

# EFFECT OF THE SOMATIC FACTOR ON PERFORMANCE IN SHOT PUT IN RELATION TO THE SPIN AND CLASSIC TECHNIQUES

Adam Haleczko\*, Leszek Korzewa\*\*,  
Ewa Misiolek\*\*, Urszula Włodarczyk\*\*

\* PhD, Wrocław, ul. Kotsisa 21/4

\*\* PhD, Department of Physical Education, University School of Physical Education in Wrocław, Poland

**Key words:** glide technique, spin technique. somatic build, fat tissue, slogan “everyone uses doping”

## SUMMARY

**Introduction.** Changing the shot put technique by replacing the linear run-up with a rotational run-up allowed athletes to increase the distance and duration by which their strength affected the shot. Thanks to the innovation, shot put distance from a running start increased between 2.5 m and 2.7 m compared to a standing start. Currently, most athletes use new technique, although it is more difficult. Statements by various authors on somatic preferences for shot-putters in terms of both discussed techniques are often contradictory and unsupported by research. As a result, these statements can be treated merely as intuitive observations.

**Aim.** This study was motivated by a lack of research on the greater effectiveness of the spin technique.

**Material and methods.** Research material comprised somatic data and results of 67 shot-putters (49 using the spin technique and 18 using the classic (glide) technique) derived from the 2009 ranking list, acquired from the Internet. A lack of differences in results and morphological parameters allowed us to combine the two groups into one group. Statistical analysis was conducted using basic numerical characteristics, with correlations calculated using the Pearson and Spearman methods. To allow a more accurate comparison, 2 groups of 18 athletes somatically similar to the shot-putters using the classic technique were chosen from the group of 49.

**Results.** Body height of the ‘spin’ group, chosen based on their body mass, was 4.2 cm lower than in the ‘classic’ group, meaning that, for all practical purposes, the values were equal. The former group showed statistically significant correlations, while the latter group showed no correlation between their results and either somatic trait as well as between the 2 variables. The observed correlations indicate that the athletes had a disproportionate body build.

A graphical comparison of the athletes’ body mass and results allowed us to divide them into the categories of lightweight (up to 114 kg) and heavyweight (above 114 kg). Lightweight shot-putters showed a negative ( $r = -0.23$ ) correlation with their results, while heavyweight shot-putters showed a positive correlation ( $r = 0.40$ ). The aforementioned relationships in a reference group of decathletes showed progression up to about 90 kg of body mass and above 90 kg showed regression, similar to the case of lightweight shot-putters. A positive correlation in the heavyweight group (above 114 kg) was inconsistent with the opinion of Forbes, who estimated the upper limit of LMB at 100 kg, and motivated us to elaborate on this phenomenon.

**Conclusions.** In summary, we emphasize the role of somatomotor measurements in assessing the level of training in athletes, noting at the same time that these measurements cannot be construed as to indicate illegal doping.

## Introduction

In the 1970s, attempts were made attempts have been made to modify the existing shot-putting technique by

replacing the linear run-up with a rotational run-up, without breaking International Association of Athletics Federations (IAAF) rules. Implementing the new method allowed athletes to increase the distance and

duration by which their strength affected the shot [1]. As Bartonietz [2] states, thanks to the innovation, putting distance from a running start increased between 2.5 m and 2.7 m compared to a standing start, while for the glide technique, the increase ranged from 1.5 to 2.0 m. However, these data need to be confirmed in a study with a larger sample. Currently, most athletes use the new technique, even though analysis of video footage showing 2 groups who were taught both methods at the same time unambiguously indicated it to be more difficult than the glide technique [3].

In addition to noting the aforementioned differences in putting distance, which determine the efficiency of the rotational run-up method, Bartonietz [2] claims that it creates opportunities for the development for some athletes, while the linear technique can result in stagnation. According to Salzer [4], the classic technique can be used to prepare an athlete for the rotational technique. Because it is more natural, easier to learn, and more likely to result in successful puts, the classic method is recommended for athletes participating in combined events. Moreover, it allows shot-putters with a light body build to apply the energy of their leg muscles more efficiently. Researchers from Poznań [5] emphasize the unique role of legs in throwing disciplines. In their opinion, leg strength determines throwing results to a greater extent than arm strength. Furthermore, Goldman [6] underlines the importance of strength and speed predispositions in shot put, regardless of somatic build. He states that apart from a strong body build and the listed motor abilities, factors that are especially important are coordination and a sense of rhythm within movement patterns, manifested through changes in muscle tension and relaxation. In discussing the basic rules and forecasts used to select the rotational method, 3 German authors [7] regard the ability to spin, sense of balance, and maintaining the putting direction as the primary criteria. At the same time, the authors indicated that athletes who show an inclination for the linear run-up should continue using it. In presenting positive and negative sides of the spin technique in a later publication, the same authors list its justification by the laws of biomechanics under its merits [8]. Among its negative aspects, they list the following: a more complicated movement route compared to the classic technique, the necessity for great speed and extreme coordination, and high risk of injury. The authors recommend the rotational run-up technique to athletes with low body height and good speed predispositions,

suggesting that tall shot-putters may find it difficult to remain within the circle.

A Polish specialist who differs in opinion [1] states that the rotational technique allows tall shot-putters with long limbs to make full use of their morphofunctional capabilities, which in the linear run-up are limited by the size of the circle. Henryk Olszewski [9, p. 148], Tomasz Majewski's coach, describes both methods in the following way: "The classic technique requires the shot putter to have greater flexibility than a javelin thrower. The spin technique suits rigid athletes better," the latter method being "obviously more effective, but in practice, it is difficult to find an athlete who is able to avoid losing speed inside the circle. If we found such an athlete, the shot could go as far as 25 meters. The technical difficulty is that the centrifugal force makes the shot fly away from its position at the athlete's neck on its own." Olszewski's opinion concerning somatic build [9, p. 147] is as follows: "The best players are up to about 195 centimeters tall. Tomek's height is giving him some trouble."

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## Aim

Statements by various authors on somatic preferences for shot-putters in terms of both discussed techniques are often contradictory and unsupported by research. As a result, these statements can be treated merely as intuitive observations. Such a state of affairs motivated us to address this subject.

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## Material and methods

Research material comprised somatic data and results of 67 shot-putters from the 2009 ranking list, as published on the Internet (iaaf.org). The technique used by these shot-putters was determined based on information provided by coach H. Olszewski and Olympic champion T. Majewski, for whose assistance we are most grateful (18 shot-putters used the glide technique and 49 used the spin technique). Tables 1a, 1b, and 1c present numerical characteristics of body build and the athletes' shot-put results, as well as correlations between variables. Due to almost identical arithmetic means of putting distance and body mass, as well as an insignificant difference of about 2 cm in body height between the 2 teams of athletes, the teams were combined into 1 group of 67. To objectify data used for making comparisons based on the same or similar measurements, 18 athletes using the spin technique from the group of 49 with appropriate body height

and body mass were paired with 18 athletes who used the classic technique. Tables 2 and 3 present data on these athletes.

Correlation analysis was selected as the basic method of analyzing the material. Spearman's rho ( $r_s$ ) was used for the groups of 18 athletes, while Pearson's  $r$  ( $r$ ) was used for groups of 30 or more [10].

