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EUROPEAN EDUCATION AND CULTURE EXECUTIVE AGENCY (EACEA)

EDATS - European Digital Assisted Training in Team Sports

Project acronym:

EDATS

D3.1 - ICT SPORT tool

Project number:
101133614
Call:

ERASMUS-SPORT-2023

Topic: ERASMUS-SPORT-2023-SCP

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DELIVERABLE INTRODUCTION

DOCUMENT DETAILS	
Project Title	EDATS - European Digital Assisted Training in Team Sports
Project Number	101133614
Work Package	WP3 - Planning and implementation of training modules]
Activity	T3.1 - Technical requirements definition T3.2 - Development of the platform T3.3 - Integration with sensors for datacollection
Deliverable	D3.1 - ICT SPORT tool
Delivery Date	31/10/2025
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1 INTRODUCTION

The objective of Deliverable D3.1 is to provide a first functional prototype of the ICT SPORT Tool, the digital platform developed within the EDATS project to collect, process and analyse biomechanical data from wearable sensors, and to support the definition of personalised training methodologies for athletes.

This deliverable marks a key milestone in WP3, as it demonstrates the technical feasibility of the platform and enables its validation through partner testing and pilot activities.

Objectives and scope:

- Provide a secure, cloud-based platform accessible via web interface.
- Enable data collection and integration from heterogeneous biomechanical sensors.
- Offer visualisation dashboards and basic analytics for athletes, coaches and managers.
- Support multilingual use (English + partner languages).
- Facilitate pilot testing within participating sport organisations.

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2 BACKGROUND AND SCIENTIFIC RATIONALE

Athletic performance is the result of the synergic work of professionals from various disciplines — medical doctors, physical therapists, coaches, psychologists, nutritionists, and sport scientists — who collaborate to guide the development of each athlete. In modern sport, every field increasingly relies on technology to collect and interpret data that inform training and performance improvement. The impact of technology has grown enormously: in elite sport, the use of analytics and wearable devices is now indispensable to monitor progress, optimize training and reduce injury risks, while even amateur and sub-elite athletes have started to use affordable sensors and data-driven tools to improve their performance. Yet, while collecting sport-related data is easier than ever, the real challenge lies in learning how to use them properly — a goal that requires improving the technological literacy of coaches, trainers, and all other professionals involved.

This is the motivation behind the EDATS – European Digital Assisted Training in Team Sports project, which aims to integrate accessible digital technologies into training methodologies. The initiative promotes the use of quantitative tools to assess postural control and vertical jump performance in volleyball, improving talent identification, performance evaluation, and rehabilitation monitoring. By combining scientific rigor with practical applicability, EDATS seeks to make biomechanical analysis available beyond the laboratory, through a low-cost, easy-to-use hardware and software platform based on wearable inertial sensors (IMUs).

Volleyball was chosen as the reference sport because it offers an ideal context to study balance and explosive movements. Players constantly perform complex technical actions under unstable conditions, and those with superior postural control can execute them more efficiently and with a lower risk of injuries, particularly in the lower limbs. Traditionally, postural control has been measured with force or pressure platforms, which track the trajectory of the Center of Pressure (COP) during static balance tests (Figure 1). From these trajectories, metrics such as displacement, velocity, and ellipse area are computed: lower values indicate better balance performance. However, while accurate, such equipment is expensive, non-portable, and impractical for everyday training.

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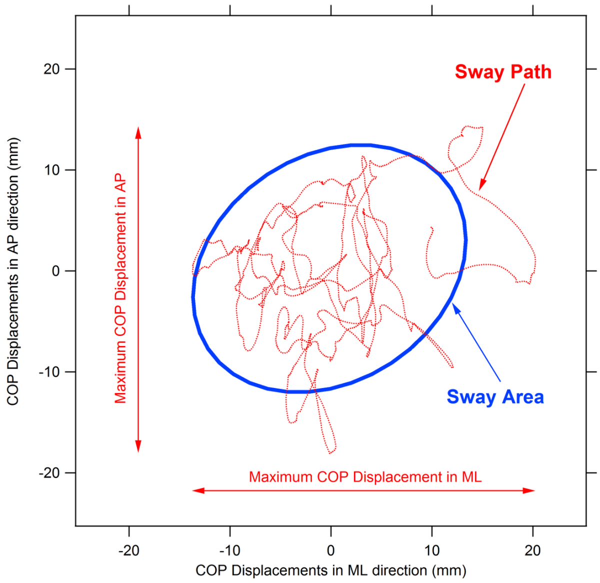

Figure 1: Example of a COP trajectory recorded with a force platform during postural control testing.

To overcome these limitations, EDATS introduced wearable Inertial Measurement Units (IMUs)—lightweight sensors that record accelerations, angular velocity, and orientation with high precision and low energy consumption. The project adopted the Muse V3 sensor developed by the Italian company 221e (Figure 2), which combines accelerometers, gyroscopes, and magnetometers with Bluetooth connectivity and an integrated Kalman filter.

Figure 2: MuseV3 IMU sensor used in the EDATS project (source: 221e Srl)

Each device is positioned near the L5–S1 vertebrae, corresponding to the athlete's Center of Mass (COM) (Figure 3). Although the COM and COP trajectories are not identical, they are strongly correlated, making it possible to replicate balance assessments using wearable sensors. To validate this approach, tests were carried out simultaneously with IMUs and force platforms, enabling direct comparison of the two systems.

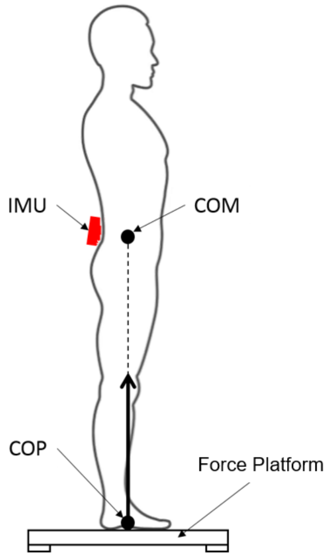

Figure 3: Position of the IMU sensor near the athlete's center of mass (L5–S1)

The validation campaign included 585 trials performed by 110 participants, both athletes and non-athletes, who completed various postural control tests: bipedal with eyes open or closed, and unipedal on both legs. Results showed a good correlation (R = 0.62–0.71) between IMU- and force-platform-derived parameters, confirming the feasibility of IMUs as a reliable alternative for balance evaluation (Figure 4).

