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BME 200/300

Section 303

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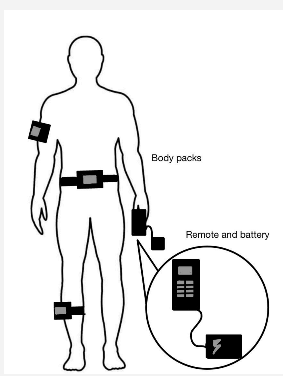
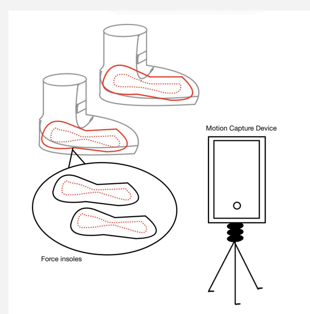
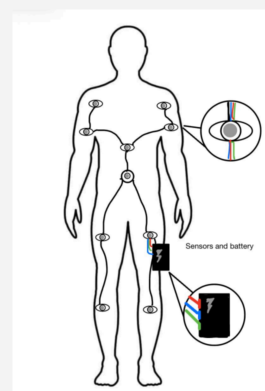
Design Matrix

		Design 1: **Accelerometers (IMUS)** 		**Design 2:** **Force Plate + Motion Capture** 		**Design 3:** **EMG Sensors** 	
Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Repeatability	25	3/5	15	5/5	25	2/5	10
Accuracy	25	3/5	15	4/5	20	4/5	20
Athlete Comfort/Interference	15	3/5	9	4/5	12	2/5	6
Ease of Use (Setup and Takedown)	10	4/5	8	4/5	8	2/5	4

Data Feasibility/Processing Burden	10	1/5	2	4/5	8	3/5	6
Durability	5	4/5	4	4/5	4	2/5	2
Safety	5	5/5	5	5/5	5	5/5	5
Cost	5	5/5	5	3/5	3	5/5	5
Total (Out of 100):		63		85		58	

Design 1: Accelerometer (IMU)

- **Design Description:** The Accelerometers (IMUS) design is based around the use of various Inertial Measurement Units that would look to provide high-frequency motion data, with a specific focus on acceleration, angular velocity, and spatial relation. Several small IMU devices would be placed on the user in several specific locations dictated by an associating machine learning software. These locations would be easy to reach, practical, and relevant locations on the body such as the left foot, right shoulder, and waist. The IMU's would be apart of a larger circuit that would involve a central microcontroller functioning both as a voltage distributor and as a processing hub for the raw data being recorded by the IMUs, as well as a battery for voltage supply. These two components would be placed on the waist, along with one of the IMU's. This design ranked in the middle of the three designs in terms of overall score due to a specific lack of feasibility and a general difficulty with reliable data capture.
- **Repeatability:** The repeatability of the system is based around the level to which similar results can be obtained under identical conditions. During a ski jump, where there is such a large magnitude of variation being introduced by the user, a very robust system is required to eliminate the system as a significant variable. Where the system fails to meet this robust requirement is in accelerometer placement. The predetermined IMU placement on the user is significant for the understanding of the analyzing software. Variations to these locations, even relatively small, change the comprehension of the system for the analyzation process which could significantly alter how the data is interpreted and could lead to inconsistent conclusions across trials.
- **Accuracy:** The Accelerometers (IMUS) design relies on the detection of non-uniform forces applied on an electromechanical sensor within the unit. Though sound in principle and practically demonstrated, in such a dynamic and variable environment such as a ski hill, a significant amount of noise would be generated which would hinder data reliability. Accelerometers are not specifically designed for high-velocity, rapid acceleration movement which could result in the registration of incorrect values or a potential failure to register all together if placed under these conditions.
- **Athlete Comfort/Interference:** Despite being individually small, the amalgamation of components associated with the Accelerometers (IMUS) design would result in, best case, an acknowledgment of presence from the user. The necessity of snug attachment of the entire circuit, including the battery, microcontroller, and IMU devices to the user would require the use of some form of fixtures including straps, clips, and packs. The addition of these items to the user's frame

would not completely hinder their abilities, but would certainly be noticeable and would require a level of getting used to which is why the design was given a ⅗.

