

HIGH JUMP: ARE BODY HEIGHT AND BODY WEIGHT GOOD PREDICTORS OF PERFORMANCE IN ELITE HIGH JUMPERS?

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ABSTRACT

High jump is athletic discipline which counts in the so-called altitude or vertical jumps. It is a discipline that combines speed, explosive strength, flexibility in technique, and morphologic characteristics of the competitor. The main goal of the research is to determine the influence of Body height (BH) and Body weight (BW) with the best achieved results of in High jump. In study included 38 top male jumpers (BH=192.68 ± 6.77 cm; BW=76.79 ± 5.96 kg). Their achieved best results were analyzed. Pearson correlation coefficient was used to determine the relationship between body height and body weight and the results of high jumpers. Univariate model of regression analysis was applied and the relevant coefficients were calculated. The level of acceptance of statistical significance was set to $p < 0.05$. Simple regression analysis did not show a statistically significant effect of Body height on the results in the high jump (BH vs. High jump $R = 0.034$; $p > 0.05$), and Body weight with the results of the jump (BW vs. High jump $R = -0.066$; $p < 0.05$). The results confirmed that were morphological characteristics are a good but not decisive factor for the success of the high jump.

Keywords: Anthropometric characteristics, influence, high jump.

1. INTRODUCTION

High jump is a very attractive athletic discipline which counts in the so-called altitude or vertical jumps. In comparison to other jumps, this technique is based on a different biomechanical basis (Khan, Hussain, & Mohammad, 2013). The jumper goes over the bar, facing back, during the transverse position of the body. That position is suitable for connected transmission of body parts over the bar with the usage of compensatory effect (Hay, 1993; Dapena, 2000). Transverse transit over the bar also has an impact on the increase of the speed of horizontal transit of the body over the bar and on successful lifting of the highest point of the trajectory of the body gravity center (BGC). From the mechanical point of view (maximal height of the jump) high jump is composed of three reference heights: the height of the body gravity center in the moment of leg placement on the base, the height of the body gravity center in the moment of completion of launching (a moment before leaving the base), the height of launching of the body gravity center, which is determined by the vertical speed of the jumper (Khan, Hussain, & Mohammad, 2013; Smajlović, 2010; Pavlović, 2016, 2017).

We can say that the launching is the most important element of the overall technique of the high jump because starting vertical speed of the launching of the body gravity center

of the jumper is detected, or horizontal component is transformed into vertical. The launching is conducted with both left and right legs, depending on which side of the bar is the jump-off is done, i.e. if it is a right-handed or left-handed jumper. This phase depends on previously done preparatory actions of the jumper and correct timing. The peak height of the jumper's centre of mass (CM) during the flight over the bar is dependent on the height and the vertical velocity of the CM at toe-off. This in turn is governed by the jumper's vertical velocity at the instant of touchdown and the vertical impulse transmitted via the takeoff foot to jumper's body during the take-off phase (Khan, Hussain, & Mohammad, 2013; Dapena, 1990; Hay, 1993, Pavlović, 2017).

According to Pavlović (2017) positioning of the launching leg is done by long running step with the transition over the heel onto the full foot, in front of the vertical projection of the knee from 15° to 30°, hips around 45° and shoulders 90°. If the inclination of the jumper is towards the center of circular trajectory, the foot of the launching leg in the moment of the launching will be closer to the bar from the projection of the other body parts (knee-hipshoulders). The distance of the launching place from the bar is bigger if the jumper comes to a place of launching in a higher running speed. Dapena et al. (1990) found a positive relationship ($r=0.79$) between the horizontal velocity at the end of the approach and the vertical velocity of the CM the end of the take-off phase. Dapena and Chung (1988) suggest that a fast approach run can help the jumper to exert a larger vertical force to the ground. The result of the competitor is the difference between the maximal height of the launching of the body gravity center and the distance between the bar and body gravity center of the jumper.