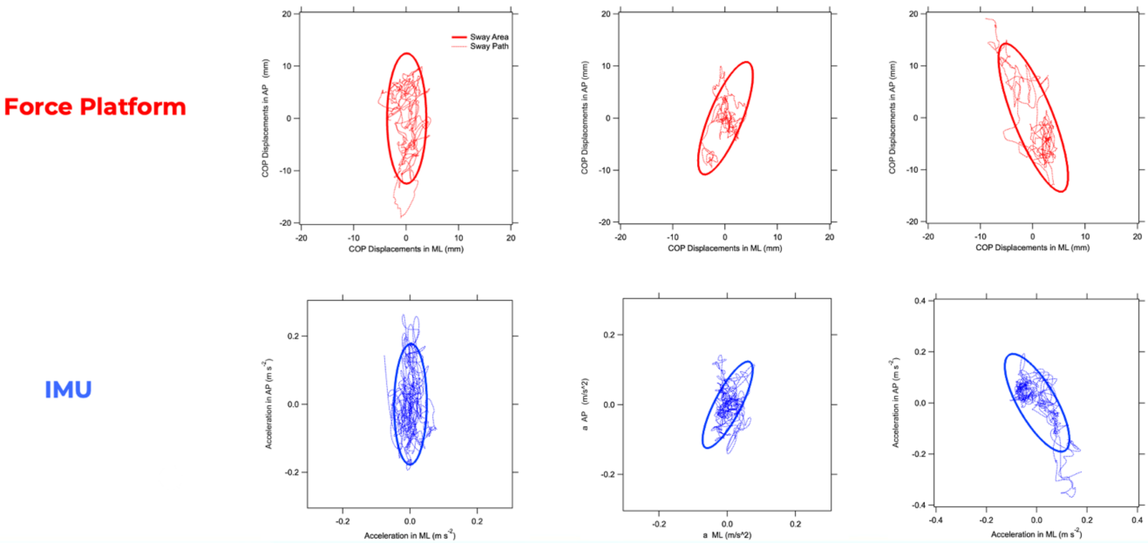

Figure 4: Correlation between IMU- and force-platform-derived parameters for postural control.

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The same device was also used to measure vertical jump height, a critical component in volleyball training. By processing acceleration signals, the system determines the time of flight, which is used to estimate jump height. Data from 454 trials conducted on about 100 subjects revealed a strong correlation (R = 0.92) between IMU and force platform measurements, especially among experienced athletes. These findings confirm that IMUs can provide accurate and repeatable jump assessments even in on-field conditions. The collected dataset also allowed comparisons with literature values, leading to the definition of reference benchmarks according to age, sex, experience, and level of play.

Beyond static and explosive performance, the project explored dynamic balance through the analysis of Time to Stability (TTS)—a measure of how quickly an athlete regains balance after landing. In this test, participants performed submaximal forward jumps with bipedal take-off and single-leg landings. TTS was calculated from both ground reaction forces (force platform) and total acceleration (IMU). The accelerometric TTS (aTTS) was defined as the time when acceleration returned within ±5% of baseline for at least one second. The correlation between the two systems (R = 0.87) demonstrated that IMUs can capture both take-off and landing dynamics, providing a complete picture of movement recovery.

All these validated procedures were subsequently implemented into the ICT SPORT Tool, the web-based application developed by Dauvea within EDATS. The platform integrates the results of biomechanical research into a practical environment where coaches and sport professionals can conduct standardized tests—posturography, jump analysis, and time-to-stability—while managing multiple athletes and visualizing results in real time. Each module corresponds to a research outcome: static balance, explosive power, and dynamic balance. Upcoming updates will further expand its features to include multi-sensor acquisition and sport-specific tasks for team monitoring.

In comparison with existing commercial systems such as Xsens, APDM Opal, or Vert, the EDATS solution distinguishes itself by being open, validated, and sport-specific, offering transparency in data processing and affordability for clubs, schools, and academies.

Finally, the success of EDATS lies in its collaborative and European dimension. Every phase of the project — from laboratory studies to field testing — has benefited from the contributions of all partners. Through meetings, workshops, and practical sessions, the consortium has fostered a common understanding of how technology can enhance training, injury prevention, and communication between coaches and scientists. This continuous exchange of ideas represents not only the backbone of the project but also a model for how digital transformation can support the future of team sports.

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3 INTRODUCTION ON TECHNICAL DETAILS

The guide explains the hight level overview of EDATS Application (ICT Sport Tool). Edats Application is a digital platform created to connect the world of sports research with sports technicians. It collects data about human movement using small inertial sensors (IMU). All data acquired go into a web application that processes the information in real time.

In this way, the platform helps to apply new training methods, improve performance, and reduce the risk of injuries or help rehabilitation. The platform has two main parts: the physical sensors and the web application that manages and analyses the data.

This document describes the technical specifications of an integrated system designed to collect, transmit, and analyze data from IMU (Inertial Measurement Unit) sensors. The system architecture involves multiple layers, including devices, a cloud backend, and user-facing front-end applications. The solution ensures secure communication, data integrity, and scalability for large-scale deployments.

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4 SYSTEM ARCHITECTURE OVERVIEW

The IMU Data Collection System is composed of interconnected modules that communicate seamlessly to acquire, process, and visualize motion and orientation data from sensors. The system architecture includes the following main layers:

- **Device Layer** – IMU sensors connected to user devices via Bluetooth.
- **Front-End Layer** – A responsive web application developed with Ionic and Angular.
- **Cloud Layer** – Backend hosted on AWS, managing data storage and analytics.
- **Data Storage** – NoSQL database (MongoDB) and a Data Lake for raw data.

