Promotion System for Home-Based Squat Training Using OpenPose

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***Abstract*—This study aims to develop a support system to promote daily home-based squat training for beginners, using an achievement score and video annotation as inputs for improvement. In this work-in-progress paper, we propose three feedback functions for maintaining and improving motivation and for learning correct training forms. We conducted a pilot study to confirm the extent to which scoring can utilize the squat postures, based on the joint center detected using OpenPose. Accordingly, we were able to detect the important points necessary to score and evaluate the squat postures accurately. Thus, the effectiveness of using OpenPose was verified.**

Keywords—home-based training, OpenPose, training beginners, video annotation

I. Introduction

The novel coronavirus disease (COVID-19) has had a significant impact on the physical activities of people around the world because they have been forced to stay at home. The World Health Organization recommends moderate to vigorous physical activity at 60 min/day for children between the ages of 6 and 17 and at 75 min/week for adults and the elderly. Therefore, under the current circumstances, it is necessary for us to exercise at home without using special equipment, such as resistance training by using body weight that can be easily conducted at home.

Proper knowledge of training, the ability to embody it, and motivation are required to carry out appropriate and effective training by oneself regularly. Particularly, training beginners are likely to have none of these. They could learn the right way to train from books and other materials; however, it is difficult for them to judge the correctness of training by oneself. This makes it difficult for beginners to stay motivated. As a result, it is expected that beginners will not be able to continue their training.

One way to encourage beginners to continue their training is to use a training support system. Existing systems allow instructors to evaluate the training behavior and performance of the user to provide feedback [1,2,3]. However, as the number of users increases, the burden on instructors increases and proper support becomes more difficult. Hence, a system that provides automated and instantaneous training evaluations and feedback to users is required. We aim to develop such a system to promote daily home-based training for beginners.

To evaluate the training posture automatically, it is necessary to perform motion analysis. Three-dimensional motion analysis is one type of a motion analysis method which requires multiple markers and sensors [4,5,6]. Therefore, it is difficult to use it at home due to time, space, and money constraints. Hence, we use OpenPose, which can analyze the two-dimensional motion of images captured using smartphones and/or tablets. The specific method of filming is to fix the camera and show the whole body. During the training, the camera constantly takes pictures. Moreover, human movement is evaluated in three dimensions because it is three-dimensional. However, OpenPose can only acquire two-dimensional images, and consequently, complex motions are sometimes not detected correctly when using OpenPose [7]. Therefore, it is necessary to solve this problem by changing the angle of the photograph/image.

Effective feedback to the user is essential to ensure that the user learns appropriate training movements and stays motivated. Therefore, this system expresses a score astraining results. Additionally, we propose two immediate feedback functions (i.e., video comparisons and text comments).

II. Three Feedback Functions

A. Scoring

This system uses OpenPose to detect the skeleton, as shown in Fig. 1, and evaluate human movement.Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

Ideally, for the parallel squat, the thigh should be level with the floor, the knee should not be pulled forward, and the width of the feet should be that of the shoulders. Among the above, the most important posture is that of the thighs in parallel with the floor [10]. Therefore, this posture is given the highest score. As shown in Fig. 2, the posture of the right-side is scored higher than that of the left-side during the training. The method for determining the specific points is described below. To evaluate the ideal parallel squat, four important joint centers are used: the knees and hips, the hips and ankles, the ankles and shoulders, and the ankles and heart. In this study, the four centers are expressed as the thigh-angle, knee-points, stance-width, and heart-points. In addition, the four centers are represented as check-point. The points are determined by using the numerical values of the X and Y coordinate. The check-point is given a score of 1–3 or 1–2. For the thigh-angle, 3 points are given if the thighs are close to the horizontal, 2 points are given if the hip is below the knee, and 1 point is given if the hip is above the knee. For the knee-points, 2 points are given if the knee is almost vertical, and 1 point is given if the knee is in front of the ankle. For the stance-width, 2 points are given if the ankles and shoulders are vertical, and 1 point is given if the ankles and shoulders are not vertical. Regarding the heart-points, 2 points are given if the heart is perpendicular to the midpoint of both ankles; otherwise, 1 point is given. These scores are visually presented as numbers, and the user can verify these numbers after training.

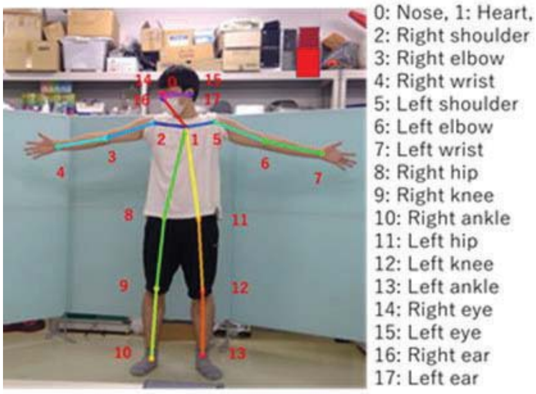

Fig. 1. Skeletal position.

