THE EVOLUTION OF FLIGHT ELEMENTS IN COMPETITIVE UNEVEN BARS ROUTINES

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Abstract

The purpose of this study was to evaluate and characterize external load trends related to flight elements in elite level uneven bars routines, based on analyses from 83 uneven bars routines from the world championships and the Olympic Games finals between 1989 and 2004. An observation category was constructed and validated, comprising eleven variables: number, difficulty, direct combinations of 2 and 3 flight elements, execution with straight or closed body configuration, preparatory elements, direction outwards or inwards to the low bar, and execution on the 1st or 2nd phase of the routine. Results showed a significant decrease in the number of preparatory elements, and the number of flight elements outwards from low bar and inwards to low bar significantly changed. With regards to the other observed variables we found no significant differences. Elite gymnasts usually perform 1 or 2 flight elements during uneven bars routines.. The difficulty of flight elements ranged from 1 to 2 D value flight elements in all cycles and gymnasts performed using predominantly closed body configurations. Based on the results it can be concluded that the number, direct combinations, and difficulty of the flight elements contradict what has been reported in the gymnastics literature, where a large increase of variables of external load in uneven bars routines was predicted.

Keywords: *artistic gymnastics, uneven bars, flight element, trends.*

INTRODUCTION

Literature in Artistic Gymnastics (AG) has frequently addressed evolution trends of difficulty or complexity of elements and routines performed by elite level gymnasts (Arkaev and Suchilin, 2004; Caine, DiFiori, and Maffulli, 2006; Irwin, Hanton, and Kerwin, 2005; Jemni, Friemel, and Delamarche, 2002; Sands, Caine, and Borms, 2003), as well as the increase in acrobatic elements that AG has experienced in recent years (Daly, Bass, and Finch, 2001; Hofmann, 1999; Smolevsky and Gaverdovsky, 1996). In the specific case of Uneven Bars (UB), considerations about evolution trends of number, difficulty, and special connections with flight elements in competition routines have been investigated (Arkaev and Suchilin, 2004; Smolevsky and Gaverdovsky, 1996; Touricheva, 1986).

However, few studies have used objective measures of AG routines to come to their conclusions. Some of the

International Federation of Gymnastics (FIG) analyses have been published after each world championship and Olympic Games, addressing important aspects of routine evolution. Based on the analysis of total participants in world championships and Olympic Games (Table 1), it is possible to observe that gymnasts performed more flight elements per routine in the last Olympics compared with previous ones (FIG, 1994, 1997b, 1999, 2000, 2001, 2003, 2004). However, these analyses lack the measurement of global load in competition routines.

Table 1. *Evolution of flight elements from "C" executed by total participants in some world championships and Olympic Games (FIG, 1994, 1997b, 1999, 2000, 2001, 2003, 2004).*

		Nº of flight elements from "C" executed						
		0	1	2	3	4	5	6
Year	N	Nº of gymnasts (percentage of total participants)						
1994	58	3 (5.2%)	13 (22.4%)	32 (55.2%)	7 (12.0%)	3 (5.2%)	-	-
1996	94	-	28 (29.8%)	42 (44.7%)	21 (22.3%)	3 (3.2%)	-	-
1997	133	9 (6.7%)	44 (33.1%)	63 (47.4%)	16 (12.0%)	1 (0.8%)	-	-
1999	225	25 (11.1%)	66 (29.3%)	94 (41.8%)	34 (15.1%)	6 (2.7%)	-	-
2000	84	1 (1.2%)	13 (15.5%)	45 (53.6%)	21 (25.0%)	3 (3.5%)	1 (1.2%)	-
2001	151	12 (7.9%)	22 (14.6%)	45 (29.8%)	43 (28.5%)	25 (16.5%)	3 (2.0%)	1 (0.7%)
2003	197	8 (4.1%)	19 (9.6%)	41 (20.8%)	88 (44.7%)	35 (17.8%)	5 (2.5%)	1 (0.5%)
2004	85	1 (1.2%)	1 (1.2%)	13 (15.3%)	29 (34.1%)	33 (38.8%)	6 (7.1%)	2 (2.4%)

The origin and evolution of different gymnastics elements are directly related to factors including body positions or postures, and the number of rotations (Arkaev and Suchilin, 2004; Liang and Tian, 2003). The gymnastics Code of Points (CP) states that the difficulty value of elements increases according to the number of rotations and/or body configurations during each execution. According to Arkaev and Suchilin (2004) the structural complexity of movements can also be increased through the execution of complex elements without prior acceleration, i.e. without preparatory elements.

