RELATIVE AGE EFFECT AMONG OLYMPIAN GYMNASTS

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Abstract

Relative age effect (RAE) is a worldwide phenomenon described as consequences of age variations between individuals competing in the same cohort. RAE is based on systems that use January 1 as a cut-off date, probably used to attempt to minimize developmental differences between ages and to ensure a more equitable competition. Previously, in artistic gymnastics, a majority of studies on RAE was conducted in gymnasts of national levels. This study analysed RAE both among and between elite female (N_F=1268) and male gymnasts (N_M=1186) who participated at all Olympic Games held from 1964 to 2016. By using χ^2 test, significant difference were found: 1) within frequencies of total sample of male gymnasts born in a certain month (p<0.001); 2) within frequencies of groups of male gymnasts apparatus finalists born in a certain month (p<0.005); 3) within frequencies of groups of male apparatus finalists born in a certain quarter of the year (p<0.005); 4) within frequencies of groups of male apparatus finalists born in a certain half of the year (p<0.005). As far as female gymnasts are concerned, significant differences have not been found within frequencies of any female group born in a certain month, quarter or halves of the year. Regarding differences between genders, no significant differences have been obtained between frequencies of male and female gymnasts born in certain month, quarter and halves of the year. Despite certain differences among and between genders, the general conclusion was that RAE is not present in elite gymnasts of both genders.

Key words: *RAE, female gymnasts, male gymnasts, differences.*

INTRODUCTION

On the way of reaching Olympic quality, gymnasts are confronting with many factors, and one of the them is time: time needed for reaching the peak of performance of the continuously increased number of the most difficult elements from Code of Point (CoP; prescribed by the Technical Committee (TC) of the Fédération de Internationale de Gymnastique (FIG). Furthermore, from all those Olympians, only those who perform the most difficult elements with the highest technical end aesthetical precision qualify for the highest levels of Olympic gymnast competition – Apparatus Finals.

However, time (irrespective of whether it is a time-period of changes that are followed by biological maturation or time-length of the training process) is not equal

from the point of the female and male artistic gymnastics.

Female gymnasts start with training around the age of 6 and are included in trainings characterised by deliberate practice-high-quality practice (Ericsson, 2007, 2008) around the age of 10 in order to reach peak strength and peak performance of all required skills somewhere around the age of 16 (Tofler, Stryer, Micheli, & Herman, 1996; Arkaev & Suchilin, 2004). "Catching up" of the peaks is correlated with attempts to teach female gymnasts as many skills as possible before reaching their biological maturity. Although it is delayed, compared to the "normal" population (as a consequence of long hours of training (Caine, Bass, & Daly, 2003; Georgopoulos et al., 2012) and/or because gymnasts have been selected as short, normal, late-maturing individuals (Malina et al., 2013)), influence of the maturity on the female gymnasts is the same as on the "normal" population: hips and torso are widening, and the volume of fat tissue is increased. These morphological changes disrupt performance of even basic gymnastic elements (Ryan, 1995) and cause loosing of an "ideal" female gymnast body (tiny "pixie-like" feminine bodies with a superhuman power; Barker-Ruchti, 2009; Weber & Barker-Ruchti, 2012; Cohen, 2013).

Male gymnasts, unlike from female gymnasts, typically do not experience intensive, rigorous training before the age of 14 or 15, due to performance dependence of the most male gymnastics skills for the extreme levels of strength, especially of the upper body. Because male gymnasts are also typically characterized with a shorter stature, later maturation and a slower rate of growth than the normal population (Malina, 2014), this is the period when increasing of levels of the Testosterone (required for the development of the muscle mass and development of the strength and power) happens. An increase of muscle mass and development of power and strength, without significantly mobilizing the aerobic processes, enables male gymnasts to

perform the most difficult elements (Dallas, Zacharogiannis, & Paradisis, 2013).

Despite different time of starting the intensive training, deliberate practice is considered to be a fundamental factor for success in artistic gymnastics (Côté & Fraser-Thomas, 2008). However, many previous studies, conducted primarily on female gymnasts, argued about a "negative" impact of the earlier attainment of deliberate practice on maturity. Results of those studies suggested that early deliberate practice was causing a range of physical problems like stunted growth, bone deformity and a delayed onset of menarche (Caine, Lewis, O'Connor, Howe, & Bass, 2001; Cassas & Cassettari-Wayhs, 2006; Daly, Bass, & Finch, 2001; Dresler, 1997; Lindholm, Hagenfeldt, & Hagman, 1995; Tofler, Stryer, Micheli, & Herman, 1996) as well as some psychological problems like distorted body-image, self-confidence, and dietary habits (Lindholm et al., 1995; Martinsen, Bratland-Sanda, Eriksson, & Sundgot-Borgen, 2010). It was specially noted from the mid-1960s through the 1980s when the decrease of the mean age, height, and weight of world class female artistic gymnasts was confirmed (Malina, 1994; Ryan, 1995; Malina, Bouchard, & Bar-Or, 2004; Claessens, Lefevre, Beunen, & Malina, 2006; Kerr, Berman, & De Souza, 2006; Martindale, Collins, & Abraham, 2007; Barker-Ruchti, 2009). Although the above mentioned problems were far more contentious in Women's Artistic Gymnastics (WAG) rather than in Men's Artistic Gymnastics (MAG), with the aim of protecting the musculoskeletal development of young competitors, lengthening gymnasts careers, preventing early burnout, helping to reduce injuries, and redirecting a positive image of sport to the public, spectators, and media (Eagleman, Rodenberg, & Lee, 2014), during the last three decades the FIG gradually increased its minimum age requirements for both genders. The minimum age requirement for gymnasts refers to the chronological age requirement for participation in senior competitions sanctioned by the FIG. Prior to 1981 the

minimum required age was 14 years of age, in 1981 it was increased to 15 years of age and from 1997 both genders older than 16 could participate in World Championships. However, female gymnasts who turned 16 and male gymnasts who turned 18 in the current year could participate in the Olympic Games (OG) but only as members of national teams. These increases of minimum required age probably influenced the increase of the average age of female gymnasts and decrease of the percentage of youngest female gymnasts in the period from 1966 to 2016 (Delaš Kalinski, Atiković, & Jelaska, 2018). However, an increase in average age for male gymnasts in the period from 1984 to 2016 was never attributed to increase of the FIG's minimum age but to the increased demands of MAG, respectively to the prolonged training processes in order to attain a necessary level of strength required to perform the most difficult skills of MAG (Delaš Kalinski, Jelaska, & Knežević, 2017).

