Computer Vision
Analysing Archer's Body Posture with Motion Capture System

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The code discussed in this work and instructions to run it can be found on GitHub.

Abstract

This project analyses the fundamental body posture of an archer using MoCap technology to capture key postural parameters such as joint angles and foot distances. The aim is to provide insights that could lead to an automatic method for evaluating posture and classifying it as proper or incorrect in future work. The result of the analysis highlights a significant difference between the reference correct and incorrect body postures, showing the potential for objective classification based on measurable postural features.

1 Introduction

Proper body posture is essential for archers, influencing body balance, shooting performance and preventing injuries such as muscle fatigue, spinal and lower back pain, and tendon tears. This project focuses on analysing key posture joints—shoulder, spine, hips, and feet—that affect balance and performance, and used Motion Capture technology to capture postural parameters, including joint tilting angles and distances between key points. The analysis compares correct and incorrect postures by estimating joint angles and distances, motivated by the need for archers to monitor their posture during training without coach supervision. While this work focuses on body posture, the bow and shooting performance are not analysed here.

2 Related works

In the field of archery, a limited number of works have been done on analysing body posture. Most of the works used marker-less motion capture and deep learning approaches, such as [1], [2]. The similar work [3] was done on a posture images processed with a deep learning pose estimation model to study the relationship between postural consistency and scoring performance using an automated posture estimation mechanism. However, no work has been conducted on analysing body posture with the purpose of differentiating between correct and incorrect posture using a marker-based system.

3 Implementation

3.1 Data collection

Training recordings conducted using OptiTrack cameras with 360 frames per second at MotionCaptureLaboratory, providing high resolution recordings for kinematic analysis. The archer wore a suit and held a bow, both equipped with reflective markers. For the purpose of the project, we collected recordings for both correct posture and incorrect **shoulder**, **hips** and **feet** postures.

3.2 Analysis of the Data

Choice of key joints

For the purpose of the project I extracted the joints such as **arm**, **spine**, **hips**, **legs**, and **feet** for estimating the angle and distance. The joints marked with points can be shown in Figure 1a.

3.2.1 Shoulder Raising

To estimate the incorrect posture around shoulder (Fig 2a), I estimated the angle between the joints vectors of $\overrightarrow{\texttt{LUArm} - \texttt{LShoulder}}$ and $\overrightarrow{\texttt{LUArm} - \texttt{LFArm}}$. The result is shown in Figure 4.

The angle θ between two vectors $\vec{v}_1$ and $\vec{v}_2$ is computed as:

$$\theta = \cos^{-1}\left(\frac{\vec{v}_1 \cdot \vec{v}_2}{\|\vec{v}_1\|\|\vec{v}_2\|}\right) \tag{1}$$

where $\vec{v}_1 = (x_1, y_1, z_1)$ and $\vec{v}_2 = (x_2, y_2, z_2)$ are 3D vectors.

The archer raises the shoulder due to a heavy bow or weak muscles. As a result, the archer focuses on holding the bow instead of aiming at the target, which causes difficulty in shooting accurately.

3.2.2 Feet Distance

To estimate the excessive distance of feet (Fig 2b), The distance is calculated between both toes and heels by estimating the Euclidean distance between the positions between `LToe-RToe` and the left and right heel `LFoot-RFoot`. The result is shown in Figure 5. The Euclidean distance D between the left and right toe positions in 3D space is computed as:

$$\underbrace{\|p_L - p_R\|}_{D} = \sqrt{(x_L - x_R)^2 + (y_L - y_R)^2 + (z_L - z_R)^2} \tag{2}$$

where $\vec{p}_L = (x_L, y_L, z_L)$ and $\vec{p}_R = (x_R, y_R, z_R)$ are the 3D coordinates of the left and right toes. Feet distance affects the overall body balance and further the aiming.

