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Science Fair

Grade 7

Working Log

**Purpose / Objective**

Every day we perform various physical movements. Analyzing these movements can help enlighten how to successfully improve our physical performance in a long run using latest technologies, which can produce reliable key indicators, assess key areas of health focus, and help accurately address areas of physical concern. For these reasons, people of different physical levels/states [have started using latest technologies, such as sensors](https://www.researchgate.net/publication/306259444_Sensors_and_wearable_technologies_in_Sport_Technologies_trends_and_approaches_for_implementation) and multi-angle, and video-capture analyses to better understand their movements. For instance, using multiple cameras to record/visualize an action has been utilized for some time; however, utilization of sensors is becoming more and more popular due to a wider usability, easier quantification, and faster analysis of these data (https://www.athleticbusiness.com/media-technology/the-present-and-future-of-motion-tracking-in-sports.html).

Better understanding of the physical motion and capture has become vital in various areas, such as competitive sports, recreational sports, and rehabilitation after different traumas. With consistent technological advancements, more innovative gadgets (*i.e.* apps, sensors, etc.) are developed that help us capture physical movement, data collection, and data evaluation, which improves research and interpretation of how certain physical movements can hurt our body, or enhance its physical performance.

There are three major categories that can substantially benefit from this Study Project.

1. People who already have been injured, because of overexertion or trauma, which causes them to have painful and limited mobility.
2. People who consistently exercise using inadequate techniques that eventually cause movement deterioration and mobility loss.
3. People who are high performance athletes who seek to further enhance their physical performance in a safe, conscientious, and knowledge-based way.

Hence, the objective of this Study Project is to evaluate and analyze various technologies that collect physical data and quantify performance and progression. While each technology is focused on statistical outputs by evaluating quantities, movement precision, and movement range, this Study Project will assess optimal sampling frequency and ability to improve overall physical performance.

**Study Project**

The scope of this research is to understand and evaluate how innovative technology (*i.e.* sensors) can help improve physical and athletic performance. This will be achieved through theoretical investigation of previously published work and analysis of the relevant publications on this topic.

**Where will this research take place**?

Home

**Hypothesis**

If sensors can help better understand the physical motion, then we can better and faster improve physical and athletic performance. In other words, sensors improve awareness of the physical movement and understanding/solution on how to safely improve physical and athletic performance.

**Research**

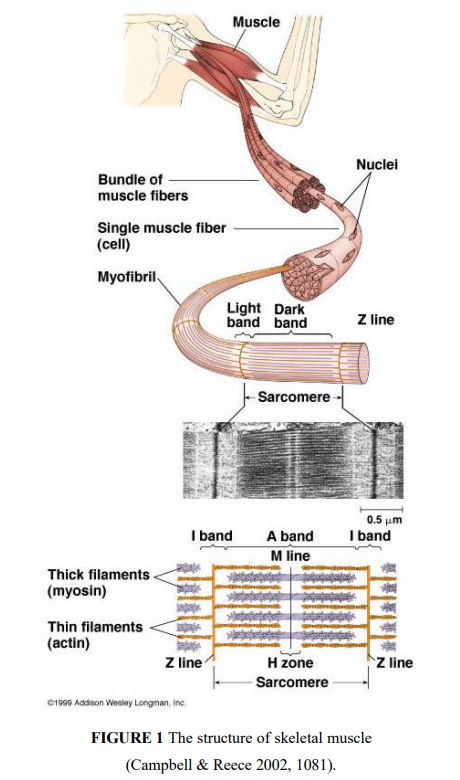
From the very first day we are born, we start moving. Movement is an important part of our existence, success, and wellbeing. As a matter of fact, movement is one of the vital characteristics of our human life, yet our range of motion changes throughout the years.

The range of motion (ROM) is defined as the joint’s ability to move to its full potential that includes distance and direction (<https://www.verywellhealth.com/what-is-normal-range-of-motion-in-a-joint-3120361>). A joint is defined as connection location of bones in the body. Joints have been evolutionary designed to permit movement in certain directions and certain ranges. Each joint is distinctive and has a specific type of movement that it can perform. Curiously, skull is the joint of bones that does not allow movement, it rather has a protective function.

