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ANGLE VALUES AS KINEMATIC PARAMETERS FOR DESCRIBIN-GMOVEMENT ON SKI SIMULATOR

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Abstract

Alpine skiing as a winter sport is limited by the specific conditions in which it can be performed. Due to mentioned, athletes and recreational skiers are trying to find alternative activities that can replace snow conditions but are biomechanically similar. Moreover, it is desirable that during mentioned activities, like in alpine skiing, muscles are predominantly eccentrically activated. The PRO SKI SIMULATOR is a possible alternative. It is an exercise machine on which an athlete can perform specific motion biomechanically similar to carving turn performed on an actual ski slope along with predominantly eccentrically activated muscles. The purpose of this study is to measure the kinematic parameters and describe biomechanical model using the MVN BIOMECH XSENS inertial suit while participant performs simulation of the carving turn on the simulator. Participant is a male ski instructor. Kinematic variables that were used are joint angles (ankle, knee, hip, shoulder, elbow), measured in degrees (°), and height of centre of mass measured in centimetres (cm). MVN BIOMECH XSENS inertial suit consists of seventeen wireless motion trackers. It ensures real-time human motion analysis. After adjusting the suit and calibration of the system, participant performs sixteen cycles of turn in each side. PRO SKI SIMULATOR has option of adjusting the resistance by using six springs. Adding each spring resistance increases matching the weight interval of an athlete. In this case resistance of three springs was used. Basic descriptive parameters were calculated for all variables. Variables ADLRT and ADRLT are significantly different (p=0,00); also variables HALRT and HARLT differ (p=0,00). Statistically different is angle of flexion in the outer knee joint (KFLRT, KFRLT) p=0,00; shoulder joint in the abduction (SALRT,SARLT- p=0,00) and flexion (SFLRT,SFRLT- p=0,00). Also to be noted is the difference between elbow flexion (EFLRT, EFRLT- p=0,00). We did not find signifficant difference between outer hip angle of flexion (HFLRT, HFRLT- P=0,58). Height of the center of the mass in right turn was not statistically different from height of the center of the mass in left turn (COMR, COML- p=0,68). From the all obtained results it is possible to conclude that participant does not have the same quality of the left and right turn. The future studies should concentrate on using a kinematic suit but on an actual slope and compare that parameters with ones obtained in this study during laboratory conditions.

***Key words**: Ski simulation, kinematic suit, alpine skiing, biomechanics, rhythm, balance*

Introduction

Alpine skiing as a winter sport is limited by specific weather conditions which are prerequisite for its performance (Cigrovski & Matković, 2015). Ski centres need to fulfil specific requirements; mainly related to amount of either natural or artificial snow during winter period. When ski competitors need to train alpine skiing they either go to glaciers or ski centres on south hemisphere. Glaciers are in general providing good skiing conditions all year long, but due to heights (mainly 3000 m, or higher) training can be hard and challenging. Moreover, training at glaciers or in ski resorts on south hemisphere significantly raises the costs of skiing. Those are some of the reasons why alpine skiers during off season seek for alternative ways of training, which would from biomechanical aspect share similarities with skiing. One of the most important issue is to choose training which is compatible in terms of muscle contractions, primarily sharing eccentric contractions (Hoppeler & Vogt, 2009; Ferguson, 2009). Most similar way of alpine ski training is indoor skiing where snow conditions can be controlled. On the other hand, down side of such trainings is in short length of ski terrains which are also not as demanding, so they are mostly used for training of technical ski disciplines. One of the attractive alternatives is a PRO SKI SIMULATOR, a training machine offering a possibility to perform similar specific movements as those during ski turns at ski slopes (Lee et al., 2016; Nourrit-Lucas et al., 2015). Ski simulator offers different possibilities such as use of ski poles which even more specifically relates to skiing (Moon et al., 2015). Moreover, one can also regulate resistance on the ski simulator by adjusting springs. The aim of our report is to measure kinematic parameters and describe biomechanical model of skier while performing turn simulations on PRO SKI SIMULATOR, with help of kinematic suit.

