

Exercise & Sports Biomechanics
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Week 04
Lecture 20
OpenCap

[Hello, everyone! Welcome back to this course. In this video, we will explore the new tool called OpenCap].

OpenCap:

It is an open-source software developed at Stanford University. The software is designed for capturing human motion data, and it is widely used in sports, biomechanics, rehabilitation, and research to analyze movement without the requirement of any specialized equipment. In this video, we will go step by step on how to set up OpenCap and collect accurate movement data.

What is OpenCap?

OpenCap is a markerless motion capture system that provides accurate skeletal motion. Based on these two cameras from the video, it will be converted into a skeletal model and musculoskeletal force estimates without requiring any expensive hardware. Because OpenCap will be connected with the **OpenSim software** for the musculoskeletal force.

In the traditional motion capture system, it is a highly complex setup that requires significant time for installation, calibration, and data processing. In OpenCap, we are going to use just two iOS devices. Making it cost-effective and easy to use. This makes OpenCap a powerful tool for biomechanics researchers, coaches, and physiotherapists.

Now, why should we use OpenCap over the traditional motion capture system?

Because it is low-cost and easy to use. We do not need any expensive cameras or complex software. You just need two iOS devices like an iPhone or iPad. The entire setup takes only five minutes, and data processing will complete within a few minutes. The system is validated against a marker-based motion capture system, which is the gold standard in biomechanical research and force plates, ensuring reliable data. That is why OpenCap is a game-changer in human movement analysis because it is affordable, quick, and highly precise.

What equipment is required for biomechanical analysis in this software?

The first one is the two iOS devices. These devices will act as motion capture cameras. The second one is the tripod to keep the cameras stable. The third one is the internet connection. It is required for cloud-based data processing. In addition, we need one laptop, to access the OpenCap web platform. Only through this can you collect human movement data, process it, and visualize the results. At last, we need a printed checkerboard. It will be used

for camera calibration. Once you have all this equipment, you are ready to set up the OpenCap motion capture system.

Next, we will proceed to setup and installation:

The entire setup of OpenCap is very simple. First, we need to install the OpenCap mobile app by scanning this QR code to install it on your iOS devices. Alternatively, You can open the Apple App Store. Just type OpenCap in the search box and then press the Get button to install the application. You are now ready to record **3D human movement** with two cameras.

Next, we will set up the recording environment:

First, identify an area with sufficient light, and it is always best to avoid people or objects in the background to ensure clean data capture and minimize distractions. Next, from the iOS devices, OpenCap uses the Rear-facing camera for recording. So, always make sure the back camera is facing the participant while setting up. When performing any sporting movement, there may be a chance of segment occlusion. What does that mean? Segment occlusion happens when one body part blocks another body part from the camera's view.

To get accurate motion data, we need to position the camera carefully to avoid body parts being hidden during the movement. You know, we need at least two cameras in the image. You can see we have placed two cameras, and they should capture every body segment at all times during the movement. That is why the camera should be placed at least at a **30-degree angle to a 45-degree angle from the checkerboard**, and as a biomechanist, we need to ensure the participants stay within the field of view. If you feel the body segments are still getting blocked, you can add an extra camera for a different perspective. In the end, we need to make sure the body segments do not get occluded. When you are placing the camera, you should avoid placing the camera directly from the side view, which is the **sagittal view**. Because it will definitely lead to limb occlusion, where either one arm or one leg will definitely block. So, you will not get the data.

One most important rule when we are recording is that the player should never exit and re-enter the capture area during recording. Moving out of the frame means the camera is unable to track the human, which disturbs the complete motion tracking. This leads to incomplete or inaccurate data.

Go to Google, type OpenCap, and there will be an option called **OpenCap.ai**. Click on the link. You will be directed to the home page of the OpenCap application. If you press start recording, it will direct you to the home page. So, you have to log in with your credentials.

And on the left-hand side, there is an option called new session. [So, I will click on the new session]. You can see the QR code on the screen, which facilitates you to connect both your iOS devices. Next, open the OpenCap app on your phone. Scan the QR code from the web application. Then, mount your phone either vertically or horizontally on a tripod. Make sure to position the tripod and camera to capture the volume of interest as discussed before. You can go up to a maximum of 4 cameras, then repeat the process and connect all the phones.

After connecting the phone, verify whether you can see the checkerboard on both devices. Before initiating the calibration, the best practice is to ask the player to perform within the field of view and check in both cameras to ensure the players remain fully visible throughout the motion. If not, reposition the camera and repeat the process.

Once the recording environment is ready and both mobile devices are connected to the web app, then press the button next.

Next we will move to the important step in OpenCap called calibration.