World class gymnasts provide the best reference point for AG development status. In order to identify how AG has progressed competition routines from recent tournaments must be compared with routines from past years.

The purpose of this study therefore, was to evaluate and characterize external load trends in elite level uneven bars routines, specifically related to flight element parameters, based on the analyses extracted from world championships and Olympic Games finalists in four Olympic cycles between 1989 and 2004.

METHODS

The study sample comprised a group of world elite gymnasts in Women's Artistic Gymnastics (WAG). Uneven bars routines from world championships and Olympic Games finals between 1989 and 2004 were analyzed. From a total of 96 finalists, 13 failed during their competition routine, these were excluded since they might have changed their routine for that reason, leaving 83 routines for analyses. Participants were measured during 12 competitions including 4 Olympic cycles, 2 world championships, and 1 Olympic Games (Table 2).

Table 2. *World championships and Olympic Games observed.*

Cycle		World Championships		Olympic Games
1º	1989 - 1992	1989 (Stuttgart)	1991 (Indianapolis)	1992 (Barcelona)
2º	1993 - 1996	1993 (Birmingham)	1995 (Sabae)	1996 (Atlanta)
3º	1997 - 2000	1997 (Lausanne)	1999 (Tianjin)	2000 (Sydney)
4º	2001 - 2004	2001 (Ghent)	2003 (Anaheim)	2004 (Athens)

Through observational methodology, an observation category was constructed and validated, comprising eleven variables considered as indicators of external load during flight elements in uneven bars.

The flight elements observed are understood as those performed on the same bar in accordance with the CP (FIG, 2006), including the backwards giant circle with hop 1/1 turn (360º) in handstand phase, which was removed from this category after 1996.

To record the complexity and difficulty associated with the execution of flight elements, five variables were considered:

1 – Nº of flight elements;
2 – Total difficulty of flight elements performed;
3 – Nº of direct connections of 2 flight elements;
4 - Nº of direct connections of 3 flight elements;
5 – Nº of preparatory elements.

The execution of a simple giant swings (forward and backward) immediately before the flight element was regarded as a preparatory element and to classify the element's difficulty the values assigned by the CP of 2006 (FIG, 2006) were used.

For the observation of body positions in flight elements execution, four positions were considered, two regarding the position related to the low bar (facing inwards or outwards) and two concerning the body shape (closed or straight):

6 – Nº of flight elements facing inwards to low bar;

7 - Nº of flight elements facing outwards from low bar;

8 - Nº of flight elements with closed (straddle or piked) body configuration;

9 - Nº of flight elements with straight body configuration.

Finally, in order to observe the distribution of the flight elements by half routines the following variables were observed:

10 – Nº of flight elements executed on the 1º part of the routine;

11 - Nº of flight elements executed on the 2º part of the routine.

Instrument validation was based on the expert judgement of WAG coaches, judges, and academics or researchers. Two individuals from each field were selected.

To assess the internal validity, a first observation of 20 routines (5 from each studied cycle randomly selected from 3 different time periods) was performed. In the first two evaluations (A and B) the leading researcher performed the observations with a month interval. A third evaluation (C) was performed by a team of 4 experts (international judges of AG) previously trained.

The intra and inter-observer agreement was calculated using Spearman correlation coefficient. To assess the intra-observer agreement data from the first 2 observations (A-B) were compared (a total of 20 routines), and the inter-observer agreement was assessed by comparing data from the first two observations with the third observation separately (A-C and B-C).

