RELATIVE STRENGTH REQUIREMENT FOR SWALLOW ELEMENT PROPER EXECUTION: A PREDICTIVE TEST

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Research article

Abstract

The present study analyzes the correlation between gymnast´s relative strength and the time in seconds that the athlete can hold the swallow on rings with the idea to identify the minimum relative strength required for the proper execution of this element. In addition, a dumbbells exercise is proposed as a convenient evaluation and training method for swallow conditioning. Furthermore, gymnast body ratios were evaluated in order to achieve whether these parameters represent an advantage or disadvantage for swallow execution on rings. A Spearman's correlation test was used to compare the relative strength, height/sitting height and height/wingspan ratios versus the swallow holding time of 14 senior Elite level male gymnasts from the Argentinean team. A significant correlation (p<0.01) between the relative strength and the time in seconds that the swallow was held by the athletes was found, proving that the execution of this element on rings is explained almost in a 90% by the gymnast´s relative strength. No correlation between the swallow holding time and the height/sitting height and height/wingspan ratios were found. These results could provide to gymnasts and coaches with a useful tool for easily recognize if the gymnast´s physical condition is appropriate to perform a swallow on rings.

Keywords: *male gymnastics, rings, metrics.*

INTRODUCTION

Within the six male artistic gymnastics (MAG) disciplines, rings event differs greatly from the rest because it demands an important show of strength from the upper body muscles when executing different skills requiring constant static, eccentric and concentric contractions. These movements imply a constant fight against gravity, having as a goal to overcome the own bodyweight load, thus giving an important role to the relative strength of the gymnast. According to Arkaev & Suchilin (2004), gymnast´s weight is the major obstacle to performing exercises. To move corporal weight it is necessary to apply strength and perform mechanical work of certain power. Here, relative indicators of muscle strength and speed-strength, and not the absolutes indicators, are more important because the first ones are calculated taking into account the gymnast´s own weight.

Gymnastics Code of Points stated that rings routine must be composed of different element groups such as swings elements, swings-to-hold elements and hold elements. Within the latter group, there are four key exercises for a high level routine: the cross, the support scale, the inverted cross, and the swallow. All those elements need to be held (*i.e.*, static strength) a minimum of two seconds for approval by the Jury (FIG, 2009). Among all of them, the swallow is the one that gives more bonuses to a rings routine. The swallow is a strength holding element, supported only by hands with the body and arms straight in a horizontal position at the rings level (Fig. 1) (Bernasconi & Tordi, 2005; Bernasconi, Tordi, Parratte, & Rouillon, 2009; Sands, Dunlavy, Smith, Stone, & Mcneal, 2006). This exercise is considered one of the most difficult strength elements to perform on rings routines (Čuk & Karacsony, 2002), and is frequently executed by the best world gymnasts (Campos, Sousa, & Lebre, 2011).

Figure 1. *The proper execution of the swallow element on rings (taken from http://www.chinasportsbeat.com)*

In the Artistic Gymnastics World Championships held in Stuttgart (2007), 212 rings routines were evaluated; most of the top teams included in their gymnast routines two variants of the swallow element, increasing the start value of the performance and getting a higher score for the classification (Campos, Lebre, & Corte-Real, 2009).

