An Educational App for ACL Injury Risk Assessment Using Machine Learning: A Proof of Concept

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Abstract

ACL injuries remain a significant concern in both male and female populations, with incidence rates showing little decline despite extensive research and prevention programs. This suggests a need for novel, accessible methods to tackle this issue. In this proof-of-concept (POC) study, we introduce a simple, web-based application designed to educate individuals at risk of ACL injuries. Using machine learning (ML) techniques, specifically Google's Teachable Machine, the app provides real-time feedback on movement patterns, classifying them as high-risk or low-risk for injury. While this study is limited by the size and diversity of its dataset, it demonstrates the potential of ML and AI models in enhancing education and injury prevention. Future iterations with larger datasets and advanced AI techniques could improve the app's precision, scalability, and applicability in real-world scenarios. We hypothesize that ACL injuries, like many others, can be reduced through proper education, personalized feedback, and training. This POC lays the foundation for future efforts in injury prevention by combining ML-driven insights with accessible, user-friendly tools.

Check out the **ACL-IQ app**: acl-iq.netlify.app
Watch the tutorial: YouTube Video

Keywords: ACL injury, Injury prevention, Machine learning in sports, Real-time feedback, Biomechanics

Note: This app is **not** a medical device or app and does not provide certified medical advice.

It is a simple yet potentially powerful educational and research tool for real-time assessment of ACL injury risk. Currently, it analyzes single-leg and double-leg landing simulations, focusing on the final posture associated with ACL injury risk. Use it to teach students or teams proper movement mechanics and explore its practical applications.

Introduction

ACL injuries are increasing among athletes and non-athletes alike, often occurring during simple movements such as jumping or landing, with high-risk moments lasting less than a second [1,2,3]. Despite the availability of numerous prevention programs, the rising number of injuries suggests gaps in current educational approaches. We propose that simpler, more interactive tools leveraging machine learning (ML) and artificial intelligence (AI) could enhance education and awareness of risky movement patterns.

In this study, we developed a web-based application utilizing Google's Teachable Machine and Mediapipe to classify movements as high-risk or low-risk for ACL injury. By training the ML model on labeled pose data, the app provides real-time feedback to users, enabling them to understand and visualize proper movement mechanics [4]. This tool can be utilized by students, athletes, coaches, and trainers to improve their understanding of injury risk.

Although this POC focuses on static moments and lacks dynamic motion analysis, it serves as an initial step toward a more comprehensive injury prevention framework. Future work will expand the app to include dynamic movements and personalized feedback, with the ultimate goal of reducing ACL injuries through education and technology-driven interventions.

Methods

Objective

The aim of this study was to develop and evaluate a machine learning-based application for assessing ACL injury risk using Google's Teachable Machine and Mediapipe for pose detection. The app provides real-time feedback on high-risk and low-risk movements, focusing on biomechanical measures to prevent ACL injuries (Figures 1-4, Table 1).

Data Collection

- **Pose Categories**:
    - **High Risk**: Movements with poor biomechanics, such as excessive knee valgus, asymmetrical weight distribution, or improper landing techniques.
    - **Low Risk**: Properly aligned movements with neutral knee positioning and balanced landing mechanics.
- **Sample Size**:
    - A total of 683 pose samples were collected: 342 labeled as "High Risk" and 341 labeled as "Low Risk."
- **Pose Detection**:
    - Google's MoveNet was used to extract keypoints (e.g., joint positions) from the collected video samples, forming the basis for model training.

Model Training

- **Platform**: Google's Teachable Machine.
- **Model Architecture**:
  - A classification layer was trained on top of MoveNet's keypoint extraction.
- **Training Parameters**:
  - Epochs: 50
  - Batch Size: 16
  - Learning Rate: 0.0001
- **Training and Validation**:
  - A real-time validation split was applied to monitor performance during training.

Integration

- The trained model was exported and integrated into a web-based application.
- The app uses Mediapipe to estimate poses from a webcam feed and classifies movements in real time using the trained model (Figure 1).

