THE EVOLUTION OF REAL DIFFICULTY VALUE OF UNEVEN BARS ROUTINES FROM ELITE GYMNASTS IN LAST 5 OLYMPIC CYCLES

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Original research article

Abstract

Purpose of the present study was to characterize and analyse the evolution of real difficulty value of full routines, parts and specific kind of elements of Uneven Bars. Besides the full routine difficulty were analyzed the mount, dismount, flight elements, first and second half routines, bars changes, elements executed on low and high bar, number of elements of value D and higher, "in bar elements" and special connections. In total, 104 routines from world championships and Olympic Games finals of uneven bars were analysed between 1989 and 2008. As main results was observed significant increases in all studied variables. Real difficulty value of complete routines ranged from 3.15 to 5.80 points between first and last Olympic cycles analyzed. Special evolution of difficulty values was observed in number of elements D, E and F (from 2.80 to 8.05), total number of bonus connections (from 0.40 to 4.19) and in "in bar" elements (0.25 to 1.57). Based on results we may conclude that uneven bars routines suffered a significant evolution in difficulty and, in some specific kind of elements, just with last changes in Code of Points was possible to confirm the announced increases in quantity and difficulty such as the flight elements.

Keywords: *women artistic gymnastics, Uneven Bars, Difficulty.*

INTRODUCTION

Artistic Gymnastics (AG) is one of the most popular Olympic sports which practice is generally characterized as highly difficult and complex. Several authors carried out studies claiming the increase of the difficulty or complexity of routines and elements performed by high level gymnasts (Arkaev & Suchilin, 2004; Caine, DiFiori & Maffulli, 2006; Hadjiev, 1991; Hofmann, 1999; Irwin, Hanton & Kerwin, 2005; James, 1987; Jemni, Friemel & Delamarche, 2002; Radoulov, 1986; Sands, Caine & Borms, 2003; Smolevsky & Gaverdovsky, 1996; Takei, Nohara & Kaminura, 1992), or the great acrobatic development that AG suffered in recent years (Daly, Bass & Finch, 2001; Hofmann, 1999; Kaneko, 1986; Smolevsky & Gaverdovsky, 1996). However, the training load in AG has been rarely defined and quantified or systematically reported (Caine, Bass & Daly, 2003; Claessens, Lefevre, Beunen & Malina, 2006). Jemni et. al (2003) state that the existence of many studies in morphological, behavioral and biomechanical areas contrasts with the little information related with internal or physiological parameters of training load in gymnastics.

An exception are some reports from International Federation of Gymnastics (FIG) performed after each world cup and Olympic Games (FIG, 1994, 1997, 1999, 2000), which address some important aspects and consider the quantities and trends of some parameters of the routines composition in all apparatus but don't report to all factors of the external load which competition routines represent.

In order to determine the direction of the preparation for which should train the young gymnasts who start their practice today, it is important to know, with enough detail the current characteristics of the performances from the elite gymnasts, relating to its full competition routines, but also regarding specific parts or elements.

Since children and young gymnasts that start today their preparation should only reach its maximal performances within 6 to 9 years (Arkaev & Suchilin, 2004; Hofmann, 1999; Smolevsky, 1978; Touricheva, 1986), the references for their preparation should not be limited to the characteristics of the current elite athletes, being necessary to predict and characterize the requirements of the load for which they should prepare, through an analysis of development trends of Gymnastics in general and the load of the competition routines in particular.

In AG, the volume of the load is typically described as the number of elements or routines performed (Arkaev & Suchilin, 2004; Sands, 1999; Ukran, 1978). For the same authors intensity means the difficulty of the elements performed or the number of elements performed per unit of time. The concepts of difficulty and complexity of gymnastics exercises are close but not identical (Arkaev & Suchilin, 2004). For the authors, the complexity of AG routines has grown in structural and parametric directions, with three parameters which cover most of the increases in the complexity of the Gymnastics elements. They distinguish the number of rotations around transverse and longitudinal axis and the body position of (tucked, picked, stretched and stretched with high arms). According Ukran (1978) the inclusion of longitudinal rotation in the elements is the most used way to make it more difficult

In competition, the references of difficulty presented by gymnasts in their competition routines are limited to regulatory, i.e., counting only the elements of difficulty required (in earlier versions of CP) or the 8 more valuable excluding for effect the repeated elements. Whereas all performed elements, counting or not to the final score of the gymnast, means external load, with a corresponding internal load, we propose in the present study the measurement of all load that the athletes are subject, by adding of all executed elements, multiplied by its coefficient of difficulty. We call to this indicator Real Difficulty Value.

