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Kinematic analysis of the “Straddle jump to push up” technique in Mongolian youth aerobic gymnasts

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Abstract-This study examines the performance of Mongolian junior athletes executing the "Straddle jump to push up" element through two distinct preparatory techniques: initiating from a preliminary jump (Group A, n=7) and taking a 2-3 step approach (Group B, n=5). The aim is to determine which technique enables athletes to achieve a greater vertical center of gravity (CG) height at various stages of the movement. The "Straddle jump to push up" was segmented into six technical components (E1-E6) for analysis. Participants, aged 13±1 (N=12), were evaluated in the biomechanics laboratory at Chungnam University, South Korea, using a 100-frame-per-second speed camera (Motion Master), control space meter, and the Kwon 3D XP software. Biomechanical study of jumping performance of athletes allows to detect errors. Findings reveal that the CG of Group A athletes was consistently higher than that of Group B from E1 through E4, the average value was 1.11 cm at E4, the peak component. These results suggest that initiating the "Straddle jump to push up" from a preliminary jump results in a higher CG elevation.

Keywords- Preliminary jump, Difficulty elements, Center of gravity, Joint angles

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1. INTRODUCTION

The International Aerobic Gymnastics Competition consists of five age categories: men's and women's individual, double, triple, team, aerobic step, and aerobic dance. Performances are assessed by judges based on three primary criteria-execution, artistry, and difficulty-to identify the overall champions in each category. The choreographed routine in the competition requires athletes to develop a high level of physical speed, strength, flexibility, endurance, coordination, and movement skills. The composition of competition routines, which encompasses fundamental aerobic steps, auxiliary steps, transitions, acrobatics, and difficulty elements, as well as the seamless and rapid execution of skill exercises within continuous, straightforward musical movement, plays a crucial role in the evaluation of athletes' performances.

In the choreographed routines for competition, athletes perform difficulty elements-including static and dynamic strength, jumps, flexibility, and rotations-that are tailored to their respective age categories. According to the rules of the competition, junior athletes must perform 7 elements of difficulty in the simulated exercises of the competition. In the simulated exercises of the competition of Mongolian junior athletes, 57 % is the difficulty elements of the jumping group.
In the previous analysis comparing the use of Group C difficulty elements (jumps and leaps) and Group D elements (balance and flexibility) in the World Aerobic Gymnastics Championships, it was found that Group C elements (jumps) were used at a higher rate than Group D elements (balance and flexibility) across individual women's, individual men's, pairs, trios, and team categories. Furthermore, it is noteworthy that Group C contains the greatest variety of element types [1]. Junior athletes' motor training has been shown to influence the performance of the mandatory elements of competition practice, but external factors may influence the performance of the mandatory elements in combination or individually. It has been emphasized that more research is needed at this level of performance in aerobic gymnastics, which shows the possibility of the exact execution of the elements imposed by the scoring code of the sports category [2].

The purpose of this study was to analyze the changes in the height of the center of gravity depending on the pre-jumping technique of the "Straddle jump to push up" exercise of Mongolian junior athletes. This is important for the efficient execution for the athletes.
In the sports of gymnastics, the performance of difficult elements has a significant impact on the success score of athletes in competitions. Therefore, there is a need for us to conduct this research.

2. THEORETICAL BACKGROUND

2.1 AEROBIC GYMNASTICS JUMP

The elements of the jumps group are numerous. The changes of the body attitude in flight, the addition of round trips on different floors or the different arrivals, modify the jump to which is assigned a value based on the level of difficulty. Beyond what the athlete can perform during the jump, after the takeoff phase, it is essential to perform with the best technical perfection the pre-jump that strongly affects the subsequent phases of the jump itself [3]. The factors that affect the vertical force in the pre-jump have been analyzed, proving that the weight, the length of the legs,

the knee angle significantly affect it [4]. Previous study use T-test for subjects' movements and analyzed the action law of straddle jump to push up of sports aerobics so that we can find the technology structure and character. The results showed the effect was better of takeoff, but the posture of small joints was not good enough in the air; the structure was that the center of gravity was the highest firstly, secondly,the hip angle was the smallest and then divided legs angle was the biggest; the upper and lower limbs were buffering synchronization [5].

In the process of document research, it was found by scientists that the coordination of lower limb strength and stretching exercises during training and competition is very important for training athletes in jumping technique.

The final phase of the warm-up routine incorporates general and athletic explosive movements designed to stimulate post-activation potentiation. This phase is marked by an increase in muscle strength and power, which is sustained over the subsequent 4–20 minutes of high-intensity muscle contractions [6]. Warm-up exercises, including stretching and strength exercises, have distinct impacts on muscle function. While stretching exercises tend to reduce muscle strength, strength exercises enhance it. Key findings indicate that both short (15-second) and long (45-second) stretches yield comparable effects; however, a 45-second stretch led to a 12.6% increase in hip flexor flexibility, while follow-up jump performance showed a 5.5% decrease [7].