From the 99 correlations analyzed (9 comparisons x 11 variables) we found that for 10 studied variables, the correlation coefficient was equal to 1.00 (p=0.000) for all comparisons made (inter and intra-observer), i.e. a perfect correlation showing full agreement between observations. For the remaining variable (Nº of flight elements with straight body configuration) 6 correlation values were slightly less than 1.00 but showed high correlations ($0.921 \leq r_s \leq 0.987$). These are positive results, showing good correlations for both inter and intra-observer agreement.

Descriptive statistics were calculated (Mean, standard deviation, median and range), and Kruskal Wallis (k-w) test was used to compare the values found over the four cycles studied with a significance level of 5% ($p \leq 0.05$). Wilcoxon test was used to analyze the significance of the differences observed between similar variables. Correlations between variables were analyzed using Spearman correlation coefficient, with a significance level of 5%. Only results with $r_s \geq 0.40$ were considered, which represent a moderate or high level of linear association.

RESULTS

Table 3 shows that the mean number of flight elements decreased slightly between the first and last cycles, from 1.85 to 1.63. No significant changes were observed in the other variables, except the number of preparatory elements ($p = 0.044$) and the positions related to the low bar ($p = 0.019$ and $p = 0.001$). Preparatory elements decreased to zero on last cycle, and the number of flight elements executed facing inwards to low bar increased from 0.45 in first cycle to 1.13 in last, while the flight elements performed facing outwards to low bar decreased from 1.40 to 0.50 over the same period.

Table 3. *Descriptive and Kruskal Wallis (k-w) test values to the analyzed variables, during the four studied cycles (* $p \leq 0.05$).*

Indicator	Statistics	Cycle 1989-1992	1993-1996	1997-2000	2001-2004
Nº of flight elements	Mean ± sd	1.85 ± 0.67	1.83 ± 0.78	1.79 ± 0.66	1.63 ± 0.72
	Median / Range	2.00 / 2	2.00 / 2	2.00 / 2	1.50 / 2
	k-w	$X^2 = 1.199$		p = 0.753	
Nº of direct combinations of 2 flight elements	Mean ± sd	0.15 ± 0.37	0.26 ± 0.62	0.08 ± 0.28	0.19 ± 0.40
	Median / Range	0.00 / 1	0.00 / 2	0.00 / 1	0.00 / 1
	k-w	$X^2 = 1.213$		p = 0.750	
Nº of direct combinations of 3 flight elements	Mean ± sd	0.00 ± 0.00	0.09 ± 0.29	0.00 ± 0.00	0.00 ± 0.00
	Median / Range	0.00 / 0	0.00 / 1	0.00 / 0	0.00 / 0
	k-w	$X^2 = 5.282$		p = 0.152	
Nº of preparatory elements	Mean ± sd	0.15 ± 0.37	0.30 ± 0.47	0.08 ± 0.28	0.00 ± 0.00
	Median / Range	0.00 / 1	0.00 / 1	0.00 / 1	0.00 / 0
	k-w	$X^2 = 8.085$		p = **0.044** *	
Nº of flight elements on the 1º part of routine	Mean ± sd	1.20 ± 0.41	1.17 ± 0.49	1.13 ± 0.45	0.94 ± 0.44
	Median / Range	1.00 / 1	1.00 / 2	1.00 / 2	1.00 / 2
	k-w	$X^2 = 3.404$		p = 0.333	
Nº of flight elements on the 2º part of routine	Mean ± sd	0.65 ± 0.49	0.65 ± 0.49	0.67 ± 0.48	0.69 ± 0.87
	Median / Range	1.00 / 1	1.00 / 1	1.00 / 1	0.50 / 3
	k-w	$X^2 = 0.307$		p = 0.959	
Difficulty coefficient of flight elements	Mean ± sd	0.76 ± 0.31	0.76 ± 0.32	0.73 ± 0.27	0.68 ± 0.31
	Median / Range	0.80 / 1	0.80 / 0.80	0.80 / 0.90	0.65 / 0.80
	k-w	$X^2 = 0.572$		p = 0.903	
Nº of flight elements outwards from low bar	Mean ± sd	1.40 ± 0.82	1.17 ± 1.11	0.88 ± 0.74	0.50 ± 0.82
	Median / Range	1.50 / 3	1.00 / 3	1.00 / 2	0.00 / 2
	k-w	$X^2 = 9.947$		p = **0.019** *	
Nº of flight elements inwards to low bar	Mean ± sd	0.45 ± 0.51	0.61 ± 0.58	0.92 ± 0.50	1.13 ± 0.50
	Median / Range	0.00 / 1	1.00 / 2	1.00 / 2	1.00 / 2
	k-w	$X^2 = 15.702$		p = **0.001** *	