In this context, the purpose of this study was to characterize the current status of the external load of Uneven Bars (UB) in Women's Artistic Gymnastics (WAG), searching some of its trends, based on analysis of the real difficulty value of their competition routines, through the observation of the finalists form World Championships and Olympic Games over the last five Olympic cycles.

METHODS

The studied sample comprised a group of world elite gymnasts in WAG. For that purpose, uneven bars routines from world championships and Olympic Games finals between 1989 and 2008 were analyzed. From a total of 120 finalists, 16 failed during their competition routine, which were excluded since they might have changed his routine for that reason, so were observed only 104 routines. The 15 competitions observed were framed in 5 Olympic cycles with 2 world championships and 1 Olympic Games each one.

Through observational methodology, an observation category was constructed and validated, comprising fifteen indicators or variables:

1. real difficulty value of the routine,
2. difficulty of mount,
3. difficulty of dismount,
4. difficulty of flight elements,
5. difficulty of changes from high bar to low bar,
6. difficulty of changes from low bar to high bar,
7. difficulty of elements performed on low bar,
8. difficulty of elements performed on high bar,
9. difficulty of elements performed on 1ª middle of the routine,
10. difficulty of elements performed on 2ª middle of the routine,
11. difficulty of "in bar" elements,
12. total number of special combinations with bonus points,
13. number of combinations of 0.1 bonus points,
14. number of combinations of 0.2 bonus points,
15. number of elements of difficulty D, E and F.

For the registration of the difficulty presented in each of the above described variables, was considered all performed elements, regardless the regulatory issues or repeated elements. To determine the difficulty value of each element and combination was used the 2006 version of the CP (FIG, 2006).

The instrument validation was based on the authority judgement, through the overhaul of WAG experts, which were framed in three categories, coaches, judges and academics or researchers. For each category two individuals were selected.

To assess the internal validity, a first observation of 25 routines (5 of each studied cycle by random selection in 3 different moments) was performed. In the first two moments of the evaluation (A and B) the leading researcher performed the observations with a month of interval. A third moment of evaluation (C) was performed by a team of 5 experts (international judges of AG) previously trained.

The intra and inter-observer agreement was calculated through the Spearman correlation coefficient. To assess the intra-observer agreement the encodings performed in the first 2 moments (A-B) were compared, a total of 25 routines, and the inter-observer agreement was assessed by comparisons between the first and second codifications with the third moment, separately (A-C and B-C).

From the 165 correlations analyzed (11 comparisons x 15 variables) we found that for 13 studied variables, the correlation coefficient was equal to 1.00 (p=0.000) for all comparisons made (inter and intra-observer), ie, a perfect correlation showing full agreement between observations. For the remaining 2 variables (Difficulty of elements performed on 1ª and 2ª middles of the routine) were found 6 events with correlations values not equal to 1.00 but shows very high correlations ($0.895 \leq r_s \leq 0.975$), probably due to the different criteria to divide the elements in the 1º and 2º half routines by the observers. These results are highly satisfactory, showing a high correlation and agreement, both inter and intra-observer.

Data was analyzed with descriptive statistics (median and range, being also observed mean and standard deviation) and Kruskal Wallis (k-w) test was used to compare the values found over the five cycles studied with a significance level of 5% ($p \leq 0.05$). In order to analyse differences between cycles was used Mann-Whitney test with the *Bonferroni* correction, for a value of $p \leq 0.0125$.