Overall, the inclusion of stretching and strength exercises in warm-up routines influences an athlete's flexibility, muscle strength, and performance. In gymnastics, athletes typically exhibit high levels of strength and flexibility relative to their body weight, which are crucial for optimal performance [8]. The static stretching should include an adequate warm-up and dynamic sport-specific activities with at least 5 or more minutes of recovery before their sport [9]. Sports that necessitate a high degree of static flexibility should use short duration static stretches with lower intensity stretches in a trained population to minimize the possibilities of impairments [10]. The results for female aerobics athletes to perform ballistic stretching in warm-up in order to improve flexibility without decreasing the following vertical jumping event and may also reduce the risk of ankle sprain injury [11]. Lower limb strength may be decreased after long periods of stretching, but performance of explosive exercises may reverse this phenomenon [12]. However, this effect is transient [13] and depends on time and stretching force [14].

The effect of pliometric and tabata training applied to aerobic gymnasts between the ages of 12-14 on jump performance and respiratory function parameters was investigated. As a result, it is recommended to trainers to use pliometric training for jumping strength and performance increase, tabata training method to increase the continuity of the series, reduce energy expenditure and increase anaerobic capacity [15]. In executing aerobic gymnastics technical elements, a high level of explosive power is needed, especially at lower-body muscle groups. In addition, to maintain the specific effort during routine length (1 min 30 s - 1 min 45 s), an optimal development of specific endurance training and a high capacity of focusing is required, in order to execute the technical elements with accuracy [16].

The research of the above scientists shows that performing the pre-jump with perfect technical performance in performing the difficulty element of the jump affects the flight phase.

2.2 BIOMECHANICS OF JUMPING

In recent years, athletes have been performing the technique of the difficulty element of the competition at a higher level, which is associated with tactics that influence success by obtaining high performance ratings. A person uses leg muscles to jump straight up in a semi-sitting position, and the center of gravity shifts to a certain height. During squatting, the center of gravity goes down in the d-distance, which means that the leg muscles do the work of jumping. F-muscle force, m-total body mass, and (d+h) is the displacement of the center of gravity from semi-squatting to maximal height. Therefore, muscle force (F~L2) depends on the displacement (d~L), and mass (m~L3) depends on length. From this, it is concluded that the height of the jump does not depend on the height of the body [18].

The center of gravity of the best jumping man moves about 0.6 meters. During a jump, the leg muscles work at about 0.3 meters. When jumping, the force of leg muscles is 3 times greater than human weight. According to the world records of high jumpers, if the center of gravity is approximately 1 meter, it means that the center of gravity is raised to an additional 1.4 meters. Therefore the remaining 0.9 meters of the center of gravity, which is raised by 0.6 meters when jumping from a standing position, can be understood as rising with the energy obtained from running [17].

Relaxation, which is inherent in the biomechanical properties of muscle, occurs when the contraction force gradually decreases for a fixed length of muscle. If the muscle relaxation during jumping is prolonged, the pushing force and jumping ability will decrease [18]. Therefore, E1 and E2, or preliminary jumps, are very important. If we consider the breakdown of the technique of jumping with legs apart, it has the following stages (photo 1):

1. Step forward with a small jump from the right (left) foot (E1)
2. Do half squats leg together or small jumps (E2)
3. Vertical jump 2 legs apart (E3)
4. Legs behind take off (E4)
5. Land in push up (E5)
6. Push up position (E6)

E1 E2 E3 E4 E5 E6

Fig 1. “Straddle jump to push up” element

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3. RESEARCH METHODOLY

12 “Gainer” and “Light” clubs junior aerobic gymnasts aged 12-14 participated in our study. When performing the "Straddle jump to push up" element, kinematic analysis was performed on the athletes performing the preliminary jump as group A, and the athletes performing 2-3 steps as group B. "Straddle jump to push up" jump is divided into E1, E2, E3, E4, E5, and E6 phases of the technical structure of the element (photo 1). 100 speed camera (Motion master), control space meter (control object), software program (Kwon 3D XP) were used in the biomechanics laboratory of Chungnam University, South Korea on November 26, 2018. Athletes were first warmed up for 10 minutes. "Straddle jump to push up" was performed 1-3 times. After attaching the sensors to the joints of the athletes, the athlete performed 1 time "Straddle jump to push up" on the field prepared with spatial sensors. The results were analyzed by extracting the average speed, average height of the center of gravity, and their standard deviation of each of the athletes E1-E6.

4. RESULTS

The athletes were divided into groups A and B because they performed the E1 step of the exercise technique breakdown in 2 ways. Depending on the push of E1-E2, the jump height of E3-E4 varies. From Table 1, the average time for Group A athletes to perform the technique is 2.21 seconds, while for Group B, it is 2.63 seconds-0.42 seconds slower.

Table 1. Average performance time (sec) for each technical component of the “Straddle jump to push up” for athletes in groups A and B.

