Differencies in Morphologic Characteristics Between Top Level Gymnasts of Year 1933 and 2000

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A B S T R A C T

In 1933, at the 5th Regional Sokol Meeting in Ljubljana which was at the time a place in the Yugoslav Kingdom, Škerlj carried out the first measurements of 189 gymnasts, active competitors; in 2000, at the World Cup Meeting in Ljubljana, Čuk and associates carried out measurements of 40 top gymnasts. Our analysis of identical variables has shown that there is no difference in body height and weight of the gymnasts in 1933 and those in 2000, while there is a significant difference in the width of their shoulders and pelvis, the contemporary athletes being wider in their shoulders and narrower in their pelvis. The differences can be assigned to the new requirements in contemporary gymnastics as exercises are becoming more difficult, including more rotation around the vertical and horizontal axis.

Key words: *anthropometrics, male artistic gymnastics, Sokol, changes, training*

Introduction

Gymnastics is one of the oldest organised sports in the world, with the International Gymnastic Federation (FIG) being founded already in 1881[1]. Soon after the Federation came to existence, the first competitions had been organised. The first World Championships were thus held in Antwerpen, Netherlands, in 1903. As years passed, the competition programs changed, however, in the mid 30s of the previous century, the male gymnastics program was already quite similar to what we have today. Gymnasts competed in Free Program (what we call 'floor' today), Pommel Horse, Rings, Vault, Parallel Bars and High Bar, both in the compulsory and optional program, and occasionally also in field and track and swimming[2]. These days, a program in artistic gymnastics consists only of free program on various apparatus[3].

In the 30s of the 20th century, gymnastics was by far the most developed sport both by the number of competitors and by the level of quality; for this reason, it was the first sport researchers, called »anthropologists« at the time, became interested in. The first major research was carried out at the Olympic Games in Amsterdam, Netherlands, in 1928, where Bach (according to Škerlj[4]) came to the conclusion that shorter persons probably stand a better chance of succeeding in gymnastics while taller persons are more likely to succeed in track and field.

Between the two world wars, the Slovenian and Yugoslav gymnasts were at the forefront of the world gymnastics. The results achieved by Peter Šumi, two time back-to-back world champion; Leon Štukelj, Olympic all around champion; Jože Primožič, world champion; the national team which came third at the OG 1928, second at the WC 1922 and 1926, and third at the WC 1930 and 1938, show that gymnasts of this generation were indeed world class[5]. In 1933, Škerlj[4] carried out the first anthropological research at the 5th Regional Sokol Meeting in Ljubljana and next year published his results.

After World War II, gymnastics turned towards an increased complexity of movement on each apparatus[6], which on one side led to new developments in each apparatus – they became more pre-tensed and thus more elastic[7–9], and to new developments in the theory of training[10–12], introducing research results and methods into training.

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Comparing the content of exercises by apparatus, it becomes clear that the greatest changes occurred due to the changed surface (from grass or sand to the elastic floor podium) in the floor exercise and to the vaulting apparatus (elastic vault board, elastic vaulting table). The least changes occurred in the rings exercises where all types of elements of strength remain the key elements and in exercises on parallel bars and pommel horse where support position and dynamic changes in support positions are still the essence of such exercises. On high bar, exercises have changed from a combination of swinging and static exercises to swinging exercises only[13].

In terms of training, the main changes can be seen in the more systematic approach to selecting gymnasts. In the Sokol times, competitors were selected exclusively on the basis of their competition results whereas these days children are admitted to training gymnastics on the basis of their physical characteristics and mobility abilities at the age of six years[14]. There is also a difference in the intensity of training: experts believe (nobody publicly publishes such details) that the hours of training have trebled (from 2-hour training a day in the 30s to 6-hour training sessions per day these days).

The specificity of an athlete in a specific sports discipline is the result on one side of selection and on the other of the specific effect the activity in a particular sports discipline creates[15–16]. This training effect, however, does have its limitations: research on twins have shown that training can affect only weight, shoulder width, chest size and upper arm length. Exogenic factors, however, cannot affect body height[17].

