INVERSE DYNAMICS OF TAKE-OFF ON SKI-JUMPING SIMULATOR

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INTRODUCTION

Possibilities for learning ski-jump take-offs are relatively limited as the number of daily jumps on the ski-jump is limited and can be carried out only at long intervals. To increase the number of jumps and especially ensure faster succession of repetitions necessary in motoric learning, a special ski-jump simulator was developed. The simulatorshould enable a higher frequency of ski-jump training on the take-off run, especially for junior as well as senior jumpers, in specific ski-jump take-off conditions. At the same time such training could present an interesting variegation and possibilities of executing various coordination tasks, the use of additional loads, etc.

The aim of the research is to determine parameters of a normally executed takeoff on the simulator, which would help in the evaluation of adequacy of the ski-jump simulator.

METHODS

An experienced 22 year old ski jumper (181 cm hight, 78,8 kg weight) former member of the Slovene national team, performed a series of jumps on the simulator so that he also mastered the take-off technique on the equipment.

At the start the jumper took the position of the ski-jump crouch on a wheel-cart and started

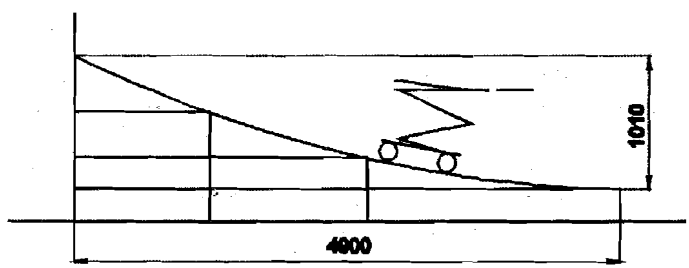

Figure 1 Scheme of ski-jump simulator

down the run. The length of the run was 4.5 m (figure 1), speed at the moment of take-off was 3.7 m/s. The jumper jumped on a special padded wheel-cart which enabled an imitation of the take-off position and in this way ensured conditions for a correct execution of the take-off and also of the passage to the flying position. We placed markers on selected parts (points) of the body: toes, ankles, knees, hips, shoulders, wrists, neck and temples.

The jumps were filmed by two SVHS cameras. The frequency of shots was 25 per second. The shots were digitalised and analysed by a kinetic system CMAS (CONSPORT, Prague, Czech Republic). For the 15-segment 3D model the speed and accelleration were calculated for the selected points - joints of the body. The obtained results were smoothened by the Butterworth filtre and interpolated to the frequency of 50 Hz. The obtained results of the kinematic analysis were used in calculating the inverse dynamics. The model of inverse dynamics was calculated from physical equations for dynamic balance of a rigid body in a sagital plan:

$$\sum \vec{F}_i + \vec{F}_V = 0 \qquad \sum \vec{M}_{iT} + \vec{M}_V = 0$$

$\vec{F}_V = -m \bullet \vec{a}_T$ - represents force of inertia where : m - segment mass

$\vec{a}_T$ - acceleration of gravitational centre of segment

$\vec{M}_V = -I_z \bullet \vec{\alpha}$ - represents moment of inertia

where : I_z - moment of inertia of segment, Z - axis of rotation of segment

$\vec{\alpha}$ - angle acceleration T - gravitational centre of segment

A 5-segment 2D model was used: foot, shank. thigh, body and head, arm. The calculation of the gravitational centre and moment of inertia of individual body parts, the anthropometric model of Fischer (Willimczik, 1977) was used. Net forces and net torques in joints were calculated: hips, knee, ankle and the force exerted on the surface. The calculated values of forces and torques are the sums of each respectively for the left and right side of the body.

RESULTS

Figure 2 shows changes of force in joints through time. The forces were calculated by aid of inverse mechanics. The same inverse model was used for calculating forces at takeoff on the normal ski-jump. The results of this calculation are shown in Figure 3. The obtained results are comparable to the results measured by the tensiometric plate (Virmavirta and Komi, 1993). On the curves calculated for jumps on the simulator, certain oscillations have occured appearing with a frequency of approx. 8 Hz at regular intervals at different frequency of smoothing. Figure 2 shows average values of three jumps, meaning that the sample of oscillation appears in a pattern. Force curves follow each other almost in parallel without prominent phase discrepancies during aproaching run. Two significant peaks in time 0.3 sec. before takeoff are noted, pointing towards a similarity to the jump on the real ski-jump. Between the two peaks there is a significant decrease of force, but still the smallest force between the peaks is still greater than the average force on the run.