Group		**E1**	**E2**	**E3**	**E4**	**E5**	**E6**
A	**M±SD**	0.52±1.12	1.16±1.12	1.27±1.11	1.59±1.10	1.89±1.10	2.21±1.11
B	**M±SD**	0.69±0.63	1.47±0.59	1.68±0.59	2.00±0.60	2.28±0.62	2.63±0.65

During the transition from E1 to E2, Group A athletes take 0.64 seconds, while Group B takes 0.78 seconds - Group A athletes transition more quickly. Group B’s slower time is attributed to performing E1 with 2-3 steps, unlike Group A. For the critical push in “Straddle Jump to Push Up” during E2 (semi-squat phase), Group B takes 0.29 seconds longer than Group A athletes.
For the next component, E3, Group B takes 0.41 seconds longer than Group A to perform the straddle jump. In the E4 phase, where athletes bring their legs together in the air, Group B is 0.01 seconds slower than Group A but Group B's transitions to this component is faster.

Table 2. Average height of the center of gravity (Z axis) for each component of the “Straddle jump to push up” for athletes in groups A and B (meters).

Group		E1	E2	E3	E4	E5	E6
A	**M±SD**	0.88±0.03	0.90±0.01	1.07±0.01	1.11±0.02	0.37±0.03	0.17±0.04
B	**M±SD**	0.84±0.02	0.71±0.03	1.04±0.04	1.06±0.06	0.37±0.08	0.17±0.07

From Table 2, during the semi-squat phase (E2), the average height of the center of gravity for Group B athletes is 0.71 meters—0.19 meters lower than Group A. Group B athletes have a deeper squat, leading to a lower center of gravity. For Group A athletes performing the technique after a jump, the center of gravity in E2 is 0.91 meters. The highest center of gravity shift occurs during the transition from E3 to E4, reaching 1.11 meters for Group A and 1.04 meters for Group B. There is no significant difference between Group A and B in the center of gravity for E5-E6 components.

Table 3. Average Knee Joint Angle (Degrees) for Each Component of the “Straddle Jump to Push Up” Technique by Group A and Group B

Group	food	E1	E2	E3	E4	E5	E6
A	L	155.5± 6.7	145.4±12.5	171.2±4.3	160.7±10.0	173.0±3.7	174.9±3.1
	R	156.4±9.9	146.9±11.3	171.5±1.8	156.7±10.4	171.6±2.6	174.5±3.8
B	L	148±12.5	114.3±9.1	170.2±4.5	160.4±5.0	172.2±3.4	174.9±3.8
	R	156.2±10.2	110.9±9.5	170.0±2.4	155.3±4.3	169.8±4.5	174.5±2.0

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The optimal knee angle for jumping is between 135° and 150° [20]. The effectiveness of the push during the jump can be analyzed using knee joint angle data. If the squat is too deep or prolonged, it reduces the ability to shift the center of gravity upwards. According to Table 3, during E2 (semi-squat phase), Group A athletes who do the "Straddle jump to push" element by doing a preliminary jump have an optimal knee angle of 145°–146° for both legs. In contrast, Group B athletes (who use 2-3 steps) show knee angles of 114° for the left leg and 110° for the right leg, approximately, 32°–36° less than Group A.

When checking whether there is a correlation between the total completed time of "Straddle jump to push up" jumps with knee bending E2, group A $r=0.66$ has a strong correlation, $p<0.0001$, and group B has a strong correlation $r=0.55$ with $p<0.05$.

5. CONCLUSION

Mongolian junior athletes perform the preliminary jump (E1) of the “Straddle Jump to Push Up” technique in two ways: either initiating from a preliminary jump or with 2-3 steps approach. Comparing these approaches by dividing athletes into Groups A and B shows that those in Group B (using 2-3 steps) take longer in the semi-squat phase (E2) and push with a suboptimal knee

angle due to an excessively deep squat. Furthermore, during the center of gravity shift in E3-E4, Group B athletes exhibit lower average values than Group A. This suggests that slower muscle relaxation reduces push force. Further research is required to examine the role of muscle strength in this performance.

When analyzing the correlation between the "Straddle jump to push" element's total execution time and the semi-squat phase (E2), there was a strong statistical correlation for both groups, for Group A ($r = 0.66$, $p < 0.0001$), for Group B ($r = 0.55$, $p < 0.05$). Finally, the study found that performing "Straddle jump to push" with a preliminary jump is more efficient for junior athletes.

6. DISCUSSION

Aerobic gymnastics, as a relatively young discipline within the broader field of gymnastics, distinguishes itself through dynamic, high-energy routines set to fast-paced music. This sport seamlessly integrates intricate movements, challenging elements, and fluid transitions, fostering creativity and athleticism. Although aerobic gymnastics has yet to achieve Olympic status, it continues to evolve under the guidance of the International Gymnastics Federation, garnering growing interest, particularly among youth.

In Mongolia, the number of athletes engaging in aerobic gymnastics is steadily increasing. However, the development of internationally competitive athletes necessitates a structured and consistent approach to preparation. A strong emphasis must be placed on instilling correct foundational techniques from the earliest stages of training, as these serve as the cornerstone for mastering advanced skills. Regular evaluations of junior athletes' physical readiness, coupled with the identification and correction of technical errors, are essential for refining performance and informing progressive training plans.

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