BIOMECHANICS OF JUMPS IN RHYTHMIC SPORT GYMNASTICS (RSG)
A KINEMATIC ANALYSIS OF THE PRINCIPAL JUMPS IN RSG

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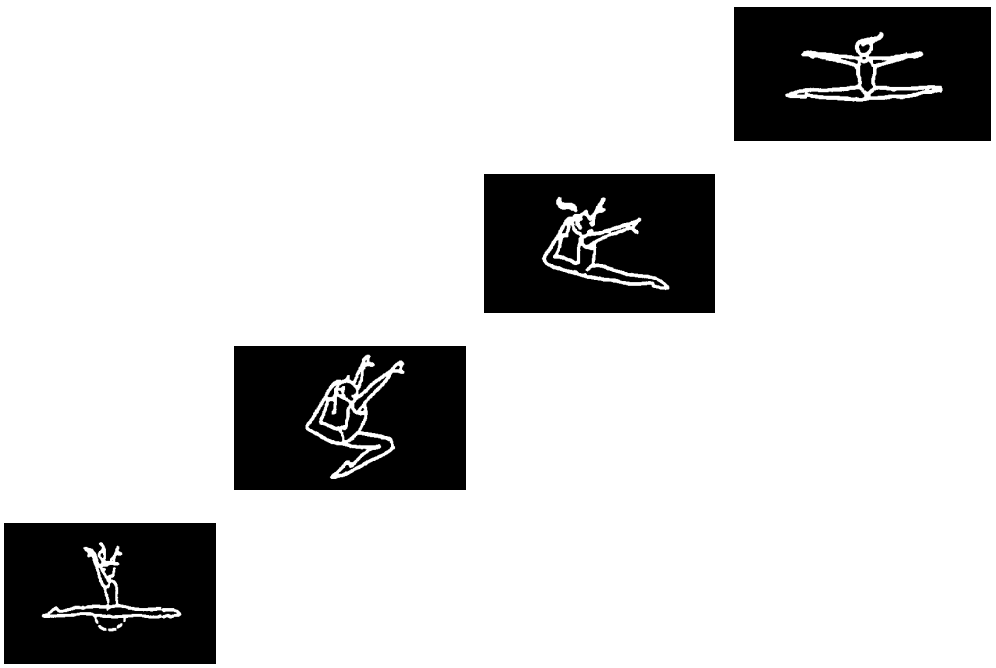
INTRODUCTION: The aim of this study was to analyze the fundamental kinematic parameters and the technique used in RSG to perform the "leap jump" (A), the "leap jump with trunk extension and foot at head" (B), the "corso jump with trunk extension and foot at head" (C), and the "lateral removal jump" (D) (Fig. 1), and identify the degree of importance of the kinematic parameters considered, by taking into account the level of competition of the gymnasts studied. These jumps are the most basic jumps in RSG, the most usual in the routines of the high level RSG gymnasts; besides, jumps are the technical skills group that RSG gymnasts often perform during their routines (Lebre & Sousa, 1997). Nevertheless, most RSG coaches find it hard to analyze the most common errors in their execution.



A B C D

Figure 1: A - "leap jump", B - "leap jump with trunk extension and foot at head", C - "corso jump with trunk extension and foot at head", D - "lateral removal jump".