RESULTS

Table 1. *Kruskal Wallis (k-w) test results for the indicators related to difficulty of Routines and Parts, in the five Olympic cycles considered (* p ≤ 0.05).*

		Cycle				
		1º	2º	3º	4º	5º
Indicator	Statistics	1989-1992	1993-1996	1997-2000	2001-2004	2005-2008
Real Difficulty of Routine	Mean ± sd	3.15 ±0.55	3.88 ± 0.56	4.25 ± 0.57	4.63 ± 0.57	5.80 ± 0.83
	Median/Range	3.00/2.00	3.90/2.40	4.20/2.20	4.60/2.10	6.00/2.70
	k-w	X^2 = 67.979		p = **0.000 ***		
Mount Difficulty	Mean ± sd	0.12 ± 0.05	0.13 ± 0.07	0.16 ± 0.05	0.16 ± 0.08	0.18 ± 0.10
	Median/Range	0.10/0.20	0.10/0.30	0.20/0.10	0.15/0.30	0.20/0.30
	k-w	X^2 = 15.558		p = **0.004 ***		
Dismount Difficulty	Mean ± sd	0.30 ± 0.10	0.41 ± 0.04	0.40 ± 0.02	0.41 ± 0.05	0.41 ± 0.03
	Median/Range	0.30/0.20	0.40/0.20	0.40/0.10	0.40/0.20	0.40/0.10
	k-w	X^2 = 40.806		p = **0.000 ***		
Flight Elements Difficulty	Mean ± sd	0.76 ± 0.31	0.76 ± 0.32	0.73 ± 0.27	0.68 ± 0.31	1.06 ± 0.40
	Median/Range	0.80/1.00	0.80/0.80	0.80/0.90	0.65/0.80	0.90/1.50
	k-w	X^2 = 14.018		p = **0.007 ***		
Changes Low to High Bar Difficulty	Mean ± sd	0.23 ± 0.14	0.35 ± 0.18	0.41 ± 0.12	0.43 ± 0.12	0.55 ± 0.23
	Median/Range	0.20/0.40	0.30/0.70	0.40/0.40	0.40/0.40	0.50/0.70
	k-w	X^2 = 28.263		p = **0.000 ***		
Changes High to Low Bar Difficulty	Mean ± sd	0.21 ± 0.13	0.27 ± 0.20	0.35 ± 0.09	0.39 ± 0.05	0.50 ± 0.17
	Median/Range	0.20/0.40	0.20/0.80	0.40/0.20	0.40/0.20	0.40/0.40
	k-w	X^2 = 43.693		p = **0.000 ***		
Low Bar Elements Difficulty	Mean ± sd	0.50 ± 0.37	0.62 ± 0.43	0.70 ± 0.28	0.83 ± 0.35	1.00 ± 0.39
	Median/Range	0.50/1.20	0.70/1.50	0.70/0.80	0.80/1.20	1.10/1.30
	k-w	X^2 = 19.721		p = **0.001 ***		
High Bar Elements Difficulty	Mean ± sd	2.65 ± 0.49	3.26 ± 0.44	3.39 ± 0.80	3.80 ± 0.68	4.80 ± 0.91
	Median/Range	2.50/1.70	3.30/2.30	3.35/4.10	3.85/2.20	4.80/3.10
	k-w	X^2 = 57.891		p = **0.000 ***		
1º Middle Routine Difficulty	Mean ± sd	1.57 ± 0.25	1.93 ± 0.34	2.19 ± 0.31	2.38 ± 0.33	2.98 ± 0.56
	Median/Range	1.55/1.00	1.85/1.20	2.30/1.25	2.30/1.10	2.75/1.85
	k-w	X^2 = 65.274		p = **0.000 ***		
2º Middle Routine Difficulty	Mean ± sd	1.58 ± 0.35	1.95 ± 0.28	2.10 ± 0.31	2.26 ± 0.30	2.82 ± 0.41
	Median/Range	1.55/1.40	1.90/1.40	2.10/1.15	2.27/1.15	2.80/1.50
	k-w	X^2 = 60.974		p = **0.000 ***		
"in bar" Elements Difficulty	Mean ± sd	0.25 ± 0.31	0.41 ± 0.46	0.48 ± 0.38	1.06 ± 0.66	1.57 ± 0.65
	Median/Range	0.15/1.00	0.30/1.50	0.30/1.20	1.25/1.80	1.70/2.00
	k-w	X^2 = 46.787		p = **0.000 ***		
Total Number of Connections	Mean ± sd	0.40 ± 0.94	0.70 ± 0.93	1.54 ± 0.88	2.00 ± 0.73	4.19 ± 1.17
	Median/Range	0.00/3.00	0.00/3.00	1.00/3.00	2.00/2.00	4.00/4.00

