CLASSIFICATION OF V1 AND V2 SUB-TECHNIQUES OF A SINGLE IMU SENSOR THROUGH COMPARISON OF MOTION-SPECIFIC DATA (PITCH, YAW AND ROLL ANGLE VALUES-ORIENTATION ANGLE VALUE) IN XC SKI

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The purpose of this study is to confirm whether the single IMU sensor module (LGE developing and providing for the experiments) that attached to the pelvis can distinguish the motion of the sub-techniques (V1, V2, V2A) with the accuracy of commercial XSENS (equipment consisting of 17 sensors) in freestyle (skate) XC skiing. Therefore, one elite male XC skier with eleven years' experience was investigated by measuring the three-directional rotation angle for each of the three sub-techniques used in XC ski freestyle. Through this method, we could found not only the difference of motion patterns of each sub-techniques but also the possibility for replacement of multiple sensor system by a single IMU sensor module from LGE. Thus, it is expected that a single LGE IMU sensor module could be applied to repetitive and periodic sports such as XC ski.

KEYWORDS: cross-country ski ,xsens, lge imu sensor module, terrain

INTRODUCTION: In sports field, the IMU sensor which has advantages such as small size, low price, unlimited capture volume and wireless form, is evaluated as suitable for kinematic motion analysis (Myklebust, 2016). In the last decade, IMU system has been increasingly used for technique analysis in a range of team sports (Chambers et al., 2015), and in many individual sports including running (e.g. Lee et al., 2010), ski jumping (e.g. Chardonnens et al., 2014), and alpine skiing (e.g. Supej, 2010; Kruger & Edelmann-Nusser, 2010). Especially, during the past five years, the high-speed camera technique used for motion analysis has been replaced by the inertial sensor-based analysis, and cross-country (XC) skiing research using IMU sensors has increased. Recently, XC skiing and alpine skiing studies have used XSENS, which consists of 17 inertial sensors. However, this method is not only costly, but also too complex and difficult to apply immediately in the field for analysis and training of ski coaches and athletes. Yu et al. (2016) showed that pelvis is the ideal location for estimating the performance and characteristics of the skier by statistical analyses and the hierarchical clustering method, as well as easy to detach and attach without affecting the athlete's movement. In this study a single LGE IMU sensor module was designed for convenient and accurate use by field XC skiers and coaches. To verify the accuracy of a single LGE IMU sensor module and the possibility of sub-techniques classification, the XSENS data of pelvis area which is a representative value among 17 measured channels are used. The experiment was conducted at Alpensia XC Center where 2018 PyeongChang Winter Olympic XC ski competition was held.

METHODS: 1) One elite male XC Skier was informed of the content and procedures of this study and gave written consent to own voluntary participation. This study was approved by the Korea National Sport University's institutional ethics committee (IRB number: Industry-academic Cooperation Foundation 20170424-004) and comply with the ethical principles of the Declaration of Helsinki (1975, revised 1983).
2) XC skier was asked to run 2.5km competition tracks consist of a variety of different terrains (flat, uphill, downhill) using free style (V1, V2, V2A). The V1 technique is generally regarded as an uphill technique characterized by asymmetrical use of the upper body in one

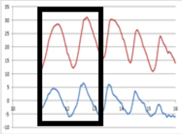
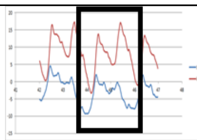
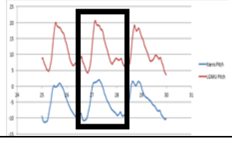
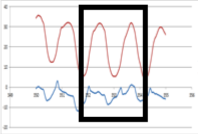
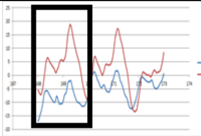
asynchronous double-poling action per cycle, timed with one of the ski pushoffs. In contrast, the V2 technique is seen as a "high speed" technique, and it is symmetrical in that there is one synchronous double-poling action with each ski pushoff (Myklebust, 2016). The V2A technique is used in gradual terrain characterized by synchronous double-poling action per cycle, timed with one of the ski pushoffs.
3) Video was captured to analyse the athlete's movement pattern according to the terrain.
4) A single LGE IMU sensor module acquired the orientation angle (deg) data of the Pitch, Yaw and Roll angle values of an average of 50 Hz at the pelvis. (Table 1)
5) XSENS acquired the orientation angle (deg) data of the Pitch, Yaw and Roll angle values of 240Hz at the pelvis position among 17 sensors. (Table 1)
6) The captured clips and Matlab program were used for matching between the data captured from a single LGE IMU sensor module and XSENS data.
7) In order to synchronize the two data, we tuned individually for each sub-technique. Because of the sampling rate between the two sensors is different, resampling is performed based on LGE sensor module data, and we use the method of determining the synchronized point by finding the minimum or maximum value through comparing the correlation coefficients of two data.

Table 1: Characteristics of the two IMU sensor.

Item	**LGE IMU sensor module**	**XSENS (In this experiment)**
1. Image		
2. Sensor	3-axes accelerometer 3-axes gyroscope 3-axes magnetometer Pressure sensor	3-axes linear accelerometer 3-axes rate gyroscopes 3-axes magnetometers Barometer
3. Data Log	SD memory	PC/Laptop (normal recording mode) Body pack (on-body recording mode)
4. Time Log	Global Time Index	Global Time Index Local Time Index
5. Size	47 × 45 × 21 mm	36 x 24.5 x 10mm
6. Battery	380mAh	No internal battery. There's one battery pack (10.8V, 2.9Ah) and the power is delivered to 17 IMUs and 1 body pack via cable.
7. Frequency	50Hz	Internal update rate: 1000Hz; Output rate: 60Hz, 100Hz, 120Hz, 240Hz

RESULTS: In all the graphs shown below, the blue line is the XSENS data and the red line is the single LGE IMU sensor module data. In addition, the graph below shows the 5-seconds period extracted among entire data.

