Bulletin of Networking, Computing, Systems, and Software – www.bncss.org, ISSN 2186-5140
Volume 13, Number 1, pages 42–44, January 2024

Baby-Holding Posture Determination System using Pose Estimation

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***Abstract*—Currently, one out of three postpartum mothers experiences hand or wrist pain. The physical symptoms of postpartum mothers are associated with baby-holding posture [1], which is important for the prevention of physical problems such as tendinitis. However, the baby-holding posture determination requires an expert and is time-consuming. Therefore, we propose a baby-holding posture determination system using pose estimation (BABYP). The BABYP system enables mothers to easily determine whether the baby-holding posture is good or bad by themselves. In this paper, we conducted experiments with 29 postpartum mother-child pairs and validated that the BABYP system can determine the baby-holding posture with 83.0% average of mean accuracy.**

***Keywords*—posture determination, baby-holding posture, pose estimation**

I. Introduction

In recent years, the physical symptoms of postpartum mothers are gaining increasing attention of researchers. For example, the percentage of postpartum mothers who experienced hand or wrist pain during the first month postpartum is 35.2% (48.9% of first-time mothers and 24.9% of multiparas) [1]. The physical symptoms of postpartum mothers are associated with baby-holding posture [1], which is important for the prevention of physical problems such as tendinitis. However, no system currently exists that enables mothers to easily determine baby-holding posture by themselves; therefore, baby-holding posture determination requires an expert, such as a midwife, and is time-consuming [2][3]. To overcome this problem, we proposed a baby-holding posture determination system using posture estimation (BABYP). The BABYP system enables mothers to easily determine whether their baby-holding postures are good or bad. In this study, we conducted experiments to determine the baby-holding posture with 29 mother-child pairs and validated that the baby-holding posture could be determined with 83.0% average of mean accuracy.

II. Baby-Holding Posture Determination System using Pose Estimation

A. System

The BABYP system is shown in Fig. 1 (left). The BABYP system consists of three parts: image capture part, pose estimation part, and posture determination part. The image capture part uses a smartphone camera to capture RGB images. The pose estimation part estimates the baby-holding keypoints from the RGB image of the baby-holding posture. The posture determination part determines whether the baby-holding posture is good or bad from the baby-holding keypoints.

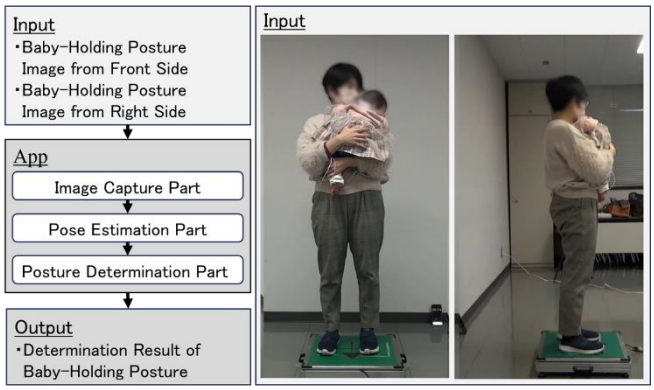

Fig. 1. (left) BABYP system outline; (right) Sample RGB images of baby-holding postures.

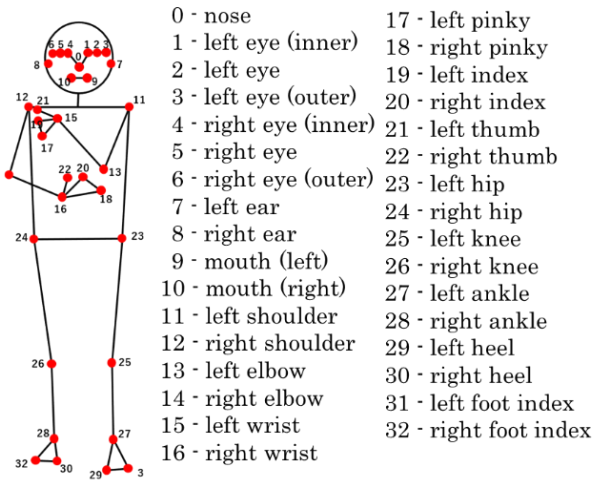

Fig. 2. BlazePose 33 keypoints.