With that being said, most common joint movements are(<https://www.verywellhealth.com/what-is-normal-range-of-motion-in-a-joint-3120361>):

* Extension – “increases the angle between bones of the limb at a joint” by contracting the muscles to a straightened position.
* Flexion – “opposite of extension” decreases the angle by bending.
* Abduction – “moving away from the central axis of the body”.
* Adduction – opposite of abduction “moving towards the central axis of the body”.

Human skeletal muscles, just like most vertebrates’, are attached to the bones to facilitate the safe movement (p 1080 Biology). A skeletal muscle is formed of a bundle of long fibers that are usually the length of the muscle. Each fiber, formed by fusion, represents a single cell that has multiple nuclei. Also, each fiber is a collection of smaller longitudinal myofibrils (p 1080 Biology). Please see the below figure for a visual representation.



Furthermore, to facilitate the full range of motions “muscle actively contract, but they elongate only when passively stretched. Back-and-forth movement is generally accomplished by antagonistic muscles, each working against the other.” (p 1080 Biology) Although each person is different and with unique physical ability, there are commonly accepted ROM values for specific joints measured in degrees (<https://www.verywellhealth.com/what-is-normal-range-of-motion-in-a-joint-3120361>). For instance:

* Hip flexion ranges from 0 to 125 degrees, while hip extension ranges from 115 to 0 degrees. Hip abduction ranges from 0 to 45 degrees, while hip adduction- being the opposite of abduction- ranges from 45 to 0 degrees.
* Knee flection ranges from 0 to 130 degrees, while extension is from 120 to 0 degrees.
* Foot inversion ranges from 0 to 35 degrees, while the opposite, foot eversion, ranges from 25 to 0 degrees.
* Shoulder flexion ranges from 0 to 180 degrees. Shoulder extension from 0 to 50 degrees. Shoulder abduction ranges from 0 to 90 degrees and adduction from 90 to 0 degrees.
* Elbow flexion ranges from 0 to 160 degrees, while extension ranges from 145 to 0 degrees.
* Wrist flexion ranges from 0 to 90 degrees and extension from 0 to 70 degrees. Wrist abduction ranges from 0 to 25 degrees and adduction from 0 to 65 degrees.

There are several factors, such as genetics and situational, both of which are outside of our control, that dictate our initial/basic personal range of movements (e.g. muscle tissue elasticity, types of joints, internal resistance, muscle’s ability to relax, etc.) (<https://www.verywellhealth.com/what-is-normal-range-of-motion-in-a-joint-3120361>). In addition to outside of our control factors that affect our range of movements is age. Older we grow smaller the ROM factors; hence, a more limited range of motions. This is due to metabolic and cellular changes that happen in our bodies when we grow older. Yet, in order to control muscle deterioration and maintain the full range of motion over time, physicians recommend we practice an active lifestyle and exercise regularly.

Using latest technologies we can capture our movements and learn from our historical progress (or regress), and control and enhance our physical state over time, as well as minimize muscle deterioration (<https://simplifaster.com/articles/3d-motion-capture-sport/?fbclid=IwAR0S6TbFprtVdbpHyAi5RTeF408ieNQjXC8IV5HusIM-MqS7PhUOwj8K0I0>). Some of the technological advancements that help us capture motion are specialized optical cameras and/or various sensors that translate this information into data for further analysis. Some of these technologies are:

* Qualisys – uses latest engineering and animation.
* Vicon – uses optical camera and sensors.
* Motion Analysis – has done extensive research for ongoing product enhancements.
* Xsens – uses wearable motion capture technology.
* OtiTrack – combines traditional and innovative methodologies, such as optical solutions, animation, virtual reality, and robotics.
* NDI – focuses on exploiting precision.
* Phoenix Technologies, Inc.- centers on compact and wireless sensor technologies.
* myoMOTION – collects and shows multiple data sets.
* DARI Motion – centers on kinematic and kinetic analysis.

These technologies can help the user learn more about their physical ability, enhance physical performance, and minimize the risk of injuries. Furthermore, biomechanical simulation and sensor data synthesis can help us build new models and simulate various what-if scenarios for further study (<https://www.nature.com/articles/s41598-020-68225-6>). Computer simulations empower us to further analyze, combine, and manipulate motion sensor data using various methodologies and algorithms. The studies could be grouped in reasonable categories, such as professional athletes, recreational athletes, and people recovering from injuries. The collected data could allow us to extrapolate similarities among each category, as well as predisposed individual characteristics that could help design personalized training routine for better performance as well as faster recoveries. Hence, “accurate biomechanical simulations have been demonstrated for human motion analysis and could provide a basis to explore and evaluate wearable system configurations”, which could help provide substantial understanding of motion and how to prolong it over time with minimal deterioration (<https://www.nature.com/articles/s41598-020-68225-6>).