METHODS: Twenty-nine junior high level RSG gymnasts aged 12.9±1.1years, 36.4±6.4 Kg weight and 152.8±8.2 cm height, and seventeen senior high level RSG gymnasts aged 15.7±1.1 years, 47.6±5.5 Kg weight and 165.0±6.2 cm height were observed. Each gymnast performed the four different jumps of their routines, and an international judge selected the best of three attempts. The jumps were filmed and analyzed using the *Peak 5 System* (*Peak Performance Technologies Inc. – Video and Analog Motion Measurement Systems*), and the different kinematic parameters observed were: duration of the take off (DurTakeoff), flight phase (Ff) and total time of the jumps (Tt); horizontal distance traveled (Hdt); height of the center of mass (CM) at take-off (Hcm), highest point (Hcmh), and the total height of the jumps (Th); linear velocity of CM on take off (horizontal - Vhor, vertical - Vvert and resultant - VRes); angle of outlet on take off (AngTakeoff); angle of maximal removal of inferior members (IM) during the flight phase (Maxim); angle trunk/thigh at the highest point of the jump (AngT) and finally the minimal angle the trunk/thigh reached during the flight phase (MinT).
Mean and standard-deviation were used to describe the data. The degree of dependence of the kinematic parameters of the value of the mark obtained (execution mark) was analyzed with Stepwise multiple regression.

RESULTS AND DISCUSSION: The main results for the different kinematic parameters evaluated are summarized in Tables 1 and 2. The main findings are related both to the duration of the take-off phase and the vertical and horizontal displacement of the CM. In relation to the first topic, the results pointed to a certain anticipation of the IM above the trunk, emphasized by the bending of the longitudinal axis of the gymnast relative to the horizontal plane of movement. This anticipation is a characteristic element of every jump, allowing the gymnast to delay the duration of the take-off and obtain the higher elevation of CM to comfortably perform several motor skills during the flight phase.

Table 1. Main results for the different kinematic parameters observed in the four jumps studied - juniors.

Variable	Jump A $\bar{X} \pm$ sd	Jump B $\bar{X} \pm$ sd	Jump C $\bar{X} \pm$ sd	Jump D $\bar{X} \pm$ sd
DurTakeoff	**0.19±0.02**	0.22±**0.03**	**0.20±0.03**	**0.20± 0.02**
Ff	**0.44±0.04**	**0.45±0.03**	**0.45±0.02**	**0.45±0.02**
Tt	**0.64±0.03**	0.69±**0.04**	**0.67±0.04**	**0.68±0.04**
Hdt	**1.20±0.20**	**1.14±0.15**	1.22±**0.20**	**1.14±0.17**
Hcm	**1.15±0.10**	1.18±**0.11**	**1.16±0.11**	**1.10±0.26**
Hcmh	**1.34±0.11**	1.37±**0.12**	**1.36±0.12**	1.37±**0.17**
Th	**0.37±0.05**	0.44±**0.21**	**0.39±0.06**	**0.38±0.06**
Vhor	1.70±**0.22**	**1.41±0.26**	**1.62±0.30**	**1.46±0.26**
Vvert	**1.86±0.20**	**1.91±0.20**	1.99±**0.21**	**1.86±0.24**
Vres	**2.53±0.28**	**2.38±0.25**	2.57±**0.31**	**2.38±0.29**
AngTakeoff	**84.28±5.95**	**81.41±5.65**	**83.33±4.35**	88.59±**2.98**
Maxim	**187.77±9.63**	154.41±**25.92**	**174.08±11.24**	205.82±**16.72**
AngT	-	107.59±**13.16**	107.78±**10.76**	-
MinT	-	**80.75±8.14**	88.36±**9.19**	-

Table 2. Main results for the different kinematic parameters observed in the four jumps studied - seniors.