B. Image Capture Part

The image capture part uses a smartphone camera to capture the RGB images of the baby-holding posture. The BABYP system captures the RGB image of the baby-holding posture from the front and right sides, capturing the entire body. The resolution of the RGB image of the baby-holding posture was set to 720 × 480 pixels. Sample RGB images of the baby-holding posture from the front and right sides are shown in Fig. 1 (right).

Pose Estimation Part

The pose estimation part estimates the baby-holding pose from the RGB image of the baby-holding posture. We used the MediaPipe Pose [4] to estimate the baby-holding pose. MediaPipe Pose is a single-person pose estimation framework that uses BlazePose 33 keypoints, as illustrated in

Fig. 2. Here, we define the coordinate of the i-th keypoint of the front and right sides image by $(x_{f,i}, y_{f,i})$ and $(x_{r,i}, y_{r,i})$, respectively, where $0 \leq i \leq 32$.

C. Posture Determination Part

1) Outline: The posture determination part determines whether the baby-holding posture is good or bad using baby-holding keypoints. We held an instructional session on baby-holding posture by midwives for 29 pairs of mothers and babies under 6 months of age. From the instruction items in the instructional session, we focus on three relatively frequent instruction items: "wrist position", "shoulder distortion", and "spinal distortion", and the BABYP system determines whether each of the three instruction items is good or bad. The wrist position is whether the wrist position is appropriate. The shoulder distortion refers to whether the shoulders are level with one another and parallel to the ground. The spinal distortion refers to slouching or hunching. The BABYP system defines the evaluation criteria R, A, and B and the thresholds ε_R, ε_A, and ε_B for the three instruction items and determines baby-holding posture based on whether the value of the evaluation criterion exceeds the corresponding threshold. In Sections D.2, D.3, and D.4, we define the evaluation criteria R, A, and B, respectively. In Section D.5, we propose the method for deciding the thresholds ε_R, ε_A, and ε_B.

2) Wrist Position: In this section, we define the evaluation criterion for the wrist position, R. First, we calculated the height of the wrist keypoint supporting the buttocks of the baby as the larger height of right or left wrist keypoint:

$$Y_H = \begin{cases} y_{f,15} & \text{if } y_{f,15} > y_{f,16} \\ y_{f,16} & \text{otherwise} \end{cases}. \quad (1)$$

Second, we normalized the height of the wrist keypoint supporting the buttocks of the baby, as follows:

$$R = \frac{Y_w - Y_H}{Y_w - Y_s}, \quad (2)$$

where Y_H is the average height of the right and left hip keypoints and Y_s is the average height of the right and left shoulder keypoints, as follows:

$$Y_w = \frac{y_{f,23} + y_{f,24}}{2}, \qquad Y_s = \frac{y_{f,11} + y_{f,12}}{2}. \quad (3)$$

3) Shoulder Distortion: In this section, we define the evaluation criterion for the shoulder distortion, A. We define the evaluation criterion A as the angle between the line through the left and right shoulder keypoints and the line parallel to the ground, which is calculated as follows:

$$A = \left| \tan^{-1}\left(\frac{y_{f,11} - y_{f,12}}{x_{f,11} - x_{f,12}} \right) \right|. \quad (4)$$

Fig. 3. Sample RGB images of baby-holding postures

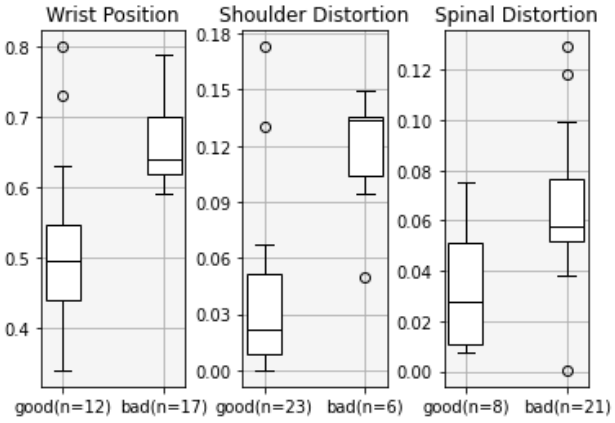

Fig. 4. Box-and-whisker plots of evaluation criteria R, A, and B for each determination result by midwives.