	k-w	X^2 = 66.103		p = **0.000 ***		
Number of 0.1 Connections	Mean ± sd	0.25 ± 0.64	0.30 ± 0.56	1.33 ± 0.96	1.37 ± 0.96	2.43 ± 1.25
	Median/Range	0.00/2.00	0.00/2.00	1.00/3.00	1.00/3.00	2.00/5.00
	k-w	X^2 = 49.650		p = **0.000 ***		
Number of 0.2 Connections	Mean ± sd	0.15 ± 0.37	0.39 ± 0.72	0.21 ± 0.42	0.63 ± 0.50	1.76 ± 1.09
	Median/Range	0.00/1.00	0.00/2.00	0.00/1.00	1.00/1.00	1.00/4.00
	k-w	X^2 = 45.139		p = **0.000 ***		
Number of Elements D-E-F	Mean ± sd	2.80 ± 1.40	3.87 ± 1.06	4.83 ± 1.01	5.81 ± 0.83	8.05 ± 1.43
	Median/Range	3.00/5.00	4.00/4.00	5.00/4.00	6.00/3.00	8.00/5.00
	k-w	X^2 = 70.915		p = **0.000 ***		

The observation of the results presented in Table 1 shows statistically significant differences in all analyzed variables, with an evolution of the average values of the real difficulty of the routines from 3.15 to 5.80 points between the first and last studied cycle (p = 0.000).

Despite the significant differences found for all variables, it is possible to distinguish a group with relatively low amplitudes of their values from other one, whose differences showed high absolute values. In the first group are the difficulty of mount, dismount, flight elements, both types of bar changes and the elements performed in low bar, all with variations not exceeding 0.50 points of difference between the first and last cycle. In the second are those indicators related to the increase in the number of elements in general, and the number of elements of high coefficient of difficulty or special combinations between them.

Table 2. *Mann-Whitney test results for the indicators related to difficulty of Routines and Parts, in the fourth considered cycle changes (* p ≤ 0.0125).*

Indicator	Mann-Whitney	Cycle change			
		1º - 2º	2º- 3º	3º- 4º	4º- 5º
Real Difficulty of Routine	Z	-3.604	-2.111	-1.909	-3.928
	p	**0.000 ***	0.035	0.056	**0.000***
Mount Difficulty	Z	-0.987	-2.589	-0.523	-0.356
	p	0.324	**0.010 ***	0.601	0.722
Dismount Difficulty	Z	-4.063	-0.061	-0.329	-0.291
	p	**0.000 ***	0.951	0.742	0.771
Flight Elements Difficulty	Z	-0.052	-0.316	-0.426	-2.894
	p	0.959	0.752	0.670	**0.004***
Changes Low to High Bar Difficulty	Z	-2.400	-1.418	-0.328	-1.809
	p	0.016	0.156	0.743	0.070
Changes High to Low Bar Difficulty	Z	-0.685	-2.694	-1.728	-2.299
	p	0.494	**0.007 ***	0.084	0.022
Low Bar Elements Difficulty	Z	-1.131	-1.414	-1.030	-1.424
	p	0.258	0.157	0.303	0.154
High Bar Elements Difficulty	Z	-3.724	-1.230	-1.536	-3.040

	p	**0.000 ***	0.219	0.124	**0.002***
1º Middle Routine Difficulty	Z	-3.401	-2.700	-1.415	-3.363
	p	**0.001 ***	**0.007 ***	0.157	**0.001***
2º Middle Routine Difficulty	Z	-3.608	-1.686	-1.554	-3.613
	p	**0.000 ***	0.092	0.120	**0.000***
“in bar” Elements Difficulty	Z	-1.090	-1.115	-2.678	-2.183
	p	0.276	0.265	**0.007 ***	0.029
Total Number of Connections	Z	-1.468	-3.060	-1.700	-4.636
	p	0.142	**0.002 ***	0.089	**0.000***
Number of 0.1 Connections	Z	-0.721	-3.988	-0.120	-2.684
	p	0.471	**0.000 ***	0.904	**0.000***
Number of 0.2 Connections	Z	-1.030	-0.634	-2.633	-3.527
	p	0.303	**0.000 ***	**0.008 ***	**0.000***
Number of Elements D-E-F	Z	-2.632	-2.959	-2.995	-4.098
	p	**0.008 ***	**0.003 ***	**0.003 ***	**0.000***

From Table 2 it is possible to establish more precisely some of the observed differences. While the evolution of the real difficulty of the routine was significantly (*$p \leq 0.01$) from 1º to 2º and from 4º to 5º cycle changes, the mount, dismount, flight elements, changes from high bar to low bar and the “in bar” elements only showed significant differences in a single cycle change. Other indicators related to the number of high difficulty elements and combinations between them, showed a progressive evolution, with several significant changes over the cycles.