The efficiency of the jump is increased in accordance with the increase of the launching speed, by optimizing of the launching angle and decreasing of the distance between the bar and BGC of the jumper in the moment of crossing over the bar (Khan, Hussain, & Mohammad, 2013; Jovović, 2006; Mihajlović, 2010; Stanković & Raković, 2010). That tells us that the success in the high jump depends on rational transmission of BGC, as well as individual segments of the body over the bar, or technique by which the jump is done. Body height is also important because the BGC of taller individuals is located on a bigger height in comparison with shorter people. Women elevate their bodies over the bar which is 25 cm maximum higher from them, while that difference in men is up to 50 cm American Franklin Jacobs (173cm-2,32m) and Swedish Stefan Holm (181cm-2,40m) surpassed their height for 59 cm. (Pavlović, 2017)

The technique has an impact on the result, where there are competitors who, even besides a smaller body height make good results by jumping up to 40cm more than their own height. (S. Holm). Also, what is important are motor indicators, explosiveness, flexibility and the speed. The participation of these abilities in the technique of the performance defines the technique of high jumpers, if it is going to be "fast" or "strong" flopper. The different variations of the flop techniques enable the utilisation of the best physical capacity of each individual jumper. Therefore, it seems that there is not a single, ideal technique for achieving good results and jumpers with different body types, physical characteristics and performance techniques have good possibilities to compete successfully in the highest level (Isolehto et al., 2007). The authors (Dapena & Chung, 1988; Dapena et al., 1990) confirmed earlier findings that the vertical velocity and height of the CM at the end of the take-off phase together determine the height of the flight. The most important factor related to vertical velocity at the moment the take-off foot loses contact with the ground is the CM position when the foot touches down for the takeoff. CM height at this point is related more to arm technique than physique. It is obvious that besides morphological dimensions, kinematic parameters have impact on technical performance and result success in high jump. Study Pavlović (2017) analyzes the differences between the kinematic parameters in the discipline high jump. The sample included men and women finalists who competed in the finals of the World Championships (Daegu, 2011). The differences were recorded in the following

parameters where the motor abilities (speed and explosive power) were manifested: maximum body center height, maximum horizontal velocity of the body center, the horizontal velocity of the center of gravity of the body and the vertical velocity of the center of gravity of the body. There is a lack of research on the influence of height and body weight of the best jumpers (according to the achieved result) on the results of High jump.

The main goal of the research is to determine the influence and possible connection of Body height (BH) and Body weight (BW) with the best achieved results of (of all time) in High jump males.

2. METHODS AND MATERIALS

2.1 Participants in Study

The research included 38 competitors, top male high jumpers (mean Body Height = 192.68 ± 6.77 cm; mean Body Weight = 76.79 ± 5.96 kg). Their best results were analyzed. The criteria for inclusion in the study were that the jumper achieved the best personal result (Table 1) in the high jump (2.36m and more, concluding with a world record of 2.45m). The results are taken from the IAAF website.

2.2 Design and Statistical Analysis

For the purposes of this research, defined body height and body weight as an independent variable while the results of high jump were defined as dependent variables. First, the central and dispersion parameters (Mean, SD, Min, Max, Range, $CI \pm 95,00\%$; CV%) were calculated for all variables, while the Pearson correlation coefficient was used to determine the relationship between body height and body weight and the results of high jump. The level of acceptance of statistical significance was set to $p < 0.05$. The obtained correlations are contained in tables and graphs. In order to more accurately confirm the results defined by the research goal and to determine the influence of body height and body weight on the result performance, a univariate model of regression analysis was applied and the relevant coefficients were calculated. The statistical package STATISTICA, version 10.0 was used for data processing.

3. RESULTS

The results of the basic statistical parameters and simple regression analysis are contained in Table 1, 2 and Figures (1-4). The average height high jump result was 2.39m in the range of 2.36m (G. Wessig) to a maximum of 2.45m-WR (J. Sotomayor) in the range of 9cm. The analysis of the results (Table 1) showed that the largest number of jumpers achieved a result in the of 2.38m (34.21%), from 2.40m (21.05%) and 2.43m (21.05%), etc.