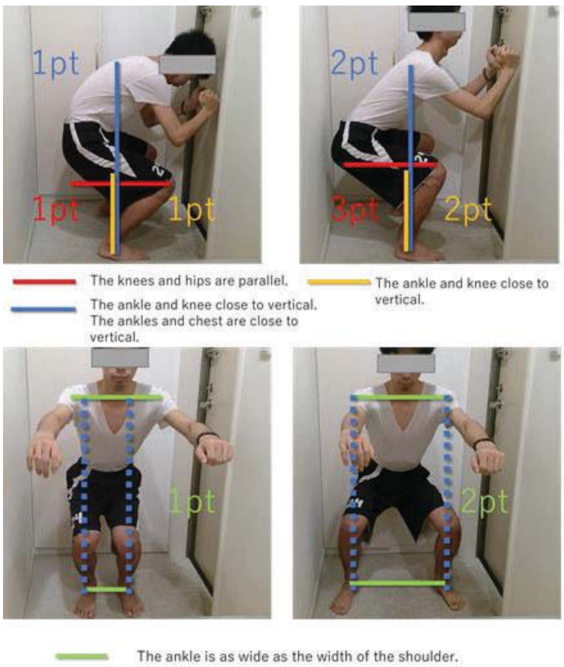

Fig. 2. Scoring method.

B. Video Annotation

In this study, we propose two feedback functions in addition to the score visualization for learning the correct movements while maintaining and improving motivation.

The first feedback function is that the users can compare the training forms of themselves and an instructor on a smartphone, tablet or personal computer (Fig. 3). The second feedback function is that the users can confirm the receive advice given automatically by the system as text comments. We provide an example of a comment if the knee is not bent ("bend the knees more," as shown in Fig. 3). Thus, the two feedback functions are termed as video annotations. The combination of video annotation and score visualization is expected to help users maintain and improve their motivation to continue training.

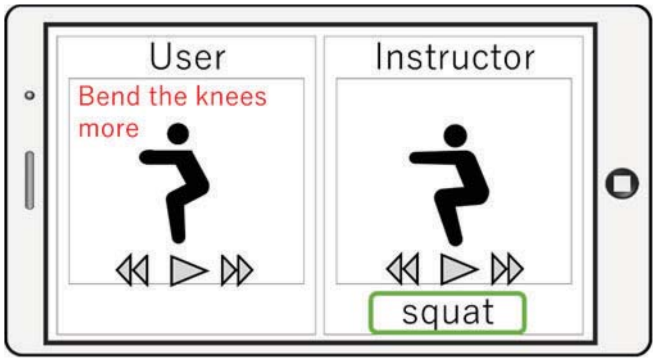

Fig. 3. Video display method.

III. Pilot Study

An OpenPose analyses two-dimensional images and the photographing angle becomes important to calculate the score using the coordinates obtained from the image based on OpenPose. Therefore, we performed a pilot study to confirm whether OpenPose can detect some of the above-mentioned important points for evaluating the motions and postures during squat training. In the pilot study, we obtained photos from three angles. The first was taken from the front, the second from the side, and the third from an oblique angle of 45°. In the first case, the difference between the position of the knee and the hip joint was small, and it was difficult to calculate the score of the thigh-angle. In the second case, the difference between the coordinate positions of the ankle width and the shoulder width was small, making it difficult to calculate the score of the stance-width. By contrast, the points necessary for assessing the motions and postures were detected in the third case. In this pilot study, OpenPose was found to be able to calculate scores with specific criteria. Although the coordinate of the left wrist was detected as that of the right wrist (in Fig. 4), this was not a significant issue because the points related to the hip, knee, and ankle joints were detected well.

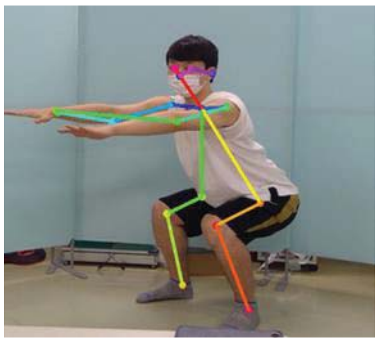

Fig. 4. Photographing method and skeleton detection result.

IV. Future Study

We proposed a promotion system using OpenPose to perform body mass-based squat training at home routinely. In this study, we focus on beginner training and propose three feedback functions to enable beginners to continue squat training. As a result of the pilot study, we were able to detect the important points necessary for scoring accurately by photographing at an angle of 45°. In this case, we were also successfully able to score the squat action. In the future, the system can be improved to enable the correction of actions even when the user cannot see the screen by introducing audio comments. We can create a system to allow users to compare training videos of instructors and users in real time. An experiment can also be conducted with user-only videos, instructor videos, and dual-screen displays to observe if there are improvements in the feedback methods. After ensuring the effectiveness of this system, it can be applied to people who want to carry out different types of training at home.

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