**Websites:**

<https://www.safewise.com/resources/motion-sensor-guide/>

<https://www.vicon.com/resources/blog/changing-the-game/>

<https://simplifaster.com/articles/buyers-guide-imu-sensor-devices/>

<https://simplifaster.com/articles/3d-motion-capture-sport/?fbclid=IwAR0S6TbFprtVdbpHyAi5RTeF408ieNQjXC8IV5HusIM-MqS7PhUOwj8K0I0>

<https://www.nature.com/articles/s41598-020-68225-6>

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6700726/>

<https://www.sciencedirect.com/science/article/pii/S1877050918302497>

<https://www.athleticbusiness.com/media-technology/the-present-and-future-of-motion-tracking-in-sports.html>

<https://reader.elsevier.com/reader/sd/pii/S1877050918302485?token=F90F391F1E23C87D0A646DAC5946CD781CB017D6A1B6430590DB9D512C479ACFB236F165BBEDEB1D288400C47DD6C4BC>

<http://www.pc-education.mcmaster.ca/Tutorials_new/Tutorial_Sol_Ch_7.pdf>

**Variables**

Due to the fact that this is a desktop theoretical investigation, the variables analyzed are physical mobility recorded by sensors (data collection and input) and interpretation of the collected data for the educated and safe improvement of movement.

**Procedure**

This is a theoretical investigation of various work published on the topic of study.

**Observation**

Due to the fact that this is a desktop theoretical investigation, there is no practical observations collected.

**Analysis**

Healthy, safe and risk-fee physical activity is a paramount aspect of our physical and mental health. Capturing the movement and collection of movement data over time using various risk-free technologies has become more and more popular, as it has countless applications tailored specifically to the user’s physical state and ability. Understanding and studying the movement- motor learning- via repetition of a movement during practice or technique improvement can provide overtime data on physical progress and evolution. Motor learning can be achieved using sensors of choice.

Motion sensors use one or more technologies to detect movement in a specific area where the sensor is placed. (<https://www.safewise.com/resources/motion-sensor-guide/>). Sensors attached onto athletes (professional or recreational) collect and arrange data in various ways for evaluation of movement, which can improve coaching efficiently, as well as training methods. There are different sensors that can be used for different training and sports. For example, athletes who swim would use “only accelerometers with various algorithms to detect the swimming stroke style” (<https://www.sciencedirect.com/science/article/pii/S1877050918302497>). “They capture the action and record it into video, from which machine-learning analysis software finds reference points to trace over time. These points are derived from static, clearly defined features that create anchors in the background, as well as through tracking regions on moving objects.”. Analyzing movements can also allow us to predict the next movement, as well as game development. Analyzing movements could also decrease rehabilitation, recovery, and increase travel distance, and strength (<https://www.athleticbusiness.com/media-technology/the-present-and-future-of-motion-tracking-in-sports.html>). A technology-based motor learning can provide a range of solutions for movement improvement via biofeedback systems. For example, sensor signals capture and transmit signals to a processing device, and the results are processed/analyzed then conveyed back via one of the senses (*i.e.* sight, hearing, touch) (<https://reader.elsevier.com/reader/sd/pii/S1877050918302485?token=F90F391F1E23C87D0A646DAC5946CD781CB017D6A1B6430590DB9D512C479ACFB236F165BBEDEB1D288400C47DD6C4BC>). The successful outcome of a biofeedback is movement correction and control of overexertion.