## Results

Tables 1a, 1b, 1c, 2, and 3 indicate that the values of correlations differ between basic somatic traits and results in shot put. In the classic technique group, correlations between all somatic traits and results, as well as between body height and body mass, are close to zero. In other groups, body mass displays the greatest influ-

**Table 1.** Numerical characteristics of somatic build and results of the throwers

a) Glide technique (N = 18)									
On.	Traits	$\bar{x}$	Min.–Max.	Sd	V	1	2	3	4
1	Result (m)	20.237	19.24–21.95	0.687	3.4		-.01	.07	-.05
2	Body height (cm)	192.8	180–204	7.11	3.7	-.01		-.01	.67
3	Body mass (kg)	115.4	88–140	15.3	13.2	.07	-.01		-.69
4	Ponderal index	39.80	37.2–43.6	2.30	5.8	-.05	.67	-.69	

$r_s$  significant at 0.05 – .40; 0.01 – .56

b) Spin technique (N = 49)									
On.	Traits	$\bar{x}$	Min.–Max.	Sd	V	1	2	3	4
1	Result (m)	20.200	19.14–22.16	0.748	3.7		.07	.37	-.26
2	Body height (cm)	190.3	178–209	6.5	3.4	.07		.37	.50
3	Body mass (kg)	115.2	83–149	13.1	11.4	.37	.37		-.62
4	Ponderal index	39.22	35.7–42.7	1.59	4.1	-.26	.50	-.62	

$r$  significant at 0.05 – .28; 0.01 – .37

c) Both techniques (N = 67)									
On.	Traits	$\bar{x}$	Min.–Max.	Sd	V	1	2	3	4
1	Result (m)	20.211	19.14–22.16	0.727	3.6		.08	.32	-.19
2	Body height (cm)	191.0	178–209	6.7	3.5	.08		.28	.53
3	Body mass (kg)	115.2	83–149	13.6	11.8	.32	.28		-.66
4	Ponderal index	39.36	35.7–43.6	1.80	4.6	-.19	.53	-.66	

$r$  significant at 0.05 – .24; 0.01 – .31

**Table 2.** Numerical characteristics and correlation coefficients between somatic traits and results in the group of throwers using the spin technique, matched by body height to the group using the glide technique (N = 18)

On.	Traits	$\bar{x}$	Min.–Max.	Sd	V	1	2	3	4
1	Result (m)	20,274	19,14–21,78	0,720	3,6		.06	.44	–.21
2	Body height (cm)	192,7	180–209	7,3	3,8	.06		.50	.33
3	Body mass (kg)	116,3	90–149	15,0	12,	.44	.50		–.56
4	Ponderal index	39,56	37,5–42,7	1,33	3,4	–.21	.33	–.56	

rk significant at 0, 05 – .40; 0,01 – .56

ence on the results. This is confirmed in statements on shot put made by Migasiewicz [11] and Socha [12] that are more closely reliant on body build than other athletic disciplines. It is especially true for young athletes with little experience, for whom their long-term training has not yet affected their somatic structure in a way specific to the discipline, in comparison to highly qualified athletes. A study on the performance of athletes aged 16–19.25 years [13, p. 74] observed correlations of  $r = 0.72$  between their results and body height and  $r = 0.69$  between their results and body mass. In contrast, for the world-class shot-putters analyzed in this study, the correlations between their results and body height and between their results and body mass are statistically insignificant. The greatest correlation between shot put distance and body mass was observed in the group of athletes using the spin technique that were paired based on body height with athletes using the linear technique (Table 2). Correlations shown in Tables 1b and 1c are somewhat lower, with no correlation at all for the classic technique group (Table 1a). This indicates a lack of proportionality of body build in most athletes using the technique. The correlation coefficient between body mass and the results exceeds the 1% statistical threshold (Tables 1c); however, due to the possibility of curvilinear correlations, it is assumed in statistics

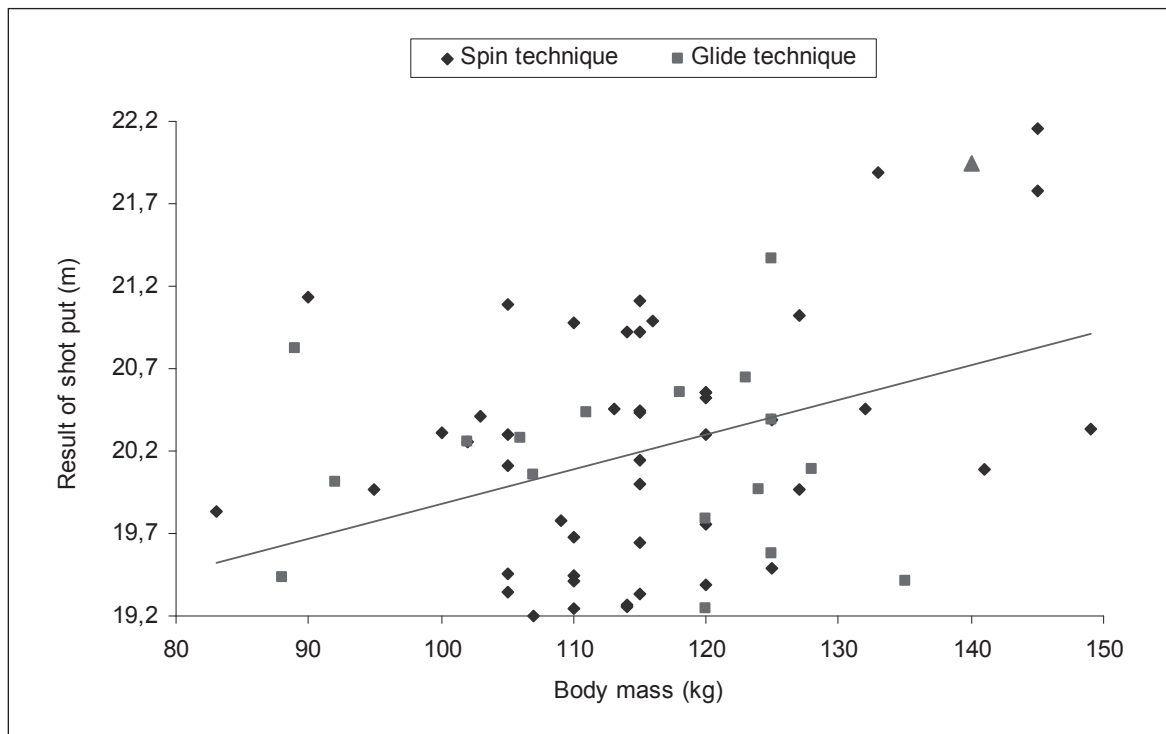
that the most reliable information on the direction and value of a correlation are provided by a coordinate system of both variables.

