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Biomechanical variables assisting in talent identification in alpine skiing

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Abstract
The current study focuses on the biomechanical variables which are responsible for performance enhancement or performance reduction during alpine ski races. A number of research papers have been reviewed and various biomechanical variables were included in this study. These variables include aerodynamic drag, air resistance, snow and ski frictional forces, 3D kinematics of body parts, ground reaction forces, gliding time on skies, mechanical forces and various external forces disturbing a skiers performance. The results of the study showed that there is a significant relation between specific strength and performance. 3D kinematics is helpful for measuring various body movements. It was found that greater ground reaction forces occurred during the turning phase when skies are in fall line. There was a significant increase in gliding times due to edging. Energy cost was greater during turning time. Acceleration was reduced by frictional forces. Body position and ski suit and size are very important for alpine skiing performance enhancement.

Keywords: Biomechanical variables, alpine skiing, body

Introduction

The word biomechanics is a combination of two words "Bio" and "mechanics". Bio means life and mechanics means physical laws or scientific laws. Sports biomechanics deals with the mechanical laws that are applied to the human movements so as to understand the performance of athletes and helps in the reduction of injuries. Hence, the scientific principles applied to understand the movements of the sports persons based on their specialization or sport like Cricket, Baseball, Skiing and Volleyball etc. Elements like Winguages, treadmills, cycle ergometers, speed meters and force measuring tools are utilized in biomechanical aspects. Biomechanics is the measurement of the muscular, joint and skeletal activity of the body while performing any prescribed task, skill and/or technique. So better understanding of biomechanics relates to the greatest implications on: sport's performance, rehabilitation and preventing injuries, along with sport mastery. As noted by Doctor Michael Yessis, one could say that best athlete is the one that executes his or her skill the best.

Alpine ski is a competition which is played at international and Olympic level and has a confrontation with three dimensional objects like physical, technical, and tactical perspectives. A lot of studies have been done related to physical, physiological and anthropometric variables of skiers but fewer studies have been conducted on biomechanical variables, which are responsible for performance enhancement of skiers. In World Cup events, winning or losing is decided within a fractions of a second and biomechanics plays a vital role in compensating the difference of time. Thus our study focuses on the four variables such as physical, physiological, anthropometric as well as biomechanical variables. The aim of this study is to systematically review the scientific literature to identify the biomechanical factors (especially aerodynamic drag and friction) that influence the performance of alpine ski racers, with an emphasis on slalom, giant slalom, super-G, and downhill events. The range of biomechanical factors reported to influence performance included energy dissipation and conservation, aerodynamic drag and frictional forces, ground reaction force, turn radius, and air resistance. The biomechanical differences between turn techniques, such as parallel turns and carving skiing are also factors in skiing performance.

In the case of slalom and giant slalom events, using the edges of skies helps in reducing the ski-snow friction and energy expenditure. The air resistance can be reduced by minimizing the frontal area and keeping the arms close to the body. So our aim of study is to focus on the effect of aerodynamic drag and friction of skies and snow on skier's performance.

Lower leg Kinematics in alpine skiing

Benedict *et al*. (2013) [1] studied 3D measurement of lower leg kinematics in alpine ski racing using inertial sensors. It is difficult but necessary to understand the lower limb kinematic in order to be safe from injury and show better performance. This is possible by using 3D cameras and inertial measurement units (IMUs). In this study six athletes participated and four IMUs were fixed with both thighs and calf. Acceleration and angular velocity were recorded by the by 3D fusing camcorders. A total of 8 turns were recorded each turn measuring 27m distance and 26degree slope steepness. There was a significant relationship in angle patterns between proposed system and camcorder system. However, in comparison proposed system was more portable than GSP-IMUs.