But absolute data is not the only important factor. Just as important is also relative data, e.g. length of arms or legs in relation to body height. By Soviet report of Lebedev, Rozin[19] morphologic characteristics of their gymnasts – masters of sport are as follows:

Body height 166 cm

Body weight 63 kg

Chest circle 95 cm

Arm length 44.3% of body height

Leg length 54.4% of body height

Trunk length 29.7% of body height

Soviet writer Nabatnikova[20] compiled a hierarchical ranking of abilities and characteristics which are supposed to assist in forecasting the athlete's success in gymnastics. She divided all abilities into three levels of importance.

TABLE 1
ROZIN AND ČEBURAEV[18] RESULTS OF TOP GYMNASTS AT OG

	1964	1968	1972	1976	1980
Body height (cm)	X=167.7 SD=6.4	167.9 6.9	169.1 5.0	166.7 5.6	168.2 4.6
Body weight (kg)	X=63.6 SD=7.2	63.9 6.9	64.2 4.7	62.1 5.2	62.8 5.0
Age (years)	X=25.6 SD=2.9	24.2 3.4	24.6 2.8	23.3 4.0	23.2 3.1

The first level of the most important abilities and characteristics seems to include:

a) physical characteristics: total body proportions, body structure, posture, feet structure;
b) functional abilities: mobility, vestibular and visual analyser;
c) locomotive abilities: coordination, mobility, relative strength.

The second level of important abilities and characteristics includes:

a) physical characteristics: body proportions, body structure;
b) functional abilities: peripheral neuro-muscular system, audio analyser, endocrine system, cardio-vascular system, respiratory system, metabolism;
c) locomotive abilities: specific endurance, explosive strength, speed, speed force.

The third level of important abilities and characteristics includes:

a) physical characteristics: specific body weight;
b) functional abilities: temperature regulation;
c) locomotive abilities: absolute strength and endurance.

In their work Čuk and Novak[14] ascertained which dimensions have the most important effect on the sports results of young gymnasts. A successful gymnast from the anthropometric perspective is one who is:

a) short: the ratio between the length of trunk and the length of legs should be such that muscles can quickly move these levers,
b) light,
c) has a strong chest with a relatively high and good quality muscular mass;
d) has very little subcutaneous fat.

At the World Championships in Gymnastics in Rotterdam in 1987, Claessens and associates[21] carried out measurements of anthropometric characteristics in top gymnasts. They published data (Table 2, Table 3) of the key characteristics measured at major competitions.

In 1997, gymnastics saw a major change in its rules: FIG[23] abolished compulsory exercises on apparatus which reduced the need for a large number of hours in training, while in 1997, FIG also introduced World Cup on individual apparatus which enabled gymnasts to further adjust their training to their personal needs and abilities in order to be successful on individual apparatus.

In 2000, a World Cup in Male Gymnastics was organised in Ljubljana. The meeting was attended by 40 competitors, two of them Olympic Champions, Deffer of Spain and Csollany of Hungary, and many medal winners from European and World Championships. This event presented an opportunity for Čuk[22] and associates to measure physical characteristics of top male gymnasts.

TABLE 2
ANTHROPOMETRIC CHARACTERISTICS OF TOP GYMNASTS DURING MAJOR COMPETITIONS[21]

Competition	N	Age (year) (X)	Height (cm) (X)	Weight (kg) (X)	Source
OG 1928 Amsterdam	19*	25.0	166.6	64.1	Dybowska and Dybowski (1929)
OG 1948 London	15'	24.5	172.7	74.5	Cureton (1951)
OG 1964 Tokyo	122	26.0	167.2	63.3	Hirata (1966.1979b)
OG 1968 Mexico City	28	23.6	167.4	65.5	De Gray at all (1974)
OG 1972 Munich	126	24.7	168.0	64.1	Hirata (1979a.b)
OG 1976 Montreal	101	23.4	168.5	62.0	Hirata (1979a.b)
WC 1983 Budapest	169	22.0	167.8	62.4	Gajdos (1984)
WC 1987 Rotterdam	165	21.9	167.0	63.6	Claessens at all (1991)

OG – Olympic Games, WC – World Championships, * – Polish gymnasts only, ' – Danish gymnasts only

TABLE 3
ANTHROPOMETRIC CHARACTERISTICS OF TOP GYMNASTS AT WORLD CHAMPIONSHIPS IN ROTTERDAM IN 1989[21] (N=165)