Methods

This was a single subject analysis and participant was a 25 years old male alpine ski instructor. His weight at the time of investigation was 66 kg and height 174cm. He was informed about the study aims in detail, and gave his consent to participate. Participant performed sixteen turns on a ski simulator, eight in each side. Turns were used as entities for describing movement on ski simulator.

Variables: Kinematic parameters measured in this investigation included angles in different joints (ankle, knee, hip, shoulder, elbow) in degrees (°) as well as centre of mass, measured in centimetres (cm) in both turns on a simulator. Variables were as following: Ankle joint angle of dorsiflexion of left leg in right turn (ADLRT), ankle joint angle of dorsiflexion of right leg in right turn (ADRRT), ankle joint angle of dorsiflexion of left leg in left turn (ADLLT), ankle joint angle of dorsiflexion of right leg in left turn (ADRLT), knee angle of flexion of left leg in right turn (KFLRT), knee angle of flexion of right leg in right turn (KFRRT), knee angle of flexion of left leg in left turn (KFLLT), knee angle of flexion of right leg in left turn (KFRLT), hip joint angle of flexion of left leg in right turn (HFLRT), hip joint angle of flexion of right leg in right turn (HFRRT), hip joint angle of flexion of left leg in left turn (HFLLT), hip joint angle of flexion of right leg in left turn (HFRRT), hip joint angle of abduction of left leg in right turn (HALRT), hip joint angle of abduction of right leg in right turn (HARRT), hip joint angle of abduction of left leg in left turn (HALLT), hip joint angle of abduction of right leg in left turn (HARLT), shoulder joint angle of flexion of left arm in right turn (SFLRT), shoulder joint angle of flexion of right arm in right turn (SFRRT), shoulder joint angle of flexion of left arm in left turn (SFLLT), shoulder joint angle of flexion of right arm in left turn (SFRRT), shoulder joint angle of abduction of left arm in right turn (SALRT), shoulder joint angle of abduction of right arm in right turn (SARRT), shoulder joint angle of abduction of left arm in left turn (SALLT), shoulder joint angle of abduction of right arm in left turn (SARLT), elbow joint angle of flexion of left arm in right turn (EFLRT), elbow joint angle of flexion of right arm in right turn (EFRRT), elbow joint angle of flexion of left arm in left turn (EFLLT), elbow joint angle of flexion of right arm in left turn (EFRLT), height of centre of mass in right turn (COMR) and height of centre of mass in left turn (COML).

Research protocol: Kinematic parameters were measured using kinematic suit MVN BIOMECH XSENS. MVN BIOMECH XSENS inertial suit consists of seventeen wireless motion trackers, battery and 240 Hz output rate and it ensures real-time human motion analysis without an effect on movement or rate of motion. Subject performed turn simulations on a PRO SKI SIMULATOR (Figure 1). Simulator offers option of adjusting the resistance by adding springs. Matching number of springs, situated on a simulator basis, is attached on a cart on which subject is standing. Cart is moving laterally on two parallel guides. There are six levels of resistance each matching the weight of an athlete. One spring equals certain weight interval. In this case resistance of 3 springs was used which matches weight interval from 65 to 80 kilos. After dressing the suit and adjusting the sensors, calibration of the system was performed, and subject performed 16 simulations of turn in each side. The ski simulator (Pro ski simulator; Slovenia) was fixed to a flat surface consisting of a platform on wheels moving left and right on two bowed parallel metal rails. Rubber belts fastened the platform to the rails and ensured that it regained resting position in the middle of the apparatus.

