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# BIOMECHANICS OF FIGURE SKATING JUMP DOUBLE AXEL PERFORMED IN ON ICE AND OFF ICE CONDITIONS

**Abstract:** Figure skating is considered a highly technical discipline. Coaches and researchers are constantly looking for the most effective and safest movement model for jumps, especially Axel Paulsen, which is the hardest kind of all jumps. This research was taken to verify the usefulness of performing double Axel under off- ice conditions as a part of general figure skating training. Research was based on video analysis made in APAS 2000 programme. Parameters taken into account were: joints and take off angle, displacement of centre body mass, horizontal and vertical velocity. Results helped in finding out parameters which are trained during off-ice session.

**Key words**: figure skating, Axel, Axel Paulsen, off-ice, on-ice, jump, biomechanics

## 1. INTRODUCTION

Figure skating is a sport discipline with great traditions, but constantly evolving. Its beauty can be characterized as the equal connection of artistry and athleticism. Nowadays to be successful competitor, figure skater must perform complex athletic and technical skills which requires extremely high level of strength, stamina, balance, body movement control. Complexed jumping elements like double Axel (2A) is performed in a high speed (5-6 m/s) [3] in a short period of time (0,65s) [1], overcoming enormous forces (even 8 times eight times their body weight within 50-125 milliseconds, which is not a lot of time for the body to absorb that magnitude of force.) [8]. In this kind of situations it appears almost impossible for coach to discern subtle technique differences necessary for executing triple and quadruple jumps. Experts in other sports snicer at the lack of consistent teaching methods in figure skating [5]. This research was the first one discussing biomechanical analysis of figure skating Axel jump performed in off-ice conditions as a subsidiary simulation of a proper figure skater's movement. The primary research purpose was a verification of the usefulness of performing double Axel under off- ice conditions during training process of teaching the jump on- ice.

### 1.1 Former similar researches:

In a year 1981 Alexey Mishin who is considered as one of the best figure skating coaches in the world did the extensive kinematic research of each jump in figure skating [3]. He based his research on video analysis and shape of 'figures' left on the ice by the blade of figure skater. Unfortunately, the specific results of that research have not been made available to the general public. Another figure skating coach and researcher Trevor Laak used kinenamic 3D analysis in order to create a list of characteristics that can be used as rules or guidelines for coaches [4]. Canadian scientist King was the one who made the biggest contribution in researches considering Axel jump [1],[2]. Moreover Lockwood focused on landing forces [6].

## 2. METHODS

During the research one Polish elite male junior skater was tested (the first one who performed triple Axel (3A), quadruple Toe Loop (4T) or quadruple Salchow (4S)). He was 170 cm tall and 68 kg body mass. He performed double Axel jump (2A) on the ice and under off- ice conditions in the gym (S2A). Double Axel is the most difficult and complex type of all double jumps (highly scored according to ISU rules). It is the only one with outside front edge entrance. During flying phase skater has to perform 2,5 rotation around his axis in the air than land properly backward in the outside edge. Off-ice DOUBLE AXEL (S2A) is performed in similar way as on the ice. The introduction phase is being made by skipping sideways directly to pre take- off position, after take- off there is 2,5 rotation in the air and landing on the single leg backward without gliding phase. Off- ice Axel is being used by coaches as a proper training-support (imitations). However, it has never been biomechanically studied, so its usefulness is still a debatable issue**.** In order to obtain kinematic data, 2 cameras Canon LEGRIA HV40 (frame rate 50Hz) were positioned in relation to each other at an angle of approx. 90 degrees ( to achieve a 3D effect ) Following the warm up skater performed 6 jumps on-ice and off- ice in the gym without the skates. Three technically the best on-ice and off-ice jumps were chosen to further analysis. Using APAS 2000 Program, the records of each jump and each camera was manually digitized and synchronized. 17 check points were manually marked on each frame of the records. Based on marked check points APAS 2000 program automatically generated 12- segment 3D model of the figure skaters movement (stick figure) (Figure 1).