A graphical comparison of body mass values with shot put results (Figure 1) indicates an inverse effect of this somatic trait on the results. For lower values, body mass displays an insignificant, yet still negative, effect on putting distance; for higher values, the effect is positive. Using correlation, after a few attempts based on the distribution of points on the chart with values of correlations between the athletes' body mass and their results, we were able to find a critical point that allowed us to divide the athletes into lightweight and heavyweight groups (Figure 2). The lightweight group comprised 31 athletes with body mass ranging from 83 kg to 114 kg ( $\bar{x} = 104.3$ ,  $S = 8.3$ , and  $V = 8.0$ ), while the heavyweight group comprised 36 athletes with body mass ranging from 115 kg to 145 kg ( $\bar{x} = 124.7$ ,  $S = 9.6$ , and  $V = 7.7$ ). The former group showed a negative correlation between the variables ( $r = -0.23$ ), and the latter showed a positive correlation ( $r = 0.40$ ). Guilford [10] considers a correlation between 0.20 to 0.40 as low, indicating a noticeable but weak relationship. However, according to Table D [p. 554], which presents statistical thresholds according to degrees of freedom (i.e., sample size), a statistically significant correlation for a sample of 31 persons begins at  $r = 0.36$ .

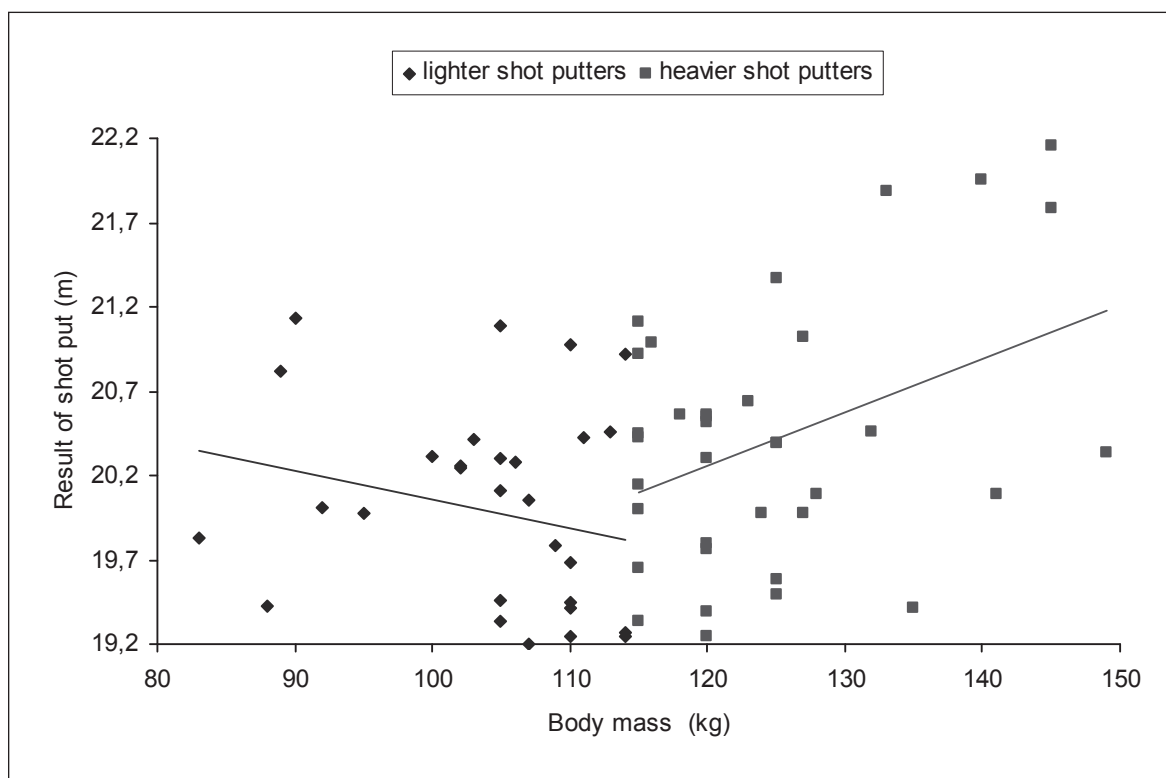
**Table 3.** Numerical characteristics and correlation coefficients between somatic traits and results in the group of throwers using the spin technique, matched by body mass to the group using the glide technique (N = 18)

On.	Traits	$\bar{x}$	Min.–Max.	Sd	V	1	2	3	4
1	Result (m)	20,246	19,20–21,89	0,659	3,3		–.08	.25	–.18
2	Body height (cm)	188,6	178–202	6,8	3,6	–.08		.42	.30
3	Body mass (kg)	115,7	83–141	15,9	13,7	.25	.42		–.63
4	Ponderal index	38,84	35,7–42,7	1,81	4,7	–.18	.30	–.63	

rk significant at 0, 05 – .40; 0,01 – .56



**Figure 1.** Juxtaposition of the results of shot put and body mass of throwers using the glide technique and the spin technique (result of T. Majewski marked with a triangle)



**Figure 2.** Juxtaposition of the results of shot put and body mass of lighter throwers and heavier throwers

**Table 4.** The results of shot put in the group of decathletes and throwers at intervals of body mass and their correlations

Group	N	n	Body mass (kg)		$\bar{x}$ Result (m)	r	r significant at	
			Intervals	$\bar{x}$				
Decathletes	56 (61)	17	78–82	80,1	13,69	.72	0.05– .25 0.01– .32	
		20	83–87	85,2	14,24			
		13	88–92	90,1	14,99			
		6	93–97	94,7	14,83			
Shot putters	lighter	7	83–100	91,0	20,21	-.23	0.05– .36 0.01– .46	
		11	101–107	104,7	20,07			
		13	108–114	111,1	19,78			
		31		78–114	104,3	19,98	.40	0.05– .32 0.01– .41
	heavier	17	115–120	117,4	20,21			
		8	121–125	124,9	20,24			
		5	126–135	130,3	20,47			
		6	136–149	144,0	21,26			
	36		115–149	124,7	20,41			

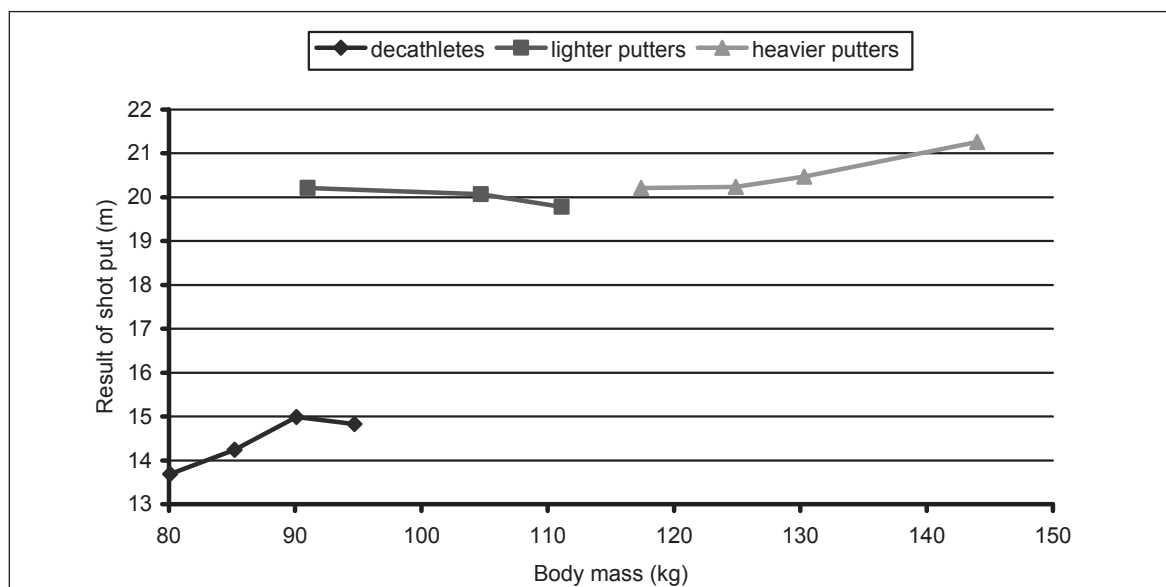
To obtain information on correlations between these traits in athletes with lower body mass than shot-putters, we used somatic data and shot putting results of 61 decathletes from the ranking list of world's best athletes from 1971 to 1974 [14]. Strength was assessed based on the suggestions of Wazny [15], who assumed that most contemporary motor tests measure speed and endurance based on results in running, strength based on throwing, and power based on jumping. The correlation coefficient between body mass and shot putting results for this group amounted to  $r = 0.72$ . Table 4 and Figure 3 present the results of both the lightweight group and the heavyweight group of shot-putters together with the data on decathletes (bearing in mind the low number of athletes with extreme parameters, and that extreme categories were not included in the table; thus, only 56 athletes were qualified for the Table). The results of the decathletes increase together with the increase in their body mass up to the 82-92 kg category; above this, the progression diminishes slightly. This tendency is consistent with the one