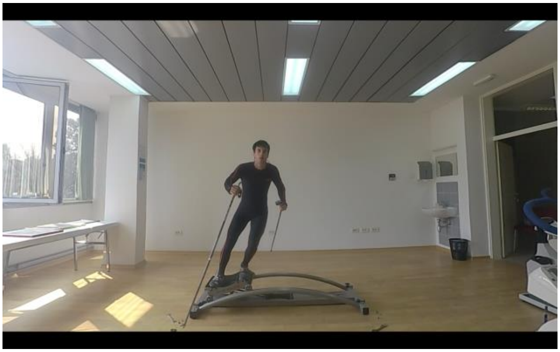

Figure 1. An athlete on a PRO SKI SIMULATOR

Statistical methods

Data was analysed by statistical program Statistica ver. 12. Basic descriptive parameters were calculated for all thirty (fifteen in each turn) previously described variables. In further analysis we measured outer joint angles in relation to the axis of the turn rotation and height of the center of mass. T-test was conducted in order to determine the difference between each outer joint angle in right turn with associated outer joint angle in left turn, and also to differentiate the height of the center of the mass in right turn and in the left turn. Significant difference was considered at $p<0.05$.

Results

In total thirty variables were measured; fifteen in each turn. As noted above only outer joint angles and height of center of mass were described in this paper. In Table 1 are shown basic descriptive parameters for those variables. Table 2 is showing results of t-test. Six variables were associated with $p<0.05$. Variables ADLRT and ADRLT are significantly different (p=0,00); also variables HALRT and HARLT differ (p=0,00). Statistically different is angle of flexion in the outer knee joint (KFLRT,KFRLT) p=0,00; shoulder joint in the abduction (SALRT,SARLT- p=0,00) and flexion (SFLRT,SFRLT- p=0,00). Also, difference between elbow flexion (EFLRT,EFRLT- p=0,00) was statistically significant. There were no signifficant differences between outer hip angle of flexion (HFLRT,HFRLT- P=0,58). Height of the center of the mass in right turn was not statistically different from height of the center of the mass in left turn (COMR,COML- p=0,68). The same methodology can be used for comparison between simulated turn on PRO SKI SIMULATOR and turn on an actual ski slope.

Table 1. Descriptive statistics for sixteen chosen variables

Variable	M	Min	Max	SD
ADLRT	79,9	77,1	84,2	1,8
ADRLT	84,1	80,9	89,5	2,2
HALRT	169,3	165,5	173,4	2
HARLT	164,5	161,8	168,7	1,7
HFLRT	160,3	157,8	164,5	1,7
HFRLT	160,6	157,6	166,6	3
KFLRT	143,7	140,3	148,8	2,9
KFRLT	148,2	144,6	153,3	2,7
SALRT	46,7	45,2	48,6	1,1
SARLT	58,2	56,1	61,3	1,4
SFLRT	56,5	49,6	65,1	3,5
SFRLT	60,2	54,3	61,8	1,8
EFLRT	52,3	42,6	59,5	4,8
EFRLT	40,7	35,7	48,6	3,1
COMR	94,7	93,5	97	0,8
COML	94,8	94	95,7	0,5

Notes: ADLRT - Ankle joint angle of dorsiflexion of left leg in right turn; *ADRLT- Ankle joint angle of dorsiflexion of right leg in left turn; HALRT - hip joint angle of abduction of left leg in right turn; HARLT - hip joint angle of abduction of right leg in left turn; HFLRT- hip joint angle of flexion of left leg in right turn; HFRLT- hip joint angle of flexion of right leg in left turn; KFLRT- knee angle of flexion of left leg in right turn; KFRLT- knee angle of flexion of right leg in left turn; SALRT- shoulder joint angle of abduction of left arm in right turn; SARLT- shoulder joint angle of abduction of right arm in left turn; SFLRT - shoulder joint angle of flexion of left arm in right turn; SFRRT - shoulder joint angle of flexion of right arm in right turn; EFLRT - elbow joint angle of flexion of left arm in right turn; EFRLT- elbow joint angle of flexion of left arm in right turn; COMR - height of centre of mass in right turn; COML - height of centre of mass in left turn*