The use of motion sensors has become affordable and marketable as the technology advances. These sensors capture the athlete recovery and the sports performance from swimming, baseball, tennis to ping pong, volleyball, basketball, and weightlifting. “The sports performance analysis field is seeing the rise of ‘inertial’ motion capture technology (also called Inertial Measurement Units or the **IMUs**)“ (<https://www.vicon.com/resources/blog/changing-the-game/>). The IMUs are sensors that collect action/motion data. This data can be used to calculate estimation of work, acceleration, and movement angles (<https://simplifaster.com/articles/buyers-guide-imu-sensor-devices/>). Also, IMUs use more information/data on joint impacts, limb movement, as well as limb loads. This motion sensor is lightweight on the athlete and collects insights and analysis on the athlete’s performance and athlete rehabilitation (<https://www.vicon.com/resources/blog/changing-the-game/>).

Motion capture usually refers to the “the recording of the total body motion in three dimensions” **3D**. Measuring motions with small sensors and capturing a body action have two distinct values:

* Minimal weight without impacting the movement, and
* Custom-tailored performance insights.

With that being said, a small sensor does not usually contain the power to hold much orientation data; however, when the sensor collects “all of the body, those systems should be seen as motion sensors”. In order to follow the 3D capture of motion, the sensor collected data should:

1. “Creates a complete and fully authentic acquisition of total body motion,
2. Provides anatomical orientation of points of reference,
3. Requires a direct recording of three dimensions of data, and
4. Able to collect ballistic activities with high frequency of measurement.”

A motion capture is when the sensors are tracking the body rate and converting information into data which can be useful for application, analyzing, markets, and research.

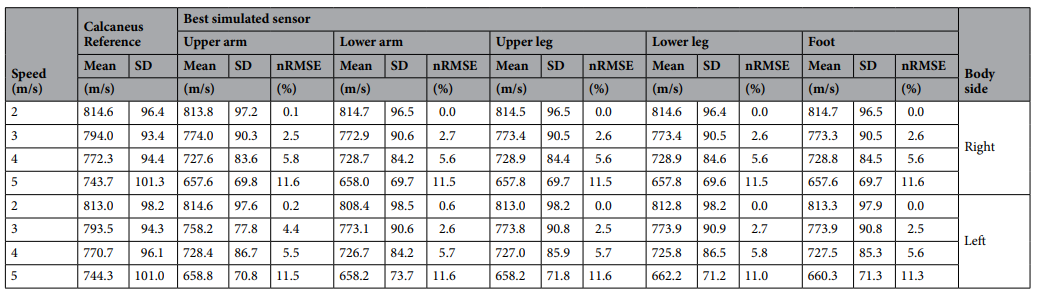
To understand the gathered data, predict future performance, enhanced physical movement, we should not use conventional video as the technology can have an issue with the lighting restrictions and other factors which can limit the perceptible data making it less proficient to use. Instead, the goal of motion capture sensors and software is to capture and exhibit the motion without having outside visual distortions. This type of data is considered clean, and can be manipulated further using various statistical analyses to better understand the movement and its consequences on performance, ultimately helping the user/athlete tailor the physical exercise/training for an enhance and safe movement performance. Motor learning and statistical analysis becomes more and more accurate with more and more data collected that has a wider range and higher sampling frequency (<https://reader.elsevier.com/reader/sd/pii/S1877050918302485?token=F90F391F1E23C87D0A646DAC5946CD781CB017D6A1B6430590DB9D512C479ACFB236F165BBEDEB1D288400C47DD6C4BC>). Data processing and data mining can be further exploited and analyzed using artificial intelligence that will provide additional understanding of the movement (<https://reader.elsevier.com/reader/sd/pii/S1877050918302485?token=F90F391F1E23C87D0A646DAC5946CD781CB017D6A1B6430590DB9D512C479ACFB236F165BBEDEB1D288400C47DD6C4BC>). Occasionally, the movement of the motion capture is converted into qualitive/kinetic motion data. The use of motion capture on athletes are to perceive how athletes advance/move, performance after injury, reduce the risk of new injuries, and rehabilitation of movement. It is commonly used to use the gait analysis after the motion capture of a competitor. There are many types of motion capture technology:

1. **Qualisys**- Focuses beyond sport like animation and engineering. This sport-specific motion capture system software provides a 3D player on a smartphone market and a app for recordings.
2. **Vicon**- Most of the experience come from sports performance and clinical sciences. They provide an IMU sensor choice for athletes.
3. **Motion Analysis**- “The company is well-known in sports due to their extensive development of cameras and software”
4. O**ptiTrack**- “OptiTrack provides traditional optical solutions as well as the emerging market less solutions. They lead in animation, movement sciences, virtual reality, as well as robotics.” (<https://simplifaster.com/articles/3d-motion-capture-sport/?fbclid=IwAR0S6TbFprtVdbpHyAi5RTeF408ieNQjXC8IV5HusIM-MqS7PhUOwj8K0I0>)