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Nº of flight elements with straight body	Mean ± sd	0.20 ± 0.62	0.35 ± 0.78	0.25 ± 0.53	0.37 ± 0.72
	Median / Range	0.00 / 2	0.00 / 3	0.00 / 2	0.00 / 2
	k-w	X^2 = 1.313		p = 0.726	
Nº of flight elements with closed body	Mean ± sd	1.55 ± 0.69	1.48 ± 0.67	1.54 ± 0.51	1.19 ± 0.54
	Median / Range	2.00 / 3	1.00 / 3	2.00 / 1	1.00 / 2
	k-w	X^2 = 4.232		p = 0.238	

Although there were no significant differences found in relation to body configuration, the mean values of the flight elements executed with closed body shape were consistently higher than those performed with stretched body position.

The number of direct combinations of 2 flight elements were always low, ranging from 0.08 to 0.26 and only during the third cycle were values found that were different from zero (0.09) for combinations of 3 elements, which were performed twice by the same gymnast in two different competitions.

Table 4. *Spearman correlation coefficients (r_s) between variables related to flight elements ($r_s \geq 0.40$ and $p \leq 0.05$).*

		Nº of direct combinations of 2 flight elements	Nº of flight elements on the 1º part	Nº of flight elements on the 2º part
Nº of flight elements outwards from low bar	r_s	0.548		
	p	0.000		
Nº of flight elements with straight body	r_s	0.698	0.511	
	p	0.000	0.000	
Nº of flight elements with closed body	r_s			0.608
	p			0.000
Nº of flight elements on the 1º part of routine	r_s	0.603		0.010
	p	0.000		0.926

Table 5. *Wilcoxon test results for the same-sense variables (* $p \leq 0.05$).*

Indicator	Statistics	Cycle 1989-1992	Cycle 1993-1996	Cycle 1997-2000	Cycle 2001-2004
Nº of direct combinations of flight elements (2 and 3)	Z	-1.732	-2.000	-1.414	-1.732
	p	0.083	0.046*	0.157	0.083
Nº of flight elements on each part of routine (1º and 2º part)	Z	-3.051	-3.207	-2.840	-1.136
	p	0.002*	0.001*	0.005*	0.256
Body position related to low bar during flight elements (inwards and outwards)	Z	-2.886	-1.707	-0.179	-1.904
	p	0.004*	0.088	0.858	0.057
Body configuration during flight elements (closed and straight)	Z	-3.318	-3.279	-4.031	-2.415
	p	0.001*	0.001*	0.000	0.016*

DISCUSSION

Firstly, the results show that in the four analyzed cycles there was no significant change in the number of flight elements performed by elite gymnasts in their competition routines.

The comparison between the values obtained by FIG (1994; 1997b; 1999; 2000; 2001; 2003; 2004), related to all participants in competitions included in the last three cycles studied, with our results from finalists in many of the same competitions, show a very different behavior in this kind of elements.

The observed finalists didn't perform more than three flight elements and the gymnasts that executed that amount were in the minority compared with the ones who performed one or two flight elements in their routines (between 12.50% and 21.74%).

