SOMATIC TRAITS AND MOTOR SKILL ABILITIES IN TOP-CLASS PROFESSIONAL SPEED CLIMBERS COMPARED TO RECREATIONAL CLIMBERS

Marcin Krawczyk 1, ABCDEF, Mariusz Ozimek2, DEF

1 Institute of Sport, University of Physical Education in Krakow
2 Department of Track and Fields Sports, Institute of Sport, University of Physical Education in Krakow

Key words: sport climbing, speed climbing, strength capability, speed capability, somatic constitution

Abstract

Aim of the study. To determine the basic parameters of speed climbers’ somatic constitution and to determine whether high levels of strength and speed capability characterise top-class speed climbers.

Material and methods. The study examined 5 competitors holding top positions in the Polish Mountaineering Association speed climbing ranking (during the 2009 season). The control group consisted of 10 recreational climbers. Measurements were taken of height, body mass, upper limb length and percentage level of fat; then, Body Mass Index was calculated. Strength ability was measured using dynamometric tests of the maximal local static strength of upper limbs. The following tests were used to determine the level of motor ability in subjects (standing broad jump, envelope run, sit-ups, sit and reach and spread sit, as well as a test for the maximum rate of movement of upper limbs). Maximal anaerobic work (MAW) was calculated.

Results. It was established that the best competitors in speed climbing have significantly higher levels of explosive strength and maximal anaerobic work, better muscle mobilisation ability, and higher torso strength and endurance. Clear but statistically insignificant differences between the groups were observed in strength tests and flexibility. Both professional and recreational climbers presented similar levels of the somatic traits studied.

Conclusions. High standards in speed climbing are connected with higher levels of speed capability. The scale of differences is a proof of the importance of speed capability in speed climbing. The importance of high upper limb muscle strength in climbing was confirmed. Amongst the somatic traits studied, only body mass can be treated as influencing the results in speed climbing.
of climbing competitions, both for the youngest adepts of climbing, as well as for far more advanced climbers. In 1993, during the International Olympic Committee session in Monte Carlo, climbing was included in the list of Olympic Games [2]. Amongst all types of climbing competitions, speed climbing is the most probable candidate for an Olympic competition. However, the process of introducing a new discipline is very long and so far, no climbing competitions took place at the Games. In 2010, the president of the International Federation of Sport Climbing (IFSC) Marco Scolaris revealed the goals that the federation had set for itself to make speed climbing enter the Olympic Games. He mentioned increasing media coverage for the discipline to reach a wider audience, and improving the organizational capabilities of particular national climbing federations. 2020 was pointed to by Scolaris as the nearest possible date for speed climbing to enter Olympics. The development of sport climbing in the last twenty years also coincided with the growing interest of researchers in the field of physical education. Research being conducted to date by both Polish and foreign authors facilitated discoveries of the secrets of sport climbing. In the realms of sport theory or motor preparation, Polish studies were conducted amongst competitors in lead climbing and concerned mainly the importance of strength capability [among others 3, 4, 5, 6] endurance [7, 8, 9, 10] and somatic constitution [11]. Like other disciplines, climbing presents its adept with a set of characteristic requirements. Their diversity stems from the nature of climbing itself: different parameters determine the result during rock climbing and ice climbing [6].

The Polish Mountaineering Association (PZA) regulations allow participation in three competitions within sport climbing: bouldering, speed climbing and lead climbing. These competitions differ mainly in difficulty level during the climb, the duration of the activity and respective motor requirements. Competitions in lead climbing are held with the use of belaying, and the goal is to reach the highest or farthest grip possible. The route difficulty is higher in comparison to speed climbing. Lead climbing can be divided into three types: on sight (OS), flash and rotpunkt (RP). Bouldering is the most recent addition to the competition roster. The dominant criterion in this competition is difficulty, and the goal is to climb short rock formations [2]. One of the most spectacular competitions is speed climbing, in which to win is to climb a relatively easy route as fast as possible. Analysis of the results of best competitors indicates that the time needed to complete the route is usually less than 15 seconds. However, in recent years, results of less than 15 seconds have been reported, especially after the introduction of the so-called standard, a ten to fifteen-metre tall wall, with the same routes for both competitors. Here, the results achieved by leading Polish competitors are found between 4-6 seconds/10 meters and 7-9 seconds/15 meters. Such a rapid sequence of movements, together with the specificity of climbing the wall put before the competitor specific challenges. First, they have to have certain strength capability, particularly relative strength – the ratio between absolute strength and body mass or lean body mass [12], which is the primary determinant of the effectiveness of climbing (it is opposing the force of gravity) [3, 13]. They also have to have a high level of speed capability, which determine the ability to move the whole body or its parts in shortest possible time (13), especially the speed capability that determines the short (5-8 s) efforts with maximum intensity, or maximal alactacid anaerobic power (MAAP) [14]. Thus, the nature of the competition indicates the importance of strength and speed capability and that the level thereof in leading Polish competitive climbers should be higher than in the control group. It would also seem that the level of somatic development in leading speed climbers will distinguish them from the comparative population. Therefore, the purpose of this paper is to define the basic parameters of the somatic constitution of speed climbers and to examine whether a high level of strength and speed capability will actually be characteristic of the best Polish speed climbers. The following research questions were asked:

1. Which of the morphological characteristics studied distinguish professional speed climbers from recreational climbers?
2. Will the level of strength and speed capability in leading speed climbers be significantly different than in recreational climbers?
3. Are speed climbers different from the control group in other motor ability tests?
4. Which of the characteristics and capabilities examined will determine the climbers’ class?

Material and methods of research

The research was conducted on a group of five sport climbers, all with good results in speed climbing. The average age equalled 23.6 years. At the time of the research, i.e. in 2009, they were all ranked high on PZA rankings (places 2,3,4,5 and 11). The control group (n =10), studied at the same time, consisted of people who were recreational climbers (with average age of 26.4 years). The research included: measurements of

---

1 http://www.pza.org.pl/new.acs?id=327080 (official site of the Polish Mountaineering Association; up-to-date as of 15 Nov. 2014)

2 A detailed presentation of the results can be found on the IFSC website: http://www.ifsc-climbing.org (up-to-date as of 15 Nov. 2014)
basic somatic traits, in accordance with the rules applied in anthropology and anthropometry, in physical education and sports [15]. Studied were: height (m), upper limb length (a-da) (cm), body mass (kg), percentage level of fat (%), Tanita TBF-538 scales were used, and the Body Mass Index was calculated [16]. Energy ability measurements included: firstly, a measurement of static strength on the second and third phalanges of the hand (measured with a Jamar Hydraulic Hand Dynamometer (kg)) [3]. Maximal results for left and right upper limbs were recorded, and where subsequently summed up and divided by two [17]. The end results were presented in absolute and relative units. Consecutively, the measurement of standing broad jump (m) [12]; predisposition of speed capability – maximal anaerobic work (J) [18]; the ability to mobilise muscles rapidly, in a form of an envelope run (s) [19]; strength and endurance of the torso, which were tested with the use of sit-ups (the number of sit-ups done in 30 seconds was recorded) [20]. In the

Normalising the results achieved by the study group to medium reference groups was intended to show the differences in somatic constitution and in motor ability between professional and recreational climbers. The results of appropriate tests show that the condition that the studied variables should have normal distribution was met.

The study material was analysed and compiled using StatSoft® STATISTICA 8. Microsoft® Excel was also used to prepare the graphic representation of the results.

### Results

In Table 1, mean and normalised values of somatic traits of the professional climbers are presented, along with the mean values of the control group. It can be seen from the data presented in Table 1 that both professional and recreational climbers presented similar levels of most somatic traits studied (body mass, upper limb

<table>
<thead>
<tr>
<th>Somatic Traits and Motor Skill Abilities in Top-Class Professional Speed Climbers Compared...</th>
<th>Somatic Traits and Motor Skill Abilities in Top-Class Professional Speed Climbers Compared...</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH (m)</td>
<td>1.74 0.06 1.65 1.80 1.70 0.06 1.59 1.79 0.65 NS</td>
</tr>
<tr>
<td>BM (kg)</td>
<td>67.18 3.40 62.40 70.20 65.68 7.67 54.20 83.00 0.20 NS</td>
</tr>
<tr>
<td>FM (%)</td>
<td>13.40 1.64 11.50 15.00 17.20 4.78 10.00 27.00 –0.80 NS</td>
</tr>
<tr>
<td>a-da (cm)</td>
<td>80.28 1.77 77.60 82.00 79.18 3.48 75.00 83.60 0.32 NS</td>
</tr>
<tr>
<td>BMI [kg/m²]</td>
<td>22.11 1.12 20.85 23.80 22.56 1.51 20.77 25.90 –0.30 NS</td>
</tr>
</tbody>
</table>