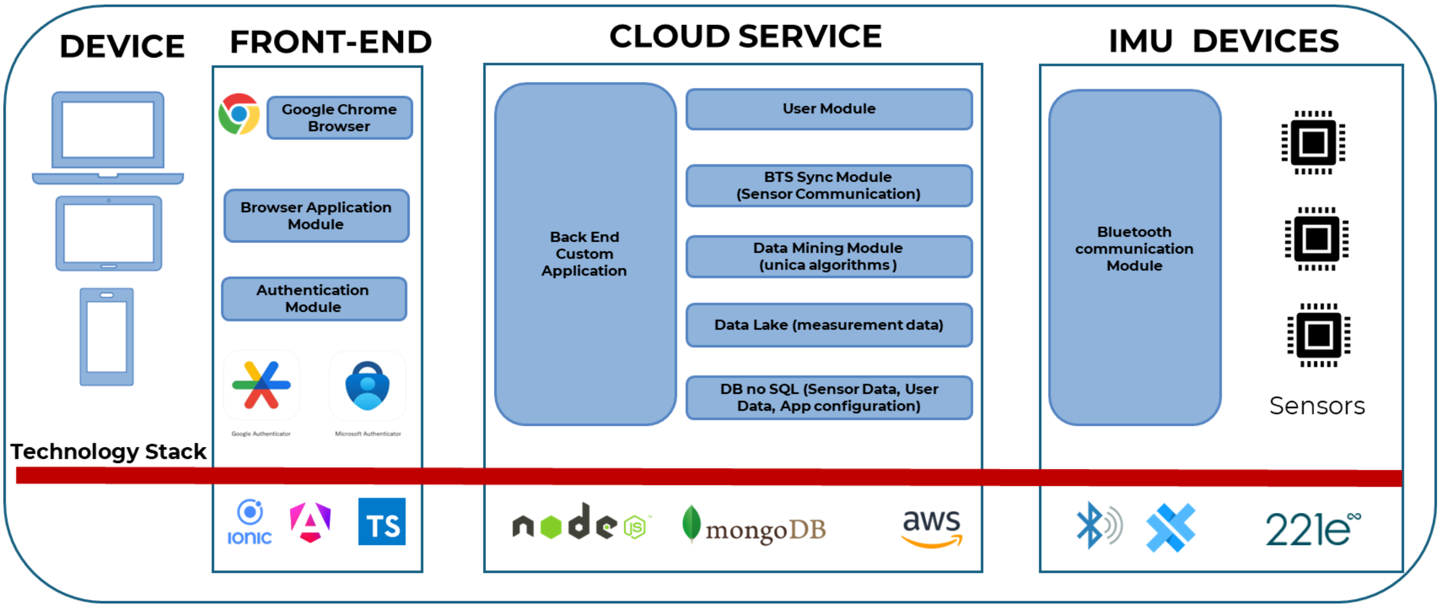

Figure 5: System Architecture

On the left, we have the **front-end layer**, which is accessed through Google Chrome on laptops, tablets and smartphones. It includes the browser application module and the authentication module, supporting secure login with Google or Microsoft Authenticator.

In the middle, the **custom back-end application**. This contains several core components: the User Module; the BTS Sync Module, which manages sensor communication; the Data Mining Module, where our proprietary algorithms run; the Data Lake, where all measurement data are stored; and a NoSQL database holding sensor data, user data and application configuration.

On the right is the **Bluetooth Communication Module**, which handles direct data exchange with the sensors.

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At the bottom of the diagram the main technologies powering each layer: Ionic, Angular and TypeScript for the front end; Node.js, MongoDB and AWS for the back end; and Bluetooth protocols for device communication.

Altogether, this architecture ensures a secure, scalable and efficient environment for collecting, processing and presenting measurement data. Architecture allows coaches and researchers to see the information quickly and make decisions in real time

5 DATA FLOW

The data flow describes how sensor readings are transmitted, processed, and stored. The process involves the following stages:

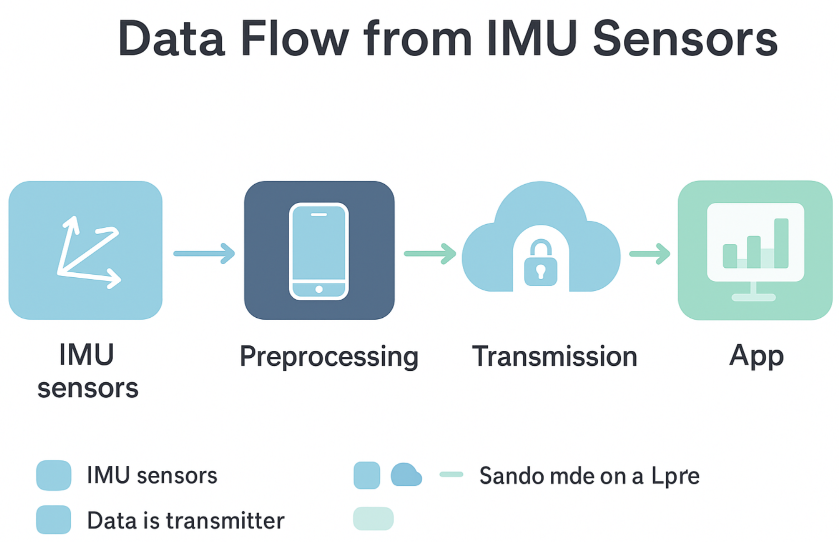

Figure 6: Data Flow

STEP 1. IMU sensors collect motion and orientation data.

STEP 2. Data is transmitted via Bluetooth to the connected device.

STEP 3. The front-end synchronizes data with the cloud using HTTPS and secure APIs.

STEP 4. The backend stores raw data in a Data Lake and structured summaries in MongoDB.

STEP 5. Analytical modules process data, apply algorithms and generate visual insights for the user by static benchmark.