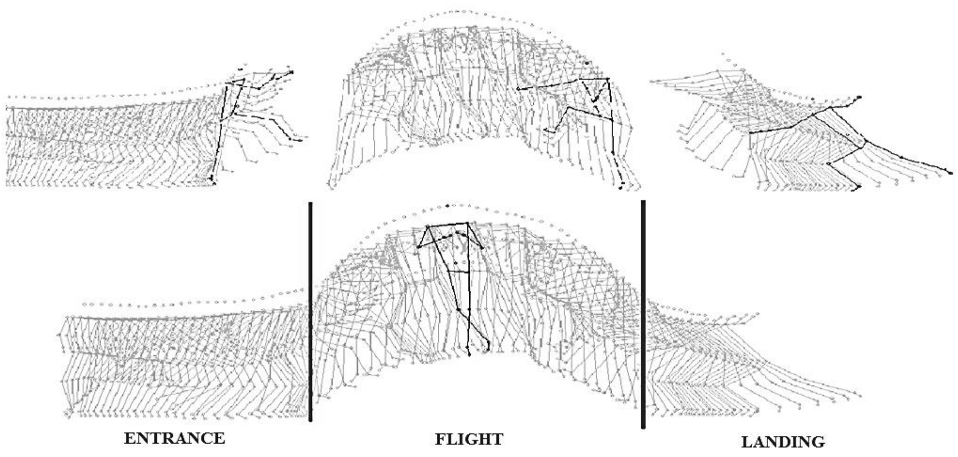


**Fig. 1. Stick figure created in the APAS 2000 program showing on ice double axel divided on jump phases used in analysis**

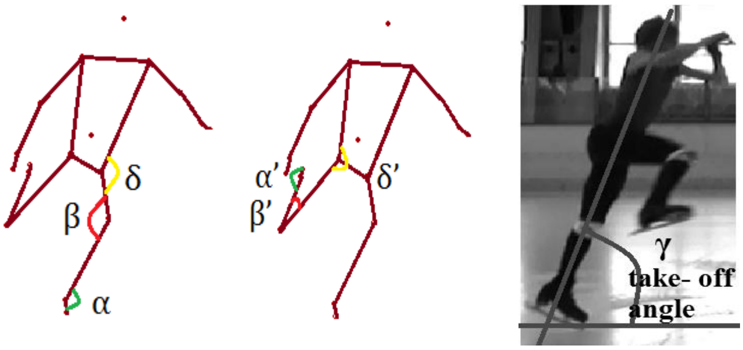


**Fig. 2. Pictures demonstrating the angles measured in the research. α- angle between foot and tibia of the left leg, β- angle between tibia and femur of the left leg, δ- between torso and thigh of the left leg, α'- angle between foot and tibia of the right leg, β'- angle between tibia and femur of the right leg, δ'- between torso and thigh of the right leg, γ (Take- off angle)- angle between ice rink surface and the long axis of the skaters' body**

**Parameters which were chosen to analysis were:** both legs joint angles [°] (α, β, δ, α', β', δ') and take off angle (γ [°]) (showed on the Figure 2), height of flight (h $_{max}$ [m]) (counted on the base of body mass centre displacement), horizontal ($v_{xz}$ [m/s]) and vertical velocity ($v_y$ [m/s]) of body mass centre.

## 3. RESULTS

In order to check the repeatability of performing jumps, the relative error was counted. The average error for 2A was 3,6%, for S2A (off-ice) it was 2,2%. Low percentages in results confirmed very good repeatability of the same kind of jump. It was also noticed that results were more similar in off-ice axel.

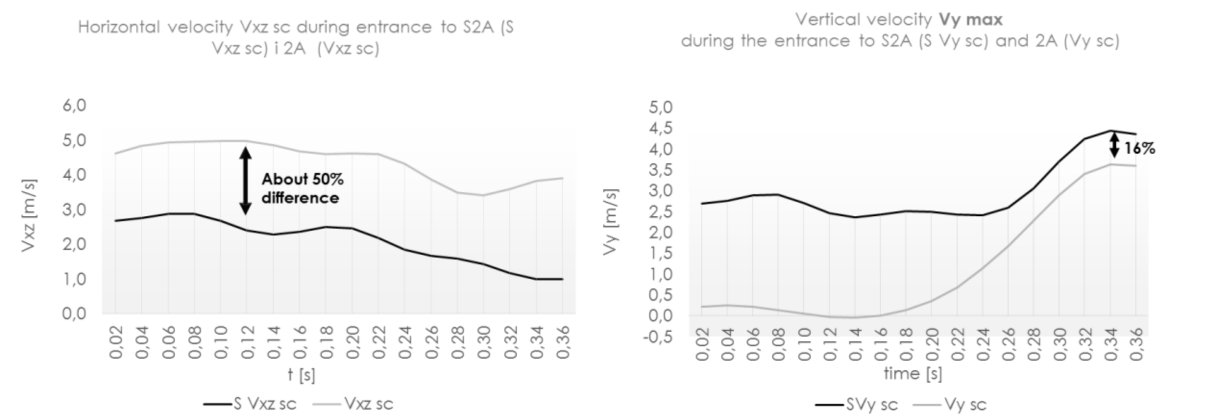


**Fig. 3. Changes of the horizontal (chart on the left) and vertical velocity (chart on the right) in time during on ice Axel (2A) (grey lines) and off- ice Axel (S2A) (black lines)**

Comparing horizontal velocities of 2A and S2A significant (even more than 50% ) differences were noticed in entrance phases (Figure 3, left chart). In off- ice double Axel (S2A) horizontal velocity was much lower than during on ice double Axel 2A. Vertical velocity during entrance phase was significantly different in 2A and S2A (even more than 2 times), but during pre-take off – phase the difference got much smaller (16%) (Figure 3, right chart).