- **Ease of Use:** Once the system has been completely configured and the placement of all circuit components has been determined, the specific application and set up on the user would not be too difficult. The accessible locations of all components of the circuit would limit specific problems with hard to reach areas. Difficulties could arise when it comes to snug attachment of the IMU units as this is essential for their functionality. The design would also require a level of user-based training for the appropriate set up of the system which further introduces potential error. If set up is done correctly, the take down process would be intuitive and easy.
- **Feasibility/Processing Burden:** IMUs require a reference point to obtain data from. While this would work fine in a small room, collecting data outside on a large ski jump hill makes it very difficult to obtain the data we need. Therefore, since it is hard to obtain the data, it is hard to process and do a data analysis on data that you can’t obtain easily. This is why this design received a score of ⅕ for Feasibility/Processing Burden.
- **Durability:** It is possible while wearing the IMU on a ski jump that the jumper falls on a landing and potentially lands on the IMU. The impact force of this would undoubtedly break it, however, with the small size of an IMU this is very unlikely. While it would break if the jumper landed on it during a fall, given its small size and the unlikelihood of this event occurring, this design received a score of ⅘ for durability.
- **Safety:** This design with the use of an IMU poses no safety threats to the client or his daughter. Wearing an IMU is a safe way for us to gather data from her ski jump without putting her in harm’s way. As we are not posing a threat of harm with the use of the accelerometer, this design received a score of 5/5 for safety.
- **Cost:** This design requires the purchase of IMUs to measure linear acceleration during takeoff and landing. The accelerometer would collect this data for the young ski jumper and her coach for us to compare her data to her coaches and give feedback on how she can improve. IMUs are not very expensive which is why the cost criteria for this design received a score of 5/5.

Design 2: Force Plate + Motion Capture

- **Design Description:** The design of the force plate and motion capture is centered around having force plate insoles in the skier's shoes. These force plates are portable devices that we would manually place in the soles of the ski boots. The motion capture aspect of the design would record 3D body images and segments of movement during the jump. This would include the angles of the body, the velocity of the jump, and the kinematics of the takeoff. The motion capture device would be a compact camera or mobile device suitable for outdoor usage, and would be placed directed towards the side view of the jump/jumper.
- **Repeatability:** Force plates and motion capture systems are very repeatable since the force insoles are high technology specifically for finding the force on a specific downwards motion. The force plates would measure GRFs with consistent accuracy across trials. Motion capture systems also provide us with repeatable data when the camera remains stationary and no external forces are acting against it. With both of these systems combined, we can do trial-to-trial comparisons between jumps to measure performance.

- **Accuracy:**This design is one of the most accurate for biomechanical measurement. The force plates directly measure the force placed on the take-off by the jumper. Additionally, the motion capture gives high spatial accuracy for joint kinematics. One thing to consider in the accuracy of this design is that wind or other outdoor forces could slightly alter the results of the hump and/or the data taken by the force plates and motion capture.
- **Athlete Comfort/Interference:** The design should cause minimal interference when in use. The force plates will be properly and safely mounted inside the shoe and can be covered with an additional layer to reduce the feeling. However, the force plates may add slight height or a bump at the bottom of the sole, which may be felt by the skier. The motion capture should not cause any disturbance to the skier.
- **Ease of Use:** The only setup required for this design is placing the force insoles inside the user's shoes and setting up a mobile device with OpenSim downloaded to record a sideview of the user's in-run and takeoff. The placement of the recording device could pose initial problems, but establishing the most efficient angle for the motion capture system will not be a long-term issue. On the user's side, the system is relatively simple to use which is why the design was given an ⅘ for ease of use.
- **Feasibility/Processing Burden:** Using force plate insoles alongside a motion capture system is highly feasible since both technologies are commercially available and portable. The two sensors look at separate aspects of the user's ski jump; the motion capture system records joint angles while the insoles provide ground reaction forces. This means the processing burden for the data gathering tools will be quite manageable which is why this design received an ⅘ for this section.
- **Durability:** Both force plate insoles and the motion capture system are designed for repeated use, even under athletic conditions, but they aren't completely immune to damage. The insoles are built to withstand impact forces and repeated jump takeoffs and landings, but the extreme cold temperatures plus the high altitude of the jumps could reduce their lifespan over time. Similarly, the device housing the motion capture application may fall down or receive wear and tear after continuous usage. Overall, the equipment can reliably survive with reasonable care, but extreme environments can alter that which is why this design has a ⅘ for durability.
- **Safety:** This design with the use of force insoles and a motion capture system doesn't pose any significant risks to the athlete while jumping. The insoles are lightweight and embedded within the ski boot so as to not significantly alter balance or technique and the motion capture system doesn't affect the user's safety at all. Since both systems record data without applying external forces or restricting movement, there is no risk of injury which is why this design receives a 5/5 for safety.
- **Cost:** While OpenSim is a free application to download, the price for force plate insoles that measure ground forces and center of pressure typically range from $2,000-$5,000 which is the reason why this design received the lowest score for cost, a ⅗.