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6 USER AUTHENTICATION FLOW

Authentication is implemented via OAuth 2.0, integrating Google and Microsoft accounts. Users authenticate once and gain access to personalized dashboards. Access to the tool is only permitted with correct authentication. The authentication flow includes:

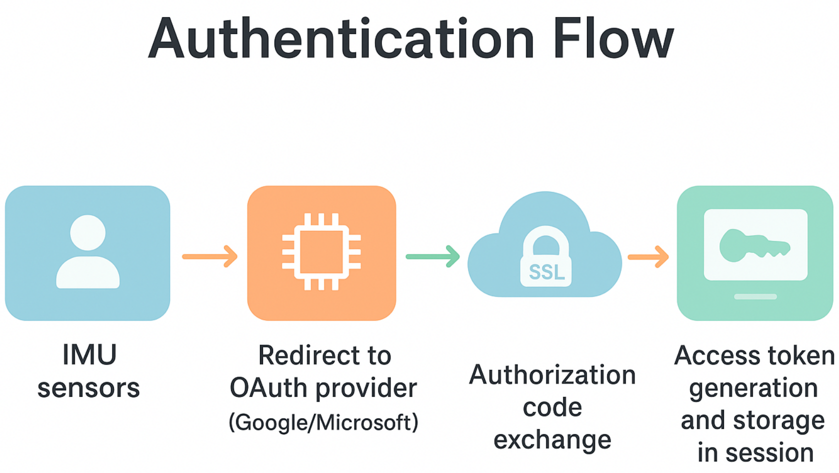

Figure 7: Authentication Flow

STEP 1. User accesses the login page.

STEP 2. Redirect to OAuth provider (Google/Microsoft), or custom login.

STEP 3. Authorization code exchange.

STEP 4. Access token generation and storage in session.

7 BLUETOOTH COMMUNICATION SEQUENCE

The IMU sensors communicate via Bluetooth Low Energy (BLE) using secure pairing. The backend leverages the Chrome Web Bluetooth API for device discovery and data exchange.

For the project we selected the Muse miniaturized multi-sensor IMU. The Muse sensor is produced by 221e, an Italian company. This sensor includes an accelerometer, a gyroscope, a compass, temperature and humidity sensors, a barometer and ambient light detection. It can send data live by Bluetooth and it its small size and weight under 50 grams, it is very practical for sports use.

Sequence steps:

STEP 1. Device scanning initiated by user action.

STEP 2. IMU sensor advertisement detected.

STEP 3. ECDH key exchange performed for secure connection.

STEP 4. Data transmission via BLE characteristics (streaming data).

STEP 5. Live synchronization with the cloud backend via TLS protocol.

8 SOFTWARE DEVELOPMENT AND SECURITY

Security is ensured through encryption, authentication, and controlled data access. The main security measures include:

- End-to-end encryption using ECDH for Bluetooth communication.
- HTTPS and TLS 1.3 for all client-server communication.
- Role-based access control (RBAC) within the cloud environment.
- Regular vulnerability scans and penetration testing.
- Backup and recovery policies for Database.

The development activities and processes are organized into operational blocks according to their functional scope:

- **Data Collection and Data Mining**
- **Web Application Prototyping and Front-End/Back-End Modules** – developed in compliance with W3C specifications to ensure responsive systems for seamless use and interaction across mobile and desktop devices, meeting all security and privacy requirements.
- **Database Prototyping and Data Access Services**

Across these three workstreams, the goal of software security is to ensure **confidentiality, integrity, and availability** of information through the implementation of specific technical security controls designed to mitigate vulnerabilities.

Below is the **security checklist** applied during development and validation phases:

- **Input Validation**
  Identify all data sources, classify them as trusted or untrusted, and validate all inputs originating from untrusted sources.
- **Output Encoding**
  Sanitize any untrusted data output that could interact with operating system commands.
- **Authentication and Password Management**
  Use a centralized implementation for all authentication controls, including

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libraries that interface with external authentication services.
The application adopts **federated authentication** via **Google** and **Microsoft** with **multi-factor authentication (MFA)** enabled.

- **Session Management**
  Sessions are always handled on a trusted system where session management controls rely on strong algorithms ensuring sufficient randomness to prevent overflow or session hijacking.

- **Access Control**
  Implement a comprehensive access control policy documenting business rules, data types, application access, and authorization criteria, ensuring proper provisioning and control of permissions.

- **Error Handling and Logging**
  Prevent sensitive information disclosure in error responses (e.g., system details, session identifiers, or account information).
  Restrict access to logs to authorized personnel only.

- **Data Protection**
  Enforce appropriate access controls for sensitive data stored on the server, including cached data, temporary files, and user-specific resources accessible only by authorized users.

- **Communication Security**
  Ensure all **TLS certificates** are valid, correctly bound to the domain, not expired, and include properly validated intermediate certificates when required.

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9 ICT SPORT TOOL PAGE

The following images are sample screenshots that illustrate how the tool can be used. For more comprehensive information, please refer to the user manual available at EDATS PLATFORM USER GUIDE

9.1 ICT SPORT TOOL - WEBSITE STARTUP PAGE

The project portal provides all the information needed to correctly use the ICT SPORT TOOL . An example of the relevant section is shown in the screenshot below.

