Exercise & Sports Biomechanics
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Week 07
Lecture 33
Timing Gates

[Hello! So, in this section, we are going to delve into the fascinating world of timing aids and their applications in exercise and sports science].

This session will provide you with a comprehensive understanding of how timing gates work, their importance, and how they are used in various sports.

Timing gates:

Timing gates are essential tools in sports science, providing precise measurements of an athlete's speed and acceleration. They are commonly used in track and field events, as well as in training sessions, to monitor progress and performance. Electronic timing systems have revolutionized sports biomechanics by providing precise measurements of speed, reaction time, acceleration, and movement efficiency. These systems are essential for performance analysis, injury prevention, and optimizing training methods.

Timing gates have a variety of features, ranging from different hardware functionalities to widely varying apps and software infrastructure. These features can significantly impact users' experience or their suitability for certain environments, applications, organizations, and practitioners.

Talking about the evaluation of timing gates technology, it has changed a lot since its inception in the 1980s.Yes, timing gates first emerged in speed assessment during the 1980s. The earliest models used infrared photocells to track time trial speed events such as track sprinting, ski racing, and autocross events. Technological advancements in beam-break detection, data analysis, and timing accuracy have given rise to modern timing gates technology. The same core elements of timing gate assessments hold true.

Modern timing technologies provide accurate automated timing functions remove the complexities in setup, analysis, and data tracking of traditional speed testing methods. So, if you see in the picture, the first kind of timing gates that we were having is basically based on the infrared photocells. This was basically revolutionized to the RFID-enabled finishing timings, so with this, it was easier to take the timing data of multiple athletes at a time, which has been advanced to wireless technology in the year 2003. So, before that, whatever we were having is like each gate is connected to another gate with a wire, so there is a limitation of the distance between the gates. Then we will be having the magnetic field timing aids, so the size is basically getting reduced and it becomes more compact with a beam, followed by the cloud-based system for data transfer.

Nowadays, we are having the most advanced technology, which is basically providing highly accurate data. Like, you know, we can have the data up to the thousandth of a

second. Talking about the parts of the timing gate, the first part which we are discussing is the photocell. The photocell is a sensor that detects changes in light, and in timing gates, it detects the interruption of an infrared beam, signaling the start or stop of the timer.

So, the photocell emits infrared light, which basically goes to the reflector, which is just positioned opposite to the photocell to bounce the infrared beam back to the sensor. So, it ensures that the beam is continuous and can be interrupted by an athlete passing through. So, the photocell is emitting the light, and the reflector is reflecting it back. So, there is an invisible beam of light which is in between the reflector and the photocell. So, once the athlete crosses this invisible beam of light, the data is collected by the data collection hub. So, the data collection hub receives the signal from the photocell and records the timing data. It may also process and store this data for later analysis. After this, once the data is collected by the hub, then it has been connected to the software. This specialized software is used to analyze the data collected by the timing gates. It provides insights into performance metrics such as speed, acceleration, and split times. Understanding the components of timing gates is crucial for their effective use. The photocell and the reflector work together to detect motion.

While the data collection hub and the software process and analyze the data. This setup ensures accurate and reliable performance measurement. So, we just discussed how it works. So, again, just to revise, the timing gates operate using infrared sensors that detect the motion of an athlete as they pass through the gate. When the infrared beam is broken, the timer starts or stops depending on the setup.

A similar kind of setup may be used in factories to count the number of bottles, as you can see here. So, when the bottle crosses the gates, the beam of light gets broken, and that bottle gets counted. So, in the bigger picture, you can see that this is nothing but a photocell, and this is a reflector. The orange beam of light is basically the light that is emitted from the photocell and reflected by the reflector. So, once the athlete crosses this particular light, at the same time, the timing gets recorded into the hub, and that is connected to the software.

The most common timing gates use beam technology, emitting an infrared or lidar beam, which is constrained by a reflector, creating an invisible light that acts as a gate-initiated signal. The beam technology can also be enhanced by smart firmware features such as error correction processing or ECP, whereby the erroneous beam break from an arm or leg can be detected and ignored, ensuring the system only records the time interval when the athlete's torso has broken the beam. This mechanism allows for highly accurate time measurement, often down to the millisecond. So, when we run, usually our hands are ahead of our torso or our trunk. So, there might be a chance that our hand may break this beam of light, and the timing is recorded. So, there is a technology called **error correction processing.** What it does is basically record the longer time. For example, if the beam is broken by my hand, immediately after that, it is broken by my torso. So, it records the longer time, and definitely it is my torso because of the larger cross-sectional area than the hand. And it provides accuracy in the data.