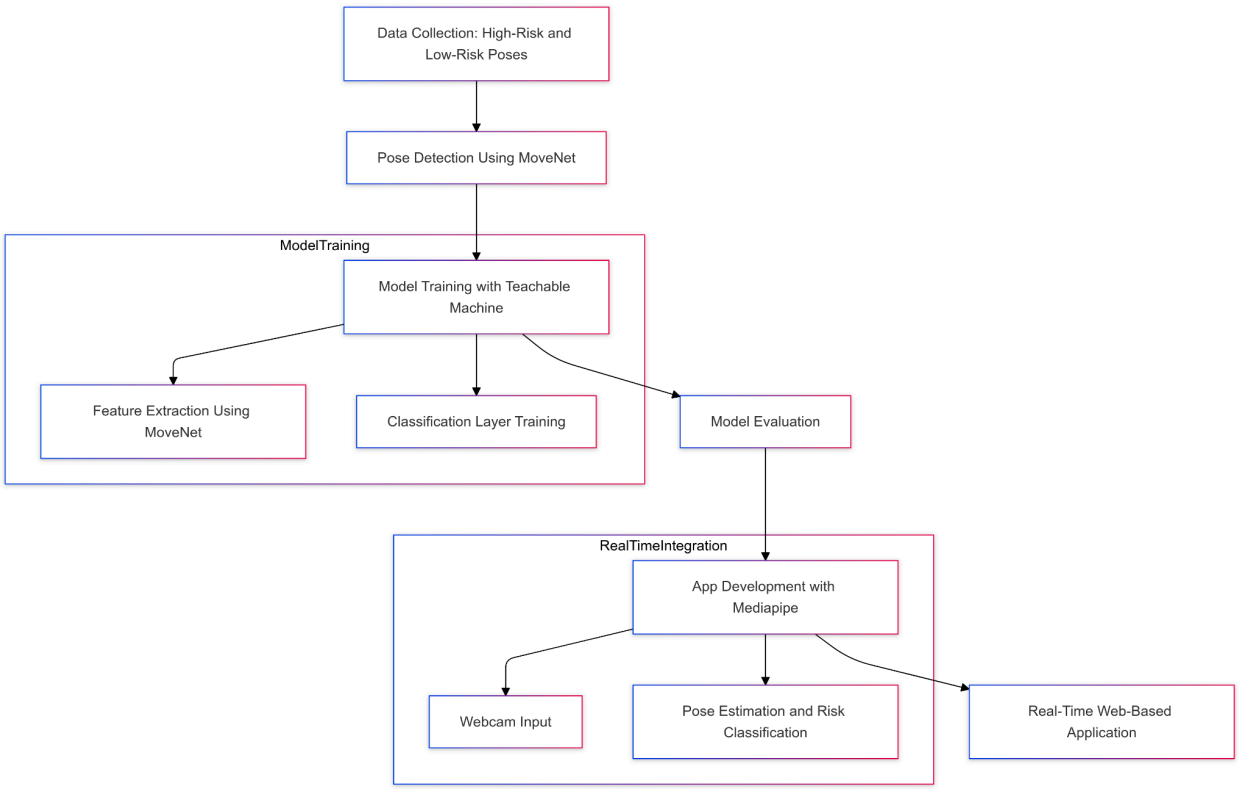

Figure 1: High-level workflow of the ACL injury risk assessment pipeline, from data collection to real-time web-based application deployment. Check out the **ACL-IQ app**: acl-iq.netlify.app. Watch the tutorial: YouTube Video.

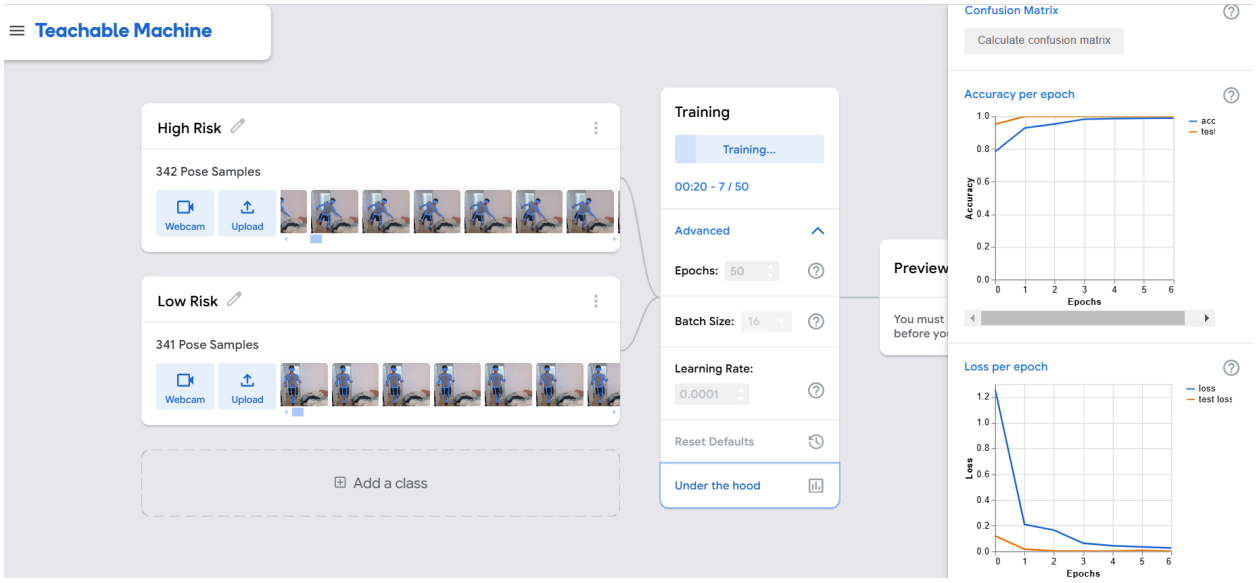

Figure 2: Training interface of Google Teachable Machine showing high-risk and low-risk pose samples, with model accuracy and loss metrics displayed during training.