**Key:** BH – body height, BM – body mass, FM% – percentage level of fat, a-da – upper limb length, BMI – Body Mass Index, NS – differences with no statistical significance, *p < 0.05; **p < 0.01

coordination abilities structure, the “plate tapping” test was used to determine the frequency of movement [21]. 15 full cycles of motion with the dominant hand were recorded, with 0.01 sec. accuracy. To test flexibility, sit and reach test was measured in cm, from the scale on the surface of the plate, and spread sit was measured as the minimal distance between the pubic symphysis and the wall, in front of which the subject was sitting (cm) [22].

To find the answers to the study questions posed, the material was compiled with the use of widely applied descriptive statistics methods [23]. In the statistical analysis of the data, included were: normalised values of professionals’ traits as opposed to recreational climbers; arithmetic mean, standard deviation; Shapiro-Wilk’s test of normality; difference significance checked with Student’s t-test (p<0.05 was considered significant and p<0.01 highly significant); Brown and Forsythe’s test for significance of differences in variances.

4 Szopa et al. (1996) present a view that this kind of strength may be seen as a bridge connecting strength and speed capabilities.
did exceed standard deviation by 1.26 in the “spread sit” test, created to measure the movement of the hip joints. The results of speed and muscle endurance tests are presented in Table 3. It can be concluded from these data that the professionals demonstrated a statistically relevant, higher level of torso muscle endurance when compared to recreational climbers: the difference amounted to 2.20 times standard deviation. Sport climbers also displayed a statistically significant, higher level in speed capability tests. In the “standing broad jump” test, their results were better than the recreational climbers’ results up to 3.61 times standard deviation. The derived maximal anaerobic work (MAW) was also a strong distinguishing feature (it amounted to 2.42 times sd). Slightly smaller yet statistically significant differences were observed in the “envelope run” test (2.06 sd). There were no statistically significant differences in the trial evaluating the rate of upper limb movement.

**Discussion**

Comparing study results with other studies [5, 13, 17, 22, 24, 25, 26, 27] shows that in terms of basic somatic traits, sport climbers of different types display comparable levels of development (Table 4). The data presented in Table 4 also show that the greatest difference between professionals, recreational climbers and those untrained was observed in the levels of body percentage level of fat. The reason for this state is that professionals are more physically active and are using higher load during training. In some studies on the importance of body height in competitive sports [28], it was stated that only in those sports in which the body height does not have a decisive influence, arithmetic means of professional competitors are similar to those of the untrained, or lower. Arithmetic mean values of body height observed among climbers and those untrained, presented in Table 4, indicate that sport climbing is a discipline in which body height is not critical for achieving championship. Table 4 also shows that, in most cases, professional climbers demonstrated higher weight levels when compared to the recreational climbers, but lower when compared with those untrained. Lower body weight in sportsmen compared to the untrained results from different (higher) level of physical activity and the particular importance of this feature, whose low level is indicated as one of the most important factors in climber’s efficiency when moving on the wall [2, 3, 22]. However, it came as a surprise that in our study, professional speed climbers had a higher level of body weight in relation to recreational climbers. Due to the fact that professional sportsmen’s weight level should be considered as the

**Table 2.** Mean values for the results of trials evaluating muscle strength and suppleness of climbers, and their normalised values (NV)

<table>
<thead>
<tr>
<th></th>
<th>Professional climbers</th>
<th>Recreational climbers</th>
<th>NV</th>
<th>SIGNIFICANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>sd</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>A.S. 2 phal (kg)</td>
<td>56.55</td>
<td>9.31</td>
<td>42.25</td>
<td>66.00</td>
</tr>
<tr>
<td>R.S. 2 phal</td>
<td>0.84</td>
<td>0.15</td>
<td>0.61</td>
<td>0.97</td>
</tr>
<tr>
<td>A.S. 3 phal (kg)</td>
<td>44.90</td>
<td>10.19</td>
<td>31.50</td>
<td>57.00</td>
</tr>
<tr>
<td>R.S. 3 phal</td>
<td>0.67</td>
<td>0.15</td>
<td>0.46</td>
<td>0.82</td>
</tr>
<tr>
<td>Sit and reach (cm)</td>
<td>28.80</td>
<td>7.26</td>
<td>20.00</td>
<td>38.00</td>
</tr>
<tr>
<td>Spread sit (cm)</td>
<td>34.50</td>
<td>19.38</td>
<td>5.00</td>
<td>54.50</td>
</tr>
</tbody>
</table>