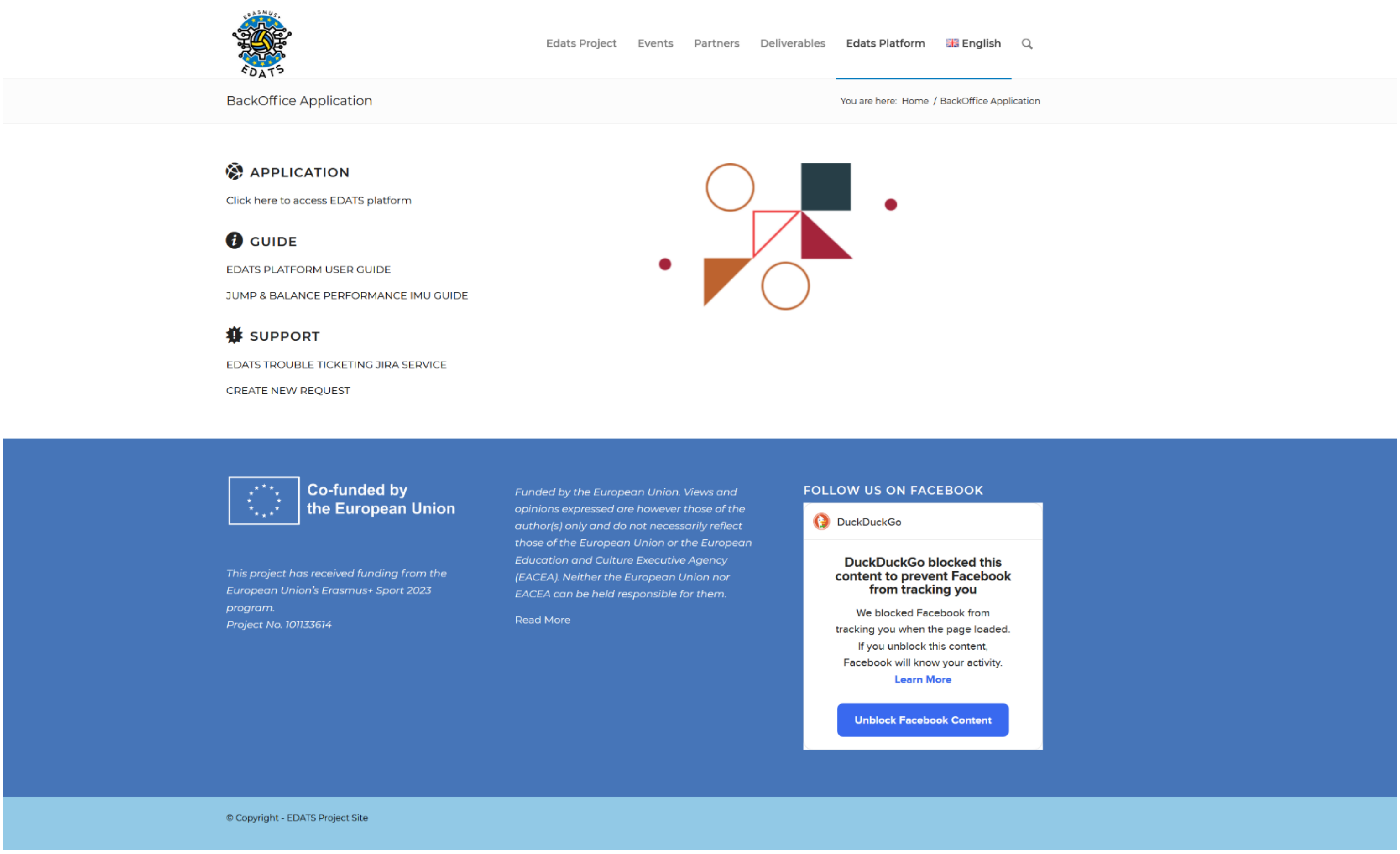

Figure 8: ICT SPORT TOOL HOME PAGE

9.2 ICT SPORT TOOL - LOGIN PAGE

The login page is available at the address https://edats-project.dauvea.it/login

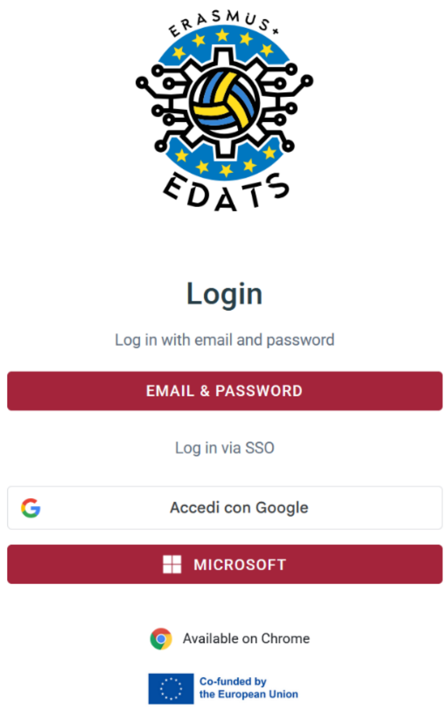

Figure9: ICT SPORT TOOL LOGIN PAGE

9.3 ICT SPORT TOOL – DASHBOARD

In the Home page you can find a synthetic review of all you app sections.

1. ATHLETES SECTION: here you can find a comprehensive list of all your athletes, either active or not.

2. SENSORS SECTION: here you can see a list of the previously registered sensors. Clicking on the arrow

3. SESSION SECTION: the graph shows all sessions registered in the last 30 days. If you don't have registered any session yet, the graph will not be shown.

4. MENU BUTTON: clicking on the hamburger button on the left of the header will open the side menu where you will find links to all key features of the application.