Talking about the **importance of timing gates in sports**. The first importance is obviously precision and accuracy. We all know that precision refers to the consistency and repeatability of timing measurements. A high-precision system ensures that repeated

measurements of the same event yield nearly identical results. And accuracy measures how close a recorded time is to the true event time.

Advanced electronic timing systems reduce errors to within milliseconds, providing highly reliable data. So, timing gates help eliminate human error in timing, provide millisecond-level accuracy, and are essential for fair competition and detailed performance analysis in competitive sports. Timing gates have their own importance in terms of their impact on performance analysis. Accurate and precise timing allows coaches and athletes to monitor even the smallest improvements in performance. They are effective in eliminating human error.

Unlike manual timing methods, electronic systems eliminate reaction time delays and inconsistencies. They can also have applications in research, as precision and accuracy are critical in biomechanics studies where small timing variations can significantly impact movement analysis and injury prevention. So, timing gates help measure reaction time, stride length, velocities, and acceleration. And they can be valuable assets in biomechanical research for technique improvement.

Talking about **reaction time measurement, electronic timing systems** measure an athlete's response to stimuli, which is crucial in sprinting, swimming, and other explosive sports. It helps us track velocity and acceleration, as systems such as laser timing gates and GPS-based trackers provide real-time velocity and acceleration data. The timing gates help in finding split and interval timings. The photoelectric beam and RFID transponders help assess split times for pacing and endurance evaluation. They help in technique evaluation, such as If the timing gate is connected to the motion capture system and the force platform system, and they are synced together, the synchronized timing data with this motion analysis system can help refine the technologies.

Timing gates are also essential for fatigue monitoring and tactical decision-making. Performance trends analyzed over multiple sessions help identify signs of fatigue and overtraining. On the other hand, coaches use timing data to develop game strategies, such as positioning and movement patterns in team sports. Timing gates help in injury prevention by identifying movement deficiencies that may lead to injuries. They also allow coaches and physiotherapists to monitor load and recovery.

In load monitoring, electronic timing tools track training intensity and workload distribution, helping prevent overuse injuries. In fatigue assessment, GPS and RFID-based timing systems detect declining performance trends, indicating potential injury risk. They can also be a valuable asset in rehabilitation tracking, as timing data helps physiotherapists monitor an athlete's recovery progress and readiness for competition. Reaction time measurement for injury prevention is another benefit of timing aids, as slow reaction times may indicate neuromuscular fatigue, increasing the risk of acute injuries. There are different types of timing gates available in the market.

But the **photoelectric beam systems** are the most common, which can be visible on the ground near you. So, they are the **infrared beam-based timing gates**. So, the photoelectric beam systems use infrared beams to accurately measure an athlete's speed, reaction time, and timing. This system consists of a transmitter and a receiver placed at designated points.

When the athlete crosses the beam, the interruption is recorded, allowing precise timing measurements, as we discussed in the previous slide. So, how does it work? So, it has a proper setup where the infrared transmitters and receivers are positioned at the start, split, and finish points. As the athlete moves past the beam, it breaks the infrared signal, and that signal break is recorded by the hub. So, the system records the exact time of beam interruption, providing accurate performance metrics. They have a variety of uses in sports, like in track and field events. So, they can be used in sprint and hurdle events to measure speed and finish timings. In cycling, they measure acceleration, top speed, and section timing.

In events which involve speed and agility drills. So, the timing gates are used in soccer, basketball, and rugby training to assess players' speed and agility. And in skiing, they help measure downhill and slalom race timings. So, the photoelectric beam system has its own advantages, like being highly accurate and eliminating human timing errors. They are non-invasive and do not affect the athlete's movement, and they can be used for both training and competitive analysis.

Another type of electronic timing system is the **touchpad timing system**. These systems use pressure-sensitive pads installed at key points, such as swimming pool walls, to record times accurately when pressed by athletes. The touchpad is activated when the swimmer physically touches it. It ensures precise timing for starts, splits, and finishes. So, they are timing gates, which are usually used only in swimming competitions.