The average height of jumpers is 192.68cm, where 4 competitors (10.52%) are over 200cm, twenty-two (57.89%) are in the range of 190-200cm and the other twelve jumpers are under 190cm (31.57%). The difference between the tallest (Freitag, 204cm) and the shortest competitor (Thörnblad, 180cm) is 24cm. The average body mass of the jumpers was 76.79 kg. Seventeen competitors (44.73%) had a body mass of 80-85kg, nine (23.68%) from 74-79kg, eight competitors in the range of 68-73kg (21.05%). The remaining 4 competitors had a smaller mass of 68 kg (10.52%), where the difference between the spread and the largest body mass is as much as 20 kg (Sonn and Kinard, 85 kg vs. Essa Barshim, 65 kg). The analyzed degree of correlation and influence of the body height of the jumper on the result success does not confirm the hypothesis of a statistically significant influence of this dimension on the result of the jump (Table 2, Figure 1, 3). A low and statistically insignificant

correlation was recorded (Body height vs. High Jump = 0.034), which was confirmed by the results of the regression function ($R^2=0.001$; $p>0.05$). Body mass recorded an inverse correlation with the result of the jump (Body weight vs. High Jump = -0.065), which is also confirmed by the result of the regression function ($R^2=0.004$; $p>0.05$) (Table 2, Figure 2, 4). A statistically significant correlation coefficient between the jumper's height and body mass is evident (Height vs. Weight = 0.668; $p<0.000$) (Figure 5), where the height of the jumper is accompanied by an increase in body weight.

Table 1: Personal best result (All time) ***

Athlete	HJ PB (m)	Body height (m)	Body weight (kg)
Javier Sotomayor	2.45	195	82
Patrik Sjöberg	2.42	200	78
Carlo Thränhardt	2.42	198	84
Igor Paklin	2.41	191	72
Bogdan Bondarenko	2.42	197	80
Ivan Ukhov	2.40	192	83
Rudolf Povarnitsyn	2.40	201	75
Sorin Matei	2.40	184	67
Hollis Conway	2.40	183	68
Charles Austin	2.40	184	77
Vyacheslav Voronin	2.40	190	78
Stefan Holm	2.40	181	69
Mutaz Essa Barshim	2.43	189	65
Derek Drouin	2.40	194	80
Zhu Jianhua	2.39	193	70
Dietmar Mögenburg	2.39	201	78
Ralf Sonn	2.39	197	85
Gennadiy Avdeyenko	2.38	200	82
Sergey Malchenko	2.38	190	74
Dragutin Topic	2.38	197	77
Steve Smith	2.38	185	70
Wolf-Hendrik Beyer	2.38	200	82
Troy Kemp	2.38	187	69
Artur Partyka	2.38	193	71
Matt Hemingway	2.38	198	81
Yaroslav Rybakov	2.38	198	84
Jacques Freitag	2.38	204	83
Andrey Sokolovskiy	2.38	196	80
Linus Thörnblad	2.38	180	76
Andrey Silnov	2.38	198	83
Valeriy Sereda	2.37	186	73
Tom McCants	2.37	185	79
Jerome Carter	2.37	185	66
Sergey Dymchenko	2.37	203	80
Jesse Williams	2.37	183	70
Robbie Grabarz	2.37	191	80
Erik Kynard	2.37	193	85
Gerd Wessig	2.36	200	82

Table 2: Results of statistical analysis

	Mean \pm SD (Min.-Max.)	Range	CV%	Parameter	Pearson (r)	Simple regression analysis		
						R^2	F	$p<0.05$
High jump	2.39 \pm 0.02 (2.36-2.45)	0.09	1.01	BH	0.034	0.001	0.042	0.839
				BW	-0.065	0.004	0.156	0.696

