DIFFERENTIATION OF PHYSICAL FITNESS IN POLISH ELITE SPORTS JU-JITSU ATHLETES

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Key words: cluster, combat, Ju-jitsu, competition, physical fitness, condition, norm, test

Abstract

Aim. Ju-jitsu athletes are expected to reach competitive readiness adequate for the demands of tournaments. Apart from technical expertise, one of the aspects of readiness is general and special preparation. This is critical to the athlete’s level of achievement since it helps him or her cope with the training load as it is linked to mental preparation and ensures that the athlete uses technical and tactical variants more accurately during a fight. The cognitive aim of this study is to characterize fitness preparation of top athletes from the Polish Ju-jitsu Association. The practical aim is to identify talented athletes who can become members of national teams participating in international tournaments.

Basic procedures The study evaluated 29 national Ju-jitsu team members in the preparation period (pre-competition mesocycle), who expressed their interest and consent to participate in the experiment. 13 of these athletes were listed in the Ju-jitsu International Federation ranking, including 3 medalists in the World Championship in Wrocław, Poland (2016). 13 tests of general physical fitness were performed by means of selected tests from the Eurofit test battery, the ICSPFT tests and additional strength tests. 8 special physical fitness tests were also used. The results were described using cluster analysis and comparison of fitness profiles.

Results and main findings. The differences between three clusters in general physical fitness were noticeable in the performance of pull-ups (1<2 and 2>3 clusters), the Cooper test (1<2 and 1>3 clusters), the shuttle-run test (1>2 and 2<3 clus-
Introduction

Ju-jitsu as a martial art emerged from two famous schools: Daityo-ryu (12th century) and Takenouchi-ryu (16th century). The Kito—ryu and Tenshin-Shinjo-ryu schools in the Edo/Tokugawa era (1603-1868) paved the way for the evolution of the Randori practice, used later in Kodokan Judo (1882). In those days, Kodokan Judo was considered a modification of Ju-jitsu [1]. This martial art of a Japanese samurai, used to capture enemies or eliminate them, gave rise to such sports as Judo [2], Brazilian Ju-jitsu [3] and sport Ju-jitsu that includes the four forms of sport competition: duo demonstration, duo show, Ne waza and the fighting system of the Ju-jitsu International Federation [4]. Our study intends to characterize the adequate level of fitness-related readiness of top contestants who participate in fighting tournaments. Therefore, we found it indispensable to present a brief description of this combat sport convention, including three phases and taking up to 3 minutes or even longer (Fig. 1).

As results from the analysis of the fighting regulations specified by the Ju-Jitsu International Federation, the fighting system is characterized by intensive bouts.
of exercise separated by short periods of rest (Ju-jitsu International Federation www.jif.org). After the Hajime! verbal command, the fight starts at the first phase in a standing position. The contestants perform punches and kicks (both single and combinations) in order to score points that give them the advantage over an opponent. The points can be scored in both attack and counterattack. The second phase starts at the moment the athlete holds the opponent. Punches and kicks are forbidden during this phase (except for the initial hold). In this phase, opponents strive to perform efficient throws on the square fighting area with dimensions of 8 x 8 m. The thrower must start performing the throw while on the fighting area. The receiver can fall onto the external safety area (2 m in width) if it is secure for the athlete. If the opponents are kneeling on both knees or one of them is sitting or lying on the mat, the fight is continued in the third phase.

The athletes can move to other phases of the fight but they have to be active in all the parts. If, in the first phase, the athlete only moves towards the opponent without performing any technique or the activity is insecure for himself of herself, s/he are punished by Shido technical penalty and the fight is continued from the first phase. After completion of the fight, the referee announces the winner (point advantage). The Hajime! command is used to begin the fight and resume it after the Matte! command. The referee announces Matte! to stop the fight in the following cases: if in the first or the third phases one or both athletes are completely outside the fighting area; if, in the third phase, both contestants are completely outside the fighting area; to announce the penalty for one or both contestants; if one or both contestants are injured or taken ill; if one of the contestants is unable to signal submission by him or herself; during a strangulation or a lock; if the Osae-komi pin time is expired; if, in the second or the third phase, the contact is lost between the contestants and they do not continue the fight in the first phase. The referee uses the Sono mama! command to temporarily stop the fighters to give one or both contestants a warning for being passive or announce penalty points for one or both contestants. After the Sono mama! command, the athletes remain in the same position as they were the moment the fight was stopped. The fight is resumed by the referee announcing the Yoshii! command.

