# Resistance Training Support System with Pose Estimation

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**Abstract:** Squat training is highly effective for improving lower limb muscle function. However, when this type of training is performed alone without a personal trainer or physical therapist, it can lead to inefficiencies and injuries among trainees. Thus, we aim to develop a system that provides visual and real-time feedback on the correct posture of a lone squat trainee using pose estimation. In this study, we propose a function that demonstrates the correct posture for each squatting discipline in the form of a line-segment posture representation and warns the trainee when he/she assumes an incorrect posture. Squatting motion in the sagittal plane was captured using a camera connected to a personal computer, and the coordinates of the acromion, hip, knee, and ankle joints were detected using MoveNet. The joint angles were calculated from the detected coordinates and the correct posture was determined according to the individual's body shape. The color of the formed line-segment posture representation changed to indicate the difference between the trainees' actual and correct postures. In future research, we plan to assess the displacement of key points detected by MoveNet using optical technologies to confirm the reliability of this system's pose estimation. Afterwards, we will evaluate the effectiveness of this system in determining whether a trainee can move appropriately.

**Keywords:** squat training, pose estimation, MoveNet, visualization support, awareness support

## 1. Introduction

Resistance training mainly focuses on improving muscle activity and is highly effective in improving muscle strength, power, and hypertrophy (Erskine et al., 2010). Resistance training is used not only in sports but also for health maintenance and rehabilitation, thus making it popular among athletes and the general population.

For effective resistance training results, they must be performed under appropriate program designs, proper progression, and motion to meet the objectives of the people undergoing resistance training. Having a personal trainer or other instructors with expertise in resistance training can make it more effective (Ratamess et al., 2008). However, it is also true that many people who perform resistance training are unable to have an instructor because of financial constraints and geographical issue (because they live in rural areas). It is difficult for them to assess objectively their posture while performing resistance training alone. Additionally, resistance training performed by adopting an incorrect posture can cause injuries such as tendon rupture and ligament damage (Bengtsson et al., 2018). Therefore, trainees must have a method that can address the problem associated with the lack of instructors.

Recently, several applications utilizing posture estimation were studied (Stenum et al., 2021). Pose estimation can detect "key points," such as the eyes, nose, and joints from video images captured by cameras by using machine learning. To the best of our knowledge, there have been no previous studies on the evaluation of posture during squat training, which helps improve both the flexion and extension torque of the knee and hip

(Akagi et al., 2020). This study proposes a system that visually teaches the correct posture to young people performing squat training alone who are adept with the use of basic personal computers (PCs) to perform squat training safely.

## 2. Functional requirements and quantitative body motion estimation

To train people undergoing squat training alone in the correct posture, it is essential to provide them with an environment wherein they can visually assess both their own and the correct postures in real-time. In addition, it is necessary to determine whether the squatting motion of the participants is correct. Moreover, because posture is determined by the joint angles involved in the squatting motion, these joint angles must be calculated as required. Therefore, the functional requirements of the squat-training support system are as follows,

A) Assessment the body motion in real-time
B) Visual instruction of the correct posture
C) Calculation of the joint angles

To satisfy B) and C) during squat training, it is necessary to capture body motions. Therefore, we focused on the pose estimation library "TensorFlow.js" which can detect feature points of the body using machine learning from video images captured from a single common camera.TensorFlow.js can complete the inference process and render the processing results on the front-end side, thus enabling a faster response time. Hence, we employed MoveNet, a pretrained model in TensorFlow.js, to quantitatively capture motion from the perspective of A) real-time performance. MoveNet can detect 17 key points in the body. The human skeleton was evaluated based on these key points.