Regarding the last analyzed cycle (2001-2004) and based on the reports from FIG Technical Committee (FIG, 2001; 2003; 2004), which analyzes all participants, we found important differences between all gymnasts and finalists, namely : 8.50% from total vs. 50.00% from finalists performed only one flight element, 22.00% vs. 37.50% executed 2, 35.80% vs. 12.50% performed 3 times this kind of element, and surprisingly, 24.40% of all gymnasts vs. 0.00% of finalists showed four flight elements in their routines, and 3.90% of all gymnasts performed it five times.

This antagonistic behavior between finalists and all the gymnasts suggests that while many coaches believe in the benefits of a large number of flight elements, those whose gymnasts reach the finals and win medals don't risk so much or simply do not master so many different elements, contrary to the ideas and trends proposed by several authors (Arkaev and Suchilin, 2004; Smolevsky and Gaverdovsky, 1996; Touricheva, 1986). In fact there are gymnasts who follow the trend of increased flight elements but don't achieve as good a result. However, the Olympic champions in uneven bars in the four cycles observed performed only one or two flight elements in their routines.

We believe the situation described above is a consequence of inconsistencies promoted by the CP, the same that also created a controversy in the High Bar (HB)

finals in the Olympic Games in Athens in 2004.

On the one hand, to promote spectacle in gymnastics and to recognize the difficulty of such elements, CP encourages its performance by assigning the coefficient of difficulty "D" or higher to the majority, requiring the execution at least once and awarding bonus points to the direct connections of flight elements or between these elements with other equally complexed elements. Also, the incentives described above do not seem to overcome the disadvantages from their inclusion, even in the absence of large faults, because associated to the execution of more flight elements in routines, gymnasts are directly penalized for small faults in the elements themselves and consequently the routines are often interrupted, thus less dynamic, due to the need to execute one or two connection elements to return to the starting position. However, due to the changes on CP after 2004, future research is needed to confirm these results, specifically the analysis of finalist's performances from the last Olympic cycle (2005-2008).

The observed evolution of flight elements performed facing inwards to low bar is in accordance with findings from Kerwin, Irwin and Exell (2007a), revealing that the Tkachev flight element performed in this direction enables gymnasts to develop more angular momentum and to release the bar with greater vertical velocity. Authors also state that changing the direction presented to female gymnasts gives the opportunity to perform piked Tkachevs and may lead to the performance of straight Tkachevs in the future.

With regards to the distribution of the flight elements by half routines, it is not possible to conclude that the intention of gymnasts to perform such elements in periods of increased energy availability, except the correlations observed showing a positive association between the number of flight elements with straight body configuration with the number of these elements performed in the first part of routine, and the ones executed with closed body configuration in the second part.

One of the variables where significant differences were found was in the number of preparatory elements for flight. It is particularly interesting to note that no preparatory elements were recorded in the fourth cycle.

According to Witten and Witten (1991) and Arampatzis and Bruggemann (1999), the execution of flight elements, in both HB and UB, requires preparation through elements capable to generate the necessary mechanical energy for the desired amplitude. Authors also state that the exercise leading up to the flight elements is most often the giant swing and the reality reflected by the results presented in this paper shows that female gymnasts have not been using giant swings to prepare their flight elements.

Arampatzis and Bruggemann (2001) studied the mechanical energy processes during the giant swing before "Tkachev" on UB and HB and observed more similarity between the "Tkachev" giant in UB with the giant executed by men on HB, when they perform "Tkachev-Tkachev", therefore without any preparation. Authors found energy loss in some UB giant phases and suggest that future research should study the way to gain the energy required for increased amplitude in this kind of element.

If the current technique used in giant swing prior to a flight element doesn't give enough energy, we understand the results, i.e. the non execution of unnecessary elements preceding flight elements. We can also interpret the absence of any exercise to prepare flight elements as an increase in the complexity of the observed routines if we consider one of the directions pointed by Arkaev and Suchilin (2004) for the development of structural complexity of movements, the execution of complex elements without prior acceleration.

