COMPARISON OF MORPHOLOGICAL CHARACTERISTICS OF TOP LEVEL MALE GYMNASTS BETWEEN THE YEARS OF 2000 AND 2015

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Abstract

Over the years gymnastics is changing, difficulty of the routines is improving, the technology and the equipment are developing, Code of Points (COP) is getting new aspects. In 15 years, from the year of 2000 to 2015 COP changed a lot. Two measurements of morphological characteristics of top level male gymnasts were taken and compared, one from the year of 2000 and one from 2015, both from a World Cup Competition in Ljubljana. Our study showed some significant differences in abdomen circumferences and percentage of muscle mass of gymnasts in 15 years. Despite there were no significant differences, the tendency is the increase in body height, with less percentage of body fat and percentage of muscle mass (with the exception of gymnasts competing on floor). With lower percentage of body fat, lower percentage of muscle mass and almost unchanged body weight we can presume bone mass probably increased and with tendency of taller gymnasts also other inner organs, increased weight.

Keywords*: male artistic gymnastics, Code of Points, morphological characteristics, differences.*

INTRODUCTION

Gymnastics as a sport has quite a long history (the first World Championship was organized in 1903 in Antwerpen, Netherlands), and as years are passing, the competition program is changing. 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 ('floor' today), Pommel Horse, Rings, Vault, Parallel Bars and High Bar, both in the compulsory and optional program (Štukelj, 1989). These days, a program in Men's Artistic Gymnastics consists only of free program on various apparatus, which are the same as back then (FIG, 2016).

The competition program is similar, but rules in Men's Artistic Gymnastics changed a lot in the last 15 years. Some parts of the COP 1997-2000 and COP 2013-2016 are even hard to compare. The most visible change is the calculation of the Final Score. In the year of 2000 the maximal score was 10.00 points (that changed in the 2006 COP (FIG, 2006)). The Score was calculated from the "B"

Score – score of execution, which was maximum 5.00 points and the "A" Score, which consisted of difficulty value, special requirements on each apparatus and bonus points (for executing difficult elements and connections of them), also maximum 5.00 points. From the year of 2006 on, the final score is calculated from "D" Score for Difficulty and "E" Score for Execution. "E" Score, starts from 10.00 points and is evaluated by deductions (the exercise presentation related to compositional requirements, technique and body position) applied in tenths of a point. In general deductions are much more defined in 2015 than they were in 2000; the level of precise errors (for deviations from the expected perfect performance) remains mostly the same though. Small, medium, large errors and falls are deducted differently in the 15 years difference (the small deduction remains the same, the medium error changes from 0.2 to 0.3 point, the large error from 0.4 to 0.5 points, the deduction for a fall raised up from 0.5 to 1.00 point deduction (FIG, 1997; FIG, 2016)).

In the year of 2000 values of difficulty elements ranged from A to Super E. The difficulty value (on each apparatus except for vault) for elements was up to 2.40 points and was calculated from 4 A (4 x 0.1 point), 3 B (3 x 0.2 points), 2 C (2 x 0.4 points) and 1 D (1 x 0.6 points). There were 3 special requirements on each apparatus (0.4 points each). The gymnasts were awarded with bonus points for execution of difficulty elements and connections of elements with a D, E or Super E values (0.1 or 0.2 points for each connection, depends on the values of the elements). The level of difficulty increased in 15 years, especially in acrobatic elements. In2015 values reach up to H (for example Kovacs with 2/1 twists on high bar, which did not yet exist in 2000 COP) and will include a difficulty value of 10 elements (8 for juniors), the best 9 (7 for juniors), but maximum 4 elements for the same Element Group inside the best counting, plus the value of the dismount. Values of elements are different (from A to H the value is increasing per 0.1 point, which is 0.1 point for A value and 0.8 point for H value). In their routines gymnasts have to include elements from five different groups and for including each element group there is a 0.5 points bonus. For short exercises, where there is not 10 elements shown, the D-Panel jury takes an appropriate neutral deduction (FIG, 2016).

Regarding dismount elements, there was a deduction in 2000 for a dismount difficulty not being corresponding to the difficulty of the exercise. The deduction was 0.1 point for B value dismount, 0.2 points for A value dismount and 0.4 points for no dismount (FIG; 1997). In 2015 the dismount element is part of the Group element requirement. The gymnast achieves a full requirement value of 0.5 points for D or higher value of a dismount, for C value dismount he receives 0.3 points as achieving partial requirement value. For lower difficulty values than C values, the gymnast does not fulfil the requirement (FIG, 2016).