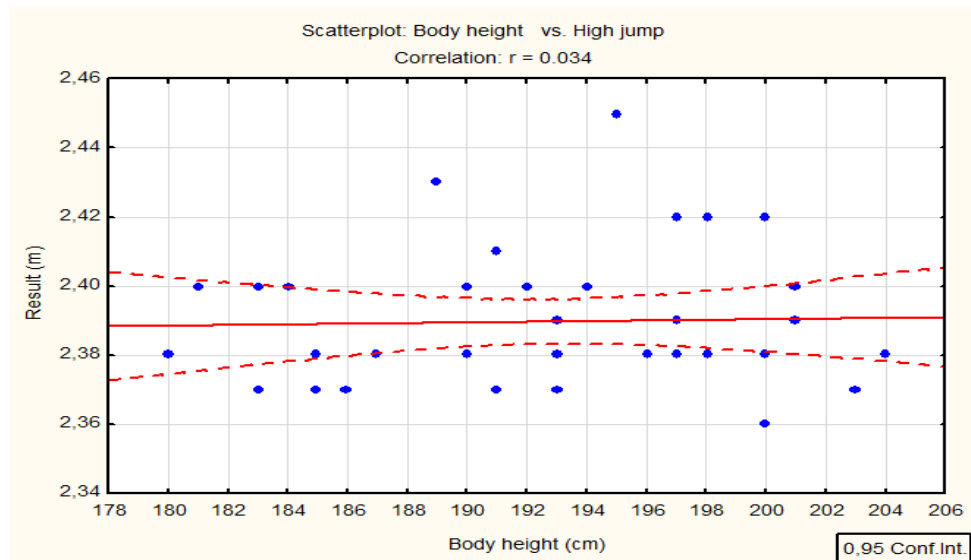


Figure 1: Pearson correlations (BH vs. High jump)

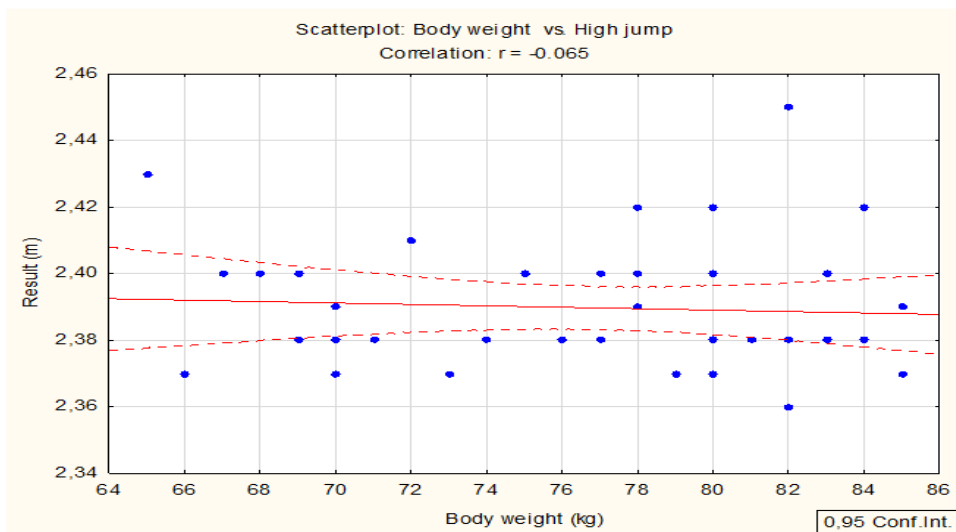


Figure 2: Pearson correlations (BW vs. High jump)

