**Methods To Be Applied Summary**

The smart assistive exosuit project will employ a multidisciplinary approach combining biomechanical principles, embedded systems, machine learning, and human-centered design. The methodology will include:

1. **Analysis of human movement** patterns and posture requirements to identify critical support points and movement assistance needs.
2. **System Architecture Design** A modular architecture will be defined, including hardware components (sensors, actuators, power units) and software modules (posture detection algorithms, feedback systems, control logic). Special emphasis will be placed on ensuring real-time responsiveness and ergonomic integration.
3. Sensor Integration and Posture Detection using IMUs (Inertial Measurement Units), flex sensors, and pressure sensors to detect posture deviations and movement intentions

Sensor Selection: Inertial Measurement Units (IMUs) and electromyography (EMG) sensors will be embedded in the exosuit to monitor joint angles, muscle activity, and body alignment.

Posture Classification: Machine learning algorithms (e.g., SVM or neural networks) will process sensor data to detect improper posture (e.g., slouching, uneven weight distribution) and predict movement intent.

1. **S****ystem design** utilizing soft robotics principles with artificial muscles or lightweight electric motors to provide targeted assistance while maintaining comfort.

Modular Exosuit Fabrication: Lightweight, flexible materials (e.g., thermoplastic elastomers) will be used for wearable components, ensuring comfort and mobility.

User Interface (UI): A mobile/web app will display posture metrics, provide corrective guidance, and allow users to customize support levels.

A detailed software flowchart will be created to describe how sensor data is interpreted, how feedback decisions are made, and how user interaction (via visual or haptic alerts) is managed. User-centered design principles will guide interface development.

1. **Real-time feedback mechanisms** through haptic, visual, or audio cues to guide users toward proper posture and movement patterns. Based on sensor input, feedback mechanisms (e.g., vibration motors, actuator-based limb support) will be simulated or prototyped to provide adaptive real-time assistance. Various scenarios will be considered, such as poor posture correction or load-bearing support.
2. **Testing**, with user feedback loops to refine the design for comfort, effectiveness, and usability.

Laboratory Trials: Motion-capture systems and force plates will quantify gait, balance, and muscle activation in healthy users and target populations (e.g., individuals with mobility impairments).

Field Testing: Usability studies in occupational settings (e.g., manual laborers) will evaluate practicality, comfort, and strain reduction.

1. **Validation through measures** of posture improvement, muscle activation reduction, and user experience surveys.
2. **System Documentation**Comprehensive documentation will be created for each phase, including diagrams, flowcharts, and use-case descriptions. While a full prototype may not be developed, the project will outline testing procedures and performance criteria for future implementation.

System Architecture Diagrams: Unified Modeling Language (UML) will outline hardware-software interactions.

Safety Protocols: Risk assessments and ethical approvals will ensure compliance with medical device standards (e.g., ISO 13485).

The smart assistive exosuit project will have an approach combining biomechanical principles, embedded systems, machine learning and human-centered design. The methods to be applied will include: Analysis of Human Movement for patterns and posture requirements to identify critical support points and movement assistance needs. System Architecture Designfor a modular architecture will be defined, including hardware and software components. Sensor Integration and Posture Detection for flex sensors, pressure sensors to detect different postures and movements. System Design for utilizing robotics with artificial muscles or lightweight electric motors to provide assistance while maintaining comfort. Real-Time Feedback Mechanisms to guide users toward proper posture and movement patterns. Testing with laboratory trials and field testing. Validation with measures of posture improvement, muscle activation reduction, and user experience surveys. Finally, System Documentation in each step to help understand the overall project, how the components interact and how the system should function.

**Describe the methods, techniques and tools to be used in the R&D activities of the project within the scope of the planned workflow**

The Smart Assistive Exosuit project will implement a multidisciplinary research and development R&D workflow, integrating biomechanics, embedded systems, machine learning and human-centered design principles.

The methods to be used:

* Analysis of human movement patterns and ergonomic posture requirements, identification of critical support points
* Modular hardware-software integration approach
* Multi-sensor data fusion and machine learning-based classification
* Human-centered design with soft robotics principles
* Material testing for flexibility and durability
* Multi-modal user feedback integration
* Iterative testing with user feedback loops
* Comprehensive integration and documentation approach

The techniques to be used:

* Motion capture analysis, musculoskeletal modeling, kinematic and kinetic analysis
* Real-time system architecture planning
* Sensor calibration and synchronization, signal processing and noise filtering
* Lightweight actuation system development, textile-integrated electronics
* Haptic and visual feedback interface development
* Laboratory trials for biomechanical assessment, field testing in occupational settings
* Component integration testing, safety and risk assessment, technical documentation development

The tools to be used:

* 3D motion capture systems
* Unified Modeling Language (UML) diagramming for system diagrams
* Flexible/wearable pressure sensors, signal processing libraries, data acquisition hardware and software
* 3D CAD software for hardware design
* Python libraries (pandas, NumPy, scikit-learn) for machine learning part
* Lightweight electric motors or artificial muscle technologies
* Thermoplastic elastomers and other flexible materials
* User experience design tools, microcontrollers for real-time feedback control
* Biomechanical analysis equipment, posture assessment tools
* User experience questionnaires/interviews/surveys