Starkes (2000) indicated that other factors besides deliberate practice contribute to sport expertise; some coaches' talents might be masked by a phenomenon known as a relative age effect (RAE). Barnsley, Thompson and Barnsley (1985) gave a definition of RAE saying it refers to the subtle chronological age discrepancies between individuals within annually age-grouped cohorts. RAE presents favouritism toward selecting athletes born early in the birth year (Kirkendall, 2014). RAEs refer to a specific selection, participation, and attainment (dis)advantages occurring as a result of physical and cognitive variability (Musch & Grondin, 2001). The main reason for RAE is to attempt to minimize results of physical maturation (increased height and mass) and their accompanying performance factors (correlated and influenced by an increase muscle mass: sprinting, explosive power (Cobley, Baker, Wattie, & McKenna, 2009) in order to provide more equitable competition.

RAE in sport was first reported in Canadian ice hockey and determined how a greater proportion of relatively older athletes (born in the first three months of the year) compete in elite team sports, when compared to their younger counterparts (ones born closer to the end of the age-band (Grondin, Deshaies, & Nault, 1984; Barnsley et al., 1985)). Later, in a review article Cobley et al. (2009) analysed 38 studies on relative age effects (spanning 1984-2007, containing 253 independent samples across 14 sports and 16 countries) and confirmed RAE, with few exceptions, for a variety of sports for both genders over a range of competition and development levels.

Compared to male athletes, only a few of the studies examined RAE in female athletes. Researchers conducted on a female team sports highlight an over-representation of athletes born in the second-quartile at elite levels of performance (Musch & Grondin, 2001; Baker, Schorer, Cobley, Bräutigam, & Büsch, 2009; Cobley et al., 2009; Baker, Janning, Wong, Cobley, & Schorer, 2014; Delorme, Boiché, & Raspaud, 2010; Weir, Smith, Paterson, & Horton, 2010; Till et al., 2010; Cobley et al., 2009; Hancock, Seal, Young, Weir, & Ste-Marie, 2013; Sedano, Vaeyens, & Redondo, 2015). Some researchers claim that the effect may be reversed at the elite level because relatively younger athletes develop superior skills to remain in the sport (Schorer, Cobley, Büsch, Braütigam, & Baker, 2009) and that relatively older elite athletes drop out of sport earlier (Bäumler, 1998; Schorer et al., 2009).

When compared with team sports, there seems to be a lack of studies of RAE in individual sports, and reported datasets are conflicting as well (Cobley et al., 2009; Raschner, Muller, & Hildebrandt, 2012; according to Albuquerque et al., 2015). Within individual sports, the presence of RAE was confirmed in skiing (downhill and Nordic; Baker et al., 2014), tennis and archery (Baxter-Jones, 1995), within heavier Olympic judo athletes (Albuquerque et al., 2013), within Olympic wrestlers (Albuquerque et al., 2014) and in athletics (Sayavera et al., 2017). Individual female aesthetic sports (dance, gymnastics, figure

skating, diving) seem less prone to RAE (van Rossum, 2006; Baker et al., 2014; Wattie et al., 2014).

General conclusion was made by comparing RAE studies between genders: the magnitude of the RAE in women's sports was smaller due to a less intense competition at an early age. Raschner et al. (2012) suggested that female sports disciplines are not as strength-related as the male variants, and as a consequence, the maturation-related developmental lead is not as decisive. Because female artistic gymnastics is a strength-related sport which prefers: 1) young "pixie-like" bodies (Barker-Ruchti, 2009; Weber & Barker-Ruchti, 2012; Cohen, 2013); 2) late-maturing individuals (Malina et al., 2013); 3) shorter, lighter in body weight, having lower values of subcutaneous fat, narrower hips and broader shoulders, athletes who "survive" early amounts of deliberate practice and become competitive gymnasts (Claessens & Lefevre, 1998); 4) shorter and lighter in body weight athletes because of biomechanical advantages (Monsma & Malina, 2005); 5) slowly growing athletes who have tendency not to pass through major problems with consistency of performance of gymnastic elements (Kerr, Barker-Ruchti, Schubring, Cervin, & Nunomura, 2015), the potential complexity of RAE is highlighted. However, only a few studies on national level gymnasts have been conducted and the following conclusions were made: 1) among elite female British gymnasts RAE was not observed (Baxter-Jones, 1995); 2) there is an atypical RAEs effect between female gymnasts; athletes born in the second and third quartiles were more frequently seen in national teams than athletes born in the first and fourth quartiles (Baker et al., 2014); 3) relatively older female gymnasts, usually because psychological responses of female gymnasts on puberty (increase of depressive symptoms and weight concerns, decrease of feelings of self-worth) have been shown to drop out more frequently than relatively younger gymnasts (Wattie et al., 2014); 4) during childhood and early adolescence (under the age of 15), relatively older female gymnasts might excel relatively younger athletes (Hancock, Starke, & Ste-Marie, 2015) due to the increased cognitive maturity that may be needed for deliberate practice training conditions (Baker et al., 2014).

Studies of RAE on a sample elite female international gymnasts have not been found, while RAE was never determined on a sample of male Olympian gymnasts, participants of Olympic Games held from 1980 to 2016 (Delaš Kalinski et al., 2017).

Considering all the above mentioned differences between men's and women's gymnastics, as well as a very few researches analysing RAE effects within the same sport, but among the different genders, the problem of this research was set and it was to analyse RAE among elite international gymnasts. The aims were: 1) to determine, for each gender, differences between frequencies of gymnasts born in a certain month, quarter and half of the year; 2) to determine differences within frequencies of male and female gymnasts born in certain month, quarter and half of the year; 3) to determine, for each gender and between genders, differences in frequencies of gymnasts who competed on different levels of Olympic gymnast competitions.