Measurement	X	SD	Max	Min
Body heigth (cm)	167.0	6.3	183.8	153.2
Body weight (kg)	63.6	6.2	80.5	50.0
Shoulder width (cm)	38.5	1.6	43.7	34.0
Pelvis width (cm)	26.3	1.4	29.9	22.7
Knee diameter (cm)	9.2	0.4	11.0	8.2
Circumference of thigh (cm)	51.1	2.7	58.0	36.9
Circumference of forearm (cm)	27.5	1.2	30.1	24.0
Circumference of flexed upper arm(cm)	34.6	1.7	39.2	29.9
Circumference of relaxed upper arm (cm)	31.2	1.7	36.5	26.3
Circumference of calf (cm)	34.7	1.7	40.0	31.0
Skinfold thickness of calf (mm)	4.7	1.2	10.2	2.8
Skinfold thickness of biceps (mm)	3.3	0.5	5.0	2.4
Skinfold thickness of triceps (mm)	5.4	1.1	10.2	3.7
Skinfold thickness of back (mm)	7.4	1.2	10.6	5.0
Skinfold thickness of stomack (mm)	4.0	0.6	6.1	2.8
Rohrer index	1.365			
Endomorphic	1.5	0.3	2.5	1.0
Mesomorphic	5.6	0.7	7.7	3.8
Ectomorphic	2.1	0.6	3.8	0.5

TABLE 4
THE BEST TEAMS MORPHOLOGIC CHARACTERISTICS
AT WORLD CHAMPIONSHIP IN DORTMUND 1994[22]

	Body height X (cm)	Body weight X (kg)
Russia	165	65
China	164	56
Belarus	166	60
Ukraine	166	61
Japan	164	59
Germany	164	59

As we found research studies written by Božo Škrlj[4] on Sokol gymnasts, it became clear we could research the changes in physical characteristics of top gymnasts in the period of almost seventy years, from 1933 to 2000, as the main outcome of our work.

Materials and Methods

We used anthropometric measurements on gymnasts from two different periods carried out by two different authors, Škerlj[4], and Čuk[22] and associates.

As the results of measurements by Škerlj[4] are already over 70 years old and we could not find the original individual measurements for each gymnast, we present here the latter only included in the overall statistical processing.

The sample of measured gymnasts thus consisted of two sub samples:

1. Sample 1 is the result of anthropometric measurements taken by Škerlj[4] in 1933 at the meeting of Yugoslav Sokol. Most of the measured gymnasts were of Slovenian background and had posted results which placed them among world top gymnasts of the time. Škerlj[4] included in his anthropometric research 189 male gymnasts aged between 18 to 33 years (on average 22 years).
2. Sample 2 is used to compare the Sokol gymnast with contemporary top gymnasts. These anthropometric measurements were taken at the Faculty of Sports, Ljubljana University, by a team led by Čuk[22]. They were carried out on the gymnasts who participated at World Cup in Gymnastics in Ljubljana in 2000. The research included 40 top world male competitors, aged between 17 and 30 years (on average 23 years).

Variables and measurement methods on Sokols by Škerlj[4] in 1933

1. BODY WEIGHT: the measured gymnasts wore underwear; the resulting error in measurements is insignificant and has not been taken into account.
2. BODY HEIGHT: taken by anthrop meter.
3. WHOLE ARM LENGTH: taken by anthrop meter, with the measured gymnast extending both arms from the body.
4. LEG LENGTH: arrived at from two measurements taken by anthrop meter, namely, the hight of *iliospinale* from the ground and the height of *symphysion* from the ground. These two measurements were added and then divided by two, thus determining the leg height from the femur head to the ground.
5. SHOULDER AND PELVIS WIDTH: taken by anthrop meter. The pelvis width was measured from the outer edge of ilium (*iliocristale-iliocristale*), while the shoulder width was measured between the two outmost points of acromion (*acromion-acromion*).

Additionally, we also calculated:

ROHRER INDEX*: RI = (weight/height^3)* x 100,000
(only as mean index calculated on the basis of mean height and weight)

Variables and measurement methods on gymnast by Čuk[22] and associates in 2000.