4) Spinal Distortion: In this section, we define the evaluation criterion for the spinal distortion, B. We define the evaluation criterion B as the angle between the line through the right hip and right ankle keypoint and the line perpendicular to the ground, which is calculated as follows:

$$B = \left| \frac{\pi}{2} - \tan^{-1}\left(\frac{|y_{r,24} - y_{r,28}|}{|x_{r,24} - x_{r,28}|} \right) \right|. \quad (5)$$

5) Deciding the Three Thresholds ε_R, ε_A, and ε_B: In this section, we propose the method for deciding the thresholds ε_R, ε_A, and ε_B. We only describe the way to decide the threshold ε_R. The method for deciding the threshold ε_A and ε_B is same. Here, we denote the set of the evaluation criteria R of the N baby-holding postures for training by $D_R = \{R_1, \cdots, R_N\}$ and the minimum and maximum value of the set D_R as R_{min} and R_{max}, respectively. The BABYP system decides the threshold ε_R so as to maximize accuracy from 100 equally spaced points in the interval $[R_{min}, R_{max}]$, where the accuracy is calculated as follows:

$$\frac{1}{N}\sum_{n=1}^{N} I\left(T_{R,n} = I(R_n > \varepsilon_R)\right). \quad (6)$$

Here, $T_{R,n}$ is the determination result of the n-th baby-holding posture by midwives; $T_{R,n} = 0$ indicates good posture, and $T_{R,n} = 1$ indicates bad posture. $I(\alpha)$ denotes

the indicator function that equals 1 if α is true and 0 otherwise.

III. Computer experiment

A. Experimental Method

In this study, we conducted a photo session for 29 pairs of mothers and babies under 6 months of age and captured baby-holding posture RGB images of the 29 pairs from the front and right sides. Sample RGB images of the baby-holding postures are shown in Fig. 3. In addition, we collected the 29 determination results for the three determination items wrist position, shoulder distortion, and spinal distortion by midwives. In this experiment, we defined the dataset as 29 pairs of RGB images of the baby-holding postures and the corresponding determination result by midwives.

B. Experimental Result

Fig. 4 shows the box-and-whisker plots of the evaluation criteria R, A, and B for each result determined by the midwives. From Fig. 4, we can observe that a significant relationship exists between the determination results by the midwives and the values of the evaluation criteria R, A, and B. Table 1 lists the mean accuracy of the determination results for the test set between the BABYP system and midwives. The mean accuracy of the test set was the average of 100 accuracy values, using a random selection of 70% of the dataset as the training set and 30% as the test set. Fig. 5 shows the box-and-whisker plots of 100 accuracy values. This experiment showed that the BABYP system can achieve 83.0% average of mean accuracy on the test set.

IV. Summary

In this study, we proposed a baby-holding posture determination system using posture estimation (BABYP). The performance of the BABYP system was assessed in experiments with 29 pairs of baby-holding posture RGB images and the determination results by midwives. This experiment showed that the BABYP system can achieve 83.0% average of mean accuracy on the test set.

TABLE I. Mean accuracy on the test set [%]

Wrist Position	Shoulder Distortion	Spinal Distortion	Mean
87.2	84.8	77.0	83.0

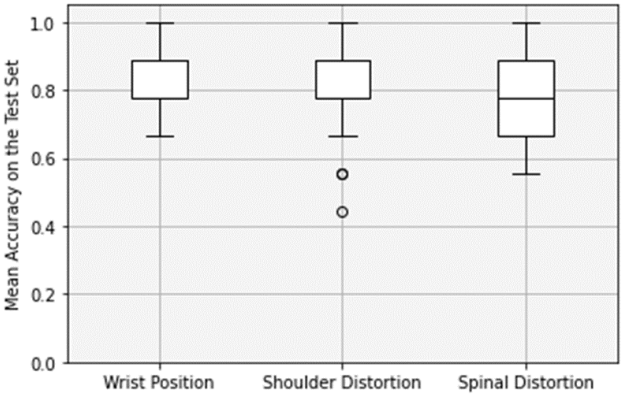

Fig. 5. Box-and-whisker plots of 100 accuracy values.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number JP22K11064.

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