BIOMECHANICAL STUDY OF PUSH-OFF TECHNIQUE FOR HANDSPRING AND FRONT SALTO VAULT

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The push-off technique has a decisive effect on the choice of vault and its successful execution during gymnastic competition. This paper presents a new technique, namely the push-off with downward extension of the shoulder. By biomechanical analysis, the two kinds of push-off techniques, which are used in the front salto and handspring maneuver were compared. High-speed photography, automatic film analysis and test comparison were used to examine the difference between two push-off techniques. Results showed that the push-off technique with the downward extension of the shoulder is logical, effective and advanced.

KEY WORDS: vault, handspring and salto forward-type, push-off, shoulder

INTRODUCTION: The high-degree of difficulty component in the handspring and front salto routine plays an important role in the men's vaulting competition. The data for this study was collected at the finals of the individual vault competition for the 34th World Gymnastic Championships in Tianjin in 1999. Of the eight vault event competitors, there were six athletes who chose the handspring and double front salto movement. It is evident that handspring front salto is more likely be chosen than handspring sideways and arab spring. However, only two athletes completed the exercise, and the probability of successful completion is 33%. The key factor that determines success in completion lies in the technique of the push-off. The correct application of the push-off has a decisive effect on the height, distance and turning speed of the body in the post-flight.

For a long time, the conventional push-off used in the handspring front salto was regarded as an effective technique, well studied and applied widely. But with the increased degree of difficulty and higher standards that were required, a new technique of extending the shoulder downward in the push-off has recently been presented. Defined by its technical characteristics, it has been identified as the push-off with shoulder extending downward. For the sake of convenience, in this paper, the two techniques mentioned above are referred to as "technique I." and "technique 2 ". At present, owing to the fact that fewer athletes are adopting technique 2, it has not attracted sufficient attention and therefore, no in-depth study of this technique is available. By using biomechanical method, this paper analyzes and contrasts the two techniques. Discussion is presented on the technical characteristics of the push-off of shoulder extending downward and theoretical framework. Results from this research will provide a sound base for development of reasonable techniques suitable for the development of handspring and front salto vault, in order to promote rapid development of the gymnastic vault in competition.

METHOD:

1. Study on documents and picture data: consult 26 pieces of related materials since 1980's and observe the video pictures of vaulting competition in the 34th World Championships(Tianjin, 1999).
2. Investigation and inquiry: Investigate and inquire about 20 specialists in China for the push-off techniques of handspring and salto forward-type vault.
3. Test comparison: Improve the push-off technique of a Chinese gymnast who is an experienced gymnast in Shandong province (C.J.). Age:15 years, Height :160cm,

Weight:47kg) Subject has mastered technique I by means of technique 2. After mastering it proficiently, photographs were taken of the handspring and 1 1/2 salto forward pike accomplished by the two techniques respectively and analyzed with contrast.

4. High-speed photograph and analysis: The site-directed photo of the process of this movement is taken by Panasonic 800 type high-speed camera (Japan). The distance between camera and horse is 12m, The height of lens is 1.30m. The frequency of shutter is 300/s. Then, the movement film was analyzed automatically by using the soft of “BAS Motion analysis (Version 2.3)” MLEDV VIDEO (Germany) with the IBM computer (Pentium 100, America), and the frequency is 50lat/s.

RESULT AND DISSCUSION: Comparison of results of two push-off techniques.

Table 1 Measured Parameters in Post-flight

Type	Angle of hand release	Height of centre of gravity (m)	Distance (m)	Angular velocity of rotation(rad/s)
9	92°	3.933	2.513	10.37
10	90°	4.005	2.625	11.22

The height, distance, and turning speed in post-flight are the main factors for evaluation of the execution of the vault. From Table1, it can be seen that the hand-release angle of technique 2 is 90°, which is the optimum hand-release angle followed by higher flight and greater distance; moreover, the corresponding motion path curvature of the centre of gravity is effective and the parabola is smooth. This is especially the case for the faster velocity of the body turning. As a result, technique 2 appears more favorable for successful completion of salto. These factors appear to indicate that the push-off technique 2 has distinct advantages.