METHODS

Subjects

The research tended to include all elite male (N_M=1193) and female (N_F=1280) senior gymnasts who participated in All-Around Qualifications (AAQ) and Apparatus Finals (AF) at all OG held from 1964 to 2016. The total frequencies of AAQ and AF participants differ in the analysed period due to FIG rules valid at certain OG. For males: at the OG1964 N_{MAAQ}=114 and N_{MAF}=16; at the OG1968 N_{MAAQ}=103 and N_{MAF}=14; at the OG1972 N_{MAAQ}=84 and N_{MAF}=11; at the OG1976 N_{MAAQ}=151 and N_{MAF}=20; at the OG1980 N_{MAAQ}=36 and N_{MAF}=36; at the OG1984 N_{MAAQ}=36 and N_{MAF}=48; at the OG1988 N_{MAAQ}=36 and N_{MAF}=48; at the OG1992 N_{MAAQ}=36 and

N_{MAF}=48; at the OG1996 N_{MAAQ}=35 and N_{MAF}=48; at the OG2000 N_{MAAQ}=36 and N_{MAF}=48; at the OG2004 N_{MAAQ}=24 and N_{MAF}=50; at the OG2008 N_{MAAQ}=24 and N_{MAF}=48; at the OG2012 N_{MAAQ}=24 and N_{MAF}=49; at the OG2016 N_{MAAQ}=22 and N_{MAF}=48. For females: at the OG1964 N_{FAAQ}=69 and N_{FAF}=14; at the OG1968 N_{FAAQ}=91 and N_{FAF}=11; at the OG1972 N_{FAAQ}=104 and N_{FAF}=13; at the OG1976 N_{FAAQ}=57 and N_{FAF}=17; at the OG1980 N_{FAAQ}=49 and N_{FAF}=16; at the OG1984 N_{FAAQ}=49 and N_{FAF}=18; at the OG1988 N_{FAAQ}=71 and N_{FAF}=17; at the OG1992 N_{FAAQ}=73 and N_{FAF}=18; at the OG1996 N_{FAAQ}=87 and N_{FAF}=18; at the OG2000 N_{FAAQ}=76 and N_{FAF}=21; at the OG2004 N_{FAAQ}=72 and N_{FAF}=26; at the OG2008 N_{FAAQ}=73 and N_{FAF}=25; at the OG2012 N_{FAAQ}=72 and N_{FAF}=25; at the OG2016 N_{FAAQ}=70 and N_{FAF}=28.

However, due to the inability to find the date of birth for all participants, the total sample of entities for male gymnasts was N_M=1186 and for female gymnasts N_F=1268. Each gender total sample was analysed trough three different insights: 1) as a group of total sample (TS); 2) as a group of participants of All-Around Qualifications (AAQ); 3) as a group of participants who qualified for Apparatus Finals (AF).

Names and birthdates of the sample were collected from open-access Internet websites, mostly from the official OG website https://www.olympic.org/gymnastics-artistic. There were no ethical issues involved in the analysis and interpretation of the data used, as these data were obtained in their secondary form and were not obtained by experimentation. The use of open access or Internet data in RAE studies has previously been described in other studies (Côté et al., 2006; Medic, Starkes, Weir, Young, & Grove, 2009; Albuquerque et al., 2012; Albuquerque et al., 2015).

Variables

The variable sample is represented by a set of: 1) date of AAQ competition at the OG held from 1964 to 2016; 2) date of birth of male gymnasts; 3) date of birth of female gymnasts; 4) participation in AAQ or in AF at all OG held from 1964 to 2016.

The information on dates of competitions and on participation of gymnasts at a certain level of competition (AAQ or AF) have been retrieved from the specialized website for gymnastics results (www.gymnasticsresults.com, accessed from 2 September to 18 October 2016).

Statistical Analysis

Conversion of a date of birth into chronological age was done using MS Excel function *YEAR*. Parameters for this function were date of birth of the competitors and the date of specific competition that was analysed.

There are two traditional investigations of RAE: 1) classifying the date of birth to a certain quarter of the year (Q1: January to March; Q2: April to June; Q3: July to September; and Q4: October to December) for data analysis (Côté et al., 2006; Delorme et al., 2010; Delorme, Chalabaev, & Raspaud, 2011; Albuquerque et al., 2012, 2013); 2) classifying the date of birth to a certain half of the year (born from January to June were classified into the first half of the year, and born from July to December were classified to the second half of the year; Edgard & O´Donoghue, 2005). In case of both genders from the current study data analysis included both mentioned methods, as well as representation and analysis of frequencies of competitors born in particular month. Within a gender (for each group (TS, AAQ, and AF)) Chi-square (χ^2) test was applied to identify differences between frequencies of affiliation of a gymnast's birth date to a certain month, a quarter of the year and half of the year. Also, for each group (TS, AAQ, and AF), χ^2 test was applied to identify differences between genders in frequencies of affiliation of the gymnast's birth date to a certain month, a quarter of the year and half of the year. For all applied analyses, type I error was set at α=5%. All data were calculated using data

analysis software system Statistica 13.2
(Dell Inc., Tulsa, OK, USA).

RESULTS

Table 1

Affiliation of the date of birth of male and female participants at the Olympic Games held from 1964 to 2016 to a particular month of the year.