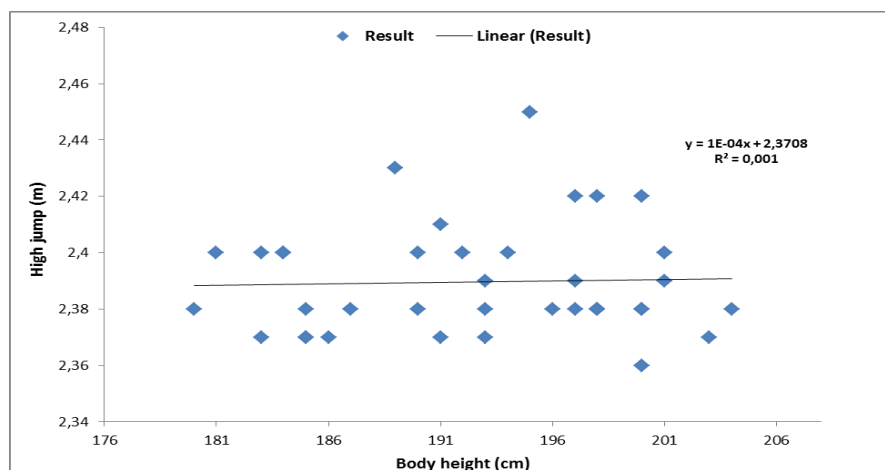


Figure 3: Simple regression analysis (BH vs. High jump)

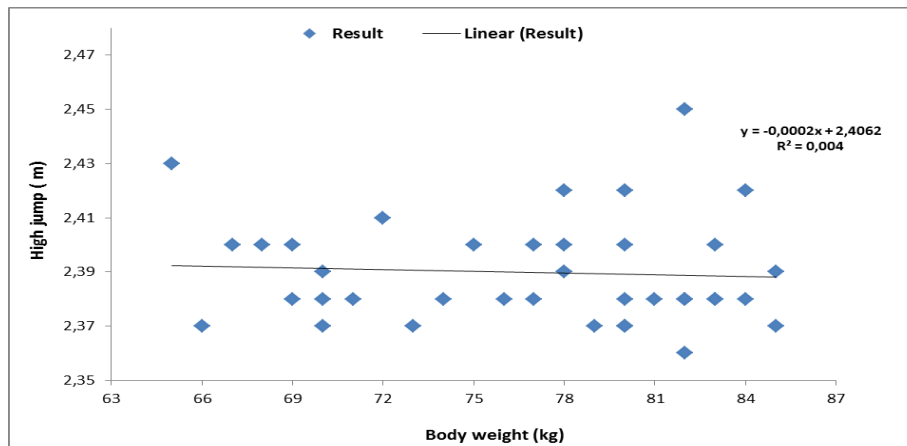


Figure 4: Simple regression analysis (BW vs. High jump)

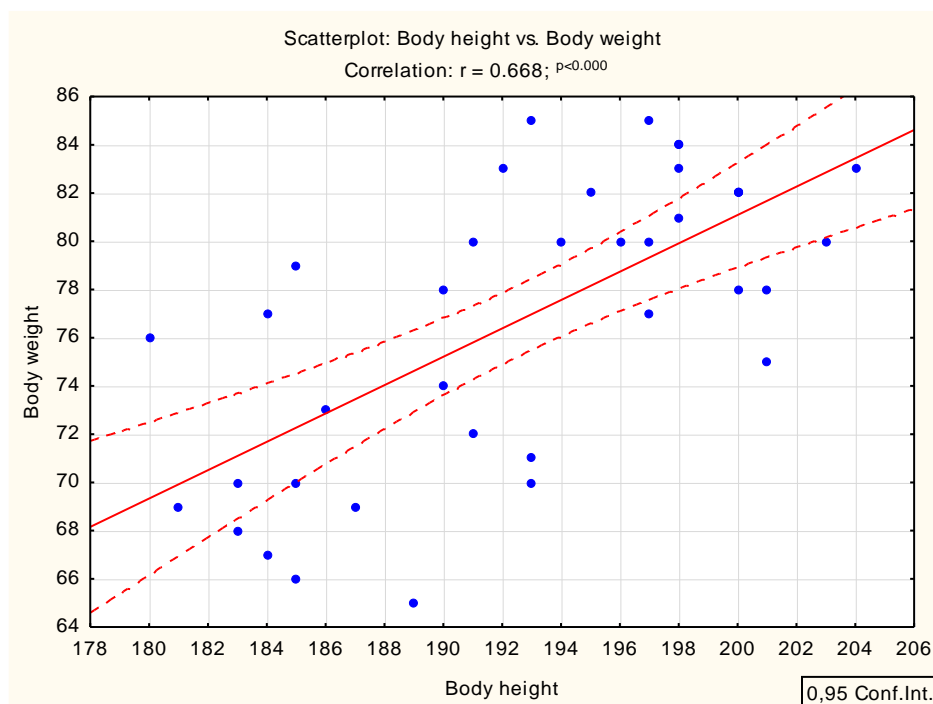


Figure 5: Pearson correlations jumpers (BH vs. BW)