observed in the lightweight group of shot-putters, who displayed a negative correlation (Table 4 and Figures 2 and 3). The reversal of the tendency in the heavyweight group is an unexpected phenomenon. One of the earlier studies [16], which compared shot-putting results of decathletes (ranking list from 1985) and shot-putters (World Championships 1983) combined into 1 group (without the division into lightweight and heavyweight categories), found opposite correlations in both groups (Table 5), similar to this study (Table 4).

Decathletes constitute a difficult reference group due to the multifunctionality of their motor tasks that determines their body build and, even more so, their body composition. This conflict between strength and endurance manifests itself in the incongruity between the results in the shot put and the 1500-m run. In terms of somatic build, this incongruity is caused by the quantitative ratio of fat tissue to muscle mass; in terms of motor capacity, by the degree of development of both abilities involved in the 2 disciplines. In motorics, such an opposing influence is called *functional antagonism*

**Table 5.** Mean values of somatic traits and results of shot put and their correlations in groups of decathletes and throwers (1990)

Group	N	$\bar{x}$ Body height (cm)	$\bar{x}$ Body mass (kg)	$\bar{x}$ Rohrer index	$\bar{x}$ Result (m)	Correlation with result (r)		
						Body height	Body mass	Rohrer index
Decathletes	30	189.0	86.2	1.280	14.81	.16	.66	.31
Shot putters	26	192.1	119.7	1.690	20.92	-.10	-.08	.00



**Figure 3.** Juxtaposition of arithmetic means of shot put results at intervals of body mass in group of decathletes and throwers – lighter and heavier

[14, 16, 17]. It occurs in specific conditions and only among highly trained athletes. As a result, these somatomotor interactions affect decathletes' results as well as correlations between their results and somatic traits. At the same time, a specific regressive indicator of relative strength, one that is calculated based on body mass and shot put results, allows for the assessment of the degree of preparation of athletes in terms of strength and, indirectly, endurance, which makes it possible to plan and conduct endurance training of decathletes for 1500-m runs in a safer way [14]. In contrast to decathletes, the somatic structure of shot-putters is determined by 1 goal: maximum putting distance theoretically achievable by athletes with a body mass as high as possible and body composition that maximizes shot speed at release. As far as body height is concerned, it should allow optimal movement within the circle.

W. E. Sinning et al. [18] present somatic parameters of athletes participating in 36 different disciplines. Among the heaviest athletes, they list shot-putters with body height of 188.2 cm, body mass of 112.5 kg, and fat percentage of 16.5%. Weightlifters from the heaviest category, where there is no upper limit of body mass, are athletes most similar to shot-putters in terms of body build. During dynamic work, muscle strength depends to a great extent on muscle flexing speed, i.e., speed, a different motor ability [19]. Strength and movement speed achieved during shot put and weightlifting are inversely proportional [20]. However, due to different

types of muscle work and a somatic similarity, it is possible to conduct a comparative analysis of the influence of body build on athletes' performance in these disciplines. Authors who discuss the relationship between strength exercises and performance in athletic throwing suggest that these disciplines, despite being classified in different sports categories, are closely linked, as evidenced, for example, by the use of weightlifting exercises as a basic method of developing strength in the training of throwers [5]. Such a close relationship between the disciplines is also supported by high correlation values between shot put and different weightlifting exercises, i.e., snatch: 0.90, clean and jerk: 0.88, supine lifting: 0.81, and squatting with the weight: 0.69 [21, p. 66]. Other sources have correlations with supine lifting of 0.789 and squatting with weight of 0.789 [22, p. 226]. Results of studies on the relationship between body mass of weightlifters with an equal training level and their performance in Olympic weightlifting and powerlifting indicate that absolute strength increases with the increase in body mass, while relative strength decreases. This decrease occurs because an athlete's body mass is proportional to the cube of their height measurements, while strength is proportional to the physiological cross section of muscles, that is, only to the square of these measurements. As a result, body mass increases faster with the increase of body size than with muscle strength. This relationship has been described by an equation and supported by analysis

of world records in Olympic weightlifting [23, 24, 25, 26]. Some authors [20, 27-29, 30-32], however, claim that the development of skeletal muscles relevant to a given discipline does not cause a decrease in relative strength, as an increase in the mass of given muscles due to hypertrophy increases both relative and absolute strength. The close relationship between athletes' performance in weightlifting and body mass is confirmed by a high correlation coefficient of  $r = 0.9688$ , as observed by Milicerowa and Olpiński [33, p. 425]. They compared the results of 60 world record breakers in powerlifting, and calculated based on the upper limits of 6 weight categories, excluding the highest weight category, which had only the lower limit. Ważny [20, p. 21] also reports correlation values similar to powerlifting that were obtained in Olympic weightlifting ( $r = 0.974$ ) and its constituent disciplines: snatch ( $r = 0.951$ ) and clean and jerk ( $r = 0.986$ ).

Correlations between body mass and strength motivated many authors to develop indicators of actual efficiency and point charts that allow for a comparison of relative strength affecting athletes' performance, regardless of their weight categories [14, 26, 31, 33-41]. However, according to Hunter et al. [42], until a detailed and accurate relationship between strength and body mass is known, all attempts at comparing performance in weightlifting will only result in approximations. Athletes from the highest weight category pose the greatest difficulty to researchers developing indicators of efficiency and tables, as their share of fat tissue in total body mass is significant. According to Hester et al. [37], the correlation between strength and body mass in weightlifters remains linear up to 180-200 lbs (81.7 to 90.7 kg).