Calibration is a critical step in OpenCap, because we need to use a checkerboard on **A4 paper with squares at least 35 mm in size** and ensure wide borders around all sides of the checkerboard. Count black to black corners, not just the number of squares when entering the data in the web app. For example, this is corner 1, corner 2, corner 3, and corner 4. So, there are 4 rows. Similarly, 1, 2, 3, 4, and 5 columns. So, we have to input 4 rows, 5 columns, and the size is 35 mm. The calibration helps OpenCap understand the spatial positioning of the cameras, which is essential for accurate motion tracking.

Once everything is done, press the calibrate button. Once the video is calibrated, you will be directed to the next page where you will provide the basic information of the subject and the session name. At this moment, we need to educate the subject about static calibration and dynamic trials. In addition, we need to make sure the subject is wearing properly fitted clothing to ensure the body movement is visible.

Next, we need to record the neutral pose. Further, ask the subject to stand still for a few seconds, which facilitates OpenCap to calibrate the model. Always remember to start recording at least one second before the movement begins. Once the neutral pose is recorded, it will direct you to the next page where you can see the skeletal model of the neutral pose.

On the left, It is indicated with a green dot in front of the neutral pose, which means it was successfully processed. At the top, you can provide the trial name and start recording the dynamic trials. Once it is done, below the neutral, we have given the trial name 'squat'. You can notice the green dot over there, which means it is also successfully processed.

In addition, you can see the skeleton model performing a squat. If you open the particular session, on the left-hand side, you can see all the neutral and dynamic trials. In addition, it is clearly indicated with green dots, which is more important because the data is successfully processed. On the right-hand side, you can see both the recorded videos, and in the middle, you can see the skeletal model. Once the recording is done, OpenCap automatically uploads the video to the cloud.

The processing time depends on video quality and internet speed. But usually, the motion data results are available within a few minutes. You can check that in the dashboard kinematics. From here, we can analyze the kinematical parameters like joint angles and movement patterns for detailed biomechanical interpretation. There is an option to export the data in different file formats like CSV or OpenSIM files for further analysis.

Once you press download, you can explore the detailed information on that. Once you download the folder, you can see four folders within it. The first one is the calibration images. You can see two images of the calibration. In addition, you can see the X-axis, Y-axis, and Z-axis of the calibration.

If this calibration is wrong, then we cannot compute the further analysis. The fourth one is the video folder where you can explore all the recorded videos like counter-movement jump, multiple times, or the neutral poses. Everything can be visualized here. Now, the third one is the OpenSim data, which is the most important thing. If you go into the model, OpenCap is generating the scaled .osim, specifically the OpenSim model, where we can do further analysis in OpenSim for musculoskeletal forces.

In kinematics, You have the .mot file, and in the marker data, you have all the .trc files, which are required for further analysis in OpenSim. Now, you can see the dynamic trials with the skeletal model. The model is performing a counter-movement jump.

Next, we move on to dashboard kinematics:

Once you click that, on the left-hand side, you have an option to choose the trial. So, we have done the three trials. We can opt for either one. And that is an option to choose X quantity and Y quantity. By default, the X quantity is time, and the Y quantity is open.

If you click on that, you can see multiple options are there. Right now, you can see the pelvis information where pelvis tilt, rotation, and movement in three different axes. Further, it comes to hip movement like flexion, adduction, and rotation. Then knee angle, ankle angle.

All this information is for the right leg, and it is a replica of the left leg. In addition, we have lumbar extension and rotation, arm flexion and rotations, elbow, both the left and the right arm. If I choose any one of the variables on the left-hand side, I will choose knee angle right. In the middle, you can see the chart. So, the X-axis is time, and the Y-axis is the knee angle.

On the right-hand side, you can see there is a title. I can change the title to knee angle. The subtitle is measured in degrees. So, what is the title of The X-axis is time, and the Y-axis is knee angle, with the title.

You have the line width and point style. Currently, it is none. If I choose maybe cross, it will take a few seconds. Now, you can see the different style of the chart. So, I can go to star.

There are multiple styles available. You can explore that. So, I will go to none. There is a point size which is 12. You can increase or decrease it. And the legend position, whether you want it on the right side or at the bottom, you can change it. And the legend alignment, which is the center, the start, or the end, and the color of the graph. So, I can choose yellow or green. You can see the changes.

Once everything is done, you can download the chart. So, it will be downloaded to your folder. In the previous video, we explored the angle-angle diagram, which means both the

X quantity and the Y quantity have different angles. For example, right now, in the Y quantity, I have the right knee angle. So, in the left one, I will go and change it to right hip flexion, then it is going to be a different perspective of the angle-angle diagram. So, you can see here at the bottom, it is automatically changed to hip flexion right with the knee flexion. This data will help us understand the coordination profiling of these joints. Once the analysis is done, you can go back to the visualizer.

[So, thank you, and see you in the next video].