Following the IBP method, the following anthropometric variables were measured and calculated:

1. BODY WEIGHT
2. BODY HEIGHT
3. CIRCUMFERENCE: of forearm, upper arm (flexed, relaxed), thigh, calf and chest.
4. DIAMETER: of elbow, wrist, knee, shoulders (*acromion-acromion*) and pelvis (*iliocrystale-iliocrystale*).
5. SKINFOLD THICKNESS: biceps, triceps, back (*subscapular*), stomach (*supraspinal*) in and calf (medial).
6. ROHRER INDEX*: RI=(weight/height^3)* x 100,000 (only as mean index calculated on the basis of mean height and weight)
7. SOMATOTYPE according to Heath and Carter[24]

We calculated the measure of central tendency and dispersion, then F-test of sample homogeneity, and finally t-test of differences between common variables in relation to F-test for homogenous and non-homogenous samples.

Results and Discussion

Here are first presented the results of Škerlj's measurements[4], followed by Čuk and associates measurements[22] and finally there is a comparison between the two groups of gymnasts.

From Škerlj's results[4] (Table 5) it is clear that his measured subjects were past their growth age. The Sokol club requirement for its members was at least 18 years of age as they did not wish to burden immature bodies with demanding methods of training for competitions. Today, the minimum required age for competing at official international meetings is 16 year[3]. Body height was then lower 170 cm which still applies today as a condition to become a successful gymnast. Body weight of 65 kg also remains the body weight of most gymnasts today; considering Rohrer index, gymnasts used to have above average voluminous bodies, and this still applies today. Even though they did not take measurements of skin fold thickness in 1933, it can be assumed from pictures that gymnasts of the time did not have significant amounts of skin fat. The ratio between the pelvis and shoulders width was clearly biased towards shoulders which in other words meant athletic bodies. The percentage of leg length in relation to body height was 53.8% which is a bit lower than the percentage (54.4%) measured in Russian gymnasts[19]. We can assume that arm length of gymnasts in 1933 by using formula: (arms length–shoulders width)/2

TABLE 5
CHARACTERISTICS OF ANTHROPOMETRIC VARIABLES FOR THE SOKOL GYMNASTS IN 1933[4]

Variable	N	X	SD
Age (years)	186	21.86	
Body height (cm)	186	169.03	4.57
Body weight (kg)	186	65.64	5.91
Shoulders width (cm)	186	39.06	1.64
Pelvis width (cm)	186	26.60	1.38
Arm length (cm)	186	176.14	5.77
Leg height (cm)	186	91.00	3.16
Rohrer index	186	1.357	

= 68.5 cm which would mean 40.3% of the total body height. However, as we measure the arm length from a position of arms extended away from the body whereby the shoulder blades are lifted and the measuring points *acromion-acromion* get closer, the measurement of arms length shortens the shoulder width which means that the actual percentage of arm length in relation to the body height is certainly higher, or rather, about the same as in Russian gymnasts (44.3%)[19].

In order to get a better idea of gymnasts of that era take a look at the following picture. (Figure 1).

In 2000, gymnasts (Table 6) again are past their growth age. Their body height is 168 cm which has been about average in most measurements for the last forty years. Their body weight is 66 kg, the highest measured since the Olympic Games in London in 1948. Rohrer index shows that their bodies are highly voluminous, yet their skin fold thickness is extremely low which together with high circumferences means we are talking about notably muscular bodies. The ratio between shoulder and pelvis width is clearly biased towards shoulder width which again indicates athleticism of gymnasts today. We also measured and presented the parameters of somatotype (Figure 2). We can draw a comparison with gymnasts in 1989: the differences in parameters are small, however, there is consistently a difference in skin fold thickness which tends to be lower in gymnasts in 2000, and there is a considerable difference in the mesomorphic component.

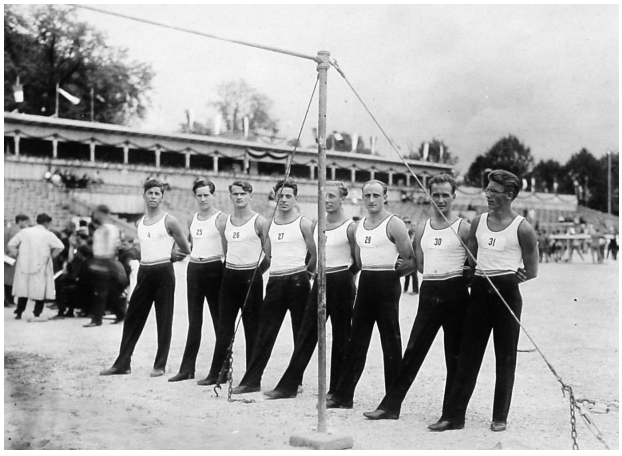

Fig 1. An example of Škerlj's measured gymnasts: Ljubljana Sokol team at the 5. Regional Sokol Meeting in Yugoslav Kingdom in Ljubljana, 1933 (Archive of R Slovenia, Ljubljanski Sokol Collection).