N month	TS			AAQ			AF		
	M	F	χ^2 p	M	F	χ^2	M	F	χ^2 p
	1186	1268	df=1	655	1003	df=1	531	265	df=1
1	117	118	0.22 0.63	67	93	0.42 0.52	50	25	0.00 0.99
2	94	105	0.10 0.75	48	78	1.92 0.17	46	27	0.50 0.42
3	105	99	0.94 0.33	59	77	0.93 0.34	46	22	0.03 0.86
4	80	104	1.88 0.17	50	88	0.68 0.41	30	16	0.05 0.82
5	87	107	1.02 0.31	49	84	0.43 0.51	38	23	0.58 0.45
6	102	102	0.25 0.62	65	74	3.33 0.07	37	28	3.05 0.08
7	74	97	1.88 0.17	44	79	0.78 0.38	30	18	0.41 0.52
8	104	122	0.53 0.45	54	100	1.41 0.24	50	22	0.27 0.60
9	129	126	0.58 0.45	68	98	0.16 0.69	61	28	0.15 0.70
10	95	101	0.00 0.97	46	77	0.24 0.62	49	24	0.01 0.92
11	102	100	0.41 0.52	50	81	0.00 0.97	52	19	1.49 0.22
12	97	87	1.54 0.22	55	74	0.57 0.45	42	13	2.88 0.09
χ^2	25.07	12.99		14.01	10.95		21.20	11.45	
df	11	11		11	11		11	11	
p	**0.01**	0.29		0.23	0.45		**0.03**	0.41	

Legend: Data are represented as frequencies of male/female gymnasts born in a certain month of the year, TS – total sample, AAQ – All-Around Qualifiers, AF – Apparatus Finalists, month – birth month, M – male gymnasts, F – female gymnasts, χ^2 – Chi square test value, p – level of significance, df – degrees of freedom

At the OG held from 1964 to 2016 the lowest percentage of all male participants was born in July (7%) while the highest percentage was born in September (10%). In the sample of female participants at the OG from 1964 to OG2016, the lowest percentage of participants was born in December (6%) while the highest percentage was born in September (10%). Similar results have been found for the male AAQ participants (the lowest percentage was born in July (7%) and the highest

percentage was born in September (10%). The lowest percentage of AAQ female participants was born in June and December (7%) and the highest percentage was born in August (10%). The lowest percentage of AF male participants were born in April and July (5%) and the highest percentage was born in September (11%). The lowest percentage of AF female participants was born in December (5%) and the highest percentage was born in September (10%).

Despite different frequencies of male and female participants born in a certain month of the year (Table 1), in all three groups (TS, AAQ and AF) a significant difference between frequencies of gymnasts born in certain month of the year, was determined only among the men's TS participants (χ^2=25.07, p=0.01) and among the frequencies of men's AF (χ^2=21.20, p=0.03). In both genders for all other groups, significant differences have not been determined between frequencies of gymnasts born in a certain month of the year. Significant differences have not been determined between genders (in all observed groups) for frequencies of OG participants born in a certain month of the year.

Table 2

Affiliation of the date of birth of male and female participants of the Olympic Games held from 1964 to 2016 to a particular quarter of the year.

N quarter	TS			AAQ			AF		
	M	F	χ^2 p	M	F	χ^2	M	F	χ^2 p
	1186	1268	df=1	655	1003	df=1	531	265	df=1
1	316	321	0.56 0.47	174	247	0.78 0.38	142	74	0.12 0.72
2	269	313	1.35 0.25	164	246	0.09 0.76	105	67	3.17 0.08
3	307	346	0.62 0.43	166	278	1.14 0.29	141	68	0.07 0.79
4	294	288	1.47 0.23	151	232	0.00 0.97	143	56	3.17 0.08
χ^2	4.23	5.41		1.67	4.51		7.76	2.55	
df	3	3		3	3		3	3	
p	0.24	0.14		0.65	0.21		**0.05**	0.47	

Legend: Data are presented as frequencies of male/female gymnasts born in a certain quarter of the year, TS – total sample, AAQ – All-Around Qualifiers, AF – Apparatus Finalists, quarter-quarter of the year, M – male gymnasts, F – female gymnasts, χ^2 – Chi square test value, p – level of significance, df – degrees of freedom

As seen through quarters (Table 2), like in analysis through the frequencies of gymnasts born in a certain month of the year, different frequencies of male and female gymnasts have been determined to be born in certain quarter of the year: 1) in the TS of male gymnasts the highest frequencies refers to gymnasts born in the first quarter (26%), and the lowest frequencies to those born in the second quarter (23%); 2) in the TS of female gymnasts the highest frequencies refer to gymnasts born in the third quarter (27%), and the lowest frequencies to those born in the fourth quarter (23%); 3) in the sample of AAQ male gymnasts the highest frequencies refer to gymnasts born in the first quarter (27%), and the lowest frequencies to those born in the fourth quarter (23%); 4) in the sample of AAQ female gymnasts the highest frequencies refer to gymnasts born in the third quarter (28%), and the lowest

frequencies to those born in the fourth quarter (23%); 5) in the sample of AF male gymnasts the highest frequencies refer to gymnasts born in the fourth quarter (27%), and the lowest frequencies to those born in the second quarter (20%); 6) in the sample of AF female gymnasts the highest frequencies refer to gymnasts born in the first quarter (28%), and the lowest frequencies to those born in the fourth

quarter (21%). However, within each group of samples significant differences, between frequencies of OG participants born in a certain quarter of the year, have not been determined. Also, significant differences have not been determined between genders (in all groups of samples) in the frequencies for OG participants born in a certain quarter of the year.

Table 3.

Affiliation of the date of birth for both male and female participants of the Olympic Games held from 1964 to 2016 to a particular half of the year

	TS			AAQ			AF		
	M	**F**	χ^2 **p**	**M**	**F**	χ^2	**M**	**F**	χ^2 **p**
N half	**1186**	**1268**	**df=1**	**655**	**1003**	**df=1**	**531**	**265**	**df=1**
1	584	635	0.17 0.68	337	495	0.70 0.40	247	140	2.82 0.09
2	602	633	0.58 0.45	318	508	0.09 0.76	284	125	2.81 0.09
χ^2	0.55	0.01		1.10	0.34		5.15	1.70	
df	1	1		1	1		1	1	
p	0.46	0.94		0.29	0.56		**0.02**	0.19	

Legend: Data are presented as frequencies of male/female gymnasts born in certain half of the year, half – half of the year, M – male gymnasts, F – female gymnasts, χ^2 – Chi square test value, p – level of significance, df – degrees of freedom

By dividing the calendar year into two equal parts (Table 3), different frequencies of male and female participants of all groups born in a certain half of the year have been determined. However, a significant difference between frequencies of participants born in a certain half of the year has been determined only within AF male gymnasts (χ^2=5.15, p=0.02). In this sample of OG participants, higher frequencies of participants were born in the second half of the year compared to frequencies of participants born in the first part of the year. Within all other samples, significant differences between frequencies of OG participants born in certain half of the year have not been determined. Furthermore, significant differences have not been determined between genders (in all observed groups) in the frequencies of OG participants born in half of the year.