Key: A.S. 2 phal – absolute strength measured for the second phalanx of hand, R.S. 2 phal – relative strength, A.S. 3 phal – absolute strength measured for the third phalanx of hand, R.S. 3 phal – relative strength, NS – differences with no statistical significance, * p < 0.05; ** p < 0.01

**Table 3.** Mean values for the results of trials evaluating speed capability and torso strength/endurance of climbers, and their normalised values (NV)

<table>
<thead>
<tr>
<th></th>
<th>Professional climbers</th>
<th>Recreational climbers</th>
<th>NV</th>
<th>SIGNIFICANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sd</td>
<td>min</td>
<td>max</td>
<td></td>
</tr>
<tr>
<td>Sit-ups</td>
<td>34.40</td>
<td>2.30</td>
<td>32.00</td>
<td>38.00</td>
</tr>
<tr>
<td>Standing broad jump</td>
<td>2.60</td>
<td>0.14</td>
<td>2.45</td>
<td>2.75</td>
</tr>
<tr>
<td>MAW (J)</td>
<td>1710.24</td>
<td>142.49</td>
<td>1498.22</td>
<td>1891.89</td>
</tr>
<tr>
<td>Tapping (s)</td>
<td>5.29</td>
<td>0.56</td>
<td>4.32</td>
<td>5.75</td>
</tr>
<tr>
<td>Envelope run (s)</td>
<td>21.94</td>
<td>2.03</td>
<td>19.94</td>
<td>24.57</td>
</tr>
</tbody>
</table>

Key: Sit-ups – strength and endurance of the torso, Standing broad jump – explosive strength, MAW – maximal anaerobic work, NS – differences with no statistical significance, * p < 0.05; ** p < 0.01
Somatic Traits and Motor Skill Abilities in Top-Class Professional Speed Climbers Compared...

resultant of lean body mass and fat [28], it can be assumed that, with their lower fat mass, their higher weight level is associated with increased lean body mass. Summarising this study and the reports of other authors, it can be concluded that high-end sport climber - as compared to the arithmetic means of untrained population – has an average body height, low weight and low body fat [25, 29, 30, 31]. Comparison of arithmetic mean of somatic traits of speed and recreational climbers showed statistically insignificant differences. Results of Student’s t-test correspond with the results of other authors in this field [11, 24]. It follows that in terms of basic somatic traits against untrained persons, high-end sports climber presents a slightly different body build. Comparing speed climbers with representatives of other climbing competitions this way, it turns out that they present a similar level of development. It can be concluded that with the exception of body weight, achieving a high level of success in speed climbing is not conditioned by a specific level of development of the basic characteristics of body build, deviating from the average population.

The rate of movement is indicated as one of the elementary manifestations of speed [14] as well as the coordination predisposition [12]. It represents the number of cycles in a time unit [32], an important property in the light of the climbing movements occurring during the run up the wall, where the climber performs sequences like: step-reach-step-reach, or more effective: a step-step-reach-reach, providing the climber with right direction and drive [1]. Interestingly, in this case, there were no statistically significant differences, and the level presented by both groups of climbers was very similar (WU: -0.14). Thus, it seems that the frequency of upper limb movement, regarded as a manifestation of overall speed is not prerequisite for achievements in speed climbing.

In previous studies, it was found that the level of flexibility does not differentiate significantly elite climbers from recreational or untrained persons [24] and that it has limited impact on the quality of sport climbing [25]. Similar, practical insights were presented by Hörst [1], who states that climbing does not require the competitor to be very supple, although he points to suppleness as valuable for climber’s training. Our results fully correspond with the results achieved by Grant et al. [24], in which the elite climbers presented higher, but not statistically significant levels of flexibility. Therefore, it is difficult to answer the question whether this property will be significant in the motor preparation of competitors on a championship level.