In an article on physiological modeling, Batterham and George [43] find it obvious that for the heaviest categories (from 90 kg to more than 150 kg), the assumption that samples are homogeneous is unreliable due to body shape, structure, and composition. The authors also found that in Olympic weightlifting, an increase in body size is accompanied by a relatively smaller increase in results. Similarly, Sinclair [38], when also analyzing results of Olympic weightlifting, observed that the increase in results relative to body mass is much lower above 82.5 kg; from about 100 kg it becomes insignificant or non-existent. It seems that weightlifters from the highest weight category are commonly characterized by both an increase in beneficial factors, such as muscle mass, and an increase in negative factors, as the athlete must move their own greater body mass together with the mass of the weight. As a result, progression of results

decreases to zero, sometimes even turning into regression. Sinclair divides athletes in the 110+ kg category (per 1983 category definitions) into 2 groups: the first group comprising athletes who train and eat like athletes from lower-weight categories, and the second group comprising those who show a psychological addiction to ample meals. Athletes in the second group often state that they do not feel strong enough until their body mass exceeds 140 kg. Sinclair's term *psychological addiction* refers to topics at a conference on mental training benefiting performance in sports. In a publication entitled "Exceeding body capabilities with the mind," K. P. Henschen [44, p. 10] describes a situation in which an athlete has already achieved the required level of motor preparation: "Among factors that contribute to high performance in sports, the influence of psychological aspects increases to 50-90% (...) Therefore, it becomes clear that sports training cannot be limited to physical aspects."

The negative influence of a large amount of fat tissue can be seen not only in weightlifting, but in other disciplines as well. In his study with boxers, Skład [45] found that a bulky build was not always accompanied by strong musculature and skeleton; instead, it is tied to excessive adiposity that constituted unnecessary ballast. This was especially noticeable in the highest weight category, where the fat tissue of some boxers weighed even as much as 25 kg. The examples above explain the need to conduct detailed somatic assessments of athletes characterized mainly by high body mass. Milicerowa [46, p. 13] proposes analyzing body build according to the following aspects:

- "internal ratios between tissue components of the body, regardless of the athlete's size;
- body size from a three-dimensional perspective;
- and external proportions, that is, ratios between the length of individual segments of limbs, ratios of the length of limbs to the length of the torso, ratios between muscle mass in different body parts, etc."

Milicerowa states that every aspect has a different role in sport activities and becomes prioritized depending on the type of the activity. Proper development of body components constitutes an aspect that is the most independent of the type of sport activity. A publication on regulating body mass [47] stresses the importance of keeping this factor within optimal range, which often determines performance, especially in disciplines that involve weight categories. In rare cases, consciously increasing one's body mass in sports is aimed only at increasing musculature, as gaining body mass due to an

increase of fat tissue leads to a decrease in physical fitness. Macedonio and Dunfort [48] present a similar opinion in a work on regulating body mass, a work they refer to as an athlete's guidebook, with the subtitle "Optimal weight for an optimal feat," written in close cooperation with professional sports groups. The authors "addressed a vital problem of adjusting an athlete's body mass and body composition to the needs of a given sports discipline." The above quote comes from an excellent review of the work, expressing all primary theses of the authors and published in the journal *Sport Wyczynowy* under the title "How to shape body mass and body composition using diet" [49, p. 108]. One of the key opinions of the authors quoted in the review states that low muscle mass can result in insufficient strength, while excessive fat tissue reduces speed and agility.

In anthropology, 2 terms are used to describe body mass without the component of fat: fat free mass (FFM) and lean body mass (LBM). The latter method is more popular for assessing sports groups. According to Skibińska [50], LMB constitutes body weight without the weight of subcutaneous fat and portions of visceral fat. LMB depends on build type, that is, body height, as well as on massiveness, that is, musculature and skeleton. Skibińska states that determining LBM can play a role in throwing disciplines, especially in shot put. She claims that shot put is one of few disciplines in which the relationship between performance and LBM is relatively linear. The authors of *Fizjologia Sportu* have a similar opinion [51, p. 215]. They suggest that there is much evidence pointing to a positive relationship between FFM and performance in power-based disciplines, such as weightlifting or throwing. Their statement on reducing the amount of body fat is especially pertinent to this study: "another considered factor is the fact that exercises lead to an increase of FFM and reduced body fat. Furthermore, because the density of muscles is greater than that of fat, an increase in muscle mass may even result in an increase in body mass." Piechaczek [52] claims that intense sports training, in addition to causing changes in the athlete's body proportions, affects the internal structure of tissues, thus significantly increasing body density and LBM. The same author quotes Welham and Behnke [52, p. 21], "who noticed that American professional football players, who had 25% greater body mass than the control group, also showed much greater body density. This allowed for the conclusion that the percentage of total fat in the football players was relatively lower than expected based on their body mass." It is important that changes in body

mass do not necessarily lead to changes in the amount of body fat. Milicerowa [46], when discussing somatic build as a criterion in sports selection, states, "Proper development of body components plays the most discipline-independent role." She also points out a certain physiological phenomenon, whereby the ratio of body fat to LMB is greater in persons with high body mass. Milicerowa suggests that the relationship between body mass and body fat shows fairly high variation. As a result, some athletes with high body mass also have a relatively low percentage of fat tissue. A similar relationship also occurs in athletes undergoing intense training, such as throwers, and athletes from top weight categories in combat sports and weightlifting. As a result, the indicator of relative strength decreases with the increase in body mass. This phenomenon can be seen in weightlifting records, the sports values of which decrease in the top weight categories. Fat tissue is sometimes referred to as *dead weight*, meaning part of body mass that is unnecessary in motor actions and shows a highly negative correlation with motor abilities.

The negative influence of high body mass on sports performance allows researchers to assume that there exists an upper limit of human LBM. Forbes [43, quoting Batterham and Georg], estimates it at 100 kg in men and 60 kg in women, while the increase of body mass above these values, within 110–120 kg in men and 70–80 kg in women, takes place primarily through an increase in fat tissue, assuming the athletes do not use anabolic or androgenic steroids or any similar substances. Using these substances can change the upper limit of human LBM. The relatively lower performance of powerfully built athletes from top weight categories is consistent with Ważny's thesis [20] that the fitness of a "large" human is proportionally lower than the fitness of a "small" one. This depends to a great extent on the ratio of active tissue, as determined by LBM, to passive tissue, i.e., adiposity.

The correlation coefficients amounting to 0 (Table 1a), which indicate a lack of correlation between performance and body height and body mass in the world's top shot-putters using the classic method, can be difficult to accept. However, this is not a result of a simultaneous, independent lack of influence on the part of these morphological parameters. Instead, this was caused by the analyzed interaction of the 2 parameters, whereby they influence sports performance in a mutually exclusive manner. Such an interaction is indicated by a lack of correlation between body height and body mass, which means that this group of athletes had an exceptionally disproportionate body build. The group includes shot-