DISCUSSION

The run on the takeoff runway is connected with oscillations which appear in knees and hips. Although these oscilations are not directly visible in the takeoff phase, there appears a significant decrease of force (and torque) which is not visible under conditions of the normal ski-jump takeoff. Therefore we can conclude that previous oscillation of the jumper influences the execution of the take-off, which is thus not optimal.

There are various reasons for the jumper's oscillation. They can result from a fault in the construction of the simulator takeoff run: too small rigidity of construction, unsmooth passages between rails, jerky movements of the wheelcart, etc. The reasons for force oscillation in joints can also be found in the motoric balance of the jumper, who, due to the short run and relatively low speed, cannot suitably stabilize his position. Most probably. these oscillations are the result of a combination of both reasons.

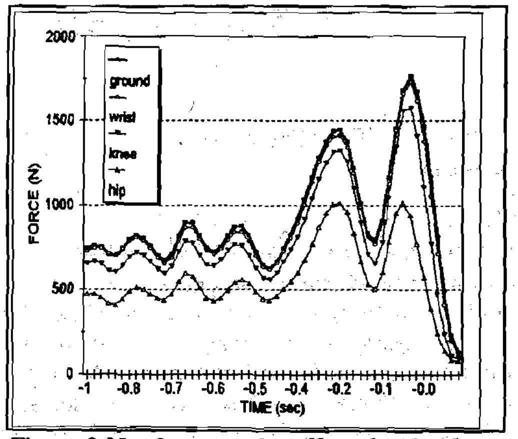

Figure 2 Net force at take-off on the simulator calculated by the inverse mechanics method.

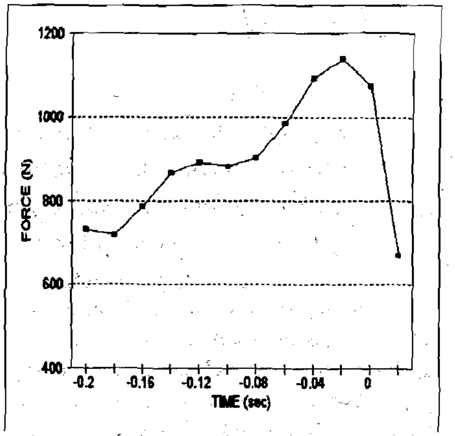

Figure 3 Force ground reaction force at take-off on normal ski-jum calculated by the inverse mechanics method.

Figure 4 shows the course of net torques in hips and knees through time. It can be clearly seen that during the run both torques oscillate in opposite directions. 0.6 sec. before the take-off both torques act in the same direction foretelling the beginning of the take-off. During take-off a phase discrepancy of both curves is noted. The torque in the knees is overtaking the torque in the hips.

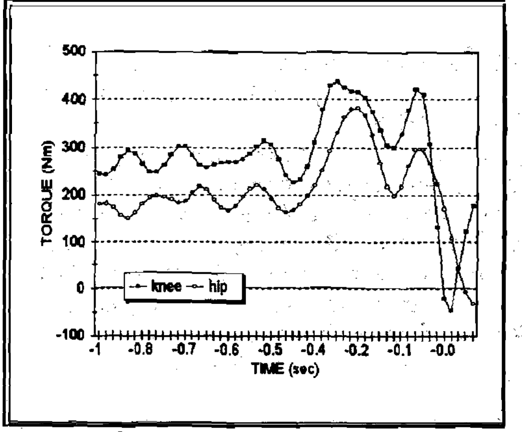

Figure 4 Net torque in hips and knees at take-off on the simulator. At the beginning of the take-off they both get the same direction of action.

CONCLUSION

Considering all this, it is possible to establish that the simulator at this phase, is not as yet suitable for performing ski-jumps, although, in general, it enables a simulation of the take-off on the ski-jump.

In the next work phase it will be necessary to analyse the rigidity of the take-off construction and the smoothness of joints on the rails. The adequacy of the wheel-cart used by the jumper instead of skis should be analysed. Special attention will have to be directed to the measures which will enable the jumper good control of balance so that he would be able to center attention on the take-off or on the task performed.

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