They have applications like being primarily used in competitive swimming to ensure accurate finish times and split times, integrated with starting blocks and electronic scoreboard systems for real-time feedback. They are utilized in research to analyze stroke efficiency and reaction time in swimmers.

[Now, let's discuss the **advantages of the touchpad system**].

They eliminate human error associated with manual timing. They provide immediate feedback for swimmers and coaches.

They ensure fair and accurate race results in competitive swimming events. They have their own limitations, such as requiring proper calibration and maintenance to ensure consistent accuracy, and can be affected by water conditions or improper touch technique by the swimmer. Another type we are discussing here is the GPS-based timing system. They utilize the Global Positioning System (GPS) technology to track an athlete's position, speed, and movement in real time. They provide highly accurate data on distance covered, velocity, and acceleration.

They can be integrated with wearable devices such as GPS watches or sensors placed on athletes. They have a variety of uses, such as extensive application in endurance sports like cycling, marathon running, and triathlon for route tracking and pacing analysis. They are common in team sports like soccer, rugby, and basketball to analyze movement patterns, player positioning, and workload distribution. They can be implemented in motorsports for real-time tracking of vehicles and lap time monitoring. Talking about the advantages of GPS-based systems, they provide real-time continuous tracking of an athlete's movements.

They offer insights into pacing, fatigue levels, and tactical positioning. They can be integrated with other biometric data such as heart rate and power output. So, there are certain equipment now in the market which come as dual systems, providing heart rate data as well as GPS data. So, the path that the athlete has followed. But the system has its own limitations, like accuracy may be affected by signal interference from buildings, tunnels, or adverse weather conditions. The battery life constraint in wearable GPS devices can limit prolonged use. It requires calibration and synchronization with other performance tracking systems for optimal accuracy.

[The next type that we are discussing here is a **motion capture system**].

We all know that in biomechanics, there is a specific motion capture system which basically consists of a number of cameras, and those could be 2D or 3D, as we have discussed in previous sessions. But here, it uses multiple high-speed cameras or sensor-based systems to track an athlete's movement in three-dimensional space. So, synchronizing the timing data with biomechanical analysis helps evaluate posture, joint angles, and movement efficiency. It is like syncing the timing gates data with the motion capture system to get a holistic approach towards performance. And it can be a marker-based motion system, markerless, or AI-powered. That is roughly regarding the holistic approach towards athlete assessment. So, it is applied in sports biomechanics to refine movement techniques such as sprint mechanics or golf swings along with timing.

It help assess rehabilitation process in injured athletes by comparing pre and post injury motion pattern. It analyze the complex movements in gymnastic, figure skating and the combat sports for performance enhancement and the integrated with the virtual reality for training simulations and the feedback. So, the advantages of the motion capture system sync with the timing gates is like they provide the highly detailed motion analysis for technique improvement. It helps the identify insufficient movement pattern that may lead to injury and can be used in both laboratory and on field setting depending on the technology types. But it has the limitations of like they are expensive and require specialized equipment and expertise.

The high speed cameras and the sensor need proper calibration for accurate data and the motion capture data processing can be time consuming and complex.

Another type of electronic timing system is basically the timing gates which are synced with the force plate. So, the force plate with timing gate data capture. So, it measures the ground friction forces. The foot contact timing and pressure distribution.

It used in conjunction with electronic timing system to analyze movement pattern and force application. It provides detailed insight into balance, stability and explosive power. So, this kind of application is commonly used in jumping, sprinting and cutting movement to assess explosive strength and agility. It helps in injury prevention by identifying asymmetries or improper load distribution. It is used in rehabilitation to track recovery progress and biomechanical efficiency and applies in gait analysis to assess movement mechanics in running and walking.

Talking about the **advantages of the timing system with the force plate** includes highly accurate data collection for force production and movement efficiency. They are essential for identifying potential injury risks and biomechanical imbalances, providing valuable data for both sports performance enhancement and clinical rehabilitation. They have limitations, such as requiring specialized equipment and expertise for data interpretation. Stationary force plates limit analysis to lab-based environments only, and the high cost and maintenance requirements of the force plate make them unaffordable for many laboratories.

[The next type of timing gates we are discussing here is the **laser timing gates**].

Laser timing gates:

Laser timing gates use infrared or visible laser beams to measure speed, reaction time, and acceleration. The laser sensors are placed at the start and finish lines, and they are common in sprint tests, agility drills, and speed assessments. They provide real-time feedback for training. How do they work? These gates consist of a transmitter and a receiver, similar to the photoelectric ones, placed at specific intervals.