The reduced presentation of direct combinations of 2 and 3 flight elements seems to contradict the UB tendencies of execution of series with three and more

flight elements presented by some authors (Arkaev and Suchilin, 2004; Smolevsky and Gaverdovsky, 1996).

The ideas of some authors mentioned above are based on the trend of general approach of techniques used by female gymnasts on UB relative to the male gymnasts on HB (Arkaev and Suchilin, 2004; Cimnaghi and Marzolla, 1988; FIG, 1994, 1997b; Sands et al., 2003; Schembri, 1983; Smolevsky and Gaverdovsky, 1996; Witten and Witten, 1991), which seems not to happen concerning flight elements, probably due to the lower amplitude presented by female gymnasts on UB compared with men on HB (Smolevsky and Gaverdovsky, 1996).

Kerwin, Irwin and Exell (2007b) affirm that apparatus construction appears to be very important in accounting for the differences between the straddle Tkachev performed by male and female gymnasts. Concerning the structure of UB, the space restrictions imposed by the width of the bars and the greater rail circumference have been presented as additional limitations by several authors (Prassas, Kwon, and Sands, 2006; Sands, 2000; Sands et al., 2003).

Krug, Knoll and Wagner (1997) justified the differences found between men and women in the techniques used in the giant swing before difficult flight elements, by the differences in the apparatus structure, based on results from studies concerning the forces applied to the apparatus during such giants, which show values related to the forces absorbed by HB with magnitude of 6 to 7 times body weight compared with lower values (4 to 5 times body weight) absorbed by UB.

Krug et al. (1997) also state that women present lower effectiveness in the utilization of elastic properties of apparatus when compared with men, probably due to differences in body weight. According Arampatzis and Bruggemann (1999), the increase of energy due to the relationship between the athlete's body and the elastic capacity of the bar was only detected in the use of “power” or “scooped” technique of backward giant swing, which is used less by female gymnasts on UB (Hiley and Yeadon, 2005).

Other studies and arguments contribute to manifest the difference between the elements performed by men on HB and the same elements performed by women on UB. One example is the preferential use of the "traditional" technique by female gymnasts to execute backward giant swing (Hiley and Yeadon, 2005), producing less angular momentum to release the bar (Arampatzis and Bruggemann, 1999), so with less energy. Smolevsky and Gaverdovsky (1996) confirm consistently lower speeds and flight amplitudes of the elements performed by women compared with men.

These differences suggest a lower ability of women to create enough energy to execute flight elements with the highest and most desirable amplitude, demonstrating an inability to execute it with the least loss of points possible, and combine it in combinations.

The closed body configuration preferred by gymnasts also suggests the referred lower amplitude, which makes the execution of preparatory elements unnecessary, namely to achieve the necessary energy to execute elements with stretched body.

Through the several observed correlations it is possible to perceive that in the rare presentations of a direct combination of 2 flight elements, gymnasts performed it typically facing outwards to low bar position and that its execution is also associated with the unusual execution of flight elements with straight body shape.

The coefficient of difficulty of flight elements also revealed no significant development and the elite gymnasts have kept the level of difficulty of the flight elements of their routines, which correspond to elements of value "D".

Through the development program "Age Group" (FIG, 1997a), FIG recommends both learning and execution of flight elements with value "E", as well as the direct combination of 2, 3 or more flight elements. As shown, the reality of the most

qualified performances on UB contradicts this approach, namely the reality of the world's best gymnasts suggests that it is not profitable to increase the routine's difficulty by adding more valuable flight elements or direct connections between these kinds of movements.

CONCLUSION

The majority of variables of the flight elements performed by elite gymnasts didn’t change, neither in volume nor in difficulty, keeping the reference of one or two elements of value "D" per routine. However, with the introduction of new rules from the CP 2006 and 2009, it is necessary to confirm these results through observation of the last Olympic cycle (2005-2008) and later. Aspects related to the apparatus structure, to the morphology of women, and to the CP seem to condition the presentation of more flight elements, broader and interconnected.

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