Unfortunately, Škerlj[4] did not provide measures of standard deviation for age to make it possible for us to

TABLE 6
CHARACTERISTICS OF ANTHROPOMETRIC VARIABLES FOR CONTEMPORARY GYMNASTS IN 2000[22]

Variable	N	X	SD	Max	Min
Age (years)	40	23.40		30	17
Body height (cm)	40	168.08	6.25	185.50	157.40
Body weight (kg)	40	66.45	8.15	84.80	51.90
Shoulder width (cm)	40	40.13	1.99	46.00	37.00
Pelvis width (cm)	40	25.46	1.49	29.40	22.20
Wrist diameter(cm)	40	6.04	0.36	6.90	4.80
Elbow diameter (cm)	40	6.79	0.41	7.70	6.10
Knee diameter (cm)	40	8.79	0.54	9.90	7.50
Circumference of thigh (cm)	40	54.07	2.84	60.6	48
Circumference of forearm (cm)	40	27.78	1.49	31.00	24.50
Circumference of flexed upper arm (cm)	40	35.84	2.63	42.00	27.00
Circumference of relaxed upper arm (cm)	40	33.15	2.12	38.00	29.00
Circumference of calf (cm)	40	35.5	1.87	39.6	29.8
Chest deep (cm)	40	96.35	4.67	106.30	88.60
Skinfold thickness of calf (mm)	40	5.01	1.31	7.60	3.00
Skinfold thickness of biceps (mm)	40	3.26	0.51	4.80	2.00
Skinfold thickness of triceps (mm)	40	4.63	1.03	8.20	3.00
Skinfold thickness of back (mm)	40	7.31	1.10	10.00	5.20
Skinfold thickness of stomach (mm)	40	4.66	1.15	8	3
Rohrer index	40	1.41			
Endomorphic	40	1.54	0.42	3.31	0.96
Mesomorphic	40	4.43	0.93	5.76	1.60
Ectomorphic	40	1.84	0.74	3.12	0.34

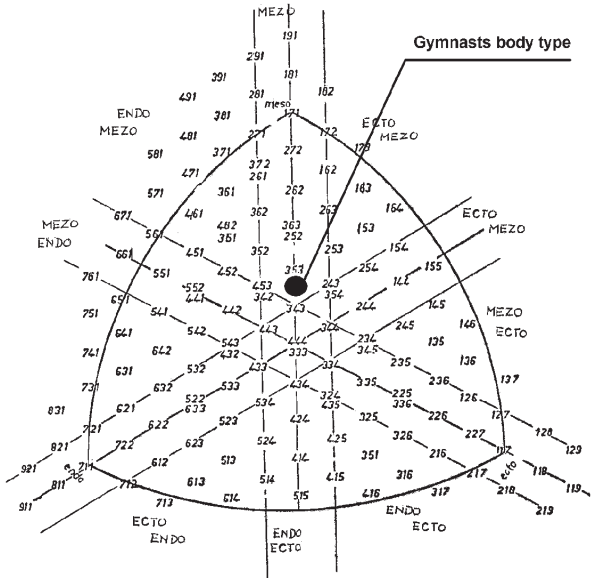

Fig. 2. Somatotype of gymnasts in 2000 (according to Heath and Carter).

calculate F-test and t-test to assess statistical differences (Table 7). Body weight, muscle circumference and skin fold thickness can change with age, however, as gymnast reach the top (applicable to gymnasts in 2000) they take a lot of care in their training to maintain constant body weight as this gives their central nerve system the optimal control over movement, be it in automated movement or in learning new moves. Considering that gymnasts both in 1933 and in 2000 were past their growth age, it is probably fine to move on to compare other variables.