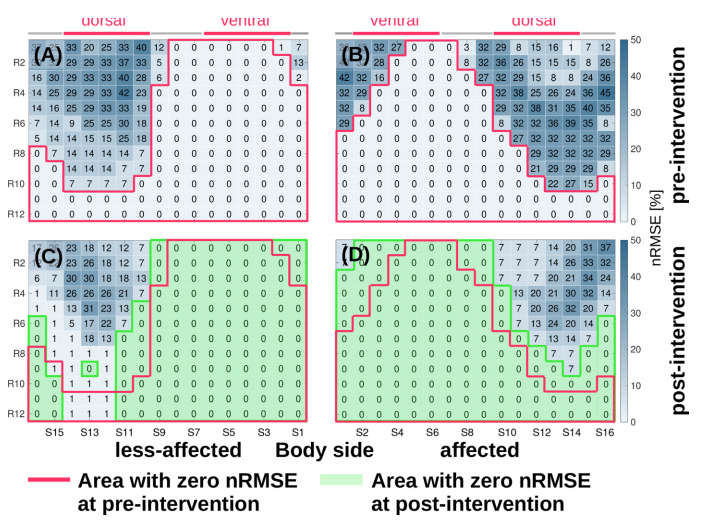
**DATA**

“Estimating wearable motion sensor performance from personal biomechanical models and sensor data synthesis” by Derung and Amft evaluated how sensors could help improve physical performance of runners. Derung and Amft summarize in the below table the stride duration, sensor position, and algorithm correlation to achieve personal speed improvement by analyzing errors collected from sensor data. Also, the below table shows that the sensors helped minimizing the performance errors by 11.6%; hence, gradually improving speed performance. (<https://www.nature.com/articles/s41598-020-68225-6.pdf>)

**TABLE 1.** Performance Speed Data Gathered by Sensors (source: <https://www.nature.com/articles/s41598-020-68225-6.pdf>)



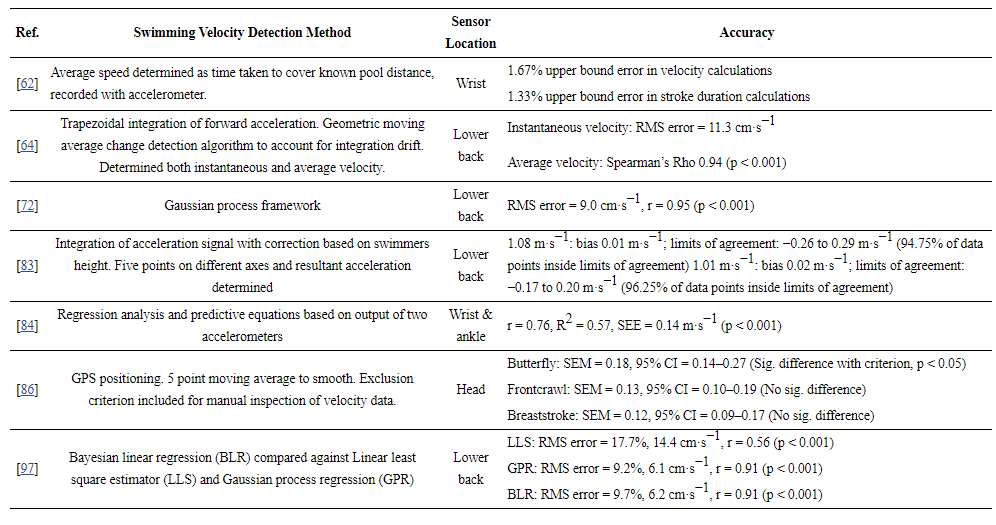
Furthermore, finding the optimal location on the body to place the sensors can provide additional benefits. For instance, Derung and Amft study example showed that it is more beneficial to place sensors in ventral position (<https://www.nature.com/articles/s41598-020-68225-6.pdf)>)



