative validity of these variables is not as great among wrestlers of an advanced level.

It is generally accepted that arm-cranking tests are biomechanically, anatomically and physiologically similar to the sport of wrestling, and therefore highly applicable in this sport [1,4]. This is supported by our results which showed that measures collected during arm-cranking test are valid in defining the differences between international and national level wrestlers. It is particularly interesting with regard to pO2d, since to date, this measure has not been applied as a fitness diagnostic tool in wrestling. Consequently, we can hypothesize that it is probable, that the difference between maximal pO2 during the incremental arm-cranking test and pO2 at the moment of exhaustion should be observed as a factor of interest in defining the athletes’ specific fitness capacity. Since the physiological background of this mechanism is unknown so far, it should be studied more precisely in future.

Figure 2. Bland-Altman Plot of the test and retest scores of the pO2max. The middle line represents the mean difference between the two trials. The two outside dashed lines represent the upper and lower limits of agreement

Figure 3. Bland-Altman Plot of the test and retest scores of the pO2exhaustion. The middle line represents the mean difference between the two trials. The two outside dashed lines represent the upper and lower limits of agreement
Conclusion

According to our results following conclusion can be drawn.

1. Standard fitness tests did not explain the differences between wrestlers who were selected or non-selected for the national team, and therefore the applicability of such tests in high-level wrestling seems to be limited.

2. It seems that the level of aerobic endurance of 50 ml/kg/min among top-level wrestlers is adequate for wrestling-specific physiological demands, and that the further improvement in this fitness capacity is not required for the sport of wrestling.

3. The pO₂ measures measured during the arm progressive arm-cranking test is found to be reliable and valid measure which clearly discriminates top-level from high-level wrestlers. This finding is particularly indicative knowing that this is one of the first studies which tried to demonstrate the fitness factors which contribute to success in wrestling among athletes of advanced level. Further studies should investigate the physiological background of such results with regard to the specifics of wrestling and the qualitative level of the observed athletes.

References


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