In body height and weight, there are no significant differences between 1933 and 2000 samples which seem to indicate that the gymnast body is fairly constant in terms of these two main features. However, F-test shows that today there is more variance in body height, as specialisation on apparatus has led to divergence, e.g., taller gymnasts are more successful on high bar, shorter and lighter gymnasts on rings.

In terms of shoulder and pelvis width, there is a significant difference, namely, gymnasts in 2000 have wider shoulders and narrower pelvis than those in 1933. We could not calculate the statistics difference in Rohrer index as we took it from mean values for height and weight, but as height and weight are not separately significant different, we can conclude also Rohrer index is not different. Increased width of shoulders and narrowing of pelvis together with hypothetic increased voluminosity are mainly the result of exercises putting an increased pressure on arms in comparison with exercises of seventy years ago. The structure of movement is equal however exercises today require a considerably higher muscle force which is a result of a higher muscle mass. In comparison with the 30s, there has also been a change in rotations around vertical and horizontal axis, as contemporary gymnasts perform a higher number of saltos and twists which require a more optimal body structure reflected in an increased shoulder width and narrower pelvis.

Conclusions

An analysis of difference between anthropometric measures of gymnasts in 1933 and 2000 did not show any significant differences in body height and weight, it did, however, gave us differences in shoulder and pelvis width. The contemporary gymnasts have wider shoulders and narrower pelvis in comparison with the Sokol members. The difference has arisen partly due to changes in difficulty levels prescribed by Code of Points by FIG, expecting gymnasts to generate higher muscle force in all body parts and to perform elements including more rotation around vertical and horizontal axis which requires adjustments in body structure. With results those who do selection process of gifted children for gymnastics more attention should give to shoulder and pelvis width. During last century a huge positive secular trend has been notified in Europe (higher population), but gymnasts have same height, what can cause in near future some problems for this sport. Partly, changes might be due to other reasons beyond gymnastics but that is a matter of further research.

TABLE 7
CHARACTERISTICS OF ANTHROPOMETRIC VARIABLES FOR TWO GENERATIONS OF GYMNASTS OF THE SAME AGE[4,22]

Variable	N1	X1	SD1	N2	X2	SD2	D	t-test	p	t0.05	F	p	F0.05
Age (years)	186	21.86		40	23.4	3.87	–1.54						
Body height (cm)	186	169.03	4.57	40	168.08	6.25	0.95	0.910	NS	1.97	1.870	*	1.59
Body weight (kg)	186	65.64	5.91	40	66.45	7.37	–0.81	0.963	NS	1.97	1.247	NS	1.46
Shoulder width (cm)	186	39.06	1.64	40	40.13	1.99	–1.07	3.176	**	1.97	1.472	NS	1.46
Pelvis width (cm)	186	26.60	1.38	40	25.46	1.49	1.14	4.446	***	1.97	1.165	NS	1.59
Rohrer index	186	1.357		40	1.41		–0.053						
	Sokols (1933)			Gymnasts (2000)			Comparison						

N1, N2 – sample size, X1, XA2 – mean, SD1, SD2 – standard deviation, d – difference in arithmetic mean values, p – probability, ns – not significant, * – $p<0.05$, ** – $p<0.01$, *** – $p<0.001$, t-test – value of t-test, F – value of F-test, t0.05 – marginal value of t-test

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RAZLIKE U MORFOLOŠKIM KARAKTERISTIKAMA VRHUNSKIH GIMNASTIČARA IZ 1933 I 2000 GODINE

SAŽETAK

Škerlj je 1933 godine na V. Pokrajinskom sletu Kraljevine Jugoslavije u Ljubljani izmjerio morfološke karakteristike na uzorku od 189 vrhunskih gimnastičara, a na Svjetskom kupu 2000 godine u Ljubljani je Čuk sa suradnicima izmjerio 40 vrhunskih gimnastičara. Rezultati analize morfoloških karakteristika pokazali su, da razlike u tjelesnoj visini i težine nisu značajne, ali razlike u širini ramena i širini karlice su značajne. Moderni gimnastičari imaju šira ramena i užu karlicu. Uzrok za razlike se prvenstveno mogu pripisati višestrukom povećanju težine elemenata sa više okreta oko čeone i dužinske ose tijela.