4. DISCUSSION

The main goal of the research is to determine the influence and possible connection of Body height (BH) and Body weight (BW) with the best achieved results of (of all time) in High jump men. From the results of the current study, it is evident that body weight had a statistically significant but inverse effect on the results of the High jump. According to (Pavlović, 2017) body mass with excess fat has a negative effect on athletic disciplines, especially those in which the body leaves the ground as in jumps (it is evident in our study) or is in high acceleration above the ground (sprint, hurdles, long runs, long jump, pole vault).

The high jump athletic discipline is a complex athletic jumping discipline that requires a good integration of morphological, motor and biomechanical parameters from the jumper. In practice, it is not a rare case that jumpers of smaller body height achieve good high jump results. Mostly they have better technical performance, good proprioception and timing to direct their body's center of gravity and transfer it with the best trajectory (eg Jacobs, Holm...). This is especially evident in top jumpers, where these segments are almost equally represented and technical finesse often determine the mutual winner. According to the structure (profile),

it is the morphological space that often records significant differences between competitors in relation to motor and technical parameters. Physical resources that increase the speed of arrival on the board (about 7-8m/s) and the strength of reflection at takeoff (more than 4.5m/s) are important determinants of the overall height of the jump. Namely, it is known that jumping disciplines are characterized by increased longitudinallity and transversality of the skeleton, lower body weight and on the basis of which is made one model of jumper. Generally, the jumpers are tall and relatively of less weight, long legs, long and thin muscles. According to the constitution the leading is leptosom type with the participation of athletics. Ten best jumpers in the world have a height of 190-201cm for males and 178-188 for females. As an indicator of physical condition of jumper, there is the potential of speed power, which is expressed at speed and a maximum strong rebound when the pressure on the soil exceeds the weight of athlete 6-7 times. This requires a specific power, not only of legs but of all muscle groups. Here comes into play synchronized actions of muscular kinetic chains, which extends from the foot to the muscles of arms and shoulders. To perform complex actions, both when entering the bounce, and during the jump, a high level of coordination of movements is needed and a good state of the vestibular apparatus (Jovović, 2006; Pavlović, 2012).

The average body height of our sample of the best jumpers (about 193cm) is in accordance with the aforementioned research, where several jumpers over 200cm were recorded, and most of them are in the range of 190-200cm. This is a significant indicator that the height of the competitor is desirable but not decisive in the resulting success of the high jump. The analyzed degree of correlation and influence of the jumper's body height on the result success does not confirm the hypothesis of a statistically significant influence of this dimension on the jump result, where a low and statistically insignificant correlation was recorded, in contrast to body mass, which had a negative impact on the jump result. The inverse relationship between body mass and jumper success leads to the conclusion that body mass manifests itself as a disturbing factor in the achieved result. This is in support of the fact that the high jump implies an integrated effect of speed, explosive power, swing with free limbs and a good jumping technique in a given space and time. In every attempt to jump, it is necessary to achieve horizontal speed in order to neutralize the force of gravity, which negatively affects the angle jump, horizontal and vertical speed and height of the jumper's body center of gravity (Bowerman, Freeman, & Gambeta, 1998).