Points during the fight have to be scored by the majority of indications by at least two of three referees. If three referees indicate various scores, the intermediate score prevails. If one of the referees did not see the action, the lower of the two remaining scores prevails. In the first phase, points can be scored for punches, strikes and kicks (unblocked punches, strikes or kicks [Ippon = 2 points], partially blocked punches, strikes or kicks [Wazaari = 1 point]). In the second phase, the points can be given for throws, take-downs (transition actions), locks and strangulations (if the contestant cannot tap out by him/herself to signal submission and the referee has to stop the fight by announcing the Matte! command [Ippon = 2 points]), strangulations and locks with tapping (Ippon = 2 points), a perfect throw or take-down (Ippon = 2 points), an imperfect throw or imperfect take-down (Wazaari = 1 point). During the third phase, the points can be given for efficient holds, locks and strangulations (strangulations and locks with tapping the mat twice; if the contestant cannot tap the mat twice by him/her and the referee has to stop the fight by announcing Matte! (Ippon = 3 points), efficient hold announced by Osae-komi! lasting 15 seconds (Ippon = 2 points), and lasting 10 seconds (Wazaari = 1 point). The lightly forbidden acts during the fight are punished by Shido and the opponent is given Wazaari. The forbidden acts are punished by Chui (the opponent scores 2 Wazaari). In the case of two forbidden acts, the fight is lost by announcing the Hansoku-make! command. The contestant can win the match before the end of fighting time if s/he scores at least one Ippon in each of the three phases of the fight. This is announced as a Full Ippon. In this case, the loser scores 0 points and the winner gets 50 points or, the number of points s/he has already achieved if the number is higher than 50 points. After the time has expired, the contestant who scored the most points is announced the winner. If the competitors scored equal number of points after this time, the contestant with at least one Ippon or more in different parts of the fight wins the match. If, after the standard time, the score and number of techniques that scored Ippon is equal, an additional 2-minute round is announced until the fight is settled. A 1-minute break is used between the additional rounds. Therefore, this situation can be repeated. The scores, Ippons and penalties from the initial round are transferred to the additional round (Ju-jitsu International Federation www.jif.org).

Based on observation and analysis of fights during Junior Ju-jitsu World Championships (Bucharest 2013), it was found that the most frequent hand techniques used in the first phase include punches gyaku-tsuki, hai-to-uchi and uraken-uchi, whereas the kicks were: yokogeri, mawashi-geri and mae geri. In the second phase of the fight, hand techniques were most frequent (i.e. morote gari and seoi nage) and foot and leg techniques (i.e. osoto gari, osoto otoshi, uchi gari) rather than hip techniques (i.e. goshi guruma, harai goshi), whereas in the third phase, more frequent techniques included pinning compared to joint locking and choking techniques [5]. This comparison and previous analyses revealing the correctness of the fight [6, 7] show that the first part of the match in the Ju-jitsu fighting system is similar to Ka-
rate, whereas the second and the third phases are more alike a Judo fight [8, 9].

In the opinion of instructors, the greatest effect on the model of athlete readiness is from technical and tactical (31.3%) and physical preparation (including body build and physical fitness, 28.4%). Lower contribution is from theoretical (25.5%) and psychological (14.8%) preparation. According to experts, on average, 5 years is needed to achieve a black belt [10]. Undoubtedly, Ju-jitsu athletes are expected to reach the readiness adequate for the demands of tournaments. Apart from technical expertise, one of the aspects of readiness is general and special preparation. This is critical for the athlete’s level of achievement since it helps him or her cope with the training load as it is linked to mental preparation and ensures that the athlete uses technical and tactical variants more accurately during a fight (both during competitions or training sessions).

The feedback between training and tournaments is provided by periodical and ecological (performed in the athlete's natural environment) physical fitness testing [11]. Seeking the relationships between the level of fitness preparation and athletes’ achievements using cluster analysis has been successful in such combat sports as Karate [12], Judo [9] and Ju-jitsu [8,13]. The following hypotheses will be verified based on the examinations planned in this study:

H1. The specific physical fitness that is needed for competition is developed over many years of Ju-jitsu training.

H2. The level of sports achievement is likely to be linked with the profile of fitness preparation.

H3. Some athletes who compete at lower levels are characterized by a fitness level similar to those competing at higher competitive levels.

The cognitive aim of this study is to characterize fitness preparation of top athletes from the Polish Ju-Jitsu Association. The practical aim is to identify talented athletes who can become members of national teams participating in international tournaments.

Material and Method

The study evaluated 29 national ju-jitsu team members in the preparation period (pre-competition mesocycle), who expressed their interest and consent to participate in the experiment. 13 athletes were listed in the Ju-Jitsu International Federation’s ranking (www.jjif.org), including 3 world medal winners in the World Championships in Wroclaw, Poland (2016). This research project was approved by the Research Bioethics Commission (Regional Medical Chamber in Kraków, Poland, No. 42/KBL/OIL/2015). The age and sports experience of study participants was 23.41 ± 1.92 years and 5.1 ± 1.39 years, respectively. They performed training sessions from 6 to 10 times a week, each session taking from 1.5 to 2 hours. Furthermore, apart from the above data derived from a standardized sports interview, the respondents claimed that they preferred only throws during the fight. They were included in a group of hand techniques (seoi nage, tai otoshi, soto makikomi, su-kui nage, daoshi), throwing from a lying position (tani otoshi, ura nage, tawara gaeshi, kani basami), hip techniques (o goshi, goshi guruma) and foot and leg techniques (uchi mata, osoto gari, ouchi gari, kouchi gari, kosoto gari, de ashi barai).