DISCUSSION

Analysis of differences between frequencies of gymnasts born in a certain month of the year revealed a disproportion between minimal frequency (74) and maximal frequency (129) and caused significant χ^2 value. However, after reviewing frequencies, it can be seen that three months of the second half of the year have frequencies higher than 100, which eliminates a possible existence of RAE effect.

In traditional investigations of RAE within a year quartile, for obtained results within the men's TS, and consequently within the sample of the men's AAQ as they make up a larger part of male TS, it has been noted that the determination of a higher frequency of male gymnasts had ones born in the first quartile. However, due to

the considerable similarity between the first quartile frequency and frequencies of the other quartiles, a significant difference between them has not been determined, and thus neither the confirmation of the RAE within these groups. Significant difference determined between the men's AF is probably the consequence of a lower frequency in the men's AF determined in the second quartile (n_{Q2}=105) compared to almost equal frequencies in other three quartiles (n_{Q1}=142; n_{Q3}=141; n_{Q4}=143). Accordingly, RAE cannot be confirmed either in this group. The analysis of the frequency of a relative date of birth to a certain half of the year also determined certain numerical differences within the men's TS and men's QAA. Since those differences were not found to be significant, RAE has failed to be confirmed within these groups. Significant differences in the frequency of the men's AF, from which can be seen that a higher frequency of the men's AF was born in the second half of the year compared to frequencies of the men's AF born in the first half of the year, suggests the existence of "reverse" RAE in this sample of gymnasts. From such obtained results it follows that the best male gymnasts, those who have qualified for the apparatus finals at all OG held from 1964 to 2016, were likely to be relatively younger than those who finished their participation at the same OG at somewhat lower levels - in qualification All-Around competitions. Because performing apparatus finals routines, composed from the most difficult elements with the highest technical and aesthetic precision, requires larger amounts of deliberate practice during a longer period of time, then the question about characteristics of gymnasts who have succeeded in overcoming the same arises. Malina et al., (2013) state that the selection of gymnasts generally prefer short, normal, late-maturing individuals while Hancock et al. (2015) explain how gymnasts born in the second half of the year might be slightly less physically mature, resulting in shorter stature, "straighter lines" (leading to increased visual aesthetics), lower weight,

and higher strength to body mass ratio than relatively older athletes. Since MAG is all about weight-to-strength ratio, and because those characteristics give biomechanical advantages to gymnasts (Monsma & Malina, 2005), it is logical to conclude that relatively younger athletes might be better suited for talent development and superior gymnastic performance. However, although male gymnasts could, and some of them have participated in the OG at the age of 14 (until 1981), respectively to the age of 15 (from 1981 to 996) and with 16 years (after 1997), from the recent studies it is evident that the average age of all OG participants have been significantly higher from the minimum age requirement (the average age of all male gymnasts participants at the OG, held in the period from 1996 to 2016, ranged from 23.21 years to 25.21 years); and it also referes to all male finalists at the OG held in the period from 1980 to 2016 (average age=23.78; Delaš Kalinski et al., 2017). Results from these studies confirmed how, despite the early start of male gymnasts (Tofler et al., 1996; Arkaev & Suchilin, 2004) the majority of best male gymnasts have experienced expert performances later in a life; especially gymnasts who have qualified for the Ring Finals − apparatus that requires extreme levels of strength (Delaš Kalinski et al., 2017). If results of this study and the study of Delaš Kalinski et al. (2017) are both considered at the same time and through the key factor of success in artistic gymnastics (deliberate practice; Côté & Fraser-Thomas, 2008), the following can be pointed out: 1) a deliberate practice hours in MAG are spread out over a longer timeframe; 2) in the mid or late twenties, as in the case of male gymnasts of the AF, deliberate practice is accompanied by smaller cognitive maturity discrepancies among competitors, because of what deliberate practice can be intensively and equally applied to all; 3) despite the similar or the same amount of deliberate practice probably applied within the men's AF, biomechanical advantages of the relatively younger male gymnasts obviously remain through their entire career

because of what they make majority of the men's AF. Additionally, one of the possible reasons for a majority of relatively younger gymnasts in the men's AF might be a consequence of higher frequency of the dropout rate by the relatively older gymnasts compared to the relatively younger gymnasts (Wattie et al., 2014). All aforementioned facts and results explain the background/reasons of the obtained "opposite" RAE in the sample of gymnasts from the AF.

The obtained results for gymnasts from the men's AF align with the previous studies on artistic sports, whereby it has been suggested that being relatively older is not automatically beneficial (van Rossum, 2006; Wattie et al., 2014; Baker et al., 2014; Hancock, Starke, & Ste-Marie, 2015).

In the sample of female gymnasts, although certain differences between frequencies of all groups have been determined (TS, AAQ, and AF) within months, quarters and halves of the year, significant differences have not found between them. Accordingly, the absence of the RAE was confirmed for this sample of athletes. Since female gymnasts, even as children, have sufficient levels of oestrogen, that enables them to perform structurally complex and energetically-demanding artistic gymnastics skills, but also due to the fear of "disturbing" effects of biological maturation, within female gymnasts deliberate practice starts around the age of 10 (Tofler et al., 1996; Arkaev & Suchilin, 2004). Previous studies confirmed how with the aim of achieving the peak performances/elite levels of performance before adulthood, investing in deliberate practice during childhood and early adolescence becomes vital to success (Côté & Fraser-Thomas, 2008; Côté et al., 2009). Entering puberty, regardless of the exact age at which it occurs (usually around 14.3 years; Anderson, Dallal, & Must, 2003) brings generally the same changes to all female gymnasts. Two facts need to be considered when factors of female gymnasts success are analysed: 1) maturity happens before female gymnasts reach minimum age