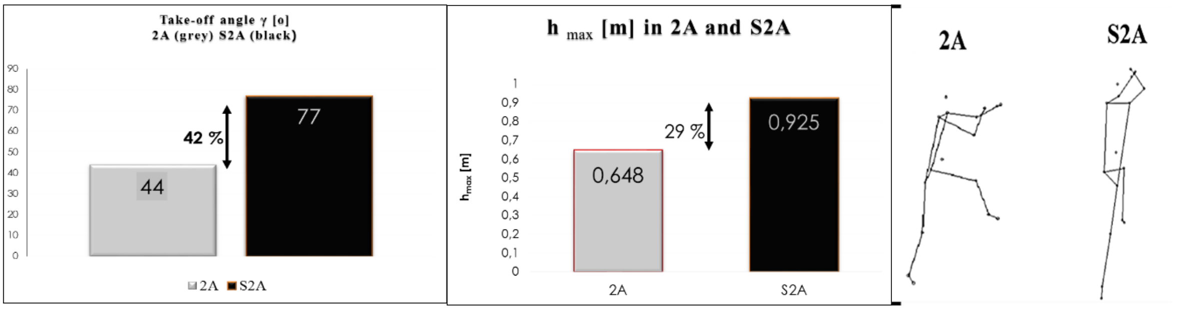


**Fig. 4. Charts showing maximal hight of jump (on the left) and take- off angle (in the midle) in on- ice (red) and off-ice (orange) Axel with stick man figure showing skaters' position in the take- off phase (on the right)**

The take-off angle of off-ice Axel (S2A) was much wider, torso position were straight and take off was directed more upwards than forward (Figure 4). Moreover, skater performed also higher jumps under off-ice conditions. Considering joint angles we can see significant differences in in ankle angle in both kind of jumps in pre take- off and landing phase. (Figure 5). The knee angle were similar in jumps and both legs especially during pre-take off and take off phase (Figure 6). Hip angle of the supporting leg during pre take-off and take-off phase was very similar. There were differences in free leg hip angle during that phase, but as it was shown before, that was caused by straightened torso position during take-off to S2A (Figure 7).

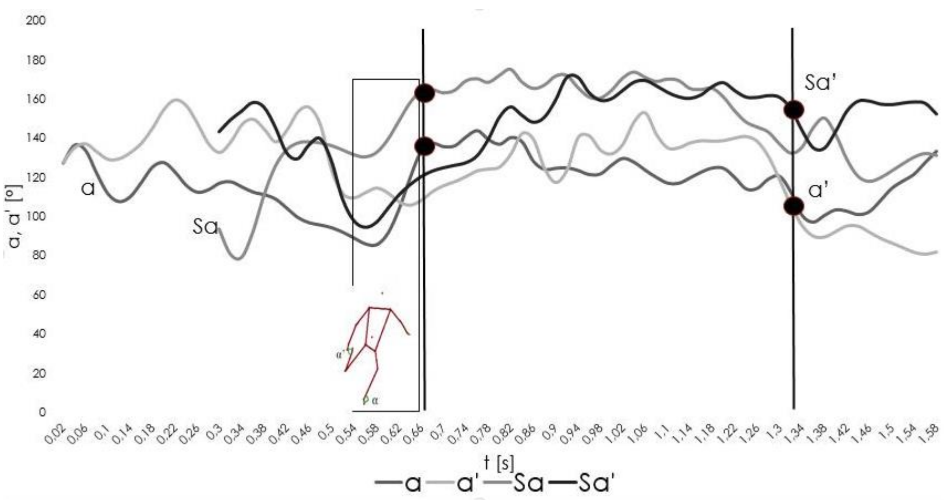


**Fig. 5. Changes of the joint angle in the ankle during on ice double Axel (2A) (blue and orange) and off-ice double Axel (S2A) (grey and yellow). Vertical blue lines shows moment of the take- off and landing**