The study participants competed in five weight categories, i.e. up to 69 kg (n=5), up to 77 kg (n=6), up to 85 kg (n=8), up to 94 kg (n=7) and over 94 kg (n=3). Mean body height of the participants was 181.03 ± 4.72 cm, with the body mass of 83.57 ± 10.71 kg. Body height was measured using the Martin-type anthropometer. Body mass was measured by means of the Beurer glass diagnostic scale, type BG17, max. 150 kg, d=100 g (Beurer GmbH Germany, limited edition 2010).

Fitness testing

Comprehensive physical fitness was tested using selected components of the Eurofit test battery. The first day of tests: maximal static strength (in kgf) of dominant hand (HGSmax) was evaluated using a handgrip dynamometer (USSR); explosive strength: standing long jump (SLJump in cm), body trunk strength: dynamic sit-ups (Sit-ups in reps), speed: shuttle run (shuttle run in sec) and plate tapping (time of 25 cycles performed in sec), flexibility: sit and reach test (S-RT in cm), overall balance: the flambinggo balance test (number of falls [n]) [14]. The second day of tests: the ICSPFT test: relative strength of hands and shoulders: pull-ups on a bar (number of pull-ups)[15], the Cooper test: continuous run for 12 minutes (in m)[16] and additional strength tests1 (the third day of tests):

• bench press with weight equal to the mass of the individual performing the exercise (BP expressed by the number of repetitions);
• conventional barbell squat with the load equal to body mass (CS expressed by the number of repetitions).

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1 These tests were implemented as additional since weight categories are used in combat sports and the success is often determined by the relative strength i.e. the ratio of the absolute strength to body mass. We used the bench press and squats not as tests but as lifts used in powerlifting. Our examinations were performed not based on the measurement of 1RM but on the number of repetitions with the load equal to the participant’s body mass.
Aerobic capacity was measured using the graded aerobic endurance test [17]. The test evaluated VO2max (ml/kg/min) and the level of the second ventilatory threshold (VT2). The test was performed using a mechanical treadmill (Saturn 250/100R, h/p/Cosmos, Germany). The exercise started with a 4-minute warm-up performed at the speed of 8 km·h⁻¹, and the treadmill inclination angle of 1°. Next, the running speed was increased by 1.0 km/h every 2 minutes. If the heart rate (bpm) reached the maximal value, the running speed was maintained and the load was increased (every minute) by the change in the angle of treadmill inclination by 1°. The test was continued until the athlete refused to continue work due to extreme fatigue. Heart rate (HRmax) during the test was measured by the Polar sport tester (S-610i, Polar, Finland).

During the following week, special fitness tests were also performed (the fourth day of testing) according to the procedures of the SPFT test batteries used in Karate [18, 19], Judo [20, 21] and Ju-jitsu [22]. They included [22]: (1) Hip turning speed test. In the hip turning speed (frequency) test, each athlete had a belt attached over the right hip and, using the fighting position, turned hips to the left. This movement caused tension of the belt held by the coach standing behind the athlete (control) and the participant returned the hip. After the Hajime! (Forward!) command, the participant performed 30 hip turns (the number of belt tension instances was counted). The results were expressed in seconds; (2) Punch speed test. The speed (frequency) of punches was evaluated from the fighting position. Each participant performed a combination composed of two fist punches: left straight punch to the head (O1 seiken jodan tsuki) and right straight punch to the body trunk (Gyaku seiken chudan tsuki), without changing the distance. The targets towards which the participant performed 30 such combinations (60 punches in total) were held by the other person at a constant height. The time to perform 30 complete combinations of punches was recorded (s); (3) The flexibility test was performed using Mawashi-geri kicks (cm) and the flexibility index = maximum range of kick/body height (cm/cm) was computed. In the flexibility test, the maximal reach (feet kick height) was measured for the roundabout kick (Jodan mawashi-geri). Five measurements were performed for the dominant limb and the maximal result was recorded (cm); (4) Rapid kick test. The speed (flexibility) of kicks was evaluated by participants performing 30 Jodan mawashi-geri kicks (high roundabout kicks) with the front of the leg towards the target held by the coach. Time measured after the last kick was recorded at the moment of lowering the leg by the study participant to the ground (s); (5) Agility test. During the agility test, the participant followed a zig-zag-shaped route, moving forward on one leg and maintaining the knee of the lifted leg at waist height. Each study participant repeated the 5 m distance 6 times with each 5 m section followed by the change in the movement direction by ca. 180°. Time of covering the distance (s) was recorded; (6) Evasive action test. In the evasive action test, study participants started from the fighting position while moving backwards between the lines at the distance of 8 m from each other. The loop-shaped track between the lines was covered 6 times. Time to perform the test was measured in seconds; (7) Push-ups. They were done with one hand clapping at one second (maximum repetitions – n) [22]; 8. Special Judo Fitness Test (SJFT) [19, 23]. Briefly, the SJFT is divided into three periods (A=15 s; B and C=30 s) at 10 s intervals. During each period, the athlete (tori) being evaluated throws two partners (uke A and B, with distance from each other of 6 m) as many times as possible using the ippon-seoi-nage technique. Both uke A and B should be of similar height and weight as the tori. Heart rate is measured immediately after and one minute following the test. The test has also been presented in visual form [Special Judo, 2015]. This study evaluated the Index in SJFT:

The SJFT index is calculated as follows:

\[
SJFT \text{ Index} = \frac{\text{Final HR (bpm) + HR1 min (bpm)}}{\text{Throw (N)}}
\]

where:
Final HR – heart rate recorded immediately after the test.
HR1 min – heart rate obtained 1 minute after test.
Throws – number of throws completed during the test.
Response to the exercise was recorded by means of a heart rate monitor S-610i (Polar, Finland).

Statistics
Means (X) and standard deviations (SD) were computed after verification of normality of distribution of variables. Structure of physical fitness among top male Ju-jitsu competitors was described using cluster analysis (Ward’s method, Euclidean distance). The input data were individual measurement of qualitative variables obtained during examinations of 29 athletes: Competitive level (I – international, n=13; N – national, n=16) and quantitative variables, such as age, training experience, body height and mass, results obtained during 13 general fitness tests and 8 special fitness tests. The standardized skewness and standardized kurtosis were used to determine whether the sample came from normal distribution. Values of these statistics outside the range of -2 to +2 indicate a significant deviation from normality. 1/Y transformation was used for the flexibility test in order for the distribution of this variable to be closer to...
normal distribution. The results were presented as tabular data (means, SD, min-max values). Before cluster analysis, individual results of measurements in fitness tests were standardized to 0, 1 based on the data collected in the entire group of study participants. Next, the division into three clusters was made and their profiles were developed. The coefficient of profile similarity was used for the comparison by applying the formula [24]:

\[ rps = 2(S/T - 0.50) \quad \text{eq. 2} \]

where:
- \( S \) – sum of corresponding profile segments which exhibit similar slope.
- \( T \) – total number of profile segments making up a profile.

In the interpretation of the results, performance of test tasks was interpreted as worse if they took longer, more falls were recorded during the Flamingo balance test and the value of the 1/Flexibility Index and SJFT Index were higher. Statgraphics Centurion v.17 software was employed for all descriptive statistics.

**Results**

The test results and the effect of grouping athletes in three clusters were illustrated in Fig. 2 and Tab. 1.

Differences in the thirteen tests of comprehensive physical fitness were pronounced in six of them: pull-ups (1<2 and 2>3 clusters, No. 3), Cooper test (1<2 and 1>3 clusters, No. 5), shuttle-run test (1>2 and 2<3 clusters, No. 7), sit-and-reach test (2<3, 2<1 clusters, No. 9), maximal hand-grip-strength test (1>3 clusters, No. 10), Flamingo balance test (1-3 and 2-3 clusters, No. 11). Of the eight special physical fitness tests, substantial differences were observed for speed punches (1>2 clusters, No.15), 1/Flexibility Index (1>3 cluster, No. 16), evasive actions (1<3, 2<3 clusters, No. 19), push-ups (1>2 and 1>3 clusters, No. 20).

Cluster 1 (n=10, left side of the dendrogram, see Fig. 2) contains 6 athletes from group I, including two finalists of the 2016 World Championship (No. 7 and 8) and 4 athletes from group N. First relationships were observed between the athletes from group I (1 and 7), and I and N (9 and 28, 4 and 23, 6 and 27). Compared to the two remaining clusters, these participants (cluster 1), were characterized by the best level of results in pull-ups (Index No. 5), HGSmax (Index No.10), HRmax (Index No.13), Rapid kicks (Index No.17), Evasive actions (No. 19) and Push-ups (No. 20). They also demonstrated the worst quality of performing the shuttle-run test (No. 7), 1/Flexibility Index (No. 16) speed punches (No. 15), and Agility tests (No. 18).

Cluster 2 (n=10) was comprised of 4 athletes from group I (including bronze medal winner in the 2016 World Championships, No. 10) and 6 athletes from group N. The first links were found between the characteristics of the representatives of group I illustrated on the dendrogram (see Fig.) (No. 11 and 13, group N) (No. 15 and 20, 16 and 22) and groups I and N (bronze medal winner (No.10 and No. 19, respectively). The fitness profile of
Table 1. Results of testing athletes included in Polish national team training