Mechanical load and mechanical expenditure in alpine skiing

Spitzenpfeil *et al*. (2006) studied mechanical load and muscular expenditure in alpine ski racing. The current study focusses on the need of strength during alpine skiing. The study comprises of seven subjects from German National Ski team. The pressure soles were fitted in both boots to measure the mechanical load on skies and goniometer was used to test the both knee angles. Data were captured by video and recorded in the data logger. Maximal isometric strength was measured by leg press. Isotonic strength both concentric and eccentric strength velocity of knees were measured by using the same equipment. The force produced due to the muscle expenditure was measured by: F_{exp} = ………………… It was resulted that muscle expenditure in lab was 50% greater. The greater expenditure was shown in Slalom upto 100% based on knee angle in many cases. While as comparing SL with other events it is only 40%. This means that there is a greater need of specific strength endurance capacities in alpine skiing.

3D kinematics of knee, hip and trunk in alpine skiing

Benedikt *et al*. (2017) [12] has done a study on inertial sensors for in-field measurement of alpine skiing. The current study focusses on making a design and validates an algorithm to measure the 3D kinematics of the knee, hip, and trunk joints during the movements performed in alpine skiing. In this study 11 subjects participated and six inertial sensors were used to evaluate the movements of skiers. The sensors were placed at 4 different places of athletes such as shanks, thighs, sacrum, and sternum. After that the joint angles were measured using ISB recommendation. After joint angles were validated against 3D stereo-photogrammetric system, a marker was set to measure joint angle. One skier skied on a typical giant slalom and the gate distance was not same. It was found that algorithm fitted to movement of alpine skiing and helps to estimate the 3D movements of the alpine skiers. Movement patterns were measured with great accuracy and precision. This system will be helpful to find the effect of equipment, course setting, and snow on skiing performance and injury prevention.

Ground reaction forces during alpine skiing

Sona Vodickova and Frantisek Veverka (year) conducted a study on the ground reaction force measurement based on strain gauges in alpine skiing. As snow skiing is a sport in which there is a continuous weight shifting from one leg to another leg so as to make an economic turn in case of energy and time. In that case it is necessary for a skier to have a thorough knowledge of load shifting and the forces acting during skiing. The current study states that a device has been established to measure the forces in three directions and the twisting movements of its axis. There are gauges called as strain gauges. Data is recorded in a disk. For the current study a device Blizzard SLK Kompressor of length 167cm, with radius 16m was used on slopes. A carving plate was attached to the binding of skies and the plate raises the center of gravity of the body in order to make the ski turn. More over the skies also consisted of rubber blocks that helps to limit the deviation and oscillation of ski. Another plate was used which consisted of two parts lower part called as "tank" and the upper part called as "cover". These were used to measure the forces created during the turn. It was reported that the greatest ground reaction forces occurred during the turning phase when the skies were in fall line. There are two phases in skiing turn one is initiation phase and the other is steering or turning phase. While as the initiation phase consists of 40% and steering phase consists of 60% of duration of total curving turn.

Ground reaction forces on force plate in alpine skiing

Kosuke *et al*. (2011) has studied a comparison of ground reaction forces determined by portable force plate and pressure insole systems in alpine skiing. The aim of the study is to find out the effect of ground force in alpine skiing and to find out difference between measurements of ground reaction forces and skiers level of skiing and pitch. Total 20 subjects were selected for the study and were divided into two groups, one was elite group and the other was intermediate group of skiers. Elite skiers were given Atomic FIS GS skies and intermediate skiers were given Atomic Drive Fiber Sport Skies with different size. Two force plates were used one was attached to the toe binding and the other was attached to the heel binding. These force plates consisted of sensors used to convert charge signals into voltage signals. Pressure insoles were kept inside the boots and other tools were attached to the belt of the backpack. The subjects were asked to ski down using carving skiing short radii and parallel ski long radii techniques. The mean of force plate measurements ranged from 1.04 to 1.28N/body weight and the pressure insole measurements ranged from 0.78 to 0.90N/body weight for inside and outside phase. It was found that vertical ground reaction force measurements were greater when measured by force plate than measuring by pressure insole. The pressure insole measurements were greater than force plate measurements at the time of short term edging phase. The pressure insoles were placed inside the boots and force plates were attached to the binding it was concluded that force plates are more capable of measuring pressure on ski than pressure insoles.