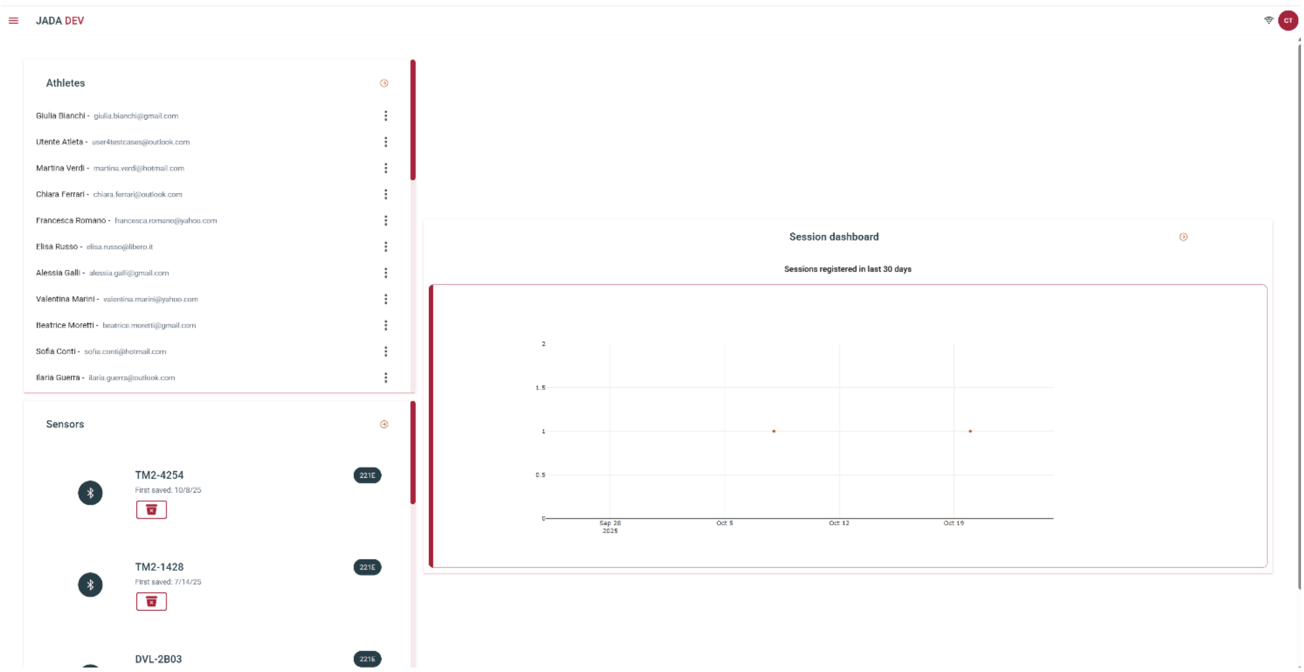

Figure 10: ICT SPORT TOOL - DASHBOARD

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9.4 ICT SPORT TOOL – SETTINGS

Access from the Home page from the button on top of your athletes list (for coaches and admins only) or from the Settings in the sidebar menu that you access from the menu button on the left of your header

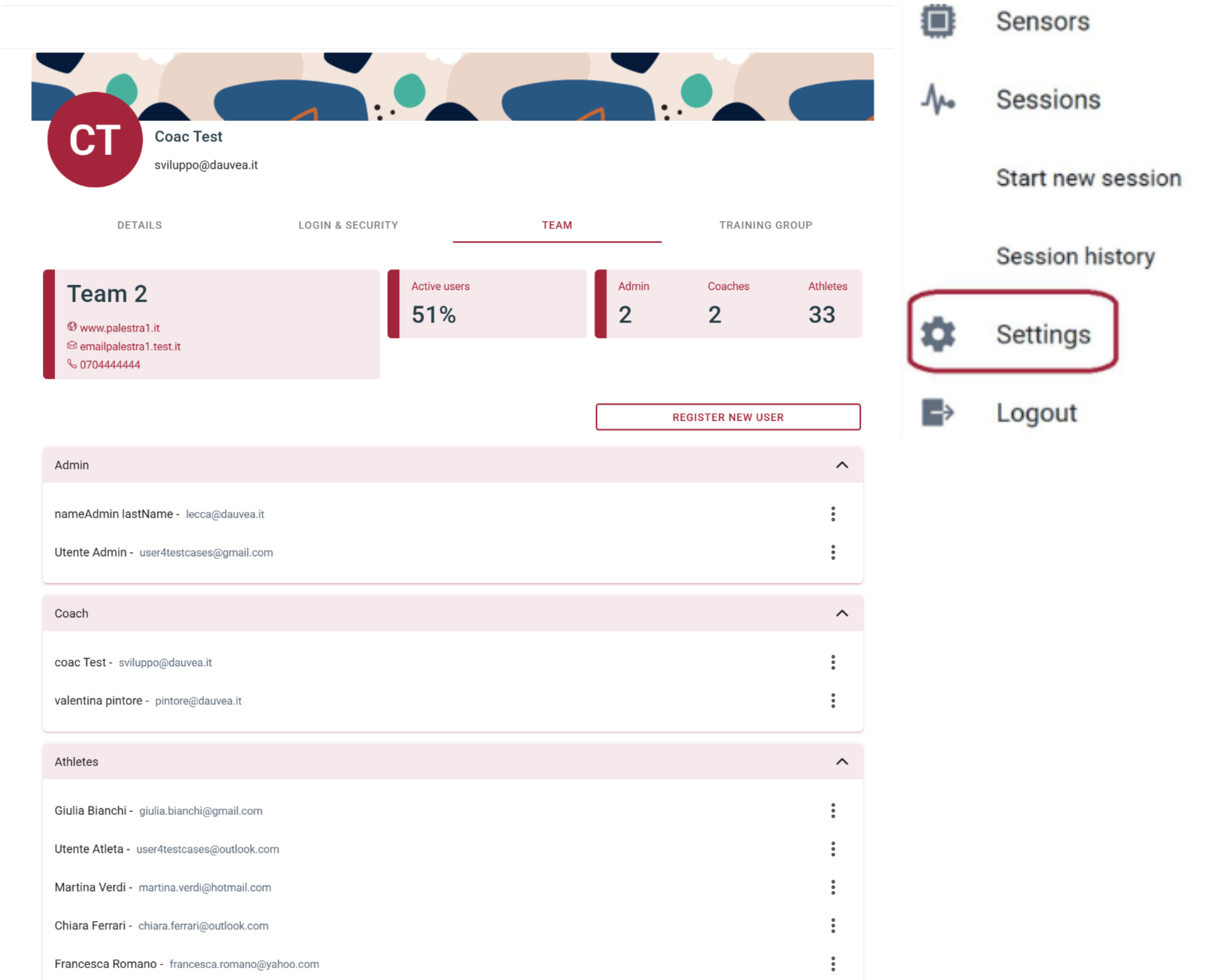

Figure 11: ICT SPORT TOOL - SETTINGS

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9.5 ICT SPORT TOOL – SENSOR

This is your sensors' home. From this page you can save new sensors, connect your existing ones or delete them.