**Table 6.** Arithmetic means of results, somatic traits and “somatic potential” in three groups of throwers

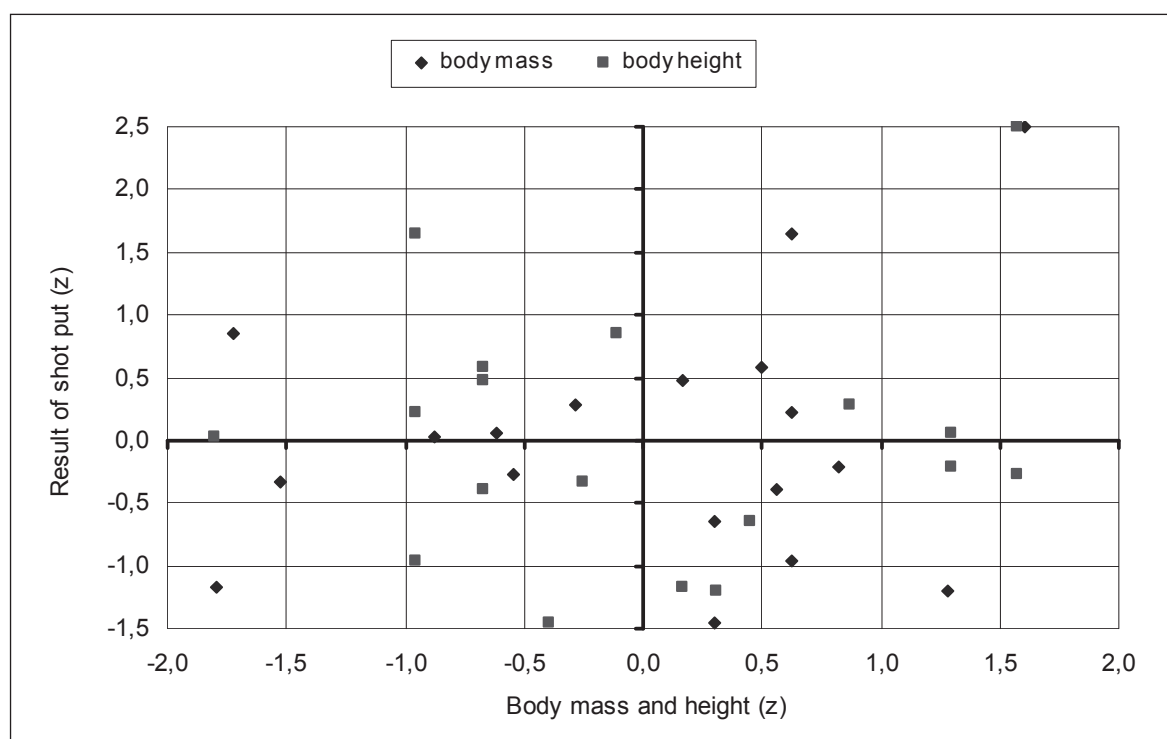
N	Group	Result (m)	Body height (cm)	Body mass (kg)	Product
		1	2	3	(2 x 3)
18	Glide technique	20,24	192,8	115,4	22269
18	Spin technique – matched by body height	20,27	192,7	116,3	22483
18	Spin technique – matched by body mass	20,25	188,6	115,7	21852
61	Decathletes	14,30	187,2	85,6	16024

putters with relatively low body height and high body mass, as well as athletes with opposite proportions, tall and non-overweight. Thus, a disadvantageous value of one of the traits cancels out a beneficial value of the other one. “The combined effect of body height and body mass” on improving sports performance has been replaced with the traits canceling each other out, resulting in no correlation between somatic traits and results.

To allow for a more comprehensive representation of the influence of the somatic factor on performance in shot put, Table 6 shows a value defined as the “so-

matic potential,” calculated by multiplying body height and body mass of the 3 groups of shot-putters and decathletes. The difference of about 6000 points between arithmetic means in shot-putters and decathletes indicates that the former have a considerable advantage in body build parameters.

This is also shown by the juxtaposition of standardized values of body height and body mass against standardized results of shot-putters using the classic technique (Figure 4) and shot-putters using the spin technique, selected based on body height (Figure 5). This

**Figure 4.** Juxtaposition of standardized values of body height and mass to standardized results of shot put in group of throwers using the glide technique

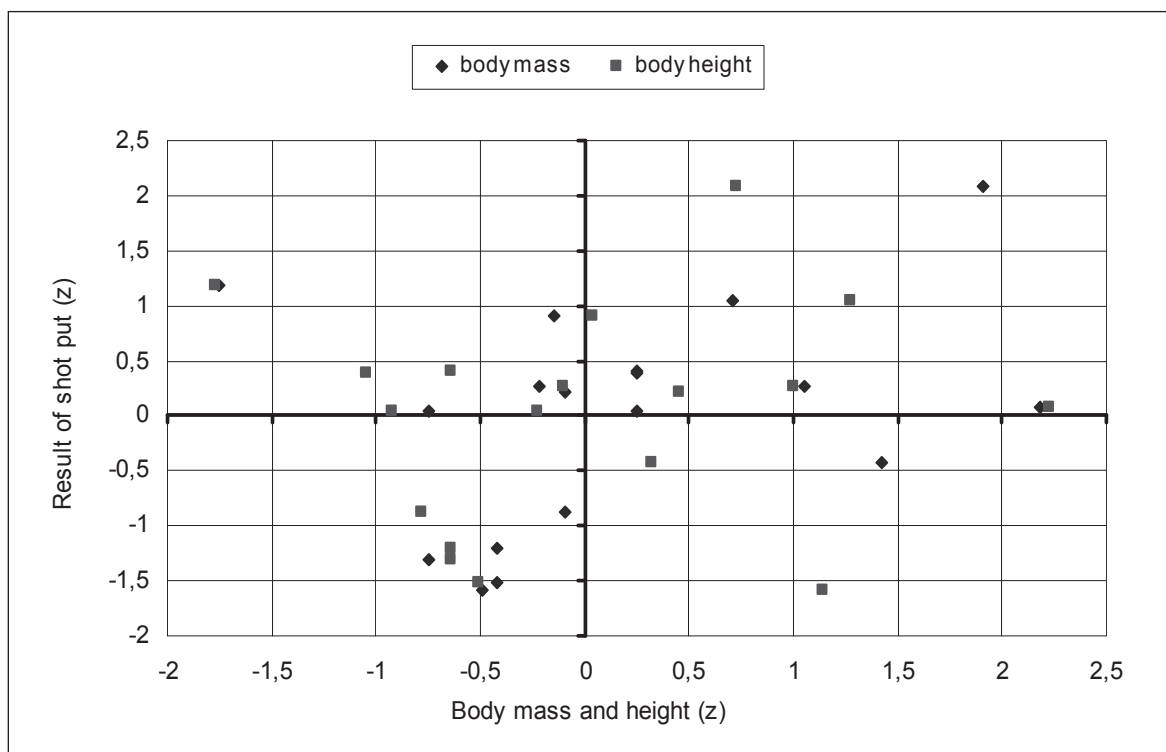


Figure 5. Juxtaposition of standardized values of body height and mass to standardized results of shot put in group of throwers using the spin technique, matched by body height to the group using the glide technique