Design 3: EMG Sensors

- **Design Description:** The EMG sensor system is designed to capture electrical signals of the ski jumper's muscles. The system includes a central hub that is wrapped around the user's waist or leg via a belt system and houses the microcontroller, filters, signal converters, and more. The electrodes are textile based and are strategically placed around the athletes body to capture signals from the most important muscles. The goal of this design is to provide insight into muscle activation patterns during the takeoff portion of the jump and may help athletes figure out optimal timing and coordination.

- **Repeatability:** Although in theory, textile electrodes are stuck onto the same spot for each jump, different variabilities may produce inconsistent voltage measurements. These variabilities including skin preparation, sweat during the training, and improper electrode placement across multiple sessions, is why we scored repeatability as a 2. Textile EMG electrodes sometimes require skin prep including cleaning or shaving of the surface for optimal use. If this process is not done properly each time measurements are taken, the data is at risk of irreproducibility. Sweat can also build up at varied levels between athletes and may cause electrode slippage or movement throughout data collection. Even small deviations in electrode placement can reduce the repeatability of the data.
- **Accuracy:** EMG systems tend to be quite accurate as they measure the electrical signal of the targeted muscles directly. Usually they do not measure any other signals, like chemical ones, and can provide very accurate timing to the millisecond. We did not give this a 5 because sometimes signal quality can be noisy and weaken accuracy even with built in filtering.
- **Athlete Comfort/Interference:** Although the textile electrodes are designed to stick flush to the athletes skin, the inclusion of electrode wiring and the central hub added weight brought this score down to 2. The extra wiring and added weight of the hub could negatively affect the form of the athlete during their jump and even perhaps the aerodynamics of the in-air portion. The electrode gel used also has to be cleaned off after each session adding to decreased comfort for the athletes.
- **Ease of Use:** This criteria specifically refers to the set up of the system and take down. As mentioned previously, skin prep is required for initial use of the electrodes including cleaning of the surface and shaving for certain individuals. The placement of the electrodes is also vital for accurate signal capturing from the desired muscle which varies within different sized athletes. Also the cleaning of the gel after causes more work for teardown of the system that all add to a lower ease of use score of 2.
- **Feasibility/Processing Burden:** This criteria specifically refers to the ease of data processing once captured. For EMG signals the raw data is relatively easy to record with standard amplifiers, however there are some post processing factors that dropped the score down to 3. This includes filtering, normalization and rectification to make the data interpretable resulting in another layer of complexity.
- **Durability:** The textile electrodes of the EMG system are designed to be sweat resistant and pliable with the body's natural movements. However, we score a 2 for this metric because of the wiring which can easily come off of these electrodes or bend and break from overuse. The central hub is also at risk of damage if an accident on a jump causes the athlete to land over it.
- **Safety:** The electrodes are very safe for use and are made of non-invasive material designed for human skin. There is also very little risk of electrical harm due to the low voltage to power the EMG device and is generally very safe for athletes. Skin irritation is possible if the gel is not cleaned off properly or on-time but this lies more on the user themselves.
- **Cost:** EMG sensors are the most cost effective out of the three designs. They are less expensive than the force plate insoles and do not require expensive IMUs either. Textile electrodes are also cheaper in bulk compared to traditional Ag/AgCl electrodes too.