As stated in Čuk et. al (2007) gymnastics saw a major change in its rules in 1997. FIG (1997) abolished compulsory exercises on apparatus. This reduced the need for a large number of hours in training. The same year 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. Top level gymnasts start with their gymnastics career as very young, usually at preschool age. Today experts believe that the hours of training are about 5-6 hour training sessions. Gymnasts train 1500 hours per year in 300-310 days (Arkaev & Suchilin, 2003), 26-28 hours per week (Georgopoulos et. al, 2011).

The consequences of COP changes for competitors and their preparation can be summarised as follows:

The deduction for fall has increased, compared to previous COP; therefore competitors do not need to risk including an insufficiently mastered element into routine, which was possible in previous code of rules. This leads to a bigger drill based on a higher number of repetitions of learned movement structures. However, it has to be noted that this measure leads to higher exercise safety. Contrary to the rules valid until 2000 when a gymnast had to perform three special requirements in individual disciplines (except for vault), the newer version of the routine must include elements from five groups. Competitors are therefore forced to perform a wider range of different movement structures within the routine, which means that they must be technically and functionally better prepared for individual disciplines.

The change in rules forces competitors to improve technique as well as condition preparation in order to perform the dismount with a full value bonification, C value element for juniors and D value element for seniors.

The above mentioned facts imply that a perfectly acquired technique of complex temporo-spatial structures is an essential factor of gymnastic sport performance. As stated in Prassas et al. (2006), a prerequisite of correctly mastered gymnastic abilities are ability to gain height, ability to rotate, generating twist, transferring angular momentum from one body part to another, increasing or decreasing rotation by altering body configuration, ability to swing and ability to land. These partial abilities are based on understanding and use of various biomechanical principles and patterns which affect the given movement structures at individual equipment.

Kinematic data, while explicitly dependent on technique, is at the same time implicitly dependent on the strength, flexibility, and somatotype of the particular athlete (Kob et al., 2003). It was already at the Olympic Games 1928 in Amsterdam, Netherlands; Bach concluded that shorter persons probably stand a better chance of succeeding in gymnastics while taller persons are more likely to succeed in track and field (Škerlj, 1934). Čuk & Novak (1985) defined successful gymnast as the one who is short (the ratio between the length of trunk and the length of legs should be such that the muscles can quickly move these levers), light and has a strong chest with a relatively high and good quality muscular mass and has a very little subcutaneous fat. According to Arkaev & Suchilin (2003) typical of both men and women modern gymnasts, is ectomorph and ecto-mesomorph type of body composition, moderately wide shoulders, narrow hips, long arms, relatively long legs and short trunk. As stated in Čuk et al. (2007) from the year 1933 up to 2000 gymnast's body height and weight was not changed, but there were changes in shoulders and hips width, where gymnasts in the beginning of the new millennium had wider shoulder and narrower hips, this being a consequence of more complex movements with more rotations around longitudinal and sagittal axis.

Gymnasts that were competing in 2015 had been born in the first years of the 1990's and most likely started to compete around year 2000. At that time rules were different, and their trainings were adjusted to the rules that were in use then. In year 2006 when the open ended COP was introduced, they had to adopt their training within new COP. Therefore, they already had almost 9 years of adaptation time towards COP.

The main purpose of the study is to verify, if with the significant change of rules in the COP between the years, consequently structural change of routines, different deduction procedure and increasing number of specialists on different apparatus have any effect on changing male artistic gymnasts morphological characteristics, specifically body height and weight, the circumferences of chest, abdomen, upper arms and the percentage of body fat and percentage of muscle mass. We expect some difference in morphological characteristics might follow,

METHODS

We used anthropometric measurements on gymnasts from two different periods, from year 2000 and year 2015. All the measurements were in accordance with Declaration of Helsinki.

The first sample of measured gymnasts consisted of 40 top male competitors, aged between 17 and 30 years (on average 23 years) who participated at World Cup in Ljubljana in 2000 and voluntarily participated in measurements. The measurements took place in Tivoli Hall during trainings before the competition. Gymnasts and their coaches were verbally informed of the purpose of the research, for the measurements they were given the instructions according to Bravničar (1987). Used anthropometrical measurements had been defined by Bravničar (1987). The calculations for percentage of body fat mass, bone mass and muscle mass were made by the devised formula by Mateighka (1933 in Bravničar, 1987). Measurements were carried out by two independent qualified persons. The percentage of body fat mass and percentage of muscle mass were calculated.