<table>
<thead>
<tr>
<th>Index/Variable</th>
<th>Cluster 1 (n=10)</th>
<th>Cluster 2 (n=10)</th>
<th>Cluster 3 (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>SD</td>
<td>Min-Max</td>
</tr>
<tr>
<td>1. BP (reps)</td>
<td>7.50</td>
<td>3.03</td>
<td>3-12</td>
</tr>
<tr>
<td>2. CS (reps)</td>
<td>22.10</td>
<td>2.23</td>
<td>19-27</td>
</tr>
<tr>
<td>5. Cooper (m)</td>
<td>3004</td>
<td>145.24</td>
<td>2800-3210</td>
</tr>
<tr>
<td>7. SLR (s)</td>
<td>12.82</td>
<td>0.52</td>
<td>11.45-13.17</td>
</tr>
<tr>
<td>8. PT (25 cycle in sec)</td>
<td>12.64</td>
<td>0.79</td>
<td>11.71-14.20</td>
</tr>
<tr>
<td>9. S-RT (cm)</td>
<td>17.40</td>
<td>4.79</td>
<td>11-25</td>
</tr>
<tr>
<td>10. HGSmax (kgf)</td>
<td>53.80</td>
<td>4.98</td>
<td>46-60</td>
</tr>
<tr>
<td>11. Flamingo (n)</td>
<td>5.4</td>
<td>1.84</td>
<td>3-9</td>
</tr>
<tr>
<td>12. VO2max (ml/kg/min)</td>
<td>52.31</td>
<td>3.858</td>
<td>48.08-58.67</td>
</tr>
<tr>
<td>13. HRmax (bpm)</td>
<td>188.4</td>
<td>4.719</td>
<td>181-197</td>
</tr>
<tr>
<td>14. HipT (s)</td>
<td>12.16</td>
<td>0.82</td>
<td>11.03-13.76</td>
</tr>
<tr>
<td>15. Punches (s)</td>
<td>12.54</td>
<td>0.8429</td>
<td>11.29-13.80</td>
</tr>
<tr>
<td>16. 1/Flexibility Ind</td>
<td>1.05</td>
<td>0.05</td>
<td>0.97-1.12</td>
</tr>
<tr>
<td>17. Kicks (s)</td>
<td>19.02</td>
<td>0.77</td>
<td>17.09-20.56</td>
</tr>
<tr>
<td>18. Agility (s)</td>
<td>16.59</td>
<td>1.202</td>
<td>14.8-18.3</td>
</tr>
<tr>
<td>19. Agility (s)</td>
<td>42.3</td>
<td>0.6346</td>
<td>41.32-43.24</td>
</tr>
<tr>
<td>21. SJFT Index</td>
<td>14.6</td>
<td>1.179</td>
<td>12.39-16.41</td>
</tr>
</tbody>
</table>
study participants is characterized by the best results in the shuttle-run test (Index 7), the plate tapping test (Index 8), hip turns (Index 14), speed punches (Index 15), similarly to the high level of performance in the evasive actions test as in cluster 1 (Index No. 19). The poorest results concerned performing the following tests: Sit-and-reach (No. 9), Flamingo balance (No. 11), HRmax (No. 13), Rapid Kicks (No. 17).

Cluster 3 (n=9, right side of the dendrogram, see Fig. 2) contains characteristics of 3 athletes from group I and 6 from group N, with the first connections occurring between fitness profiles of athletes from class I (No. 12 and 29) and N (No. 14 and 18, 21 and 24) (Fig.2). In this profile, the best results were found for: the bench press test (Index No.1), plate tapping (No. 8), Sit-and-reach test (No. 9), Flamingo balance test (No. 9), hip turns (No.14), 1/Flexibility Index (No. 16), push-ups (No. 20), SJFT Index (No. 21). The worst results compared to other clusters were recorded for the classic squat (No. 2), pull-ups (No.3), sit-ups (No. 4), the Cooper test (No. 5), HGSmax (No. 10), VO2max (No.12), Rapid kicks (No. 17) and Evasive actions (No. 19).

Fig. 2 illustrates similarities and differences between profiles. Comparison of the configuration of fitness profiles between three clusters demonstrated a very low level of similarity (cluster 1 vs. cluster 2 rps = -0.52; cluster 1 vs. cluster 3 rps = -0.24; cluster 2 vs. cluster 3 rps = -0.32).