Results

Model Performance

- **Per-Class Accuracy**:
  - High Risk: 100% accuracy (52 samples)
  - Low Risk: 100% accuracy (52 samples)
- **Confusion Matrix**:
  - All samples were correctly classified, with no false positives or false negatives observed.

Table 1: Per-class accuracy and sample count. The model achieved 100% accuracy for both high-risk and low-risk pose classification.

Class	Accuracy	Samples
High Risk	1	52
Low Risk	1	52

Training Metrics

- **Accuracy Per Epoch**:
  - Training accuracy reached 100% within 10 epochs and remained stable throughout.
  - Validation accuracy closely matched training accuracy, indicating no overfitting.

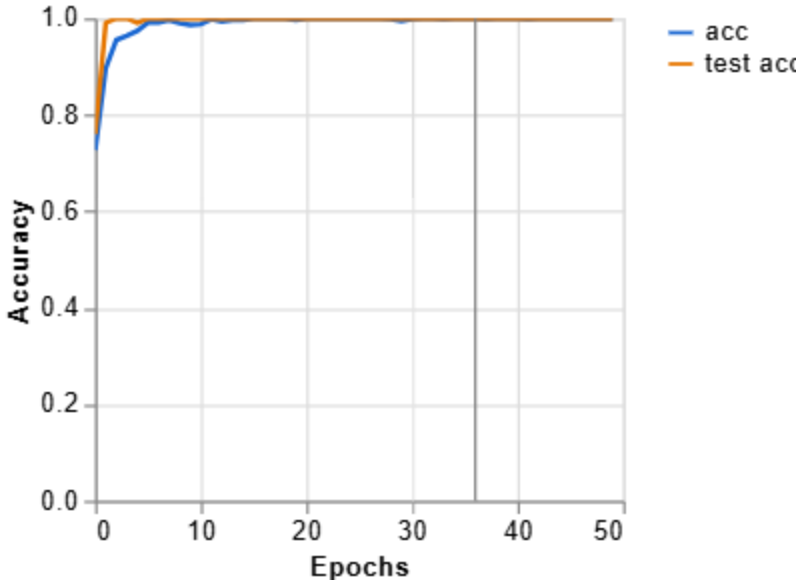

Figure 3: Training and validation accuracy over epochs, demonstrating rapid convergence and stability at 100% accuracy.

- **Loss Per Epoch**:
  - Training and validation losses dropped to near zero early in training, demonstrating strong model convergence.

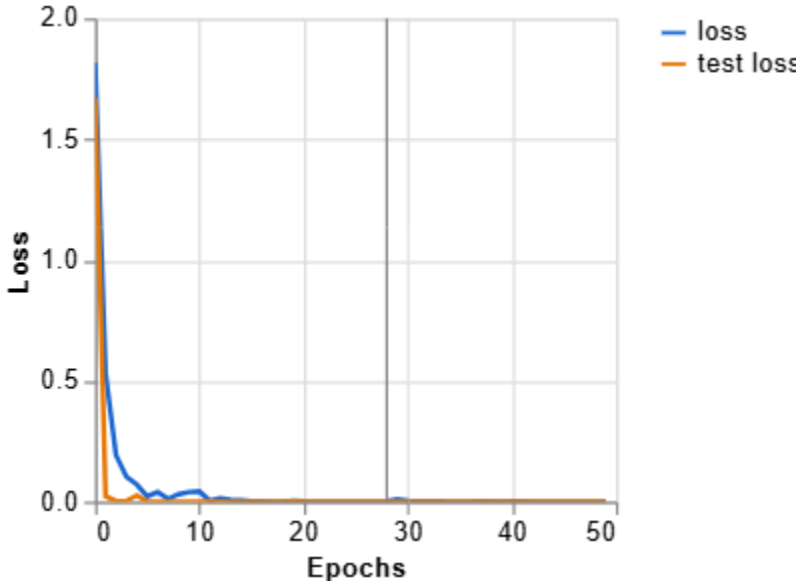

Figure 4: Training and validation loss over epochs, highlighting strong model convergence with near-zero loss.

Real-Time Implementation

- The model successfully classified high-risk and low-risk poses in real time using a standard webcam, with minimal latency.
- Users can perform movements like single-leg and double-leg landings to receive immediate feedback on biomechanical risks.