Measurements were performed with standard anthropometrical instruments (anthropometer, classic scale, measuring tape and skinfold calliper). Following anthropometric variables were measured:

- body height,
- body weight,
- chest circumference,
- belt circumference,
- upper arm circumferences (left and right),
- thigh circumferences (left and right),
- calf circumferences (left and right)
- triceps skinfold
- biceps skinfold
- forearm skinfold
- thigh skinfold
- calf skinfold
- abdominal skinfold
- chest skinfold
- subscalpula skinfold
- elbow diameter
- wrist diameter
- knee diameter
- ankle diameter

Mateigka (1933 in Bravničar, 1987) devised the formula for calculating the percentage of body fat mass, bone mass and muscle mass by defining skinfolds, circumferences, body mass, body height and diameters.

Body surface area (BSA) was calculated. Then body fat mass was calculated with the following formula:

$$Body\ fat\ mass = c * d * BSA$$

Where "*c*" is the constant of 0,13 and "*d*" is the total value of skinfolds (sum of triceps skinfold, forearm skinfold, thigh skinfold, calf skinfold, abdominal skinfold and chest skinfold, divided by 12).

The percentage of body fat mass was calculated with the following formula:

$$\%\ body\ fat\ mass = \frac{body\ fat\ mass\ (kg) * 100}{body\ mass\ (kg)}$$

The muscle mass (in kg) was calculated from a body height (ABH) and a mean value of the radius of idealized body segments (r):

$$muscle\ mass = 0{,}0065 * ABH * r^2$$

$$r = \frac{ACTR + ACF + ACTH + ACC}{25.12} - \frac{ASFB + ASFF + ASFT + ASFC}{8}$$

ACTR…. triceps circumference
ACF… forearm circumference
ACTH…. thigh circumference
ACC…. calf circumference
ASFB…. biceps skinfold

ASFF…. forearm skinfold
ASFT…. thigh skinfold
ASFC…. calf skinfold

The percentage of muscle mass was calculated from muscle mass (in kg) and body mass (ABM in kg):

$$\% \, muscle\ mass = \frac{muscle\ mass * 100}{ABM}$$

The second sample of measured gymnasts consists of 54 top male competitors, aged between 18 and 37 (on average 24 years) who participated at World Cup in Gymnastics in Ljubljana in 2015 and voluntarily participated in measurements. Gymnasts and their coaches were verbally informed of the purpose of the research. Measurements were taken at the Arena Stožice in Ljubljana, where the World Cup took place. Following anthropometric variables were measured with Inbody720, body height was measured with anthropometer. Measurements were carried out by independent qualified persons (defined by Bravničar 1987 for body height):

- body height
- body weight
- percentage of body fat mass
- percentage of body muscle mass
- belt circumference,
- upper arm circumferences (left and right),thigh circumferences, chest circumferences and percentage of skeletal lean mass were not compared because of the differences in measurement techniques (classic anthropometric measurements and InBody720). Upper arm circumferences are comparable because of the same measurement technique from both years of measurements (in the middle of the elbow and the shoulder), while there was a significant difference between InBody measurements (thighs circumference was measured at 2/3 point of the navel line and knee and chest circumference was measured right under the armpit (InBody User Manual, 1996)) and anthropometrical measurements (thighs circumference was measured under the gluteal fold and chest circumference was measured at the level of nipples).

The results were divided in groups, according to the apparatus they performed on (except for vault, because of not enough competing gymnasts on this apparatus, consequently the lack of data) and compared. BMI for each gymnast was calculated from body height (ABH in m) and body weight (ABM in kg):

$$BMI = \frac{ABM}{(ABH)^2}$$

The measures of an average, standard deviation, F and p(F-test) were calculated for both years. Then the p(t-test) for independent samples was calculated for comparing the groups on the apparatus. All the calculations were made in Microsoft Excel, for p(f-test) the standard tables for F-distribution were used and statistical significance limit for difference was 0,05 (Sagadin, 1982).