Some evidences show that swallow execution on rings demands a high coordination of the shoulder muscles. Bernasconi *et al*. (2009) compared muscle activity and coordination during a swallow performed on the rings, using a counterweight, and during two training exercises (using dumbbells or barbells). Analyzing electromyograms from the biceps brachii, triceps brachii, deltoideus (clavicular part), pectoralis major, serratus anterior, infraspinatus, trapezius (middle part), and latissimus dorsi in the right shoulder during the exercises, these authors demonstrated that for each one of the four exercises analyzed exist a specific shoulder muscle coordination. According to a research by Campos *et al*. (2011), different muscle forces act together to achieve a balance of the shoulder joint to execute a swallow. The activation of 8 upper body muscles was measured using an electromyographer during the swallow execution on the rings. This study showed that the higher muscular activation corresponded to infraspinatus with 69.3% of the maximum voluntary contraction (MVC), follow by the biceps brachii (60.9%), triceps brachii (58.1%), and anterior deltoid (54.3%). The muscles responsible for scapula mobilization, anterior serratus and inferior trapezium, achieved the corresponding MVC values of 53.3% and 45.1%, respectively. The muscle major pectoralis presented the lowest value of MVC (48.5%). On the other hand, latissimus dorsi was by far the lowest activated muscle during swallow performance on rings, with 15.0% of MVC. Near 50% of muscular co-activation indexes was represented by three agonist/antagonist muscles groups, biceps/triceps, serratus/trapezium. In the co-activation of biceps/triceps and serratus/trapezium the agonist muscles showed a slightly superior contraction in comparison to the antagonist muscles. In the case of deltoid/infraspinatus, the antagonist muscle (infraspinatus) was slightly more activated than the agonist (deltoid). The lowest co-activation index was represented by pectoralis/latissimus dorsi, indicating that pectoralis had superior levels of activation than latissimus dorsi. These results confirmed the interaction between muscles to support the body on the horizontal position (Gluck, 1982). In the particular case of serratus/trapezium co-activation, it seems that those muscles act to stabilize the scapula and to cause shoulder protraction. The high infraspinatus activation prevents humerus head forward dislocation, maintaining it on the glenoid cavity (Brukner & Khan, 1994; Kapandji, 2007; Kendall, McCreary, & Provance, 1993). The combined efforts between infraspinatus, anterior serratus and inferior trapezium are determinant for scapula and shoulder stabilization allowing the anterior muscles (pectoralis major, biceps brachii, deltoid anterior) to work as shoulder flexors and support the body in the horizontal static position at the rings level. Kapandji (2007) stated that triceps brachii push the humerus head forward at the elbow joint when the arm is extended. This means that the shoulder protraction could be related with the anterior serratus and the triceps brachii muscular actions, explaining the higher activation of infraspinatus to prevent the excessive forward action. During swallow execution, latissimus dorsi works only as scapula depressor explaining the lower activation shown by this muscle.

In the same study, Campos *et al*. (2011) also evaluated muscle activation working with auxiliary exercises not executed at the rings and commonly used to swallow training. These authors reported muscular activities below 50% of MVC for each muscle analyzed. The lowest muscular activation value found in the "dumbbells" exercise (lying on back with a dumbbell in each hand with elbows and body extended) belongs to anterior serratus and latissimus dorsi, with MVC of 36.4% and 26.6%, respectively. Inferior trapezium shows the highest activation index (48.2%) followed by anterior deltoid (46.5%), triceps brachii (44.6%), biceps brachii (44.1%), infraspinatus (42.7%), and major pectoralis (40.4%). Also, an identical level of co-contraction between agonist/antagonist muscular groups with values rounding 50% was reported (50.2% for biceps/triceps, 56.8% for serratus/trapezium, and 47.9% for deltoid/infraspinatus). The co-activation index of 39.7% informed for pectoralis/latissimus dorsi demonstrates that major pectoralis contracted more than latissimus dorsi during the swallow execution with dumbbells. After data analyzing, these authors performed a final conclusion recommending or not the use of each exercise in order to be functional as swallow educator, or simply a complementary exercise for the swallow conditioning. In the case of dumbbells, Campos *et al*. (2011) concluded that this exercise could be a useful complement for physical preparation because it gives the possibility to use different loading levels (weighs), but not recommended it for swallow position development because it has the limitation to provide a different coordination between muscles, altering or decreasing the muscular participation of scapula and shoulders stabilizers.

The study of Campos *et al*. (2011) is very interesting in order to chose exercises for swallow training but it has the disadvantage that this work was performed with only one gymnast, which is a limited sample and statistically not representative. In a related study, Bernasconi *et al*. (2009) compared muscles activation and coordination of six top-level gymnasts during training exercises using dumbbells. In this work, the authors proved that the deltoideus is more activated during the dumbbells exercise when comparing with the swallow on the rings concluding that the dumbbells exercise may be useful to carefully prepare the rotator cuff muscles for use.

In our study, we chose to evaluate the dumbbells exercise as an auxiliary and complementary exercise for swallow conditioning. We proposed that data obtained through a maximum isometric strength test could be translated into the body weight percentage that a gymnast should hold in a dumbbells test to be able to perform a valid swallow on rings. In this sense, the strength test could represent an important and useful tool that facilitates the evaluation and strength conditioning planning for swallow exercise. In addition, we evaluate some structural variables such as height, sitting height and wingspan in order to identify these variables as advantages or disadvantages for a gymnast to perform a swallow on rings.