When an athlete crosses the beam, the system records the time of the interruption. It is the same as the infrared one. They have a variety of applications in sports, such as sprinting, agility drills, and reaction time testing. They are common in track and field, soccer, and skiing to measure movement efficiency. They are employed in research settings to study gait analysis and movement patterns.

They have their own advantages like the high precision and the millisecond accuracy. The wireless and the portable options are available for field use and they can eliminate the manual reaction time error associated with the hand help stopwatches. But they have their own limitations like the environmental factors like sunlight and the obstacle can interfere with the accuracy and the proper alignment and the calibrations are necessary for consistent result.

Another type which we are discussing here is **RFID and the transponder system**:

The radio frequency identification that is the RFID tag attaches to the athletes or the equipment and they are used in marathon races cycling and the triathlon mostly and the track split times and the movement patterns could be possible with the RFID very easily. They use the radio frequency identification technologies and the transponders to track athletes movement in the rear time. So, it will be very easy to track the more number of athletes at a time with designated RFIDs. So, an RFID chip or the transmitter is attached to the athletes which communicates with the RFID reader placed at the checkpoint. It has the application like extensively used in endurance sports such as marathon, triathlon and the cycling races. And it is applied in the motorsports for real-time vehicle tracking. Integrated into the small apparel and wearable for tracking training loads.

It has its own advantage like it provides the highly accurate timing and tracking over long distance. It eliminates the need for manual checkpoint recordings work efficiently in crowded risk setting. And it has their own limitations like dependent on the battery life in active RFID transponders. The signal interference can occur in dense urban environment.

One more type of electronic timing system which we are discussing here is like the **goal line and the hawk eye technology:**

They are mostly used in the soccer, tennis and the cricket and they uses the multiple cameras and the electronic timings to determine the ball position and they ensure the accurate decision making in competitive sports. So, they uses the multiple high speed cameras and the advanced imaging process software to track the ball movements. The Hawk-Eye triangulates the exact position of the ball in real time and determines whether it has crossed the goal line or not. And the goal line technology also known as the GLT, it sends an instant signal to the referee's watch when a goal is confirmed. So, it has a wide application like used in soccer to determine if the ball has completely crossed the goal line. Implemented in tennis to track ball trajectory and assist in line call decisions and used in cricket to analyze LBW that is leg before wicket decision and ball tracking for empire reviews and applied in various other sports such as badminton and basketball for line calling accuracy. So, this technology have their own importance like they provide the highly accurate and indisputable decision. They reduce the referee's error and improve the fairness in the competition. They offer the real-time decision making to minimize game delays and enhances spectator experience by providing visual ball tracking on screens.

They have their own limitations like the high implementations and the maintenance cost. They require multiple cameras and advanced computing power. The technologies can still be subjected to rare miscalculations in extreme conditions. So, if we are talking about the beam technology, so beam can be of two types. It could be of single beam or it could be of the dual beam technologies.

Considering the researches the dual beam are considered to be the more accurate because it is they work like if both the beams breaks at the same time only then only they record the time. So, and it is only possible when your torso crosses the lights or the gates. So, the single beam timing gates use one infrared beam to detect the motion. They are simpler to set up but may be more prone to false triggers if the beam is interrupted by something other than the athlete. And the dual beam timing aids use two infrared beams to detect motion and they provide more accurate measurements by reducing the likelihood of false trigger. The timer starts when the first beam is broken and stop when the second beam is broken. So, this table differentiate between the single beam and the dual beam timing aids like you can see as the name suggests the single beam uses one infrared beam to detect the motion while the dual beam uses the two infrared beam to detect the motion.

Talking about the accuracy in the single beam may be less accurate due to the potential false trigger while the dual beam is more accurate as it reduces the likelihood of false trigger. The setup of single beam is much simpler with the fewer components while that of the dual beam is more complex because of the additional beam. The false trigger is like it has a higher chance in case of the single beam and the chances are much lower in case of the dual beam. Talking about the cost, the single beam are generally cheaper than that of the dual beam. And the data collection is like the start and stop timings with the single beam interruption.

On the other hand, in a dual beam, the timing is recorded only if both the beams are basically interrupted together.

[Thank you and see you in the next video].