Discussion

The major achievement of this study was demonstrating the internal differentiation in physical fitness of top Ju-jitsu athletes. We found that the athletes who competed at an international competitive level (group I) occurred in all three clusters. Their fraction, however, decreased in consecutive clusters. World championship medal winners were found in the cluster 1 (two) and cluster 2 (one athlete) with not only athletes from group I, but also those competing at a national competitive level (group N), who had similar fitness profiles. These athletes from group N who were present in clusters 1, 2 and 3 met the fitness-related criterion of inclusion into the national team.
Examination of muscle strength in Judo, which is a sport representing an important component in terms of techniques used in Ju-jitsu, demonstrated that many years of training leads to the development of a specific topography of muscle groups responsible for performing specialized movements i.e. using techniques during a fight [25]. Our previous study [7, 26] showed that preparation of Ju-jitsu athletes requires substantial work of the arms, shoulder girdle and the back. The best results in strength tests connected with overcoming body mass were achieved by athletes located in cluster 3 (bench press) and cluster 1 (classic squat). This organization of the results may point to a dominant role of the upper limb strength in the high level of achievement in the sport of Ju-jitsu since most elite athletes were found in clusters 1 and 2. This tendency may be an indicator for the method of preparation of athletes over the last several years. This finding is also reflected by the results of upper limb strength tests (pull-ups), with the best results obtained by athletes in cluster 2. Dynamic changes in body position and arm flexion that are often observed in Ju-jitsu matches, using two planes of movement, can be categorized as plyometric training, characterized by the work that extends muscle fibres (eccentric work) and a dynamic phase of contraction (concentric work) [27]. The best results in the explosive strength tests of athletes can be observed in the cluster 1. Integration of various exercises of explosive character of the movement into the training process may lead to improvement in speed at the initial phase of the movement in a technical action during a fight and the dynamics of the upper and lower limb movement [28]. Our own study demonstrated the critical importance of upper and lower limb and the trunk explosive strength in the physical fitness of Ju-jitsu athletes since the best results in the standing long jump and push-ups with one hand clapping and the abdominal muscle strength test were achieved by elite athletes who were present in cluster 1.

Blais et al. [29] emphasized that strength training oriented via the choice of adequate exercises in the training programme should mimic the movements performed by contestants on the mat. Furthermore, training stimuli should match the temporal profile of the fight and the required muscle strength. Meeting these assumptions should be reflected in the SJFT results. It is worth noting that the most popular [6, 7] throws i.e. morote seoi nage and ippon seoi nage are numbered as hand throws termed Te Waza [2]. Despite this classification, it is most likely that lower limb involvement in the throw performed by the athlete is substantial [30]. This type of throw belongs to physical lever-type throwing techniques applied with the variable arm (fulcrum from uke’s waist to his knees) in the biomechanical classification [31]. Therefore, better results in strength tests (relative and explosive strength) of the lower limbs were observed in the Ju-jitsu athletes in cluster 1. The athletes with higher level of muscle strength can be more efficient during performing a technical task through maintaining greater movement economy, since this leads to the increase in endurance of the athlete during a specific exercise [32, 33]. It is worth noting that the best results in the endurance tests (the Cooper test and the VO_{max} level) also occurred in the athletes grouped in cluster 1.

In mixed fights, such as Ju-jitsu matches, where the fight can be performed in vertical (the first and the second phase) and horizontal position (the third phase), characterization of exercise intensity is varied since breaks are also used between the work bouts. However, fitness level differentiates between athletes and some results point to the advantage of the elite athletes while others concern the non-elite athletes. Other factors, such as age, training experience, competitive experience [7], and even the level of competitive readiness on a specific day, can have an effect on variation of the fitness level. It is also worth highlighting that success in a sport fight is determined not only by better physical preparation. Important factors are also technical and tactical preparation (ability to distribute exercise over the fight, control over the fight time, control over the point advantage, knowledge about the opponent) and good luck (advantageous drawing of fights or scoring a point in the last second of the fight that settles the results).

The physiological characterization of the threshold values in the process of sport training control allows to find and use the individual (optimal) intensity of the loads that lead to the desired responses in the human body, and consequently, to the improvements in aerobic capacity [34]. In training practice, threshold loads are useful to determine intensity of individual training sessions, with the main goal being improvement in the indices at the level of the second ventilatory threshold [35]. The level of aerobic capacity in the studied athletes was 51.36 ± 3.79 ml·kg\(^{-1}\)·min\(^{-1}\). In similar sports, the mean level of maximal oxygen uptake was 40.8 ml·kg\(^{-1}\)·min\(^{-1}\) (Judoists) [36], 53.8 ml·kg\(^{-1}\)·min\(^{-1}\) (Judoists) [37], 63.8±4.8 ml·kg\(^{-1}\)·min\(^{-1}\) (boxers) [34], 50.3±5.3 ml·kg\(^{-1}\)·min\(^{-1}\) (boxers) [38], 44.13 ml·kg\(^{-1}\)·min\(^{-1}\) (kick-boxers) [39] and 58.4 ml·kg\(^{-1}\)·min\(^{-1}\) (MMA) [35]. This comparison shows that aerobic capacity in the Ju-jitsu athletes in our study is at an average level compared to other combat sport athletes, with the only significantly higher VO\(_{max}\) levels obtained by MMA athletes. Body build of outstanding Ju-jitsu athletes (with the dominant component being mesomorphy) can be a moderating factor in the susceptibility to training oriented towards the development of aerobic capacity. General somatotype of Polish high level Ju-jitsu players is 2.3-6.1-2.1, which reflects a balanced mesomorphic type. In this group, how-
ever, endomorphic mesomorph was dominant (14 of 30 participants), whereas 7 individuals were classified as balanced mesomorph type and 9 as mesomorph-ectomorphic [40]. The meso-ecto and mesomorphic groups, but not endo-group, showed improvements in aerobic capacity following aerobic training [41].

