Form Correctness Detection Using Pose Estimation — Project Explanation

1. Posture Rules Used

In this project, I implemented a set of rule-based checks using body landmarks extracted through MediaPipe Pose. These rules help evaluate the user's bicep curl form and detect common posture mistakes. The main rules I used are:

1. Arm Angle / Curl Angle

- I calculate the elbow angle using three keypoints: **shoulder** → **elbow** → **wrist**.
- When the angle becomes small (arm fully curled), it is counted as the "up" position.
- When the arm becomes straight (angle large), it is considered the "down" position.
- A complete rep is detected when the angle shifts from **down** → **up** → **down**.

2. Shoulder Movement Rule

- The shoulder should stay approximately steady during a proper curl.
- If the shoulder moves vertically above a certain threshold, a warning is shown:
  "Don't swing your shoulders!"

3. Back Lean Rule

- The hip position is tracked to detect whether the user leans backward.
- Excessive backward leaning usually means the weight is too heavy or form is incorrect.
- If the hip moves beyond a safe threshold, the warning appears:
  "Keep your back straight!"

4. Arm Symmetry Rule

- For two-hand curls, both arms should move in a similar range.
- If one arm's angle is drastically different from the other, the system warns:
  "Balance both arms!"

5. Elbow Flare Rule

- The elbow should remain close to the body.
- Lateral elbow drift is detected using horizontal elbow movement.
- If elbow flare crosses a threshold, warning is shown:
  "Keep elbows close to your body!"

6. Smooth Angle Estimation (Noise Reduction)

- Pose detection often fluctuates due to camera noise, lighting, or fast movements.
- I use a **running average filter** (deque buffer) to smooth the angle.
- This makes rep counting and warnings much more stable.

7. Rep Speed Analysis

To ensure the user performs each bicep curl at a controlled and safe speed, preventing cheating, momentum-based lifting, or injury-risk fast reps.

How It Works

- Each time a **rep is completed** (arm fully curled), the system notes the **timestamp** using `time.time()`.
- The duration between **current rep** and **previous rep** is calculated.
- Based on this duration, the system classifies the rep as:
  - **Too Fast (< 1 sec)** → suggests the user is using momentum, poor control.
  - **Perfect Speed (1–2.5 sec)** → ideal tempo for muscle engagement.

- **Too Slow (> 2.5 sec)** → indicates fatigue or poor form.

8. Fair Score (0–100) System :-

To give the user a single, easy-to-understand performance score based on form accuracy across multiple rules.

How It Works

Each form mistake adds a penalty.
Score = 100 – total penalties

2. Logic Behind the Rules

Why these specific rules?

These rules represent the most common form issues that happen during bicep curls:

• Curl Angle Logic :-

The angle directly tells if the rep is performed properly:

- A very small angle = full contraction.
- A large angle = full extension.
  This is the core logic for rep counting.

• Shoulder Stability Logic :-

Swinging shoulders means the user is using momentum instead of muscle power.
Tracking vertical shoulder movement helps detect cheating.

• Back Lean Logic :-

Leaning back transfers load away from the biceps and can be unsafe.
Measuring hip displacement allows early detection.

• **Symmetry Logic :-**

If one arm does more work than the other, the workout becomes imbalanced.
Comparing left and right elbow angles helps ensure even movement.

• **Elbow Flare Logic :-**

Correct curls require tight elbows.
If elbows flare outward too much, form breaks.

• **Noise Smoothing Logic :-**

Pose detection is not 100% stable, especially when limbs overlap with the torso.
Smoothing reduces sudden spikes and gives stable angles.

Rep Speed Analysis :-

- `rep_duration = current_time - last_rep_time`
- If `rep_duration < 1.0` → mark as **Too Fast**
- If `rep_duration > 2.5` → mark as **Too Slow**
- Else → **Perfect Speed**

Fair Score (0–100) System :-

- Evaluate every rule per frame
- Add penalty if rule threshold is crossed
- Keep score non-negative using `max(0, 100 − penalty)`

3. Challenges Faced and How I Plan to Handle Them

1. Overlapping Limbs Causing Wrong Angles

When the arm overlays the torso, MediaPipe sometimes predicts landmarks inaccurately.
Solution:

- Smoothing angle values using a buffer.
- Adding a “minimum confidence check” before calculating angles.
- Ignoring frames where tracking confidence is low.

2. Frequent Warning Messages

Small natural movements triggered warnings too often.
Solution:

- Increased thresholds
- Added smoothing
- Only show warnings for *sustained* wrong posture (not for single-frame mistakes)

3. Back Lean Detection Not Fully Accurate

Due to camera angle and user’s depth movement.
Solution:

- Instead of using only hip “y” movement, incorporate relative positions of shoulder–hip line.
- Future improvement: integrate depth estimation model.

4. Handling Multiple Persons in the Frame

The current model processes only one person (the most confident detection).
For multi-person support:

Plan to handle this:

1. Use **MediaPipe Holistic** or **OpenPose with multi-keypoint support**.
2. Track people using **person ID assignment** (tracking based on bounding box movement).
3. Run the posture checking logic separately for every detected person.
4. Display warnings individually per person.

This way, the system can analyze multiple gym members simultaneously.

5. Different Body Types and Heights

Fixed thresholds sometimes fail for different physiques.
Solution:

- Normalize positions using torso length.
- Use ratios instead of raw pixel distances.

4. Conclusion

This project successfully demonstrates a **rule-based posture analysis system** for bicep curls using MediaPipe Pose. It detects:

- Repetitions
- Curl angles
- Shoulder swing
- Back lean
- Arm symmetry issues
- Elbow flare issues
- Stability through smoothing

It provides real-time feedback and can be extended to multi-person scenarios, more exercises, and deeper form evaluation.

Future Improvements (Scalability + Production)

To make the system production-ready, the following improvements can be added:

1. **Exercise Classification Model**
   Automatically detect which exercise the user is performing (curl, squat, etc.).

2. **Adaptive Thresholds**
   Use AI/ML to learn each person's ideal angles and adjust rules accordingly.

3. **3D Pose Estimation**
   Use depth models (MediaPipe v3 or HPE3D) for more accurate back lean detection.

4. **Real-time Multi-Person Tracking**
   Integrate tracking-by-detection with person IDs to handle gym footage.

5. **MLflow Integration**
   Track scores, angles, rep speeds, and improvements over time for analytics.