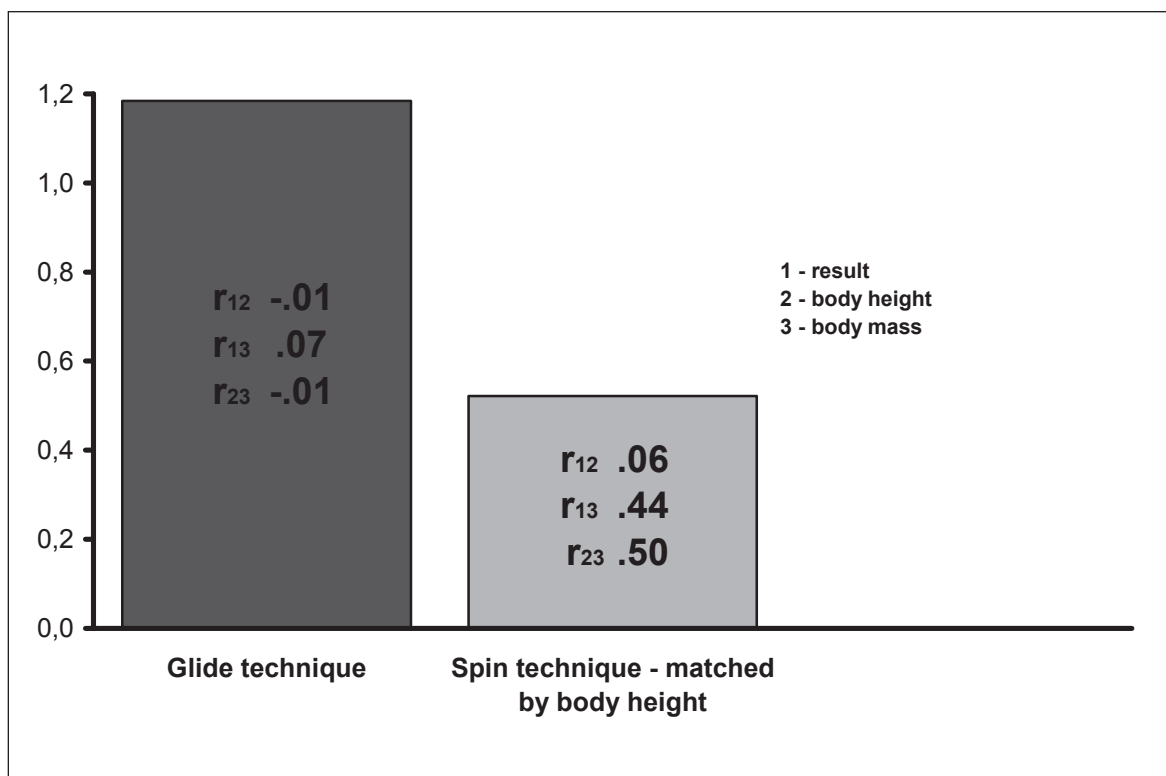


Figure 6. Arithmetic means of the distance between standardized values of body height and mass to standardized results of shot put in group of throwers using the glide technique and group of shot putters using the spin technique, matched by body height

comparison highlights the mutual correlations between the 3 variables, with the original group of 18 athletes displaying no such correlations. The considerable distances between coordinates of both traits pertaining to a given result and the spread of these coordinates indicate a lack of correlation (long distances – no correlation; short distances – significant correlation). Figure 6 shows differences between athletes using the classic technique and the spin technique expressed through arithmetic means of standardized distances between coordinates of both somatic traits, complemented by values of correlation coefficient. The Figure shows that distances between coordinates of body height and body mass converge with the values of correlations involving these traits.

In order to investigate the effect of strength on shot put results, we calculated the regressive indicator of relative strength based on our experience from our previous studies [14, 53] as well as on positive reviews of other authors [15, 19]. The body-mass-independent parameter that constitutes the difference between the actual measurement  $Y$  and predicted  $Y'$ , as suggested by Sulisz [54], was used to calculate relative strength in the form of the quotient  $\frac{Y}{Y'}$  [15, p. 318]. The original version of the indicator was also calculated based on the differences in order to enable a comparison [54]. Table 7 shows ranking positions of shot-putters according to the applied version of the indicator of relative strength. Both versions resulted in almost identi-

cal values of the athletes' relative strength in terms of their preparation for competitions. Three athletes who advanced their positions in the ranked hierarchy (numbers 6, 8, and 14 with body mass of 80 kg, 105 kg, and 89 kg, respectively) show relatively low body mass and average body height (data on somatic parameters can be found in the Appendix). The 3 athletes owe their position to their high level of training. The other 5 athletes achieved their positions in the top 8 thanks both to their level of motor preparation and physical conditioning (the arithmetic mean was 137.6 kg for their body mass and 193.2 cm for body height).

When discussing muscle strength, studies on physical fitness often use formulas and symbols derived from physics. Ważny [20] claims that the term *strength* in human motorics is a much broader concept than *force* in physics. Thus, when referring to the biological and psychological basis of *strength*, symbols taken from other sciences should not be used. Laws of physics can be used in the case of heavyweight shot-putters to explain the positive correlation ( $r = 0.40$ ) between their body mass and results, although the correlation is inconsistent with Forbes' claim [43, quoting Batterham and Georg] on proportions between fat tissue and musculature (maximum LBM of 100 kg). Borelli, the 17th-century author of *De Motu Animalium (On the Locomotion of Animals)*, a work addressing biomechanics, was the first researcher to indicate that all basic methods of locomotion can be demonstrated by a human row-

**Table 7.** The ranking of the top shot putters, dependent on the regression index of relative strength

Rank	Result	Shot putter No.	Y	Y'	$\frac{Y}{Y'}$	Shot putter No.	Y'	Y – Y'
1	22.16	1	22.16	20.72	106.9	1	20.72	143.6
2	21.95	6	21.13	19.77	106.9	3	20.52	137.3
3	21.89	3	21.89	20.52	106.7	6	19.77	135.6
4	21.78	2	21.95	20.64	106.4	2	20.64	131.2
5	21.37	14	20.82	19.76	105.4	14	19.76	106.3
6	21.13	8	21.09	20.03	105.3	8	20.03	105.7
7	21.11	4	21.78	20.72	105.1	4	20.72	105.6
8	21.09	5	21.37	20.38	104.9	5	20.38	99.1

Y – real result

Y' – expected result

ing a boat on a lake [55]. One of the methods involves rapidly pushing such items as oars or grapples in the direction opposite to the boat's direction of movement. Similarly, we provide an example of the effect of Newton's third law of action-reaction: when a person jumps from a light boat, a great part of the energy is lost on displacing the boat, while only a small part is expended on moving the person's body; as a result, they land close to where they started jumping. Jumping from a bridge is a different matter. As with the case of throwers of heavy items such as a shot or a hammer, high body mass is beneficial, as in the boat-to-bridge relationship. The weight of the item used in throwing does not change and is defined by regulations.

When we consider the opposite influence of body mass on the results of heavyweight and lightweight shot-putters, the 20 kg difference probably could not have been the determining factor in performance. It can be assumed that significant changes in the sign and value of the correlation might have occurred for such ratios of body mass as would occur between, for instance, Tom Thumb and Tomasz Majewski, or in the opposite direction and on a different scale, between Tomasz Majewski and the Biblical Goliath, who stood about 3 m tall.

Attempting to estimate the effect of the third law of dynamics on the performance of shot-putters would be extremely difficult for biological and psychological reasons. For the above reasons, one could speculate that a portable mechanical device could be built, the weight of which could be increased or decreased within a broad range, and which would propel a shot at an optimal angle and adjustable speed (for instance, a speed of 14 m/s would theoretically correspond to a result of 22-23 m); this would allow one to establish the correlation between weight (mass) of the device and the propelling distance.

## Summary

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In terms of biomechanics, authors of publications on the subject consider the spin technique to be more effective than the glide technique, but requiring highly developed coordination abilities.