The length of the run-up depends on the height of the jumper, level of physical competence and some distracting factors. The jumper starts running from 8-11 steps, and varies between 6-17 steps, almost vertical to the bar (65°-90°), and then they run circularly by coming closer to the bar with the angle of 25°-40°, holding the inclination on inner side, as with every other running in curve. In order to overcome the effect of centrifugal force in the arched part of the track and conduct optimal jump, the inclination towards the center of the arched part of the run-up is conducted. All elements of the run-up phase have to be in the function to transfer the part of the horizontal speed into vertical speed in the most efficient way, and thus achieve a bigger vertical component of the BGC movement during the ending of the launching (Mihajlović, 2010; Pavlović, 2016). In the last three steps the longest length is acquired and the decrease of BGC happens due to the decrease of the angle in knee joint, especially in the last step before launching, in order to increase the effectiveness of the triceps (141°-148°), and the angle of the vertical axle on the horizontal level (the angle of launching) is around 80°-110°. The biggest horizontal speed of the run-up top jumpers achieve on 3-5 meters before launching (7,5-7,8m/s), having in mind that it is the highest is the penultimate meter (7,8-8,4m/s), while in the ultimate it decreases (6,6-7,3 m/s) and the speed of the step shortens for around 45 cm as a consequence of the hard base reaction, whose force achieves the value of about 500kg. (Jovović, 2006; Pavlović, 2017). The best high jumpers have the average values of the third step length from the launching amount to 215-220cm, penultimate 220-230cm, ultimate 195-200 cm (Idrizović, 2010). In the phase of the last resistance, the

jumper starts expansion of the launching leg by contraction of actual musculature with central support. In the same time the other swinging leg of the curve in hip knuckle and brings it to the launching leg in the upwards direction in order to stop the movement abruptly by the influence of antagonist muscles. In that way kinetic energy, acquired by the swing transforms into potential (in comparison with the body) which brings to rotation of the body around longitudinal axis which is the extension of conducted arched momentum. During the end of the movement amplitude, launching leg is stretched and shoulders are raised, while arms are also stretched and the jumper is in the phase of ascent. It is proved that optimal angle of the launching is 55°-63°, and that during the speed of the launching from 4.2-5.0 m/sec the height of the jump from 200-221cm can be obtained (Smajlović, 2010).

During the phase of the flight rotations of the jumper around the sagittal axis are expressed and the jumper brings their body by punctual stretching into transitional positions which are manifested successively (Jovović, 2006; Tončev, 2001). During the flight the bar is behind his back side, and in the moment when BGC is located at the top of the ballistic curve, it is in front of the bar, so the axis of shoulders and hips are parallel with the bar. The best high jumpers transfer BCG above the bar on the height of 6-9 cm and it represents the result of the effects of kinetic chains which make compensatory movement happen, or concentric and eccentric musculature contractions, especially during the crossing of the lower extremities. After the crossing of the body and thighs over the bar, concentric contraction of the quadriceps happens in the knuckles of the knees, and lower legs are raised. Synchronized with these movements, under the influence of myometric contraction of abdominal wall mild flexion happens in knuckles of the spine and landing on the ground happens. Morphological parameters have significant effect on result success. According to Pavlović (2012), the average height of male finalists of the Olympic Games in Beijing 2008 amounted to 190,25cm, weight was 78,87kg, BMI 21,89kg/m². However, even among the high jumpers, apart from the gender, there are shorter ones, but that does not mean that they would not have a good result. The height is only one of the necessary parameters, but not decisive which was confirmed in this research. A positive linear correlation was achieved between the jumper's height and body mass, whereby the jumper's height was followed by an increase in body weight. In general, anthropology of high jumpers is variable, we have shorter and taller jumpers, but with different motor abilities and morphological capacities, which can be seen in the results of this research. However, good technique with adequate manifestation of kinematic parameters is a guarantee of a good result.

5. CONCLUSION

Research conducted on an elite sample of 38 high jumpers. The results confirmed that were morphological characteristics are a good but not decisive factor for the success of the high jump. The negative influence of increased body weight on jump height is evident ($r = -0.065$), which is identical in other jumping disciplines. The high jump requires significant integration of motor skills (speed, explosive power, flexibility) and morphological characteristics. Good jump technique, but with optimal body weight, is crucial, as any increase in weight has negative implications for jump height.

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