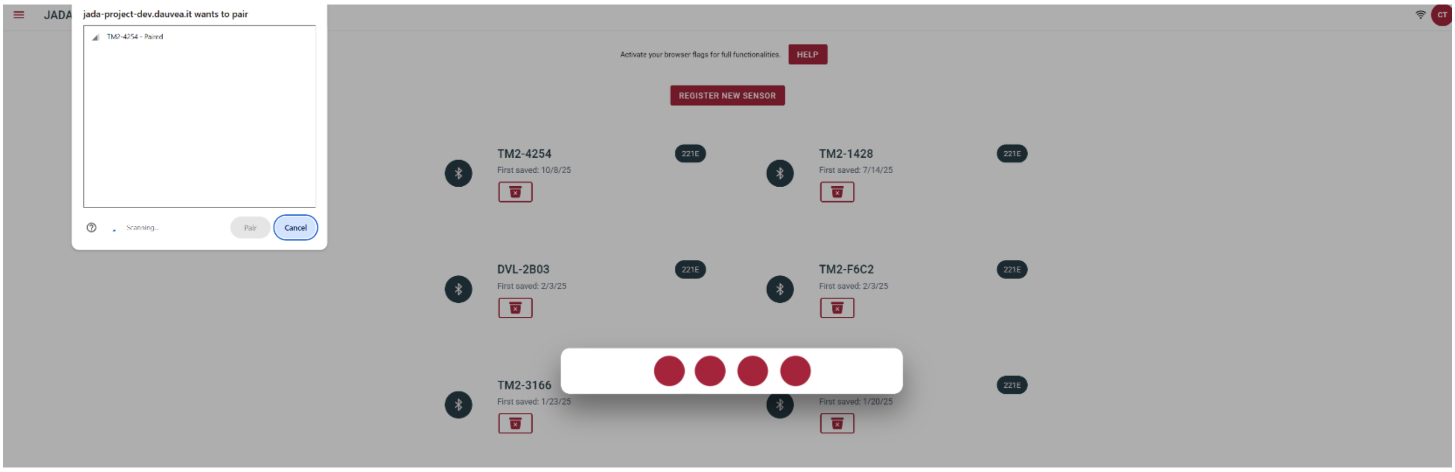

Figure 12: ICT SPORT TOOL - SENSOR

9.6 ICT SPORT TOOL - SESSION

The new session wizard is accessible via the session dashboard described above, or via the sidebar menu by clicking 'New session'. The wizard will guide you through the process.

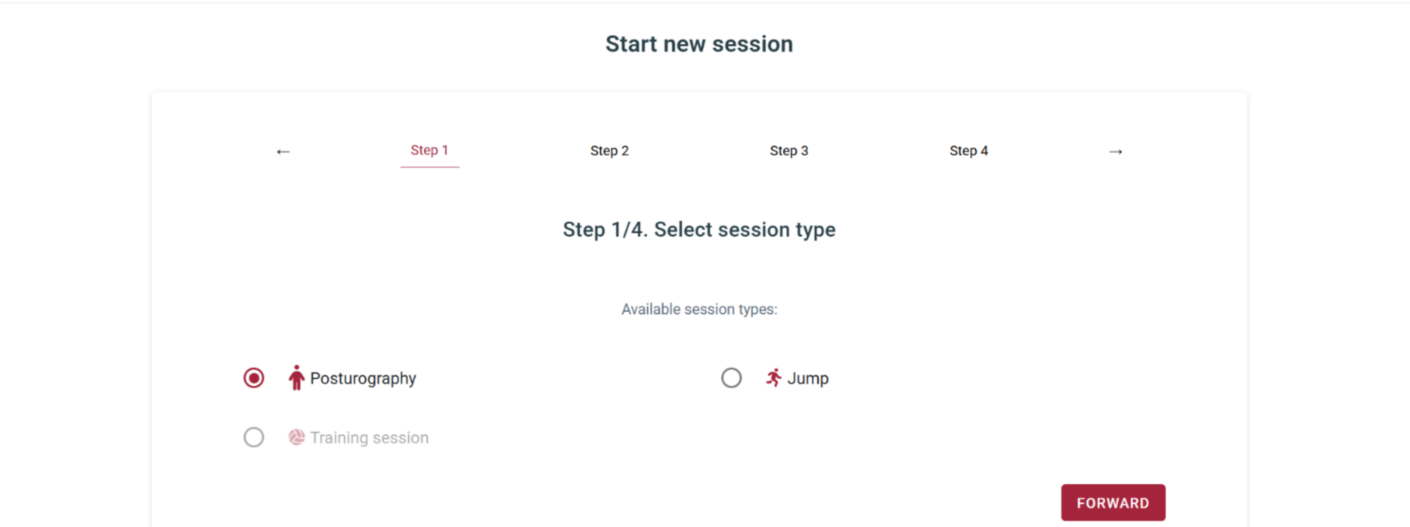

Figure 13: ICT SPORT TOOL - SESSION

9.7 ICT SPORT TOOL – SESSION RESULT

At the end of the session, you will see a recap of the registered

Figure 14: ICT SPORT TOOL - SESSION RESULT

The recap contains:

- Athlete's data
- The session's info (type, frequency,duraθon)
- Action
  - DELETE deletes the session info and all sensor data registered during it
  - DOWNLOAD exports a file with the raw sensor data, useful for debugging purpose
  - SAVE saves your session and adds it to your session history to be accessed at a later date

Benchmark drawer: opens to show your session data compared to a gold standard based on literature

Figure 15: ICT SPORT TOOL - RESULT BENCHMARK

Session graphs drawer: session graphs

Figure 16: ICT SPORT TOOL - RESULT GRAPHS

9.8 ICT SPORT TOOL - SEARCH IN SESSION HISTORY

Access sessions' history by the button on the session dashboard or from the side menu. The page presents at the top the available filters you can choose from by clicking on each one of them to expand it.