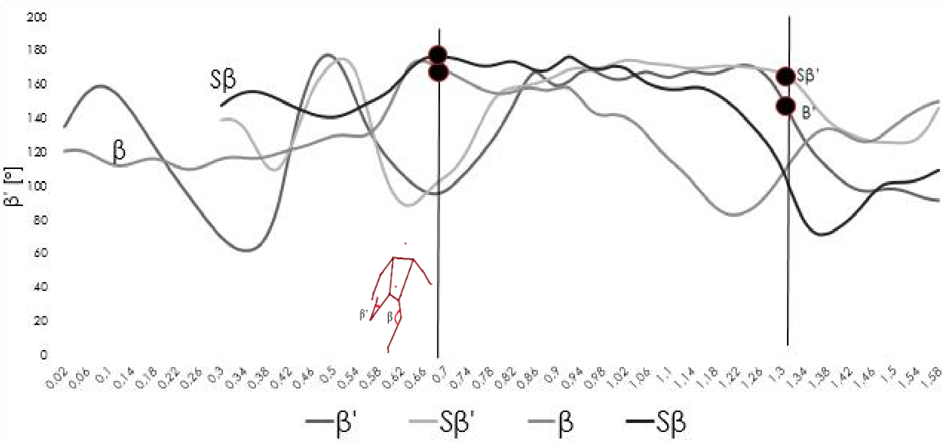


**Fig. 6. Changes of the joint angle in the knee during on ice double Axel (2A) ( β, β' ) and off- ice double Axel (S2A) ( Sβ, Sβ' ). Vertical blue lines shows moment of the take- off and landing**

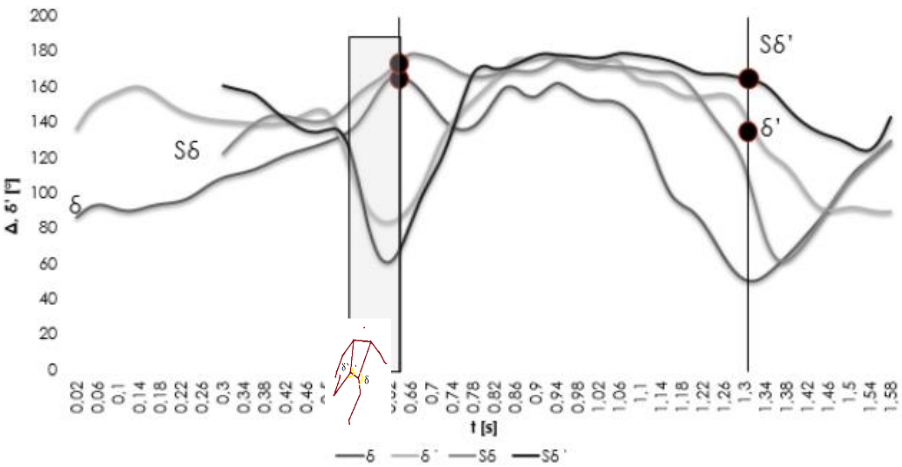


**Fig. 7. Changes of the joint angle in the hip during on ice double Axel (2A) (δ, δ') and off- ice double Axel (S2A) ( Sδ, Sδ' ). Vertical black lines shows moment of the take- off and landing**

## 4. DISCUSSION

Results clearly revelled some characteristics of performing the same type of figure skating jump but under diverse conditions. The low friction on the ice allows skaters achieving high vertical velocities. Big differences between on ice and off-ice Axel in horizontal velocity were caused by specification of conditions. Lack of skid during off-ice performance had an influence on movement. Without ability to skid on the floor skater achieved lower horizontal velocity. However, to perform S2A skater had to jump higher to make same number of rotation as on the ice rink. Take-off in S2A had to be more dynamic (elastic/resilient take-off) in order not to lose the kinematic energy and use it to jump higher. During the entrance of S2A directly after the inrun phase skater took the pre take-off position which was almost identical to the pre take- off position as in on-ice double Axel. However, during performing 2A skater had more time to achieve the pre take- off positon so it could seem easier to do it on ice. The problem appears again when we will take a look at velocities. During on-ice performance skater is struggling with high velocity. Moreover standing on the thin edge it is much easier to lose balance. During off-ice entrance skater perform without the fear caused by velocity and lack of balance. That is why it can by easier for him to focus only on achieving perfect pre take- off position. That is why off-ice jumps was even more repeatable. Joint angles measurements of this study shows that pre take-off position under on- ice and off-ice conditions is very similar. During pre take-off and take- off phase significant differences between 2A and S2A were registered in ankle angle. The most probable reason for that is reduced mobility in that joint caused by the stiffness of figure skating boots. Moreover it was noticed that during the take-off in S2A skater had more straitened torso position than during on ice performance. It is most probable that it because of low horizontal velocity and lack of glide in the gym. Knee angle during the whole off-ice jump were similar to the one registered on the ice. Nevertheless, considering other joint angles the landing technique of movement is much different in off-ice Axel than in 2A on the ice.

## 5. CONCLUSIONS

Summing up, conclusion from this study is that off- ice jumping is not 100% similar to the on- ice jumping. However it can be used as a training tool. This kind of performing can results in improvement in dynamic of take- off, and achieving the proper pre take- off position.

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# BIOMECHANIKA SKOKU ŁYŻWIARSKIEGO PODWÓJNY AXEL WYKONYWANEGO W WARUNKACH NATURALNYCH I SYMULACYJNYCH