Variable	Jump A $\bar{X} \pm$ sd	Jump B $\bar{X} \pm$ sd	Jump C $\bar{X} \pm$ sd	Jump D $\bar{X} \pm$ sd
DurTakeoff	**0.18 ± 0.03**	0.21 ± **0.03**	0.21 ± **0.03**	**0.19 ± 0.02**
Ff	**0.48 ± 0.05**	**0.48 ± 0.04**	**0.48 ± 0.04**	0.52 ± **0.03**
Tt	**0.68 ± 0.06**	**0.72 ± 0.05**	**0.71 ± 0.06**	0.73 ± **0.03**
Hdt	1.29 ± **0.25**	**1.20 ± 0.27**	1.28 ± **0.27**	**1.21 ± 0.19**
Hcm	**1.17 ± 0.34**	**1.17 ± 0.12**	1.21 ± **0.13**	**1.15 ± 0.12**
Hcmh	**1.40 ± 0.14**	**1.38 ± 0.13**	1.42 ± **0.15**	**1.39 ± 0.13**
Th	0.40 ± **0.06**	0.42 ± **0.07**	0.41 ± **0.07**	0.43 ± **0.05**
Vhor	1.79 ± **0.35**	**1.41 ± 0.45**	**1.62 ± 0.41**	**1.50 ± 0.27**
Vvert	**1.93 ± 0.28**	**1.96 ± 0.28**	**1.96 ± 0.33**	1.98 ± **0.24**
Vres	2.64 ± **0.37**	**2.39 ± 0.50**	**2.55 ± 0.49**	**2.49 ± 0.31**
AngTakeoff	**81.95 ± 5.92**	**83.00 ± 5.80**	**83.29 ± 5.58**	89.18 ± **2.70**
Maxim	**189.56 ± 9.04**	165.09 ± **13.61**	**180.63 ± 10.27**	216.67 ± **20.41**
AngT	**-**	102.17 ± **10.07**	102.21 ± **11.68**	-
MinT	**-**	80.18 ± **12.46**	**83.90 ± 9.62**	-

The study of the horizontal and vertical displacement of the CM showed that jumps can be classified in two groups of respectively higher reach and lower height (jumps A and C), and lower reach and higher height (jumps B and D). All the other kinematic parameters are coherent with this finding.
Table 3 shows the results concerning the relationship between the mark obtained by the junior and senior high level RSG gymnasts and the kinematic parameters considered.

Table 3. Results of Stepwise multiple regression: standardized regression coefficient (Stand. Coef.), correlation coefficient (R) and explained variance (R^2) between the performance and the kinematic parameters considered, in the four jumps - Junior and Senior gymnasts.

	Variable	Stand. Coef.	R	R^2
Juniors				
Jump A	**AngTakeoff**	0.47	0.47	0.22
Jump B	**AngTakeoff**	0.55	0.55	0.30
Jump C	**AngTakeoff**	0.48	0.48	0.23
Jump D	**Maxim**	0.70	0.70	0.50
Seniors				
Jump A	**Vhor**	- 1.37	0.65	0.43
	Hdt	0.83	0.78	0.60
Jump B	**DurTakeoff**	0.70	0.70	0.48
Jump C	**Maxim**	0.65	0.65	0.42
Jump D	**Vhor**	- 0.60	0.60	0.36

The results showed that in the group of junior gymnasts the angle of outlet on take-off (AngTakeoff) was the only variable with predicted influence on the performance

of gymnasts during Jumps A, B and C. In Jump D the only variable with predicted influence on the performance of gymnasts was the angle of maximal removal of IM during the flight phase (Maxim). In the group of senior gymnasts results were not so homogenous, and in jump A the linear velocity of CM during take-off (horizontal component - Vhor) and the horizontal distance traveled (Hdt) were the two variables with predicted influence on the performance of gymnasts. In Jump B the only variable with predicted influence on the performance of gymnasts was the duration of take-off. In Jump C the Maxim was the only variable with predicted influence on the performance of gymnasts, and in Jump D it was the linear velocity of CM on take-off (horizontal component - Vhor).

CONCLUSIONS: The main results of the kinematic parameters show that in both groups of gymnasts the kinematic structure of the basic jumps in RSG may be described according to the following parameters: duration of the take-off, duration of the flight phase, height of the CM at take-off, height of the CM at the highest point, linear velocity of CM at take-off (horizontal and vertical components), angle of outlet on take-off and angle of maximal removal of IM during the flight phase. The angle of outlet on take-off was the kinematic parameter with more influence on the performance of the gymnasts during the execution of these jumps.

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