METHODS

Population under study

Fourteen male amateur's gymnasts of senior Elite level, between 18 and 30 years old, were subjected to this study. The subjects (mostly member of the Argentinean team) were in competitive period at the time of the test (two days before the first qualification meet for the pre-Pan-American games, Guadalajara 2011). The analyzed group was relatively small because sample selection was not randomly selected.

Working design and study protocol

All gymnasts underwent two isometric strength tests (a dumbbells test and a swallow execution test on rings). Three weeks before the tests the gymnasts had training sessions involving the dumbbells exercise (simulating swallow) in order to become familiar with the execution technique, to know about the weight that they would try to hold the day of testing and to achieve the necessary adaptations at the elbow and shoulder, since it is an exercise that demands a lot of tension in the soft tissues such as tendons and ligaments of these joints. Evaluation protocols were sent by e-mail to each gymnast days before they were evaluated to be informed of tests procedures and, therefore, ensure an efficient process in the shortest possible time to minimize disruptions at the athlete's resting time before the competition. Evaluations were done in the morning at 9 am. Test started with fasting measurements of body weight, height, sitting height and wingspan. One hour after breakfast the subjects underwent the strength tests warming up previously as follows: 1) 5 min jogging with different displacements; 2) joint mobility, mainly upper body; 3) warm up movements for elbow and shoulder joint with elastic bands; 4) performing specific gymnastics exercises like 3 press handstand, 5 handstand dips, 10 V abs, 10 arch rocks, 2 straddle planche on parallel bars, and 3 muscle ups on rings. Following warm up they started with the isometric strength test with dumbbells, supine position, performing it with low weights to adapt the soft elbows and shoulders tissues to the exercise (Fig. 2). Prior to the valid attempt of maximal isometric strength they performed the same test with four different lower weights in ascending order. The initial practice weight was 20% of the bodyweight of each subject. The two subsequent practices could have a weight increase of 5 kg or less. Then, the two remaining attempts (one practice and the test attempt) could have a weight increase of 3 kg or less. Between each attempt, they had a resting period of 3 or 4 min (Zatsiorski, 1989). The dumbbell test was valid if the subject: i) do not bend elbows, ii) hold the position for three seconds, and iii) keep the arms in a horizontal plane at 45° of abduction respect to the trunk and parallel to the floor.

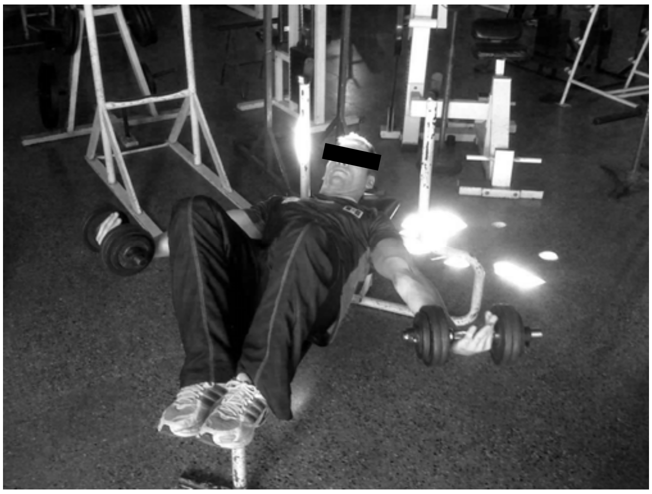

Figure 2. *The proper execution of the dumbbells test.*

After practice attempts the maximal isometric strength test was performed and the data recorded for subsequent statistical analysis. In the case that a gymnast decided to increase the load, a new attempt was performed. The swallow holding test on rings was performed after finished with the dumbbells test. All gymnasts had two turns on the rings for free warm up before executed the test and the data were recorded for statistical analysis**.** Subjects had two opportunities to hold the swallow element with 3 or 4 min of rest between each attempt (Zatsiorski, 1989). A digital camera (Panasonic Lumix) was used to record all the experience. Swallow holding time was measured by watching the recorded video in order to evaluate the correct execution of the exercise. Swallow test on rings was valid if the subject: i) do not bend elbows, and ii) the body was parallel to the ground (10° of tolerance).