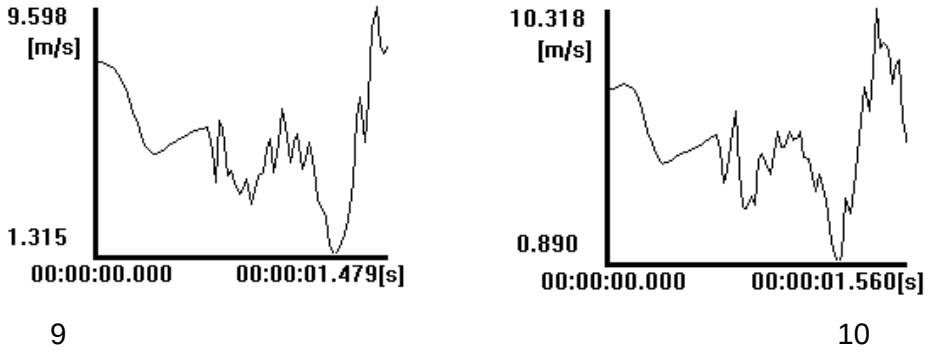
Sports biomechanical analysis. The traditional theory of vaulting technique maintains that the center of gravity (G), reaction force in support (N) and horizontal friction (Q) effect the body at the moment of support. This produces the force couple moment (Nb) turning the body in counter clockwise rotation and force couple moment (Qa) turning the body clockwise rotation. In order to raise the body higher after pushing off, it should be N>G; if Nb<Qa, body appears clockwise rotation, that is, body turning forward ;this is the mechanical condition for handspring forward-type movement.”(Teaching Material Committee of National Institute of P.E.,1997).The theory considers that the motivational force of body turning comes from the friction in horizontal direction when pushing off; the purpose of push-off not only raises the centre of body weight, more importantly, this technique obtains force couple moment which turns body in a clockwise rotation. Therefore, handspring forward in horse vaulting uses stretching arm and extending shoulder in the push-off, the direction of push-off is fore-downward.(Yao,1993),this is braking push-off.

However, traditional theory neglects several important problems. The first problem relates to the phase of pre-flight and supporting horse, owing to take-off and leg swinging backward with trunk forward leaning quickly. The body already has angular momentum, which rotates round the centre of gravity. Secondly, when using braking push-off technique, the body posture of head raising, chest casting and angle in the shoulders shortening in pre-flight is unfavourable to the movement of trunk raising. Turning quickly after the push-off; not only causes friction in horizontal direction and influences the horizontal velocity of centre of gravity, but also strongly influences the opportunity to effect explosive force. Therefore all of these factors lead to less angle of hand release, and decrease the height of centre of gravity in post-flight. The potential for injury to joints of shoulder and elbow are also greater.

From this description of the technique, it can be seen that, braking push-off technique is

neither safe nor effective, and in particular it will have great influence on the ability to complete the high-degree difficulty segment of the routine, such as handspring and double front salto. The lower probability of success of 33% of this type of movement in the 34th World Championship clearly has demonstrated this problem

According to the theorem of momentum; $F\Delta t=mV-mV_o$,the velocity of hand release(V)and initial velocity of centre of gravity (Vo)are in proportion to the impulse of push-off($F\Delta t$). That is to say, under the circumstance of body obtaining considerable angular momentum of turning in pre-flight, the main aim of push-off of front handspring is to increase the impulse of push-off based on remaining certain initial velocity. Pushing off downward with exertion may reduce negative effect of friction, which is in favour of achieving this goal and raising trunk, then accelerating body rotation and obtaining considerable angle of hand release. This is found with the push-off of shoulder extending downward, that is the new push-off technique. Comparing this with “braking” push-off, this is a kind of push-off technique with assistance



9 10

Figure1 - Curve of speed of centre of gravity—time.

force for acceleration.