RESULTS AND DISCUSSION

At the time that measurements took place, all the gymnasts were past their growth age. Adult height, or near adult height of artistic gymnasts is not compromised by intensive gymnastics training (Malina et. al, 2013).

The average age for our measured groups of competing gymnasts is very similar for both groups between the years; it is 23.7 years old for the year of 2000 and 24.1 years old for the gymnasts in the year of 2015. The slight difference is on the floor in the year of 2000, where gymnasts were slightly younger (21.4 years old). The p(t-test) confirms there's no significant difference (p(t-test) > 0.05). The difference in standard deviation in 2000 is 3,69 years and 4,21 years in 2015, which leads us to a fact that despite no significant difference in average age of gymnasts, the general range of gymnasts age is greater in 2015 that it was in 2000. The difference for the two groups in their birth year is significant (p(t-test) < 0.05) and this proves the measurements were taken with two different generations of gymnasts in 15 years' time and not one gymnast was measured at both measurements. We can assume the most of gymnasts who competed in 2015 were just in the beginning of their career in 2000.

Table 1
Descriptive statistics of morphological differences of the gymnasts, between the years of 2000 and 2015.

Birth Year [years]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	1978.63	1991.75	1975.29	1990.55	1975.33	1991.06	1976.46	1991.00	1976.81	1990.60
SD	2.43	3.73	4.38	4.42	5.12	4.82	3.31	4.24	3.21	3.86
N	19	20	17	22	9	18	13	20	16	21
F	1.53		1.01		1.06		1.28		1.20	
p(F-test)	2.21		2.31		2.55		2.56		2.33	
p(t-test)	0.000		0.000		0.000		0.000		0.000	
Age [years]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	21.37	23.25	24.71	24.46	24.67	23.94	23.54	24.21	23.19	24.40
SD	2.43	3.73	4.38	4.42	5.12	4.82	3.31	4,24	3.21	3.86
N	19	20	17	22	9	18	13	20	16	21
F	1.53		1.01		1.06		1.28		1.20	
p(F-test)	2.21		2.32		2.55		2.56		2.33	
p(t-test)	0.071		0.861		0.722		0.635		0.321	
Height [cm]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	166.85	170.16	168.94	171.65	163.03	167.37	165.85	168.68	170.79	171.65
SD	5.01	7.08	5.45	7.91	4.16	6.34	4.69	5.82	5.91	6.78
N	19	20	17	22	9	18	13	20	16	21
F	1.41		1.45		1.53		1.24		1.15	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.102		0.234		0.076		0.154		0.693	
Weight [kg]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	66.56	66.79	66.84	68.01	63.86	64.56	63.45	66.45	67.82	68.09
SD	6.32	7.73	7.18	6.97	3.51	6.23	2.94	6.91	6.70	6.81
N	19	20	17	22	9	18	13	20	16	21
F	1.22		1.03		1.78		2.35		1.07	
p(F-test)	2.21		2.15		3.18		2.56		2.20	
p(t-test)	0.919		0.608		0.756		0.153		0.907	
BMI [kg/m^2]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	23.88	23.02	23.37	23.08	24.02	23.04	23.08	23.35	23.21	23.11
SD	1.56	1.71	1.57	1.84	0.82	1.77	0.75	2.11	1.41	1.96
N	19	20	17	22	9	18	13	20	16	21
F	1.09		1.17		2.16		2.83		1.39	
p(F-test)	2.21		2.15		3.18		2.56		2.33	
p(t-test)	0.107		0.610		0.130		0.614		0.855	