Impact of Skiers action on gliding time

Fedrolf *et al*. (2008) studied the impact of skier action on gliding times in alpine skiing. As alpine ski races are won within a difference of fraction of s. So it is necessary to identify the forces which become a hurdle for a skier to show his peak performance. So the study aims to find out that skier's performance is affected by the forward or backward leaning and timing performance is affected by using the edges of skies. In the first test the subjects were asked to perform a gliding technique. While performing the gliding technique on a straight track the subjects used a bent position and kept their skies as flat as possible on the snow. While as in second test the subjects were asked to glide in their natural position but keeping the body forward and backward. The subjects were supervised by four professional skiers. To test the acceleration during gliding time four light barriers were used at four different places named as L1, L2, L3 and L4. Moreover two video cameras (V1, V2) were used to capture the movements. One camera was kept at the start and one was kept at the end. One more camera (V3) was used perpendicular to test the knee angle and body shape. The videos were analyzed using software Ikemaster. This software helped to calculate the forces applied during the start of the run and to identify the Force Application Point (FAP). After analyzing the data it was shown that FAP ranges upto 16cm from anterior and posterior direction. It was concluded that forward or backward leaning did not cause any significant difference in gliding times when compared with natural position. There was a significant increase in the gliding times due to edging. Hence, it was concluded that edging caused an increase in run time and ski- snow friction slows down the speed.

Mechanical energy in racing skiing

Supej (2008) has done a study on differential specific mechanical energy as a quality parameter in racing alpine skiing. The purpose of this study is to find the characteristics of skiers at the time of turn. As we know mechanical forces are acting on the skiers like snow friction and air drag. So a mechanical model has been framed to find out the forces acting on the skier at the time of skiing. This model consists of 15 segments along with 17 reference points. The center of gravity of skiers was measured by body segment parameters. For the conversion of 2D data into 3D data, APAS Ariel 3-D kinematical software was used. A total of 16 subjects were selected for this study and 3D videos were used for the analysis of the force acting on body. High kinetic energy is needed by the skiers to show good performance. The skier sometimes feels difficult to use a lot of kinetic energy, because he has already used the potential energy at the time of skiing down the slope. Energy utilization at the time of turn or gate is higher because ground reaction force is higher. At the time of weight shifting less energy is utilized as compared to energy utilized at the time of turning.

External forces disturbing an alpine skier's performance

Gilgien *et al*. (2013) [5] studied the determination of external forces in alpine skiing using a differential global navigation satellite system. The purpose of the study is to assess a method by which we can determine skier kinematics using a differential Global Navigation Satellite System (dGNSS). The ski course was set while using giant slalom gates and the gates were 27m apart and offset of 8m. The subjects were asked to ski down from the course and the 8th turn was recorded so that the skier may attain speed. The analysis of the turn started when there was a cross-section between center of mass and the mean ski trajectory and ended when the same was repeated. Only one turn was analyzed. Total six subjects were selected for the current study and two trails were given to each subject. The GNSS was attached to the helmet of the skier which was used to capture the head trajectories. The other satellite systems were also used to differential procedures to analyze the test. The skiers mass, center of mass acceleration and gravitational acceleration were used to evaluate the forces $F_{RES,dGNSS}$ and gravitational force respectively. Another video analysis was used to capture 3D kinematic data by using High definition cameras. After analyzing twelve trails it was realized that keeping radius less than 30 m, the forces such as F_{RES} and F_D were smaller for turning phase but the friction forces were greater resulting in reduced acceleration. It has been declared that this system is valid for evaluating and analyzing a single turn as well as many turns.