Body variables measurement

Measurement of gymnasts' body weight, height, sitting height and wingspan were evaluated. Sitting height was measured as the height from a box (where the subject sits) to the vertex, with the head in the Frankfort plane. The evaluator places his hands in the jaws of the subject, with his fingers reaching the mastoid process. He asks the subject to take a deep breath and hold it and keeping his head in the Frankfort plane the evaluator applies a gentle pressure upward on the mastoid process (Norton & Olds, 1996). Height was performed with the same technique as for sitting height but with the subject standing instead of sitting (Norton & Olds, 1996). Wingspan was measure as the distance between the ends of the middle fingers of left and right hands, when the subject stands against a wall with the arms horizontally stretched (Norton & Olds, 1996). All these measurement were performed using a steel tape attached to the wall for better readability. Body weight was measured in the morning, twelve hours after food, and after voiding (Norton & Olds, 1996). It was used a digital scale brand Powerpack 600.G BLD-model with a 100g scale.

Statistical analysis

Kolmogorov–Smirnov test was used to evaluate variables normal distribution. Spearman´s linear correlation coefficients (r) between relative strength, height/sitting height ratio, and height/wingspan ratio versus swallow holding time (swallow test) were applied and calculated using Sigma-Stat® software (Version 3.1, Systat Software Inc., California, USA). Determination coefficients (r^2) were manually calculated in order to define the variation explained by the predictive variables.

RESULTS

Table 1 shows detailed information of the gymnast´s body variables measured at the present study. Data obtained from maximal isometric strength test (dumbbells test) and swallow element execution on rings is shown in Table 2.

The relative strength calculated between the weight supported by the gymnast in the dumbbells tests and the body weight was correlated with the maximum swallow holding time for each gymnast (Table 3 and Fig. 3). At this point, it is important to notice that the variable swallow holding time failed the Kolmogorov–Smirnov test, so we applied the Spearman´s linear correlation test that is best suitable for not normally distributed variables. As we can see in Table 3, we found a significant linear correlation ($r = 0.952$; $p<0.001$) between the relative strength and the time in seconds that a gymnast can properly hold a swallow on rings. Our result shows that gymnast relative strength is related in a 90% (determination coefficient, $r^2 = 0.906$) with the swallow holding time on rings (see Table 3). Additionally, we could estimate that the minimum percentage (%) of body weight than a gymnast must hold in the dumbbell test to be able to hold the swallow element on rings for 3 sec is about 60% of their body weight.

In order to asses if some body structural factors may influence the correct execution of the swallow, variables such as height, sitting height and wingspan were measured and correlated with the maximum swallow holding time for each gymnast. As can be seen in Table 4, no significant linear correlation was found between the height/sitting height ratio or the height/wingspan ratio and the swallow holding time (r = -0.159; $p>0.5$ and r =0.391; $p>0.1$, respectively). These results suggest that none of such variables appears to be an important factor to execute a swallow. Therefore, gymnast´s body structure may not represent an advantage or disadvantage to correctly perform the swallow element on rings.

Table 1. *Body variables measures for the gymnasts evaluated at the present study.*

Gymnast	Age	Body weight (kg)	Height (cm)	Sitting height (cm)	Wingspan (cm)
1	21	71.6	165.8	87.0	185.0
2	25	76.4	173.5	90.5	185.0
3	27	66.7	164.5	88.0	171.0
4	26	62.4	156.8	84.0	166.0
5	26	72.3	169.0	89.0	180.0
6	29	61.2	164.0	88.0	175.0
7	30	66.4	162.0	86.0	175.0
8	22	76.5	167.0	89.0	173.0
9	20	67.9	166.5	85.0	175.0
10	20	65.8	164.5	90.0	168.0
11	22	63.4	170.9	90.0	183.0
12	20	62.2	161.0	87.0	168.5
13	22	68.3	165.0	85.0	174.5
14	18	72.3	176.0	92.0	185.0
Mean	23	67.8	166.0	87.8	176.0
SD	4	5.3	5.0	2.3	6.6

Table 2. *Results from dumbbell test and swallow holding time on rings for each gymnast.*

Gymnast	Weight (kg) held in one hand at the dumbbell test					Swallow test (sec)
	attempt 1	attempt 2	attempt 3	attempt 4	attempt 5	
1	14	19	22	23	24	6
2	15	17	19	20	20	0
3	13	18	23	25	27	12
4	12	17	19	20	20	5
5	14	17	18	19	19	0
6	12	15	17	19	19	2
7	13	15	16	17	17	0
8	15	20	23	25	27	6
9	14	15	16	0	16	0
10	13	17	20	22	24	6
11	13	15	16	17	17	0
12	12	16	18	0	18	0
13	14	18	23	25	27	7
14	14	18	20	22	22	4
Mean					21.2	3.4
SD					3.9	3.7