	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
Left Arm Circumference [cm]										
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	33.01	33.36	33.67	33.63	32.81	33.58	33.07	34.44	33.47	34.41
SD	2.34	2.31	1.94	2.14	1.81	3.25	1.81	3.44	2.19	3.08
N	19	20	17	22	9	18	13	20	16	21
F	1.01		1.10		1.79		1.90		1.40	
p(F-test)	2.18		2.31		3.18		2.56		2.33	
p(t-test)	0.642		0.955		0.519		0.199		0.310	
Right Arm Circumference [cm]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	32.81	33.38	33.64	33.62	32.66	33.63	32.98	34.33	33.61	34.39
SD	2.36	2.37	1.76	2.18	1.96	3.03	1.65	3.35	2.29	2.99
N	19	20	17	22	9	18	13	20	16	21
F	1.01		1.24		1.55		2.03		1.31	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.457		0.979		0.392		0.190		0.400	
Abdomen Circumference [cm]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	77.55	80.11	77.59	80.64	76.61	78.88	75.57	79.94	77.69	80.81
SD	2.83	4.11	3.11	4.42	2.65	3.16	2.25	4.72	3.08	4.77
N	19	20	17	22	9	18	13	20	16	21
F	1.46		1.42		1.94		2.09		1.55	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.030		0.021		0.076		0.004		0.030	
% Body Fat Mass										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	8.59	7.28	7.96	7.20	7.55	6.51	7.34	6.32	8.11	6.48
SD	1.56	3.16	1.18	3.04	1.04	3.20	1.16	2.77	1.59	3.01
N	19	20	17	22	9	18	13	20	16	21
F	2.02		2.58		3.07		2.39		1.89	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.113		0.294		0.355		0.222		0.058	
% Muscle Mass										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	54.89	60.80	55.34	53.11	54.25	53.58	55.96	53.46	55.80	53.63
SD	2.44	6.66	1.35	1.99	1.68	2.15	2.53	2.30	2.33	2.08
N	19	20	17	22	9	18	13	20	16	21
F	2.74		1.47		1.28		0.91		0.87	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.001		0.000		0.424		0.007		0.005	

No significant difference (p(t-test) > 0.05) is in height according to the averages for each apparatus and altogether. There was also Čuk et. al (2007) who discovered no difference in gymnasts body height between 1933 and 2000, despite the general increase of the human height in the last decades (0.99 cm per a decade note by Johnston & Padez (2009)). Nevertheless the gymnasts tend to be taller in 2015 than in 2000; however the variability is also higher in 2015 than in 2000 and therefore questionable. The bigger difference is between the tallest and the shortest gymnasts. In 2000 the shortest gymnast was 157.4 cm of height, in 2015 there were two gymnasts with only 150 cm of height. The gymnasts on high bar are the highest in both years, 185.5 cm in 2000 and 183 cm of height in 2015. The difference between the tallest and the shortest gymnast in 2000 was 28.1 cm; in 2015 that difference was 33 cm.

There's almost no difference (p(t-test) > 0.05) in gymnasts' body weight between the years. In 15 years of difference the gymnasts tend to be heavier on pommel horse, rings and parallel bar, and lighter on high bar. There is also a difference between gymnasts for the apparatus they compete on. According to the measurements the lightest gymnasts competed on rings and the heaviest on pommel horse and high bar (despite the tendency of being lighter after 15 years on that apparatus). Among all the measured gymnasts the lightest was only 49.8 kg (in 2015) and the heaviest gymnast 84.5 kg (in 2000). They were both competing on a high bar. And with the exception of a high bar this doesn't reinforce the idea that gymnasts are getting shorter and lighter, mentioned by Arkaev & Suchilin (2003).

BMI shows no significant difference (p(t-test) > 0.05), which is assumed according to the results for height and weight, although the gymnasts tend to have a lower BMI in 2015 than in 2000. The gymnasts tend to be taller and not so much heavier in 15 years of difference. By Arkaev & Suchilin (2003) the gymnast's weight is the only objective obstacle to perform exercises. To move one's weight it's necessary to apply strength and perform mechanical work of a certain power. So the gymnasts have to try to keep a certain body weight, despite the tendency to be heavier.

In measurements for circumferences there's no significant difference (p(t-test) > 0.05) in arms circumference, there's also no difference between left and right arm. The difference is significant in abdomen circumference (p(t-test) < 0.05) for all the apparatus except for rings. The average difference on the apparatus (except for rings) between the years is from 2.5 to 4.4 cm. We can confirm that in 15 years gymnasts tend to have greater abdomen circumferences.

As Arkaev & Suchilin (2003) said gymnastics cannot be performed without jumping ability, high level of development of the muscles of upper back, lower back and the trunk. The trunk is amazing in construction and a very important tool for mastering the technique of performing modern gymnastics exercises. This obviously was the leading point of perspective for gymnasts and their coaches, to pay more attention to development of the trunk muscles than they were in the past. Consequently the abdomen circumferences are greater in 2015 that they were in 2000. Here, the similarity in measurement techniques must be mentioned. Measurements in 2000 were performed with standard anthropometrical instruments (measuring tape), measurements in 2015 were taken with the InBody720. The procedure of measurements remained the same; in both techniques the circumference was measured in the navel line, so we can neglect the measurement error.