3.2.3 Hips Tilting

To estimate the incorrect posture around hips (Fig 3a, Fig 3b), I analysed two different recordings considering the hips tilted to the left and right sides. The following metrics are extracted from the hip posture:

- **Hip Drop (Asymmetry)** - The metric is computed by computing the difference in the Y-coordinates of `LThigh` and `RThigh` positions. The result is shown in Figure 6.
  The vertical hip drop is computed as:

$$\Delta y_{\text{hip}} = y_L - y_R$$
$$\text{where} \quad \vec{p}_L = (x_L, y_L, z_L), \quad \vec{p}_R = (x_R, y_R, z_R) \tag{3}$$

- **Back Leg Tilt Angle** - Computed the angle between horizontal plane and joint vector of back leg $\overrightarrow{\texttt{RFoot} - \texttt{RThigh}}$. If this angle is far from 0°, the hips are tilted left or right. The result is shown in Figure 7.
- **Spine Tilt Angle**: Computed the angle between vertical plane and spine vector of spine $\overrightarrow{\texttt{Hip} - \texttt{Neck}}$. If large, the spine is tilting left or right relative to vertical plane. The result is shown in Figure 8.
- **Hips Raising Angle**: Computed the angle between horizontal plane and joint vector of hips $\overrightarrow{\texttt{RThigh} - \texttt{LThigh}}$. If this angle is far from 0°, the hips are tilted left or right. The result is shown in Figure 9.

Hips tilting to one side is the root cause of spine and lower back injuries. It often goes unnoticed, as archers tend to lean toward the side bearing the bow's weight.

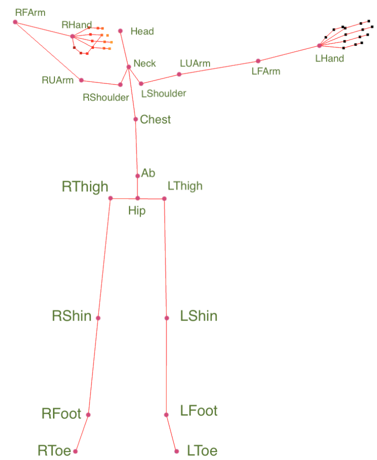

Figure 1a: Correct body posture

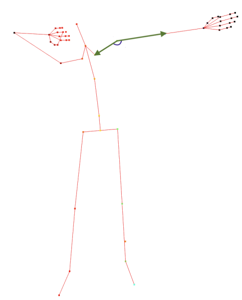

Figure 2a: Shoulder Raising

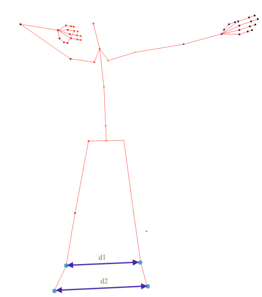

Figure 2b: Feet Distance

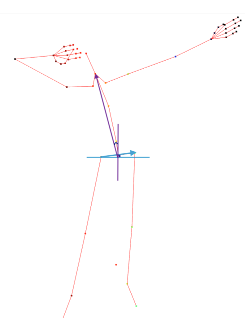

Figure 3a: Hips Tilt to the Left)

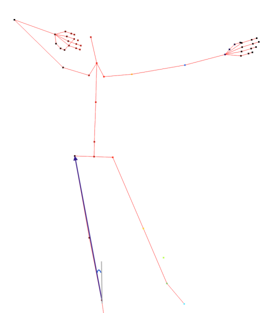

Figure 3b: Hips Tilt to the Right)

4 Results

The result of the analysis highlights the significant difference between the correct and incorrect body postures, such as shoulder angle decreases as the archer raises the shoulder. Also, shows that foot distance should remain within body width. Spine and back leg tilt angles increase as the archer leans to one side, along with a rise in vertical hip difference. The hips raising angle interprets limited insight compared to other criteria as shown in Table 1 and figures.

Area/Metric	Correct Pos	Incorrect Pos	
		Left	Right
Shoulder Raising	134.6°	125.6°	
Feet Distance	26.83 cm	42.17 cm	
Toe Distance	31.83 cm	48.80 cm	
Hips Drop	$\Delta y = -1.22$	$\Delta y = 7.01$	$\Delta y = -13.1$
Back Leg Tilt	9.97°	10.54°	7.28°
Spine Tilt	8.31°	12.05°	9.16°
Hips Raising	76.16°	72.10°	69.15°