Table 2. T-test results

Variable	M	SD	t	p
ADLRT	79,90	1,78		
ADRLT	84,10	2,24	6,25	0,00*
HALRT	169,30	2,02		
HARLT	164,50	1,75	-7,61	0,00*
HFLRT	160,30	1,67		
HFRLT	160,60	2,98	0,57	0,58
KFLRT	143,70	2,92		
KFRLT	148,20	2,66	7,47	0,00*
SALRT	46,67	1,11		
SARLT	58,24	1,42	-30,79	0,00*
SFLRT	56,47	3,52		
SFRLT	60,16	1,80	-4,05	0,00*
EFLRT	52,34	4,76		
EFRLT	40,66	3,08	8,21	0,00*
COMR	94,73	0,81		
COML	94,83	0,47	-0,42	0,68

Notes: * $p<0.05$; *ADLRT - Ankle joint angle of dorsiflexion of left leg in right turn*; *ADRLT- Ankle joint angle of dorsiflexion of right leg in left turn; HALRT - hip joint angle of abduction of left leg in right turn; HARLT - hip joint angle of abduction of right leg in left turn; HFLRT- hip joint angle of flexion of left leg in right turn; HFRLT- hip joint angle of flexion of right leg in left turn; KFLRT- knee angle of flexion of left leg in right turn; KFRLT- knee angle of flexion of right leg in left turn; SALRT- shoulder joint angle of abduction of left arm in right turn; SARLT- shoulder joint angle of abduction of right arm in left turn; SFLRT - shoulder joint angle of flexion of left arm in right turn; SFRRT - shoulder joint angle of flexion of right arm in right turn; EFLRT - elbow joint angle of flexion of left arm in right turn; EFRLT- elbow joint angle of flexion of left arm in right turn; COMR - height of centre of mass in right turn; COML - height of centre of mass in left turn*

Discussion

Obtained results indicate that outer joint angle in a relation to the axis of rotation during right turn differs from outer joint angle during left turn. Similar results appeared in six cases (between six joints), regardless of uper or lower segments of the body. Skier is trying to regain optimal dynamic balance and central balance position by using upper body and hands (Loland, 2009). During ski turn, skier tries to separate movements produced in the upper and lower part of a body, where lower part makes several synchronized movements in different planes. Movements connected in right order and in timely manner represent a ski turn. Therefore, lower body parts directly affect the ski turn, while upper body parts assist in realization of a turn by helping the skier to get into the perfect balance position and maintain the balance position through the turn (Hydren et al. 2013). If a skier for some reason makes a mistake and disrupts the ideal trajectory of the turn, or loses the rhythm, central position or dynamic balance, he/she will try to correct it through the upper body movements. When regaining of the ideal position cannot be reached solely by upper body, skier must also include movements in lower body, but during mentioned speed of the turn is lost (Hebert-Losier et al., 2014). Span of the angle values in hip angle during abduction in this research correlated with measures obtained in other investigations, some conducted on an actual ski terrain (Hraski & Hraski, 2009). It would be interesting to see comparison between same variables (HALRT, HARLT) measured on ski slope by the same methodology. From the all obtained results we can cautiously conclude that participant does not have the same quality of the left and right turn. Future studies could concentrate on the investigation of the ideal biomechanical model of the ski turn. Moreover, this could set the basis for distinguishing low quality turns. Future studies should also concentrate on using a kinematic suit on an actual slope and compare measured parameters with ones obtained during laboratory conditions. Only then it would be possible to determine exact similarities in kinematic parameters of simulation turn and turn in snow conditions. Although single subject analyses are valuable tools in biomechanical investigation of the ski turn, future studies should include larger sample of participants to ensure more precise result interpretation.

Conclusions

Mentioned results suggest that movements on PRO SKI SIMULATOR are alike carving ski turn on actual ski terrain and justifies the use of simulators for recreational and professional level skiers in conditions where it is impossible to ski. Recreational level skiers can use it as a preparation for skiing and competitive skiers during specific phases of training.

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