In previous studies of sport climbing clearly indicates that in dynamometric tests, professional climbers achieve similar results in absolute strength of the upper limbs, and much higher in the case of relative strength (mostly statistically significant) in relation to those untrained or recreational climbers [3, 22, 24, 29, 30, 31]. In the context of muscle strength, especially relative strength, indicated as a manifestation of talent in sport climbing [3], previously indicated low level of body weight is of particular importance. Also in our study, the observed differences in absolute and relative strength between the groups of climbers are considerable. Speed climbers presented higher value of both types of strength when compared to recreational climb-

| Table 4. Mean values of the basic somatic traits of climbers of different competitions, recreational climbers and untrained people |
|---------------------------------|-----------------|-----------------|---------------|-----|-----|
|                                 | Body height [m] | Body mass [kg]  | Upper limb length (a-da) [cm] | FM [%] | BMI |
| Speed climbing                  | 1.74            | 67.18           | 80.28                     | 13.4  | 22.11 |
| Recreational climbers           | 1.7             | 65.68           | 79.18                     | 17.2  | 22.56 |
| Bouldering [Grant et. al 1996]  | 1.789           | 74.5            |                           | 14.0  |     |
| Lead climbing [Mermier et al. 2000] | 1.774           | 72.8            |                           | 9.8   |     |
| Lead climbing [Rokowski 2006]   |                 |                 | 80.1                      |       |     |
| Lead climbing [Rokowski and Tokarz 2007] | 1.774           | 66.0            |                           |       |     |
| Lead climbing [Rokowski and Żak 2010] | 1.782           | 64.7            |                           |       |     |
| Bouldering [Michailov et al. 2009] | 1.746           | 67.3            |                           | 5.8   |     |
| Warsaw University of Technology Students [Piechaczek 1998] | 1.7936 | 72.11           |                           | 15.66 | 22.4 |

Journal of Kinesiology and Exercise Sciences
ers, both when measured on the second (NV of absolute strength 0.76, NV of relative strength: 0.78) and the third phalanx of the hand (NV of absolute strength: 1.34, NV of relative strength: 1.13). The results of Student’s t-test were insignificant, which was a direct consequence of the size of the group. Large normalised values indicate, however, a significant difference. Climbing significantly stimulates the strength of the upper limbs, especially their level of relative strength [6, 22]. The differences are likely a result of varying intensity and frequency of training for people from both groups. In comparison with the results of the dynamometric tests carried out among top boulders, taking part in the World Cup, Polish climbers generally presented a similar level of absolute strength of the upper limbs measured on the second phalanx (an average of 58.6 kg for boulders at 56.55 kg for speed climbers). The above also applies to the relative strength (an average of 0.9 for boulders at 0.84 for speed climbers) [17]. Comparison of the results in terms of absolute and relative strength of the upper limbs of Polish speed climbers and the bouldering World Championship competitors with Chinese climbers indicates that for all the competitors, the level of relative strength presented was similar (high) – an average of 0.81 of the Chinese competitors. The Chinese climbers displayed slightly lower average absolute strength (that is, less than 50 kg for both upper limbs) [33]. In a study conducted by Rokowski [22] relative strength level for “model” climbers had a value of 1, in a Spanish study the values were even higher (however, a different tool was used in this case: it was a TKK 5101 Grip D dynamometer, manufactured by Takei) and, depending on how advanced the climbers were, could be found in the range of 1.4 to 1.5 [26]. Judging from the material found in the cited publications and this study, it may be concluded that, regardless of the type of climbing competition or region of the world from which the competitors hail, the best climbers are characterised by a high level of relative strength, which enables them to navigate the walls efficiently.