DISCUSSION

Although the results presented denote a general evolution of the difficulty level of competition routines in UB, it is important more detailed analysis, trying to identify the most influential parameters in this development and explain or interpret the possible reasons for some changes.

First, the development of the real difficulty of full routines is associated with the increase in the number of elements performed, which evolved from 14.55 elements in the first cycle to 22.66 in the last one (Ferreirinha, 2007), thus about 8 more elements for the difficulty account. Moreover, as the results show, the number of elements of high coefficient of difficulty (D, E and F) also presented a remarkable evolution.

Other studies may help to explain the dramatic evolution of difficulty observed. In a previous study (Ferreirinha, Silva & Marques, 2008b), was observed a significant increase in the number of rotations and the number of elements with the longitudinal rotation, which evolved from 3.35 to 8.05 and from 2.35 to 4.95, respectively, in the same period here observed. In accordance with the opinion of several authors who attribute to the longitudinal rotations an important role in the increase of the complexity and difficulty of elements, we believe that the enhanced of longitudinal rotations has a strong contribution to the increased difficulty of the routines. In another study (Ferreirinha, Silva & Marques, 2008a), was found that the number of "in bar" elements grew up between these same cycles, from 0.80 to 4.48 elements, which performed with longitudinal rotation or flight, allow the presentation of different elements and increased difficulty

The results for the difficulty of dismount are clear and indicate that the gymnasts only changed from a dismount of difficulty "C" to "D", established just in the transition between the first and second cycle, coinciding with the new requirement from CP of 1993 (FIG, 1993) and suggesting a simple adjustment to regulatory requirements.

The difficulty of the flight elements, whose evolution showed a slight increase of 0.30 points between the first and last cycle analysis, remained without any significant changes until the last cycle, contrary to trends envisaged by several authors (Arkaev & Suchilin, 2004; Smolevsky & Gaverdovsky, 1996; Touricheva, 1986) for an evolution of this type of element, in quantity and difficulty. Only with the introduction of new rules that expanded the possibility of the gymnasts had higher number of difficulties (FIG, 2006), which ended with the mark of “10 points” for the final score of the athletes, was possible to observe a significant increase in the difficulty of this category of analysis.

The changes of bars evolved gradually, with small alterations, being a concern announced by the technical committee of the FIG (FIG, 1994, 1997) the absence of difficulty in this type of element.

Another kind of element that reflects the dependency of the structure of the routines from the CP, and the abuse in their excessive use are the "in bar" elements. First, because only after the CP of 2001 (FIG, 2001), requiring the inclusion of an element of this type of difficulty minimum "C", there was a significant increase, and second because after that date the athletes started to use it much more than the requirements of CP, through the introduction of longitudinal rotation, flight or executing with legs together or apart (Ferreirinha et al., 2008a).

The difficulty presented by the gymnasts in the different bars followed the general trend of difficulty of the routine, showing a preference for the execution of most elements of difficulty in the high bar. This is understandable by the greater freedom and consequently a bigger amplitude of the elements allowed by the high bar, but also by the type of elements performed progressively more close to those presented by male gymnasts in High Bar (Arkaev & Suchilin, 2004; Cimnaghi & Marzolla, 1988; FIG, 1994, 1997; Smolevsky & Gaverdovsky, 1996; Witten & Witten, 1991).

Finally, through the analysis of the difficulty in the 1st and 2nd middle of the routine we wanted to observe a possible preference for the execution of the higher difficulty in the 1st middle, due the advantage of greater energy availability, but the results showed that gymnasts equally divide its difficulty value on both half’s routines.

CONCLUSIONS

Based on the results we can conclude that the Uneven Bars routines suffered significant increases in its difficulty value. If some indicators have evolved gradually as a result of natural and continuous increase of more difficult elements, others just increased the value of difficulty at specific times, usually associated with changes of CP. The latest update of CP dictated a significant evolution of difficulty for many indicators observed and in some specific kind of elements, only at this time it was possible to confirm the changes announced by many authors, in quantity and difficulty, as the case of the flight elements.

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