Comparison of the results of other general fitness tests with athletes from other combat sports leads to the conclusion that the athletes did not differ in their fitness level from kick-boxers [42]. Differences were found in the flexibility test to the advantage of Ju-jitsu athletes, but in static strength and endurance, to the advantage of the kick-boxers.

Interesting findings were presented in our earliest study on Ju-jitsu instructors [26]. In the general motor fitness profile (ICSPFT), the best score (73.2 points) was found for body trunk strength (abdominal muscles), with the average of untrained young men =50 and SD =10 pts. Our Ju-jitsu group demonstrated good performance in flexibility (stand-and-reach test, 63.7 points), strength of the hands and shoulders (pull-ups, 63.0 points), and the static strength (HGSmax, 68.5 points). They show worse results in running (the 1,000-metre endurance run, the 4 x 10-m run, and the 50-m run) and explosive strength of the legs, i.e. standing long jump. During the 50-m run, male Ju-jitsu athletes scored only 40.9 points, i.e. below the average for the reference data [43]. The results of the standing long jump test (explosive strength) show the most significant correlations of all tests. This was not observed for the number of throws (r=0.30).

The total number of *ippon seoi nage* throws (\(\bar{x}=27\pm3\) throws), which were performed in 95 sec and interspersed by two 10 sec breaks, depended on the results of the following general fitness tests: 50-m run (speed, \(r=0.51\)), 1,000-m run (endurance, \(r=-0.40\)), shuttle run (agility, \(r=-0.44\)), the number of pull-ups (hand and shoulder strength, \(r=0.50\)) and the flexibility tests (\(r=0.41\)) [26]. Furthermore, the structure of physical fitness based on the ICSPFT test batteries and the number of *ippon seoi nage* were subjected to factor analysis with VARIMAX rotation. Three factors were found to explain 76% of common variance. The greatest weights/loadings in the first factor (49.9%), where the number of *ippon seoi nage* throws (0.731) was contained, were found for the results of the 50-m run test (-0.812), pull-ups (0.804), standing long jump (0.592), 1,000-m run (0.780) and the flexibility test (0.727). In the second factor (14.4%), the results of the shuttle run test (0.720) and body trunk strength (0.924) could be found, whereas the third factor contained HGSmax (11.9%) [10]. This analysis revealed that strength, speed and endurance supported by the anatomic aptitude of flexibility are conducive to performing a series of *ippon seoi nage* throws, with their group performance evaluated as good (4pts) [21].

Coaches of each sport would like to have tools for quick and reliable evaluation of athletes. Although the fight is the best test to evaluate the effectiveness of the training process, it is difficult to standardize this type of intermittent exercise. Therefore, additional special fitness tests have been used in combat sports. Their content reflects not only the temporal structure of the fight but also technical and tactical activities typical of a specific sport. The special Ju-jitsu fitness test battery contains Karate and Judo components which are also present in *hapkido*. Individual level of performance in special fitness tests was examined by two English instructors, outstanding members of the European Hapkido Alliance Demonstration Team. Motor effects of black belt testing were close to the values recorded in Ju-jitsu and Kyokushin Karate instructors, distinguished by 20% advantage in performance of speed punches. Compared to the red belt, advantageous differences for the black belt concern performance of speed punches, hip turns, rapid kicks and the number of throws [44]. The special fitness test battery turned out to be especially needed during professional preparation of Ju-jitsu coaches who performed the test and were experienced in this respect [22], as well as to control the training effects in athletes from the national Ju-jitsu team [8, 13]. Since no standards have been developed for athletes in this sport, we compared study participants to the normative values created for Karate [19] and Judo athletes [21]. The classification grades were specified based on the performance of male Karate fighters (n=219) and male Judo athletes (n=141). This evaluation is expressed on a five-degree scale: 1 – Very poor, 2 – Poor, 3 – Regular, 4 – Good, 5 – Excellent. Table 2 presents results for experienced male Ju-jitsu athletes.

This study revealed not only pronounced differences between clusters but also between the three medalists, with performance in individual tests ranging from 1 (flexibility index, agility, SJFT Index) to 5 (push-ups). Mean performance in the whole group was similar to previous studies [13], especially in hip turning speed, speed punches (heavyweights, but not in lightweight competitors), flexibility index, rapid kicks (lightweights but not in heavyweights), push-ups and SJFT Index (heavyweights, but not in lightweights). The differences between these two series of examinations are likely to result from the choice of material since in the present examinations, we did not examine the athletes from the lightest weight categories. In general, the group of athletes in the present study achieved worse assessment than coaches in the tests of hip turning speed, (3 vs. 4 pts), speed punches (2 vs. 4 pts), rapid kicks (3 vs. 4 pts) and better scores concerning the flexibility index (2 vs. 1 pt), agility (2 vs. 1 pt), push-ups (4 vs. 3 pt).
and SJFT Index (2 vs. 1 pt). The best performance in the special Ju-jitsu fitness test battery ranged from 3 (agility) to 5 (flexibility index and push-ups), whereas the worst performance was assessed from 1 to 2 pts. Although variation between groups was connected with individual performance of the tests, the total scores ranged from 14 pts (the worst performances of different study participants) to 33 pts (of the best performances in different people).