One of the main objectives of this study was to compare the speed capability of high-class speed climbers with recreational climbers. In three trials, they obtained statistically significant higher scores than recreational climbers (standing broad jump, MAW and the envelope run). Speed climbing is, amongst all climbing disciplines, the one in which the decisive criterion for the final result is the time in which the route is beaten. This makes the competitor move on the wall in the shortest possible period of time. The results in professional speed climbing in recent years, depending on the mode of the competition, are usually from about 4 to 9 seconds in final runs. This indicates that to a large extent, the end result will be determined by the size of muscle strength during efforts of maximum intensity and short duration, that is by maximal alactacid anaerobic power (MAAP), which is simultaneously a predisposition for strength capability [12, 14]. This, in turn, as previously mentioned, play an important role in terms of the motor requirements for sport climbing. In this study, a method of measuring MAW proposed by Szopa [19] and Januszewski [18] measurement of MAW, correlated with MAAP. The results obtained clearly indicate higher levels of MAW in the group of professional climbers (NV: 2.42 at p < 0.01). Similarly high differences (NV: 3.61 at p <0.01) were observed in explosive strength measured with the standing broad jump test. Szopa et al. [12] present the view that this kind of strength is the bridge connecting strength and speed capabilities. Explosive strength appears to play an important role in speed climbing. To a lesser extent, but also to clear the two study groups were differentiated by the results of the envelope run test (NV: 2.06 at p < 0.05). This test is pointed to as the measure of the ability for rapid muscle mobilisation [19]. The results clearly show that leading Polish speed climbers are characterised by high levels of this ability. It follows that in speed climbing, the end result may be determined, inter alia, by high strength and speed capabilities of the competitor, particularly by potential for speed, which is 80% genetically determined [34]. In light of the above, it would seem that, depending on specialisation, a professional climber presents a particular type of motor ability. In case of speed climbing, it would be a strength-speed type. Thus, one can assume that during the selection process for speed climbing, attention should be paid to speed capability; it would also seem that the test used in this study may have prognostic value when laboratory measurements cannot be performed. At this point, attention should also be paid to the fact that the tests verifying speed capability of the study group involved primarily lower limbs, and not the upper limbs, which are known to play a decisive role in climbing. When climbing vertical walls – and speed climbing events take place on such – lower limbs play an important role, and they ought to do most of the work [1]. From this point of view, the use amongst speed climbers of tests involving lower limbs seems reasonable.

Statistically significant differences in favour of professional climbers and were observed in sit-ups (NV: 2.20; p <0.01). This test is indicated as an indirect one, indicating the level of capacity for resistance to fatigue [19]. The difference between the two groups is probably due to higher and different workout routines at professional level. Comparing the results of the capacity for resistance to fatigue in speed climbers with advanced lead climbers indicates that the former presented higher level of resistance to fatigue (34.4 sit-ups to 28.9) [5]. The specificity of this test consists in performing the maximum number of sit-ups within a 30 second time limit. This forces intense, even maximum effort in a given pe-
Somatic Traits and Motor Skill Abilities in Top-Class Professional Speed Climbers Compared...

Conclusions
1. Even though the results have not confirmed it conclusively, it may be said that, among all the somatic traits chosen for analysis, body mass exclusively can be treated as a determinant of high class speed climbing and other climbing competitions.
2. The study confirmed the significance of high levels of relative upper limb strength in sport climbing.
3. In speed climbing, the end result will depend on high level of strength capability and an above-average speed capability. Maximal alactacid anaerobic power is especially important here.
4. It can be inferred that the standing broad jump test, as well as determining MAW are both valuable diagnostic tools for recruiting and selecting competitors for speed climbing.

References
Anthropometry and strength characteristics of world-class boulderers. Medicina Sportiva 2009, 13 (4), str 231-238.


Szopa J. Struktura zdolności motorycznych – identyfikacja i pomiary. Antropomotoryka 1998, nr 18, str 79-86. (The structure of motor skills)


Zak S. Zdolności kondycyjne i koordynacyjne dzieci i młodzieży populacji wielkimięskiej na tle wybranych uwarunkowań somatycznych i aktywności ruchowej. Wydawnictwo Monograficzne, Nr 43, AWF Kraków. 1991. (Fitness and coordination among children and teenagers from big cities)

Rokowski R. Główne determinatory morfo-funkcjonalne skuteczności zawodnika we wspinaczce sportowej w konkurencji na trudność w stylu ON SIGHT. Praca doktorska. AWF Kraków. 2006. (Morphofunctional determinants of lead climber’s efficacy)


Piechaczek H. Typologia budowy ciała studentów AWF i Politechniki Warszawskiej. Wychowanie Fizyczne i Sport 1998, nr 1, str 67-79. (Body build of AWF and Politechnika Warszawska students – a typology)

Ozimek M. Sprawność motoryczna zawodników i zawodniczek w wieku 15-19 lat różnych dyscyplin sportowych na tle wybranych populacji w świetle badań testem Eurofit. Wydawnictwo Podkarpackiego Towarzystwa Naukowego w Rzeszowie. 2007. (Motor ability of competitors between 15 and 19 years of age in different sports and the Eurofit test)