**FIGURE.** Sensor Location Position (source: <https://www.nature.com/articles/s41598-020-68225-6.pdf>)

On the other hand, “Inertial Sensor Technology for Elite Swimming Performance Analysis: A Systematic Review” by Mooney, et al. is looking at improving performance of highly trained swimmers. This research found that the optimal locations for placing sensors are lower back and wrist area for speed improvement (TABLE 2) and wrist and upper back for stroke improvement (TABLE 3). (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4732051>)

**TABLE 2.** Swim Speed Improvement Based on Sensor Placement (source: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4732051>)

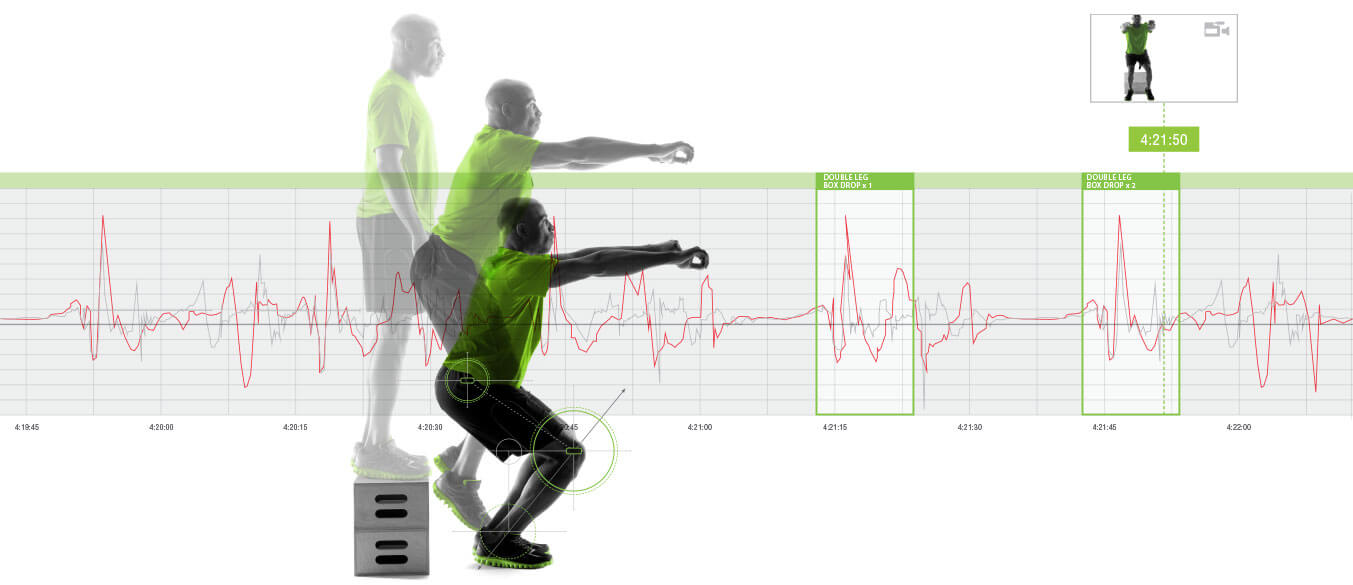


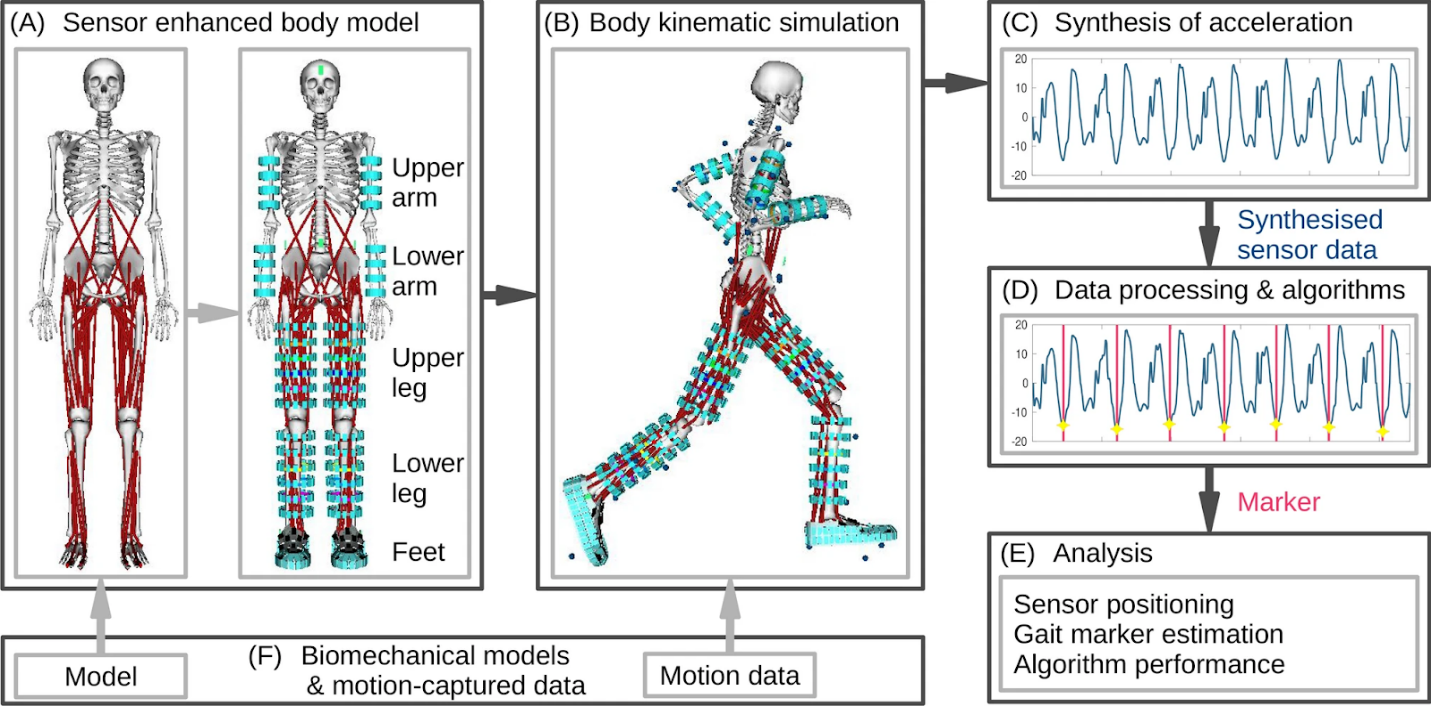
**TABLE 3.** Stroke Improvement Based on Sensor Placement (source: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4732051>)



**Conclusion**

In this theoretical investigation I provided insights into the use of latest technologies for study, analysis, and enrichment of the use of motion sensors and motion captures for improving physical movement, rehabilitation, recovery, and enhanced physical performance of athletes and individuals. I hypothesized that if we understand the physical motion, then we can better and faster improve physical and athletic performance. To reiterate, better awareness of the physical movement provides a better understanding/solution on how to safely improve physical and athletic performance. The motion sensor and motion captures measure the direct angle, body movement, facial expression, and finger movement. This information can help analyze/predict further game movement. You can record the data using graphs and measure the time, speed, and distance. Furthermore, my research supports my hypothesis.  