Comparing the percentage of gymnasts' body fat mass there's no significant difference (p(t-test) > 0.05) between the years. The fat mass percentages of the gymnasts in this study are low comparing to the general population, which once again confirms the findings and data published by other authors (Johnston & Padez (2009), Faria I.E. & Faria E.W. (1989), Caldarone et.al (1987)). Nevertheless gymnasts tend to have lower values of percentage of body fat mass in 2015, comparing to 2000.

The percentage of muscle mass shows a significant difference (p(t-test) < 0.05) on each apparatus, except for rings. On rings the relative strength of the body has a significant meaning, where additional body mass does not necessarily represents higher absolute power. The highest difference is in percentage of muscle mass of gymnasts competing on floor, and it is the only difference that shows gymnasts had more percentage of muscle mass in 2015 than in 2000. On the other three apparatus – pommel horse, parallel and high bar, the significant difference shows the gymnasts had had more percentage of muscle mass in 2000 than they had in 2015.

There is three times that F-test was significant (F > p(F-test)). In BMI on parallel bars, percentage of body fat mass on pommel horse and percentage of muscle mass on floor. Among those, the significant difference between the years (p(t-test) < 0.05) is only in percentage of muscle mass on floor, the other compared variables are not significantly different, but there is a big difference in variance between these variables in 15 years. And in almost 80% of all compared variables for the apparatus, the level of variance in variables in 2015 was much bigger than it had been in 2000. Even if there are no significant difference in measured (or calculated) values, there is a tendency for bigger differences between the lowest and the highest value of different variables, which means the change of rules, structural change of routines, different deduction procedure and increasing number of specialists on different apparatus did have some affect to morphological characteristics of gymnasts.

We don't have data for bone density, but it would be interesting to compare values of it between the years. According to the changing of bone mass density and skeletal status with trainings in artistic gymnastics (as stated in Nichols-Richardson, et. al, 2000; Dowthwaite & Scerpella, 2009; Nichols et al. 1994; Pullock, et. al, 2006; and many others), values of bone density might also change with years. As our results show, gymnasts in 2015 tend to have lower percentage of body fat, lower percentage of muscle mass and almost unchanged body weight, we assume the difference comes from higher percentage of bone mass and higher mass of inner organs. Comparing the floor routines from different years on videos, gymnasts in 2000 mostly had 3 diagonals, each with mostly one basic difficult acrobatic element within a diagonal, but gymnasts nowadays mostly have 4 diagonals of difficult acrobatic elements, also with two difficulties within a diagonal. A quantitative increase of body loan in take offs and landings of difficult acrobatic elements might also lead to an increase of percentage of bone mass. So further research is necessary to compare bone density, there might also be interesting to verify some potential changes in insertion according to the execution of higher difficulty level nowadays.

EXPERIMENT LIMITATIONS

Differences in measurement techniques limited the comparable morphological characteristics. Due to that we could not compare chest circumference, thigh circumference and skeletal lean mass. We don't know how the InBody720 calculating procedure for percentage of muscle mass and percentage of fat mass, but they were still compared to see the difference. Gymnasts competing on vault were not compared because of the lack of data.

For further analysis the same measurement techniques have to be used and compared to get more reliable results.

FIG, or UEG and other continental federations might consider integrating and connecting the researchers from different countries and organizations, to get the data and variables from all the World Cup competitions in different locations, to conduct researches and update of database for further analysis. InBody720 is inexpensive and fast method for determination of morphological characteristics and can be used in competitions.

CONCLUSION

Comparing the results of anthropometrical measurements of male gymnasts from different years gave some significant and some insignificant differences. In short we can conclude:

- There was a significant change of rules and the COP in 15 years;
- Gymnasts show elements and routines with increased difficulty;
- Gymnasts nowadays show the increase of variability in morphologic characteristics;
- Gymnasts nowadays have higher abdomen circumferences,
- Gymnasts nowadays who compete on floor have higher percentage of muscle mass; while on other apparatus the percentage of muscle mass is lower,
- Gymnasts nowadays tend to be higher, with less percentage of body fat and percentage of muscle mass (with the exception of gymnasts competing on floor).
- nowadays gymnasts with lower percentage of body fat, lower percentage of muscle mass and almost unchanged body weight have probably higher percentage of bone mass and higher mass of inner organs.

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