In terms of body build, no significant differences were found between athletes who used either of the techniques compared to the original groups. However, when athletes were more precisely selected to adjust the body mass of shot-putters using the spin technique to those using the classic technique, the analy-

sis showed that the former are 4.2 cm smaller while achieving the same result. The complete lack of correlation between performance and somatic traits in shot-putters using the glide technique, and especially the lack of correlation between body height and body mass, indicated that the athletes had a disproportionate build and allowed us to postulate for a reduction of requirements related to these traits during recruitment and selection.

Despite many indications pointing to the efficiency of the spin technique, 4 athletes using the classic technique have won medals in the last 2 Olympic Games. Thus, we should draw the conclusion that the 2 techniques are equal in terms of athletic performance.

The issue of the positive correlation between body mass and results in heavyweight athletes proved much more difficult and remained unsolved. If we take into account Forbes' statement [43, quoting Batterham and Georg] on the maximum LMB limit of 100 kg in men, bearing in mind his caveat on the use of anabolic and androgenic steroids or similar substances, and if at the same time we accept Sinclair's statement [38] on the psychological addiction of weightlifters in the heaviest categories to further increasing their body mass, which enables them to perform well, then we may speculate by analogy to weightlifters that the positive effect of body mass on performance will also concern some shot-putters who do not use illegal substances.

We would also like to address the very sensitive topic of illegal doping. In the opinion of many of those interested in sport, doping is common. Should the slogan "everyone uses doping" be accepted? It is true that the state of being highly trained (as indicated by the indicator of relative strength) and the state of readiness of the body for great performance achieved through the use of doping, are the same. If we assume that Forbes' statement is indisputable, then in heavyweight shot-putters with body mass over 120 kg, the ratio of muscle mass to fat will be disadvantageous and should have a negative effect on performance. These disadvantageous proportions change in athletes that dope, resulting in good performance. We may be almost sure to find such athletes in the group of 36 heavyweight shot-putters. Disregarding Forbes' statement on maximum LBM will allow one to accept that some shot-putters perform without taking illegal substances. Unfortunately, the fact that some of the world's top shot-putters use doping is evidenced by post-Olympic disqualifications.

## Conclusions

Using only 1 independent variable, i.e., body mass, during assessment may provide only approximate information on an athlete's potential. Measurements using 2 variables, especially the amount of fat tissue, would allow for a more precise diagnosis of the state of an athlete's preparation for high performance. During statistical analysis of the results of the world's top-ranking athletes, such as the shot-putters studied in this paper, conclusions should be drawn cautiously. At this sports level, factors of different nature exist that affect the

results and that are difficult or almost impossible to define. An example of such a factor is the lack of correlation or a correlation opposite to current knowledge between results and somatic traits, which is the outcome of a certain phenomenon, but does not explain its reason.

In sum, it should be clearly underlined that somatomotor assessments cannot be construed to indicate the use of illegal doping. However, one cannot rule out the possibility that future assessments of this kind, integrated with chemical analysis of urine, blood, or saliva, will lead to increased efficiency of anti-doping screening.

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## ANNEX

**Juxtaposition of results and data somatic of best shot putters  
in the world in 2009**

On.	Name and surname	Result (m)		Body height (cm)	Body mass (kg)	Ponderal index
		S – spin technique	G – glide technique			
1	Christian Cantwell	22,16	S	196	145	37,3
2	Majewski Tomasz	21,95	G	204	140	39,3
3	Reese Hoffa	21,89	S	182	133	35,7
4	Daniel Taylor	21,78	S	198	145	37,7
5	Ralf Bartels	21,37	G	186	125	37,2
6	Sultan Abdulmajeed Alhabashi	21,13	S	180	90	40,2
7	Adam Nelson	21,11	S	183	115	37,6
8	Dorian Scott	21,09	S	193	105	40,9
9	Andrei Mikhnevich	21,02	S	202	127	40,2
10	Ryan Whiting	20,99	S	190	116	39,0
11	Pavel Lyzhyn	20,98	S	189	110	39,4
12	Dylan Armstrong	20,92	S	193	114	39,8
13	Maksim Sidorov	20,92	S	195	115	40,1
14	Pavel Sofin	20,82	G	192	89	43,0
15	Maris Urtans	20,64	G	188	123	37,8
16	Sheldon Battle	20,56	S	188	120	38,1
17	Anton Luboslavskiy	20,56	G	188	118	38,3
18	Noah Bryant	20,55	S	185	120	37,5
19	Marco Fortes	20,52	S	189	120	38,3
20	Peter Sack	20,46	S	192	113	39,7
21	Luka Rujevic	20,46	S	200	132	39,3
22	Scott Martin	20,45	S	190	115	39,1
23	Cory Martin	20,43	S	196	115	40,3
24	David Storl	20,43	G	199	111	41,4
25	Asmir Kolašinac	20,41	S	195	103	41,6
26	Justin Anlezark	20,39	S	187	125	37,4
27	Manuel Martínez	20,39	G	186	125	37,2
28	Carl Myerscough	20,33	S	209	149	39,4
29	Nedžad Mulabegovic	20,31	S	189	100	40,7
30	Russell Winger	20,30	S	191	120	38,7
31	Hamza Alic	20,30	S	186	105	39,4
32	Marco Schmidt	20,28	G	202	106	42,7
33	Taavi Peetre	20,26	G	180	102	38,5
34	Rhuben Williams	20,25	S	178	102	38,1
35	Milan Jotanovic	20,14	S	184	115	37,8
36	Antonin Žalský	20,11	S	200	105	42,4
37	Zach Lloyd	20,09	S	191	141	36,7
38	Andriy Borodkin	20,09	G	202	128	40,1
39	Andriy Semenov	20,05	G	204	107	43,0
40	Borja Vivas	20,01	G	191	92	42,3
41	Yury Bialou	20,00	S	183	115	37,6
42	Yasser Ibrahim Farag	19,97	S	185	127	36,8
43	Yves Niaré	19,97	S	195	95	42,7
44	Jakub Giza	19,97	G	188	124	37,7
45	Krzysztof Krzywosz	19,83	S	181	83	41,5
46	Andy Dittmar	19,79	G	196	120	39,7
47	Milan Haborák	19,78	S	191	109	40,0
48	Steve Manz	19,76	S	183	120	37,1
49	Kemal Mesic	19,68	S	197	110	41,1
50	Kim Christensen	19,65	S	187	115	38,5
51	Jun Zhang	19,58	G	186	125	37,2
52	Jordan Clarke	19,49	S	193	125	38,6
53	Ross Jordaán	19,46	S	192	105	40,7
54	Ming Huang Chang	19,45	S	193	110	40,3
55	Remigius Machura	19,43	G	194	88	43,6
56	Georgi Ivanov	19,41	S	188	110	39,2
57	Gaëtan Bucki	19,41	G	195	135	38,0
58	Jason Cook	19,39	S	188	120	38,1
59	Mihaíl Stamatóyiannis	19,34	S	188	105	39,8
60	Mark Edwards	19,33	S	180	115	37,0
61	Aaron Studt	19,27	S	192	114	39,6
62	Marco Di Maggio	19,25	S	198	114	40,8
63	Daniel Vanek	19,24	S	188	110	39,2
64	Dominik Zielinski	19,24	G	190	120	38,5
65	Germán Lauro	19,20	S	184	107	38,8
66	Paolo Dal Soglio	19,18	S	189	110	39,4
67	Kevin Bookout	19,14	S	201	109	42,1