requirement for participation at the OG; 2) results of the previous studies have shown that the average age of female gymnasts, participants of the OG, have been significantly higher than the prescribed minimum age, especially of those who qualified in the women's AF (Jelaska, Delaš Kalinski, & Crnjak, 2017). Accordingly, it can be assumed that the biomechanical advantages of biologically immature female gymnasts (Monsma & Malina, 2005) and advantages in cognitive maturity of relatively older gymnasts (Baker et al., 2014) have obviously been overcome by female Olympians, because of what the key factors of success at the highest levels of WAG competition in OG need to search for in some other factors. Like at the young age of female gymnast (when achieving of success should be based on deliberate practice; Côté & Gilbert, 2009), in adulthood, the key factor of success is probably the continuation of the deliberate practice. Size of the impact of adulthood deliberate practice among female gymnasts has probably reduced the influence of other factors and has accordingly produced a result of the absence of the RAE in elite WAG.

CONCLUSIONS

Training to becoming an Olympic gymnast can be endured only by athletes with a high level of dedication and persistence during a long period of deliberate practice. Beside deliberate practice, which is the key factor for success for both genders of Olympic gymnasts, morphological advantages of relatively younger male gymnasts might have influence on their participation on the highest levels of gymnastic Olympic competition – participation in apparatus finals. Accordingly, the confirmation of the "opposite" RAE was obtained in the sample of male AF, while RAE failed to be confirmed among and between other samples of examinees.

Structural complexity of artistic gymnastics and longevity of training

processes are probably key factors for reducing negative selection effects due to unpredictable maturation of any other uncontrollable cause.

However, further research is recommended to determine RAE effect between analyzed Olympics, grouped according to time of minimum age requirement changes, with goal to obtain more precise information about RAE in elite artistic gymnastics.

REFERENCES

Albuquerque, M., Costa, V.T., Faria, L.O., Lopes, M.C., Lage, G.M., Sledziewski, D., Szmuchrowski, L.A., & Franchini, E. (2014). Weight categories do not prevent athletes from Relative Age Effect: An analysis of Olympic Games wrestlers. *Archives of Budo*, *10*, 127–132.

Albuquerque, M., Lage, G.M., Costa, V.T., Ferreira, R.M., Penna, E.M., Moraes, L. C. A., Malloy-Diniz, L.F. (2012). Relative age effect in Olympic taekwondo athletes. *Perceptual & Motor Skills*, *114*(2), 1–8. doi:10.2466/05.25.PMS.114.2.461-468

Albuquerque, M.R., Franchini, E., Lage, G.M., da Costa, V.T., Costa, I.T., & Malloy, L.F. (2015). The relative age effect in combat sports: an analysis of Olympic judo athletes, 1964-2012. Perceptual & Motor Skill, *121*(1), 1-9. doi:10.2466/10.PMS.121c15x2

Albuquerque, M.R., Tavares, V., Lage, G.M., De Paula, J.J., Costa, I.T., & Malloy-Diniz, L.F. (2013). Relative age effect in Olympic judo athletes: a weight category analysis. *Science & Sports*, *28*(3), 59-61. doi:10.1016/j.scispo.2012.09.004

Anderson, S.E., Dallal, G.E., & Must, S.M. (2003). Relative weight and race influence aver age age at menarche: Results from two nationally representative surveys of US girls studied 25 years apart. *Pediatrics*, *111*, 844-850.

Arkaev, L., & Suchilin, N.G. (2004). *Gymnastics: how to create champions*. Oxford: Meyer & Meyer Verlag.

Baker, J., Janning, C., Wong, H., Cobley, S., & Schorer, J. (2014). Variations in relative age effects in individual sports: skiing, figure skating and gymnastics. *European Journal of Sport Science*, *14*(1), 183-190. doi:10.1080/17461391.2012.671369.

Baker, J., Schorer, J., Cobley, S., Bräutigam, H., & Büsch, D. (2009). Gender, depth of competition and relative age effects in team sports. *Asian Journal of Sport & Exercise Science*, *6*, 7-13.

Barker-Ruchti, N. (2009). Ballerinas and pixies: A genealogy of the changing female gymnastics body. *The International Journal of the History of Sport, 26*(1), 45-62. doi:10.1080/09523360802500089

Barnsley, R.H., Thompson, A.H., & Barnsley, P.E. (1985). Hockey success and birthdate: The relative age effect. *Canadian Association of Health, Physical Education and Recreation (CAHPER) Journal*, *51*, 23-28.

Baxter-Jones, D. (1995). Growth and development of young athletes. Should competition levels be age related? *Sports Medicine, 20*, 59–64.

Brazo-Sayavera, J., Martínez-Valencia, M.A., Müller, L., Andronikos, G., & Martindale, R.J.J. (2017). Identifying talented track and field athletes: The impact of relative age effect on selection to the Spanish National Athletics Federation training camps. *Journal of Sports Sciences, 35(22), 2172-2178.* oi:10.1080/02640414.2016.1260151

Caine, D., Bass, S.L., & Daly, R. (2003). Does elite competition inhibit growth and delay maturation in some gymnasts? Quite possibly. *Pediatric Exercise Science, 15*(4), 360-372. doi:10.1123/pes.15.4.360

Caine, D., Lewis, R., O'Connor, P., Howe, W., & Bass, S. (2001). Does gymnastics training inhibit growth of females? *Clinical Journal of Sport Medicine, 11*(4), 260-270. doi:10.1097/00042752-200110000-00009

Cassas, K.J., & Cassettari-Wayhs, A. (2006). Childhood and adolescent sports-related overuse injuries. *American Family Physician, 73*(6), 1014-1022. Retrieved from

http://www.aafp.org/afp/2006/0315/p1014.html

Claessens, A.L., & Lefevre, J. (1998). Morphological and Performance Characteristics as Drop-out Indicators in Female Gymnasts. *The Journal of Sports Medicine and Physical Fitness, 38*(4), 305-309. doi:10.1007/s40279-013-0058-5