Practical Insights

- The model reliably detected high-risk patterns such as knee valgus and improper alignment, providing actionable feedback.
- It may also reinforce correct movement techniques via visual and real-time feedback, aiding injury prevention and movement education (Figure 5).

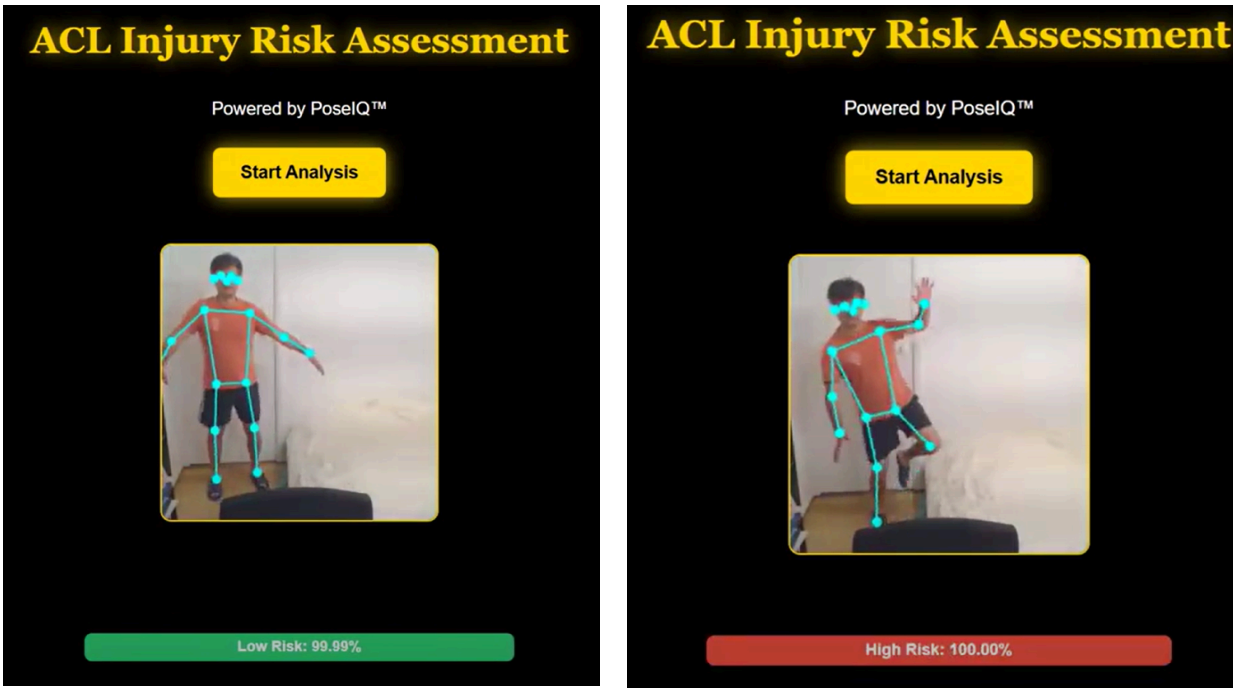

Figure 5: Real-time web-based ACL injury risk assessment app powered by PoseIQ™. High-risk and low-risk movements are classified with probabilities displayed on the interface. Check out the **ACL-IQ app**: acl-iq.netlify.app. Watch the tutorial: YouTube Video.

Conclusion and Limitations

The application demonstrates the feasibility of using machine learning (ML) for ACL injury risk assessment. With high accuracy and low latency, this proof-of-concept app shows significant promise for use in sports, rehabilitation, and education. Future work will focus on expanding the dataset and incorporating dynamic movements, such as cutting or pivoting, to enhance its capabilities further.

Limitations:

- **Basic ML Model**: The app uses a simple ML approach with Google's Teachable Machine. While effective for this proof of concept, advanced ML models could improve precision and adaptability.
- **Limited Dataset**: The dataset of 683 samples lacks diversity in movement variations, demographics, and environmental conditions. Expanding the dataset is crucial for better robustness and generalizability.
- **Static Movements Only**: Currently, the app focuses on static movements rather than dynamic activities like cutting or pivoting, which are key contributors to ACL injuries.
- **Educational Tool**: Designed for educational and research purposes, the app is not intended for clinical or diagnostic use and should not replace professional medical advice.
- **Scalability**: While promising, the app requires further testing and refinement to ensure scalability and real-world applicability. Enhancements in real-time performance and usability are necessary.

Despite these limitations, this application represents a meaningful step toward combining ML-driven insights with accessible tools for education and injury prevention. Collaborations with researchers, coaches, and athletes will be instrumental in refining and expanding its functionality.

Acknowledgment

Thanks to OpenAI/ChatGPT for helping create this document, and to Zoom, Notebook LLM, and Mermaid for their contributions. Listen to the AI-generated Podcast: Spotify Link. The podcast focuses on future directions and highlights goals rather than current features of the app.

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