Table 3. *Determination of the relative strength and the correlation and relative coefficients.*

Body weight (kg)	Isometric dumbbell test (rm)	Relative strength*	Swallow test (sec)	Spearman´s correlation coefficient for relative strength/swallow test	Determination coefficient for relative strength/swallow test (%)
71.6	24	0.67	6	0.952	90.6
76.4	20	0.52	0		
66.7	27	0.81	12		
62.4	20	0.64	5		
72.3	19	0.53	0		
61.2	19	0.62	2		
66.4	17	0.51	0		
76.5	27	0.71	6		
67.9	16	0.47	0		
65.8	24	0.73	6		
63.4	17	0.54	0		
62.2	18	0.58	0		
68.3	27	0.79	7		
72.3	22	0.61	4		

*****Relative strength is calculated as: (rm/body weight) x 2

Table 4. *Practical example of the dumbbells test application.*

Gymnast´s results during dumbbells test				
Weight held in one arm (kg)	Total amount held in test (kg)	Gymnast´s body weight (kg)	Relative strength*	Percentage (%) of body weight held
17	34	62	0.55	55
Target weight to be achieved				
Weight held in one arm (kg)	Total amount held in test (kg)	Gymnast´s body weight (kg)	Relative strength*	Percentage (%) of body weight held
18.6	37.2	62	0.60	60

*****Relative strength is calculated as: (total amount held/body weight)

DISCUSSION

Until we know, there is no scientific evidence indicating the minimum static relative strength needed by a gymnast to execute a valid swallow on rings. Moreover, there is no research based evidence proposing an indirect and objective method able to evaluate swallow condition by using alternative exercises that do not include the use of the rings, such as the complementary dumbbells exercise used at the present study. Furthermore, it is unknown in what percentage swallow execution is governed by other body structural variables. Our results showed a significant linear correlation between the isometric relative strength and the time that a gymnast held a swallow at rings. These findings support the idea to apply an evaluation method to predict what percentage of body weight must to be held by a gymnast in a dumbbells test to be able to perform a valid swallow on rings. For example, after three or four weeks performing the dumbbell exercise to be more familiar with the correct execution of the exercise, the gymnast should perform a 3 seconds maximum static test with the dumbbells. Then, dividing the total weight supported during the test by the gymnast´s body weight we obtain the relative strength. According to the results presented at the present work, a gymnast should hold at least 30% of his body weight on each hand (*i.e.*, a total of 60% of his body weight) during a dumbbell test to be able to perform a valid swallow on rings. Table 4 shows a practical example. Based on our evidence, a 62 kg gymnast should hold in the dumbbell test 37.2 kg to perform a swallow on rings because this load is the 60% of his body weight.

In other hand, the lack of correlation between anthropometric variables (height, sitting height and wingspan) and the swallow holding time can be interpreted as these variables are minor when executing a swallow.

At this point, it is important to notice some limitations of the present study. First, we have only evaluated 14 gymnasts. It would be interesting to repeat this study with a larger number of athletes. In our case, it was not possible because this is the total of senior Elite gymnasts in Argentina. Second, it would be very interesting not only measure the height, sitting height and wingspan, but also a more complete anthropometric scheme in order to identify different variables such us muscle distribution between the upper and the lower body that could affect the swallow execution.

CONCLUSIONS

The present study demonstrated a high correlation between the isometric relative strength and the swallow holding time, confirming the dumbbells test as a valid predictive method to identify the body weight percentage that must to be supported by a gymnast in an isometric test with the aim to hold a swallow at the rings. Variables such as height, sitting height and wingspan showed no significant correlation with the swallow holding time suggesting these variables are not such important during exercise execution. This work provides to gymnasts and coaches with a useful tool to easily recognize if the physical condition of a gymnast is adequate to perform the swallow element on rings. In addition, the proposed test does not require expensive equipment or tools, thus being available for any coach who wants to apply it. In fact, depending on the results obtained from the dumbbells test, this information could also provide additional data for setting a goal to achieve by the gymnast.

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