Claessens, A.L., Lefevre, J., Beunen, G.P., & Malina, R.M. (2006). Maturity-associated variation in the body size and proportions of elite female gymnasts 14-17 years of age. *European Journal of Pediatrics, 165*(3), 186-192. doi:10.1007/s00431-005-0017-8

Cobley, S., Baker, J., Wattie, N., & McKenna, J. (2009). Annual age-grouping and athlete development: a meta-analytical review of relative age effects in sport. *Sports Medicine, 39*(3), 235–256. doi:10.2165/00007256-200939030-00005

Cohen, R.L. (2013). Femininity, Childhood and the Non-Making of a Sporting Celebrity: The Beth Tweddle Case. *Sociological Research Online, 18*(3). doi:10.5153/sro.3193. Retrieved from http://openaccess.city.ac.uk/3120/3/Cohen%2C%20Rachel%202013%20Femininity%2C%20Childhood%20%26%20the%20Non-Making%20of%20a%20Sporting%20Celebrity.pdf

Côté, J., & Fraser-Thomas, J. (2008). Play, practice, and athlete development. In D. Farrow, J. Baker, & C. MacMahon (Eds.), Developing elite sport performance: Lessons from theory and practice (pp. 17-28). New York, NY: Routledge.

Côté, J., & Gilbert, W. (2009). An Integrative Definition of Coaching Effectiveness and Expertise. *International Journal of Sports Science & Coaching, 4*(3), 307-323. Retrieved from: https://www.teachingandlearning.ie/wp-content/uploads/2015/02/An-Integrative-Definition-of-Coaching-Effectiveness-and-Expertise-Cote-Gilbert-2009.pdf

Côté, J., Macdonald, D.J., Baker, J., & Albernethy, B. (2006). When ''where'' is more important than ''when'': birthplace and birthdate effects on the achievement of sporting expertise. *Journal of Sports*

Sciences, 24(10), 1065-1073. doi:10.1080/02640410500432490

Dallas, G., Zacharogiannis, E., & Paradisis, G. (2013). Physiological profile of elite Greek gymnasts. *Journal of Physical Education and Sport, 13*(1), 27-32. doi:10.7752/jpes.2013.01005

Daly, R.M., Bass, S.L., & Finch, C.F. (2001). Balancing the risk of injury to gymnasts: how effective are the counter measures? *British Journal of Sports Medicine, 35*(1), 8-19. doi:10.1136/Bjsm.35.1.8

Delaš Kalinski, S., Atiković, A., & Jelaska, I. (2018). Gender differences in consecutive participation in artistic gymnastics at the Olympic Games from 1996 to 2016. *Science of Gymnastics Journal, 10*(1), 51-67. Retrieved from: https://www.fsp.uni-lj.si/mma/-/20180228215327/

Delaš Kalinski, S., Jelaska, I., & Knežević, N. (2017). Age effects among elite male gymnasts. *Acta Kinesiologica, 11*(2), 84-89.

Delorme, N., Boiche, J., & Raspaud, M. (2010). Relative age effect in elite sports: methodological bias or real discrimination? *European Journal of Sport Science, 10*(2), 91-96. doi: 10.1080/17461390903271584

Delorme, N., Chalabaev, A., & Raspaud, M. (2011). Relative age is associated with sport dropout: evidence from youth categories of French basketball. *Scandinavian Journal of Medicine & Science in Sports, 21*(1), 120-128. doi:10.1111/j.1600-0838.2009.01060.x.

Dresler, C.M. (1997). Physical and emotional problems of elite female gymnasts. *New England Journal of Medicine, 336*(2), 140-140. doi:10.1056/NEJM199701093360216

Eagleman, A.N., Rodenberg, R.M., & Lee, S. (2014). From 'hollow-eyed pixies' to 'team of adults': Media portrayals of Olympic women's gymnastics before and after an increased minimum age policy. *Qualitative Research in Sport, Exercise and Health, 6*(3), 401-421. doi:10.1080/2159676X.2013.877961

Edgar, S., & O'Donoghue, P. (2005). Season of birth distribution of elite tennis players. *Journal of Sports Sciences*, *23*(10), 1013-1020. doi:10.1080/02640410400021468

Ericsson, K.A. (2007). Deliberate practice and the modifiability of body and mind: toward a science of the structure and acquisition of expert and elite performance. *International Journal of Sport Psychology, 38*(1), 4-34. Retrieved from http://drjj5hc4fteph.cloudfront.net/Articles/2007%20IJSP%20-%20Ericsson%20-%20Deliberate%20Practice%20target%20art.pdf

Ericsson, K.A. (2008). Deliberate Practice and Acquisition of Expert Performance: A General Overview. *Academic Emergency Medicine, 15*(11), 988-994. doi:10.1111/j.1553-2712.2008.00227.x

Georgopoulos, N.A., Markou, K.B., Theodoropoulou, A., Benardot, D., Leglise, M., & Vagenakis, A.G. (2002). Growth retardation in artistic compared with rhythmic elite female gymnasts. *Journal of Clinical Endocrinology & Metabolism, 87*(7), 3169-3173. doi:10.1210/jcem.87.7.8640

Grondin, S., Deschaies, P., & Nault, L.P. (1984). Trimester of birth and school output. *Apprentissage Social*, *16*, 169–174. doi:10.1234/12345678

Hancock, D.J., Seal, K., Young, B.W., Weir, P.L., & Ste-Marie, D.M. (2013). Examining mechanisms that contribute to relative age effects in pre-pubescent female ice hockey 2 players. *Talent Development & Excellence*, *5*, 59-66.

Hancock, D.J., Starkes, J.L., & Ste-Marie, D.M. (2015). The relative age effect in female gymnastics: A flip-flop phenomenon. *International Journal of Sport Psychology*, *46*, 714-725. doi:10.7352/IJSP.2015.46.714

https://www.gymnasticsresults.com (Accessed from the 2nd of September to the 18th of October 2016.).

https://www.olympic.org/gymnastics-artistic (Accessed June 7th 2017).

Jelaska, I., Delaš Kalinski, S., & Crnjak, T. (2017). Chronological age among olympic women's artistic gymnastics. Does it really matter? *Acta Kinesiologica*, *11*(2), 108-116.