In conclusion, this research makes me assume that if the physical motion could be understood, the better we can improve physical and athletic performances rapidly. This is because when understanding the movements of athletes, it can help us analysis parts of a game. These sensors could also improve the athletic performance, injury recovery, and rehabilitation.





<https://www.nature.com/articles/s41598-020-68225-6>

**Application**

The motion sensors have been utilized for some time now; however, with the technological advancement they are becoming more and more affordable and usable by general public providing a wider data spread for analysis to better understand and enhance physical mobility. The motion sensors can consequently help athletes and general public to better understand physical performance based on the collected data, as well as experiment further with AI-generated data to get a better-quality grasp on short- and long-term performance using a variety of what-if scenarios. Motion sensors that generate data based on the angle movement, acceleration, and facial expression could also be used for animated motivation. However, scientists, athletes, and coaches are mostly concerned with how to prevent injuries, reduce the risk of an injury, and how to improve the performance. Various and specialized motion sensors could be used for multiple purposes in the future, helping athletes to perform their finest, increase the recovery time from injury, and even prevent injuries. The sensor technology has potential during the COVID-19 pandemic, when there is limited access to in person training, as the biofeedback could proactively be used by users to improve their movements and techniques. Data mining, data acquisition, and AI provide additional insight and reinforced learning that could further enhance sensor technologies.