Aerodynamic drag during alpine ski race

M. Supej *et al*. (2013) [3] has done a study that aerodynamic drag is not a major determinant of performance during giant slalom skiing at elite level. To conduct this study they have developed a mechanical model which helps to measure the aerodynamic drag during skiing through all gates. The second objective was to measure the loss of energy caused by force application out of total energy loss and its effects on performance during giant slalom skiing. For the current study 9 well trained and expert skiers were selected from Swedish National Ski team. In order to measure aerodynamic drag and energy dissipation the test were performed while using a wind tunnel and a ski slope. Wind tunnel was used to test the aerodynamic drag and ski slope was used to test the energy dissipation. While performing the aerodynamic drag test the subjects used a force platform and three skiing stances like high, mid and low with three wind velocities 40, 60, and 80km/h. Five trails were given to each subject. The subjects used high stance when weight was shifted from one leg to another and mid stance was used at the time of turn and low stance was used when there was high velocity to reduce air drag. The results of the study show that the effect of aerodynamic drag on performance can be judged by a mechanical model and test measurements. Moreover the energy lost through aerodynamic drag is very less portion of total energy lost on each turn. It also states that less ski-snow friction increases performance.

Air drag in alpine skiing

Nicolas *et al*. (2017) [7] estimated air drag from dynamic pressure measurements for alpine ski racing. The current study is based on to find out the effect of aerodynamic drag on skiing performance. The athlete was wearing a custom made underwear and a back protector. Seven inertial sensors were lying with him and were fitted on his left shank, thigh, sacrum, sternum, C7 and head and one extra sensor was kept in the athletes back protector. Moreover one barometric pressure sensor was lying with the athlete. The subject was asked to use three types of stance such low, mid and high with 5 varying velocities ranging from 70 to 110km/h. The time duration for each test was 20 s. Data was recorded in every 2 s means 10 data points for each trail. To capture the skiers posture a 3D model was used. There was a significant correlation between dynamic pressure and total air drag. Bland–Altman A and B were displayed and the accuracy of A was 0.01N but precision was 2.3 N and the Accuracy of B was 0.1N but precision was 6.0N. It was resulted that between two different velocities and two different stances the drag precision was smaller than the air drag differences. Hence, this model can be used on both snow-training and over the entire course.

Air drag based on skier's position and ski dress

Browline *et al.* (2010) [8] studied the factors affecting the aerodynamic drag of alpine skiers. The study is based on five year investigation that helps to identify the aerodynamic drag of alpine skiers. Wind tunnel tests were performed by General Motors Wind Tunnel. One of them was situated at general motors technical center USA and another one at National Research council of Canada which was situated at Ottawa, Canada. The skiers were tested in downhill position and tuck position through the wind tunnel. Video image of skier was recorded and there was a communication system between skier and the invigilators. Drag was recorded at four distinct velocities such as 80, 90, 95 and 100km/h. suit permeability was also measured by Steinel porosity meter. It was studied that skiers whose position was open up means that spread their arms and become more upright had a greater effect of air pressure and aerodynamic drag. It was also observed that the ski suits which have been already worn create additional aerodynamic drag. There has been a correlation between suit permeability and aerodynamic drag in both tuck and downhill position. So it was conclude that body position, ski suit size and custom suit fitting are very important for skier's performance.

Conclusion

While concluding we state that due to change in equipment design and new techniques there has been a remarkable change in the performance of alpine skiers. Likewise, air resistance, sliding friction and many other hurdles can be reduced by proper body position, proper techniques and proper dress code. Using a carving ski helps to reduce the turn radius. Recent ski boots help an athlete to absorb shocks and help in maintaining balance on skies. Moreover, the binding of skies is adjusted in such a way that can be released based on the knee strength thus helps an athlete to avoid major injuries. Using 3D cameras an athlete can easily watch his movements and body position and can rectify according to the need. The side-cuts of carved skies help a skier to turn quickly which helps an athlete to reduce the time consumption. Thus, biomechanics helps an alpine skier to improve performance and reduce time consumption.

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