As Fig.1 shows, the horizontal velocity (Vx) of technique I. and technique II. are 4.67m/s and 4.92m/s respectively in the into-support phase, and the difference is small. However, the maximum (Vx) of technique II is up to 6.24m/s in the phase of hand-release, which is considerably higher than the velocity 4.15m/s of technique I. in this phase. Similarly, in the phase of into-support, the vertical velocity (Vy) of these two, is 4.30m/s and 4.04m/s respectively, and after releasing, the velocity of technique I is only 3.17m/s. Comparatively, while using technique II, the velocity can reach up to 4.34m/s. These calculations demonstrate that technique II is superior to technique I. In this way, the above theoretical hypothesis is tested at the same time

In addition, the figure of motion path of shoulder joint in the push-off phase may reflect part of technical characteristics about the push-off (See Fig.2). If using technique I, the motion of shoulder joint in the push-off phase has two platforms; which is relevant to the considerable force coming from horizontal direction when pushing off. This also can explain the reason that the hand-release angle is bigger. Adopting technique II, the analysis of the motion path of shoulder joint shows a saw-tooth configuration when pushing off, reflecting the downward effect force of the push-off. After much practice, it produces a contraction like spring which is due to cushioning of apparatus and shoulder joint, at last hand release.

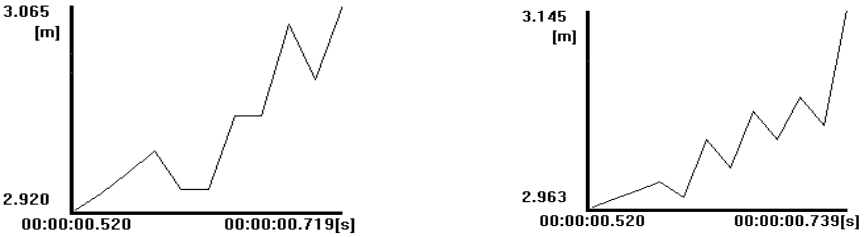


Figure 2 - Motion path of shoulder joint in push-off phase

Thus it can be seen that the result of sports practice is in accordance with the theoretical hypothesis which shows fully that the push-off of shoulder extending downward is an advanced and reasonable new technique based on correct theory.

Technical characteristic and requirement.

Table 2 Sports Parameters in Take-off, Pre-flight and Push-off Phase

Type	Jump angle	Jump angle in the hips	Angular velocity of turning in pre-flight	Angle of support	Angle in the hips of support	Angle of hand release
9	96°	156°	8.14 rad/s	51°	202°	92°
10	94°	156°	8.77 rad/s	55°	190°	90°

From Table 2, it can be see that the jump angle is large, the velocity of body turning in pre-flight is faster, the angle of support and the angle of hand release are both large with using technique II. This demonstrates that technique II emphasizes fast turning of body in pre-flight and higher position of supporting horse, thus creating a good condition for the push-off of shoulder extending downward. In order to promote the application of this new technique and enhance sports level, based on contrast with technique I, technical requirements of the push-off of shoulder extending downward, combined with training practice are presented:

1. With a faster running approach, the centre of gravity is raised in last few steps, providing a larger angle in the hips and jump angle to jump.
2. After the take-off, trunk presses down on it's own initiative, chest contracting, shoulder stretching, the back arching, head raising slightly, legs swinging fast with feet driving hips, to accelerate body rotation.
3. Both hands are supported on the near-end vault with larger angle of supporting horse; pushing off downward rapidly so that the effect point of force is from the whole palms to the joint of palms and fingers; hands release at vertical position with body kicking and legs braking.

This technique may result in the faster turning velocity of body in pre-flight and less impact on joint of shoulder and elbow; so the result is better. With flight higher, faster rotation, landing further and reasonable parabolic path, it is conducive for improved execution and development of new scores. Owing to the lower requirement of braking push-off, this technique is easy to grasp, and therefore is suitable for juvenile athletes or for adopting when finishing low difficult movement.

CONCLUSION:

1. The push-off in high-degree difficult handspring and salto forward-type has two techniques. In comparison with the braking push-off move, the shoulder extending downward technique is an advanced and logical push-off based on correct theory, providing better

results.

2. The push-off of shoulder extending downward requires fast rotation in the pre-flight stage, contraction of the chest and arching of the back, support on the near-end vault, pushing off downward, and kicking body with braking leg at the same time.

3. In this study, the application of the shoulder extending downward technique has been seen as a superior alternative to the conventional model, suitable for the development and promotion of handspring forward-type movement. Furthermore, it has positive reference to the improvement of skill in handspring forward-type.

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