The results of our study demonstrated differences between group fitness profiles presented in three clusters (Table 1, Fig. 2) and were converted into point scores (Table 2). With five 20-percent ranges used for construction of the tables of normative values, we found that: comparison of cluster 1 shows that 60% of Ju-jitsu athletes are much worse than Karatekas in the number of repeated combinations (speed punches), 20% in rapid kicks, and 80% - in agility, only 20% - in push-ups and 60% - in the special judo fitness test (index). It should be emphasized that the SJFT test provides comprehensive information about the capacity required during the fight [45]: the alactic energy system showed higher \( F = 20.9; p < 0.001; \text{power} = 1.0 \) contribution \( (86.8 \pm 23.6 \text{ kJ}; 42.3 \pm 5.9\%) \) during the test compared to both aerobic \( (57.1 \pm 11.3 \text{ kJ}; 28.2 \pm 2.9\%) \) and lactic \( (58.9 \pm 12.1 \text{ kJ}; 29.5 \pm 6.2\%) \) energy systems \( (p < 0.001 \text{ for both comparisons}) \). Therefore, coaches evaluate mainly their athletes' anaerobic alactic system, which can be considered to be the most dominant system contributing to the efficiency of actions (techniques) performed in the match [45]. The number of throws in the test is more related to anaerobic capacity (Wingate test results), whereas the number of throws performed in segment C and the index in SJFT are more related to aerobic capacity (Treadmill test results) [20]. In Ju-jitsu athletes, eight weeks of circuit training with 4 units per week aimed to develop strength and endurance caused an increase in the number of throws but it failed to increase the point scores (1 pt). Furthermore, it substantially reduced the index in SJFT, consequently leading to higher assessments (from 1 pt to 3 pts) [46]. The SJFT duration is 95 seconds and it can be expected that in the second part of the Ju-jitsu fight, aerobic contribution will be dominant. The SJFT test has been used in both scientific experiments and in empirical studies used to control training effects in women and men who practice Judo. Elimination of the Uke resistance led to a higher number of throws (in the form of tandoku-renchu) and

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<th>Flexibility index</th>
<th>Rapid kicks</th>
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Comp. – Competitor
reduced the index and HR [9]. After a review of the relevant literature, we recommended taking into account and documenting all four components of the SJFT rather than merely index values [23]. The SJFT’s adaptations to Sambo [47], wrestling [48] and kickboxing [49] are also available.

Conclusion

The studied athletes were characterized by high differences in fitness-related readiness level. Their profiles in three clusters show that some athletes from the national level group match top athletes at the international competitive level in these terms. The athletes from group I, whose fitness profiles led to the presence of the athletes in cluster 3, are likely to present a higher level of other aspects of readiness for participation in Ju-jitsu tournaments by compensating deficiencies in the level of fitness preparation.

Practical implications

Analysis of individual profiles allows for effective diagnosis and classification while revealing strengths and weaknesses of fitness preparation in Ju-jitsu athletes. Therefore, it should be used for testing and monitoring modifications over the training cycles. Knowledge of the structure and the data on baseline physical fitness and special fitness in elite athletes may be useful for the development of individual training programmes for Ju-jitsu athletes. In order to improve anaerobic capacity, it is recommended to use brief and intensive bouts of exercise and longer rests between sets of exercises using the repetitive methods. Aerobic motor abilities can be developed using the principles of endurance training (e.g. circuit or interval training).

Acknowledgements: This scientific work was funded by the Ministry of Science and Higher Education from the 2015-2018 programme “The Development of Academic Sport”; project No. N RSA3 01753.

Glossary

Cluster analysis. A technique used to differentiate subgroups within a single collection of information about a group, people or objects [50].

Combat. An activity which involves defeating an opponent in a stylized way which has similarities to war of battle [50].

Competition. A contest in which a winner is selected from among two or more participants. In sport competition it is socially regulated and is generally direct [50].

Ju-jutsu. General term for systems of combat using empty-handed or short-weapon techniques against unarmed or armed opponents [51].

Norm. The set point, reference point or system goal in a control system. An empirically-established standard. Sometimes the norm refers to the normal or average value [50].

Physical fitness. The ability of a person to function efficiently, to enjoy, to subject oneself to leisure, to be healthy, to resist hypokinetic disease and to cope with emergency situations. The health related components of physical fitness include body composition, cardiovascular fitness, flexibility, muscular endurance and strength. Skill related components include agility, balance, co-ordination, power, reaction time, and speed [50].

Test. An examination designed to reveal the relative standing of an individual in a group (e.g. with respect to achievement or fitness) [50].

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