Kerr, G., Berman, E., & De Souza, M.J. (2006). Disordered eating in women's gymnastics: Perspectives of athletes, coaches, parents, and judges. *Journal of Applied Sport Psychology, 18*(1), 28-43. doi:10.1080/10413200500471301

Kerr, R., Barker-Ruchti, N., Schubring, A., Cervin, G., & Nunomura, M. (2015). *Coming of age: Towards best practice in women's artistic gymnastics*. Canterbury: Lincoln University. Retrieved from https://researcharchive.lincoln.ac.nz/bitstream/handle/10182/6515/Leap%2037-Coming-of-age.pdf;jsessionid=2BF5B101236CE59B27C31B5FED480534?sequence=3

Kirkendall, D.T. (2014). The relative age effect has no influence on match outcome in youth soccer. *Journal of Sport and Health Science*, *3*(4), 273–278. doi:10.1016/j.jshs.2014.07.001

Lindholm, C., Hagenfeldt, K., & Hagman, U. (1995). A Nutrition Study in Juvenile Elite Gymnasts. *Acta Paediatrica, 84*(3), 273-277. doi:10.1111/j.1651-2227.1995.tb13628.x

Malina, R.M. (1994). Longitudinal Observations on Physical Growth and TW2 Skeletal Maturation of Girls in Tokyo - Radiographic Atlas of Hand and Wrist - Eto, M, Ashizawa, K. *American Journal of Human Biology, 6*(3), 408-408. doi:10.1002/ajhb.1310060318

Malina, R.M. (2014). Top 10 Research Questions Related to Growth and Maturation of Relevance to Physical Activity, Performance, and Fitness. *Research Quarterly for Exercise and Sport, 85*(2), 157-173. doi:10.1080/02701367.2014.897592

Malina, R.M., Baxter-Jones, A.D.G., Armstrong, N., Beunen, G.P., Caine, D., Daly, R.M., . . . Russell, K. (2013). Role of Intensive Training in the Growth and Maturation of Artistic Gymnasts. *Sports*

Medicine, 43(9), 783-802. doi:10.1007/s40279-013-0058-5

Malina, R.M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity*. United States: Human Kinetics.

Martindale, R.J.J., Collins, D., & Abraham, A. (2007). Effective Talent Development: The Elite Coach Perspective in UK Sport. *Journal of Applied Sport Psychology, 19*(2), 187-206. doi:10.1080/10413200701188944

Martinsen, M., Bratland-Sanda, S., Eriksson, A.K., & Sundgot-Borgen, J. (2010). Dieting to win or to be thin? A study of dieting and disordered eating among adolescent elite athletes and non-athlete controls. *British Journal of Sports Medicine, 44*(1), 70-76. doi:10.1136/bjsm.2009.068668

Medic, N., Starkes, J.L., Weir, P.L., Young, B.W., & Grove, J.R. (2009). Relative age effect in masters sports: replication and extension. *Research Quarterly for Exercise and Sport, 80*(3), 669-675. doi:10.1080/02701367.2009.10599607

Monsma, E.V., & Malina, R.M. (2005). Anthropometry and somatotype of competitive female figure skaters 11-22 years. Variation by competitive level and discipline. *The Journal of Sports Medicine and Physical Fitness, 45*, 491-500.

Musch, J., & Grondin, S. (2001). Unequal competition as an impediment to personal development: A review of the relative age effect in sport. *Developmental Review, 21*, 147-167. doi:10.1006/drev.2000.0516

Raschner, C., Müller, L., Hildebrandt, C. (2012). The role of a relative age effect in the first winter Youth Olympic Games in 2012. *British Journal of Sports Medicine, 46*, 1038–1043. doi:10.1136/bjsports-2012-091535

Ryan, J. (1995). Pretty girls in little boxes: The making and breaking of elite gymnasts and figure skaters. New York: Doubleday.

Schorer, J., Cobley, S., Büsch, D., Braütigam, H., & Baker, J. (2009). Influences of competition level, gender, player nationality, career stage and playing position on relative age effects. *Scandinavian Journal of Medicine & Science in Sports, 19*(5), 720-730. doi:10.1111/j.1600-0838.2008.00838.x.

Sedano, S., Vaeyens, R., Redondo, J.C. (2015). The relative age effect in Spanish female soccer players. Influence of the competitive level and a playing position. *Journal of Human Kinetics, 46*, 129–137. doi:10.1515/hukin-2015-0041

Starkes, J.L. (2000). The road to expertise: Is practice the only determinant? *International Journal of Sport Psychology, 31*(4), 431-451.

Till, K., Cobley, S., O'Hara, J., Brightmore, A., Cooke, C., & Chapman, C. (2011). Using 9 anthropometric and performance characteristics to predict selection in junior UK Rugby 10 League players. *Journal of Science and Medicine in Sport, 14*, 264-269. doi:11 http://dx.doi.org/10.1016/j.jsams.2011.01.006

Tofler, I.R., Stryer, B.K., Micheli, L.J., & Herman, L.R. (1996). Physical and emotional problems of elite female gymnasts. *New England Journal of Medicine, 335*(4), 281-283. doi:10.1056/Nejm199607253350412

Van Rossum, J.H.A. (2006). Relative age revisited: Findings from the dance domain. *Perceptual and Motor Skills, 102*, 302-308.

Wattie, N., Tietjens, M., Cobley, S., Schorer, J., Baker, J., & Kurz, D. (2014). Relative age-related participation and dropout trends in German youth sports clubs. *European Journal of Sport Science, 14*(1), 213-220. doi:10.1080/17461391.2012.681806

Weber, J., & Barker-Ruchti, N. (2012). Bending, flirting, floating, flying: A critical analysis of female figures in 1970s gymnastics photographs. *Sociology of sport journal, 29*(1), 22-41. doi:10.1123/ssj.29.1.22

Weir, P.L., Smith, K.L., Paterson, C., & Horton, S. (2010). Canadian women's ice hockey— 22 evidence of a relative age

effect. *Talent Development & Excellence*, *2*, 209-217.

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