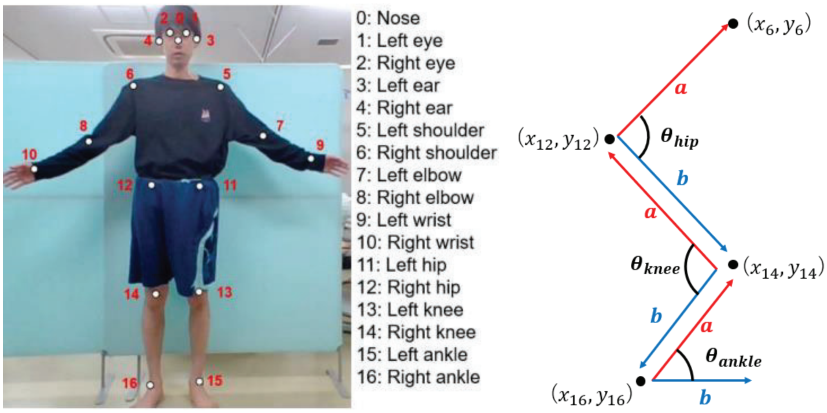


*Figure 1.* Seventeen key points defined on MoveNet and set of two vectors at each key points to calculate joint angles

## 3. Visual teaching of correct posture

In this system, a camera (connected to PC) records video images of the trainee from the side while he or she is training at 30 fps. A display connected to a PC was placed in front of the trainee so that he/she could check his/her posture and the content of the instructions in real-time.

The position X-Y coordinates of the trainees' shoulders, hips, knees, and ankle joints were obtained using MoveNet. First, the system automatically calculates the length between the shoulder and hip joints, thigh length, and lower leg length when trainee is in the standing position. In this case, each length is calculated using two vectors $\boldsymbol{a}, \boldsymbol{b}$ , as shown in Figure 1 and formula (1) (6: shoulder, 12: hip, 14: knee, and 16: ankle joints are included in $i$ and $j$). As shown in Figure 3, the ideal line-segment representations between the shoulder and hip joint, hip joint and knee joint, and knee joint and ankle joint in the squat motion are displayed by p5.js that is JavaScript library for draw in browser pages (B)), considering the trainee's calculated length between the shoulder and hip joint, thigh length and lower leg length. The trainees performed the squatting motion to match the presented ideal line-segment representation. Each joint angle ($\theta$) during the movement was calculated sequentially using the inner product as formula (2) (C)). If the trainee's posture matched the ideal line-segment representation, the color of the ideal line-segment representation changed to red to allow the trainee to know that he/she assumed the correct posture.

$$|\boldsymbol{a}|, |\boldsymbol{b}| = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (1)$$

$$\theta = cos^{-1} \frac{\boldsymbol{a} \cdot \boldsymbol{b}}{|\boldsymbol{a}||\boldsymbol{b}|} \quad (2)$$

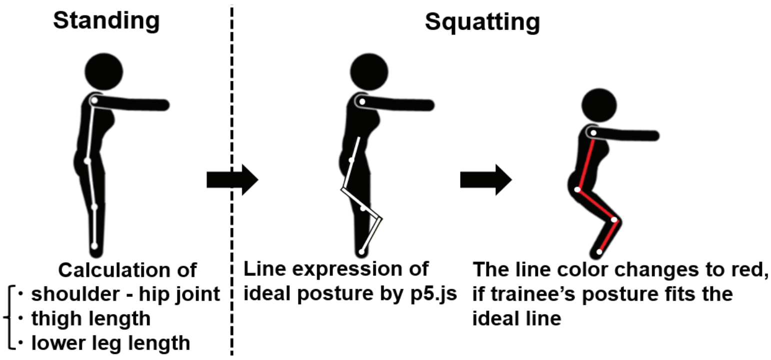

*Figure 3.* Steps to teach the correct posture

## 4. Future development

In future research, we plan to conduct an error verification test to assess the deviation between the position coordinates of the key points detected by MoveNet and the original joint position coordinates of the body using motion information captured using optical technologies to confirm the reliability of the system's posture estimation. Subsequently, we plan to evaluate the effectiveness of this system in determining whether a trainee can move appropriately according to the ideal line-segment posture representations.

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