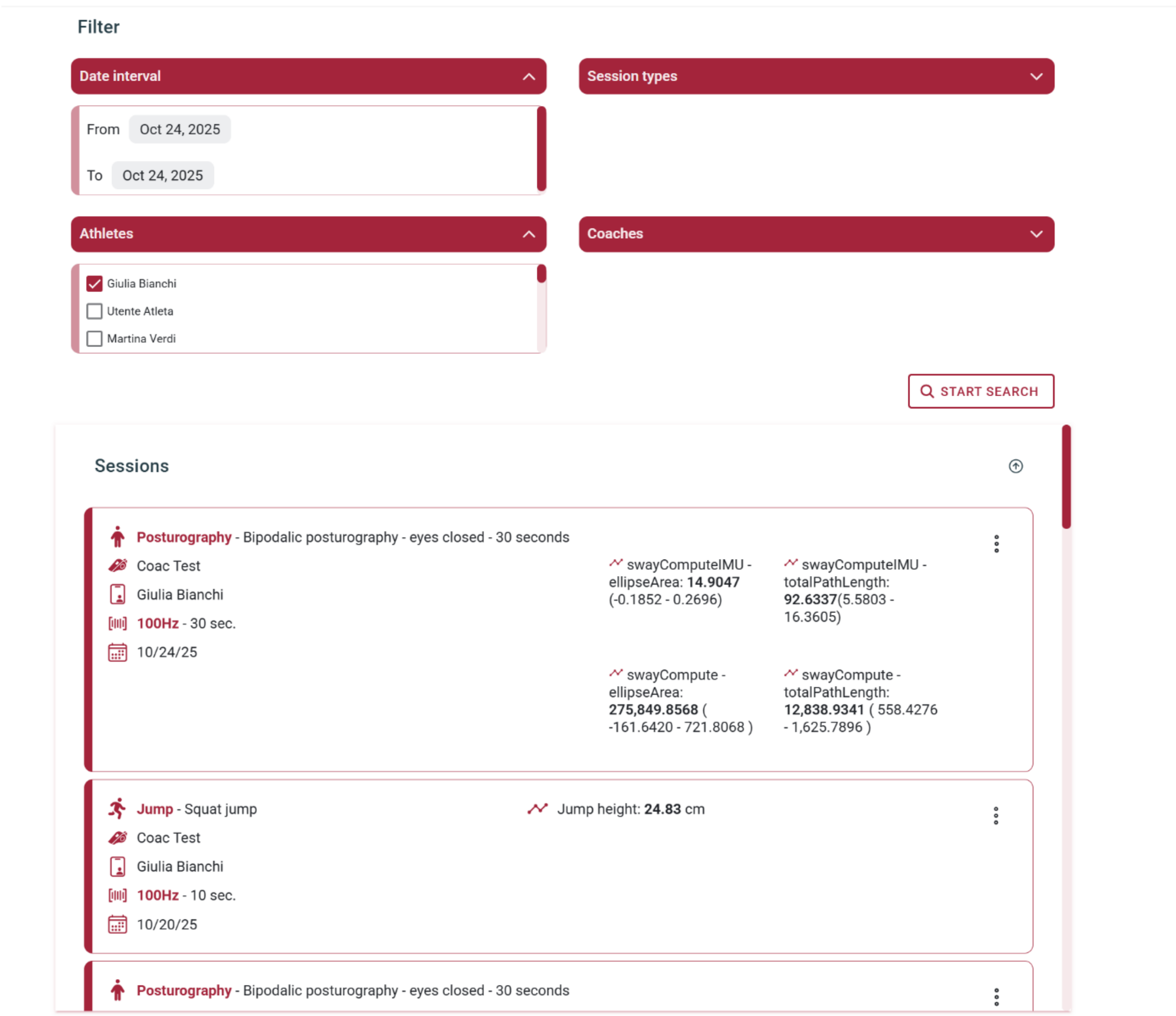

Figure 17: ICT SPORT TOOL - SEARCH

10 APPLICATION USER MANUAL

The login page is available at the address https://edats-project.dauvea.it/login

On the website https://edats.eu there are also a PDF user guide and reference pages to help users understand the system.

- EDATS PLATFORM USER GUIDE
- JUMP & BALANCE PERFORMANCE IMU GUIDE

This prototype already contains the main functions for data management.

11 PROJECT APPLICATION - CLOSE ACTIVITIES

Prototype ver 0.5 – ChangeLog (February 2025)

- ✓ **Research** - Posturography measurement protocols definition (static balance)
- ✓ **Research** - Jump measurement protocols definition - squat jump (SJ) and countermovement jump (CMJ)
- ✓ **Project Application** – sensors connection (via bluetooth)
- ✓ **Project Application** – managing output sessions (benchmark, graph)
- ✓ **Project Application** – testing application functionality (local test, lab test, test gym)

Prototype ver 1.0 – ChangeLog (August 2025)

- ✓ **Research** – algorithm definition for sessions signals
- ✓ **Project Application** – sensors streaming raw data
- ✓ **Project Application** – managing sensor, account, team and athletes
- ✓ **Project Application** – create instance for partners tenant

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12 FUTURE ENHANCEMENTS

Prototype ver 2.0 - *NEW FEATURES on-going*

- **Research** - Signal study to identify DYNAMIC BALANCE: TIME TO STABILIZATION
- **Research** - Benchmark definition for different range (AGE, SEX, ETC)
- **Project Application** - New features for measuring jumps in attack (spike) and defense (block)
- **Project Application** – new admin dashboard with advance configuration

Prototype ver 3.0 Long-term activities

- **Project Application** - Machine learning and AI algorithm integration
- **Project Application** - build project for native mobile APP

13 CONCLUSION

This document outlines the key technical aspects of the IMU Data Collection and Analysis System. The architecture ensures secure, scalable, and efficient data handling across devices, front-end, and cloud components. Future development phases will focus on expanding analytical capabilities and improving user experience.

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