Figure 1: Pitch angle value based on topographic and sub-techniques

Pitch	V1	V2	V2A
Flat area			
Uphill area			-

From the Pitch angle value shown on Table 2, we found the analogous pattern between the data from a single LGE IMU sensor module and the XSENS data in all terrain and techniques. Especially in both V1 and V2 techniques, the overall form was represented by an "M" shape, whereas V2 was characterized by a sharp form and V1 was characterized by a smooth form. Unlike V1, there was a slight variation in V2 in one vibration. This phenomenon was found in both the flat area and the uphill area. In contrast, a pattern distinct from V1 and V2 was found in the case of V2A.

Figure 2: Yaw angle value based on topographic and sub-techniques

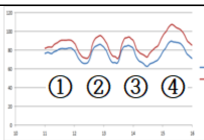
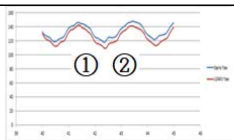
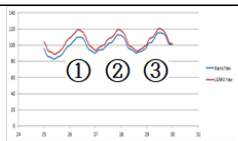
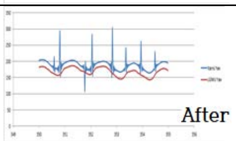
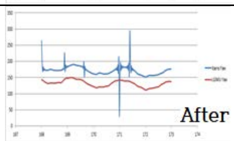
Yaw	V1	V2	V2A
Flat area			
Uphill area			-

Table 3 shows the Yaw angle value, which had high similarity to the single LGE IMU sensor module data and XSENS data in all terrain and techniques. In the case of Yaw angle value, V1, V2, V2A could be classified according to the frequency in the flat area. The frequency number of the V1 technique was the highest, followed by V2A and V2. This was due to differences between the motions; While V1 and V2A moved forward with one-sided polling based on one foot, V2 kept balance with both-sided polling. This led to smaller Yaw frequency from V2 than V1. For the uphill area, size of motion was enlarged to obtain more thrust. As the body rotates more than 180°, it was necessary to correct data by changing the negative number to the positive number. Based on data correction, no difference could be found between data from two sensors in V1, V2 techniques for the uphill area.

Figure 3: Roll angle value based on topographic and sub-techniques

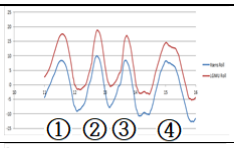
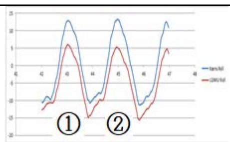
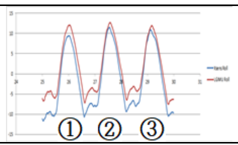
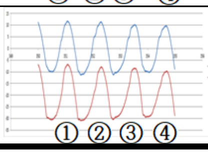
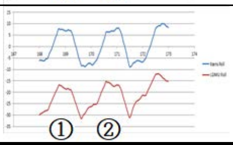
Roll	V1	V2	V2A
Flat area			
Uphill area			-

Table 4 shows the Roll angle value, which also has high similarity of the single LGE IMU sensor module data and XSENS data in all terrain and techniques. Also, Roll angle value, as like Yaw angle value, is possible to classify the technique in the flat area and uphill area by the number of frequencies. This is because both angles are indexes based on the movement to the left and right.

DISCUSSION:
When the LGE sensor module data was checked based on the XSENS data, the Pitch angle value of Table 2 showed that V2 was relatively sharp compared to V1. Because this form was similar to the XSENS data used as the reference value, it was desirable to use the Pitch angle value for the analysis of the sub-techniques through the data pattern. In the case of Yaw and Roll angle values in Table 3 and 4, it was confirmed that the frequency of V1 was higher than that of V2 and V2A. The overall data pattern of V2 was more unstable than V1 in Pitch, Yaw and Roll angle values. This was interpreted as a result of different intensities of both arms' polling depending on the individual's body balance. In Table 3, the Yaw value of the uphill area showed a slight micro-vibration, which was caused by angular conversion due to the internal algorithm of XSENS. It was confirmed that the XSENS sensor and the single LGE IMU sensor module have similar graph shapes. This means that a single IMU sensor on the pelvis can replace the multiple sensor system to analyse the athlete’s motion.

CONCLUSION: Through this study, we confirmed a player's sub-technique according to terrain in XC ski. This means that it is possible to build a customized strategy for each terrain based on the best-recorded data. It is possible to optimize Athlete’s running method according to the player's sub - technique by using the single IMU sensor data. However, until now, the running optimization process of the athletes’ was performed after the game, so it was necessary to develop an automatic algorithm that could be applied in real time in order to improve the record of the coaches and the athletes in the XC ski scene. In order to establish a data pattern between the V2 and V2A techniques, additional research is required for a large number of players and the additional attachment of sensors on the pole for grasping the polling period. This process will also help to develop an intuitive interface that coaches can use for training their athletes. For this reason, sports and engineering academic fields should continue to conducting convergent research in the future. It was confirmed that the validity of the measurement of a single LGE IMU sensor module can be widely applied in sports events consisting of repetitive and periodic motions such as XC ski.

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