Table 1: Comparison of metrics across postures

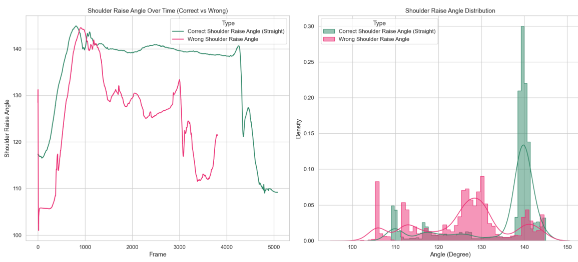

Figure 4: Shoulder Raising Angle comparison

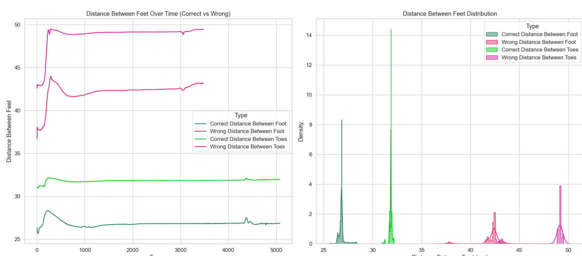

Figure 5: Distance Between Feet comparison

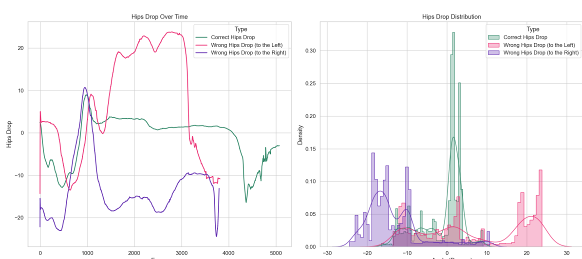

Figure 6: Hip Drop comparison

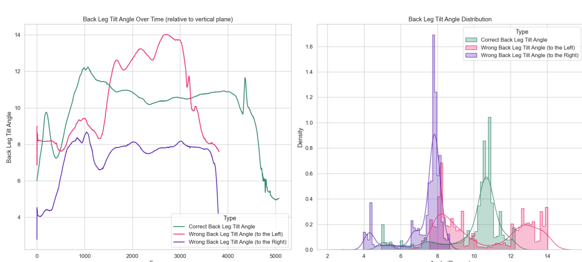

Figure 7: Back Leg Tilt Angle comparison

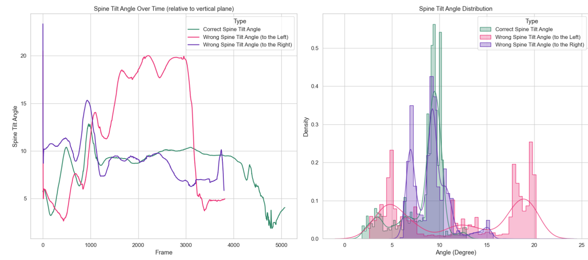

Figure 8: Spine Tilt Angle comparison

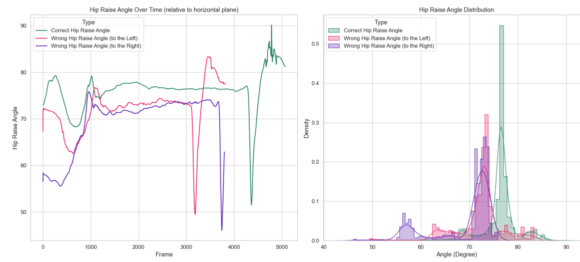

Figure 9: Hips Raising Angle comparison

5 Discussion

5.0.1 Identified Challenges

To be a complete framework to analyse the correlation between performance and body posture has not yet been implemented, as shooting was not performed and reflective markers were attached to the archer and bow, but not to the arrow.

5.0.2 Future Development

This project also has the potential to analyse the performance the shooting, that are also important factors to consider in performance, such as:

- **Arrow direction**: Analysing the arrow's trajectory and how it changes depending on body posture;
- **Quality of performance**: Analysing how body posture affects shooting performance and score changes
- **Equipment dependency**: Analysing changes in body posture depending on the weight of the bow equipment.

6 Conclusion

It is considered that an archer needs to focus on aiming rather than body posture to perform well. This project highlights the importance of monitoring posture as a foundation for consistent shooting and injury prevention, providing a basis for future work to integrate posture analysis with shooting performance evaluation.

References

[1] D. H. Chiam, J. T. S. Phang, K. H. Lim, and B. A. Lease, "Study of archery shooting phases using joint angle profile," pp. 1–5, 2023. DOI: 10.1109/ICDATE58146.2023.10248617.

[2] J. T. S. Phang, K. H. Lim, B. A. Lease, and D. H. Chiam, "Deep learning pose estimation for kinematics measurement in archery," pp. 298–302, 2022. DOI: 10.1109/GECOST55694.2022.10010619.

[3] B. A. Lease, K. H. Lim, J. T. S. Phang, and H. Zuo, "Deep learning posture estimation for archery consistency measurement," pp. 1770–1773, 2024. DOI: 10.1109/ICICML63543.2024.10957898.