**Methods, Techniques, and Tools to Be Used in R&D Activities**

1. **Human Movement Analysis:**  
   Biomechanical analysis techniques, including motion capture systems and force plate measurements, will be used to identify critical body support points, movement patterns, and posture-related requirements. These insights will guide the definition of assistance needs for various target user groups.
2. **System Architecture Design:**  
   A modular system architecture will be designed, encompassing both hardware (sensors, actuators, power units) and software modules (data processing algorithms, feedback systems, and control logic). Tools such as Unified Modeling Language (UML) diagrams will be utilized to map hardware-software interactions clearly. Special focus will be placed on ensuring real-time responsiveness, ergonomic integration, and system scalability.
3. **Sensor Integration and Posture Detection:**
   * **Sensor Technologies:** Inertial Measurement Units (IMUs), flex sensors, pressure sensors, and electromyography (EMG) sensors will be integrated into the exosuit to monitor joint angles, muscle activation, and body posture continuously.
   * **Posture Detection Techniques:** Machine learning algorithms, such as Support Vector Machines (SVM) and neural networks, will be trained to classify user posture, detect deviations like slouching or improper load distribution, and predict intended movements based on multi-sensor data fusion.
4. **System and Exosuit Design:**  
   Applying soft robotics principles, artificial muscles and lightweight electric motors will be incorporated to provide targeted assistance without compromising user comfort. Wearable components will be fabricated using flexible, lightweight materials like thermoplastic elastomers to ensure high mobility. Prototyping tools and soft robotics design kits will support this phase.
5. **Real-Time Feedback Mechanisms:**  
   Feedback mechanisms (haptic, visual, and audio cues) will be developed to provide adaptive posture correction and movement guidance in real time.
   * **Hardware:** Vibration motors, LEDs, and mini audio buzzers will be integrated into the exosuit.
   * **Software Flow:** A detailed software flowchart will map the process from sensor data acquisition to feedback decision-making and user notification management.
6. **User Interface Development:**  
   A user-friendly mobile/web application will be created to display posture metrics, provide corrective feedback, and allow users to customize their support preferences. The interface will be developed following human-centered design principles using frameworks like React (for web) or Flutter (for mobile).
7. **Testing and Evaluation:**
   * **Laboratory Trials:** Performance will be evaluated using motion-capture systems, electromyography, and gait analysis in controlled laboratory environments, focusing on parameters like posture correction accuracy and muscle strain reduction.
   * **Field Testing:** Usability studies in real-world occupational settings will assess the practicality, comfort, and strain reduction effects of the system, incorporating direct user feedback to iteratively improve the design.
8. **Validation Activities:**  
   Objective metrics such as improvements in posture alignment, reduction in muscle activation, and user satisfaction scores (via surveys and usability scales) will be used to validate system effectiveness and user acceptance.
9. **Documentation and Compliance:**  
   Throughout all phases, detailed documentation will be maintained, including system architecture diagrams, flowcharts, user manuals, and testing protocols.  
   Additionally, risk assessments and ethical approvals will be conducted to ensure compliance with relevant standards such as ISO 13485 for medical devices and human subject research protocols.

**Specify which of the following R&D phase(s) is/are covered in the proposed project.**

*(Concept Generation, Technical and Economic Feasibility studies, Experimental work in the Transition Process from Developed Concept to Design activities, Design, Design Development and Validation Studies, Prototype Production, Establishment of Pilot Facility, Trial Production and Type Tests, After-Sales Product Design Solutions etc.)*

The Smart Assistive Exosuit project will cover the following R&D phases:

* **Concept Generation**: This is covered in analysis of human movement patterns and posture requirements to identify critical support.
* **Technical Feasibility Studies:** This is covered in material testing for flexibility, durability and sensor technologies.
* **Experimental Work in the Transition Process from Developed Concept to Design Activities**: This is covered in the biomechanical analysis and sensor integration phases.
* **Design**:This is covered in architecture design of both hardware and software components.
* **Design Development and Validation Studies**: This is covered by the testing and validation protocols which includes laboratory trials and field testing.
* **Prototype Production**: This is covered particularly for sensor systems, feedback mechanisms and modular components.

The project does not cover: Economic Feasibility Studies, Establishment of a Pilot Facility, Trial Production and Type Tests, After-Sales Product Design Solutions.

**Excluded Phases**:

* **Economic Feasibility Studies**:
  + Cost-benefit analysis, market scalability, or commercialization strategies are not explicitly addressed.
* **Establishment of Pilot Facility**:
  + No large-scale manufacturing infrastructure is planned.
* **Trial Production and Type Tests**:
  + Compliance with mass-production standards (e.g., ISO 9001) is beyond the project’s research-focused scope.
* **After-Sales Product Design Solutions**:
  + Post-deployment support or iterative product updates are not included in the current workflow.