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Quantifying Breast Regional Deformation During Fast Walking with 4D Scanning Sequences

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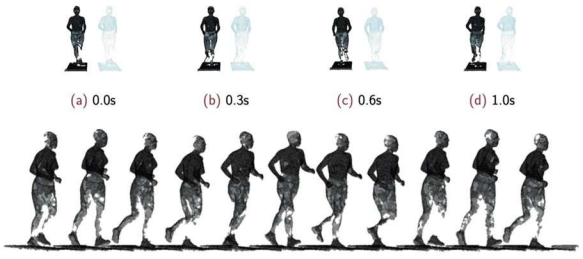
BACKGROUND

Sports bras are designed to minimize these deformations, but high pressure from these bras can have negative effects. **Therefore, understanding the dynamics of breast motion and deformation is vital for creating more effective sports bras.**

- Recent advancements in motion capture (MoCap) technology have allowed for the study of breast dynamics based on anatomical landmarks, revealing their intricate three-dimensional movements.
- However, these studies have limitations: they depend on physical markers and thus cannot capture all motions and deformations, and it's unclear whether these sparse landmarks can truly capture the complex patterns of breast movement.



(a) 0.0s (b) 0.3s (c) 0.6s (d) 1.0s

(e) From left to right are frames of 0.0s, 0.1s, ..., 1.0s.

Figure 1. 4D scanning mesh sequence recorded in the experiment.

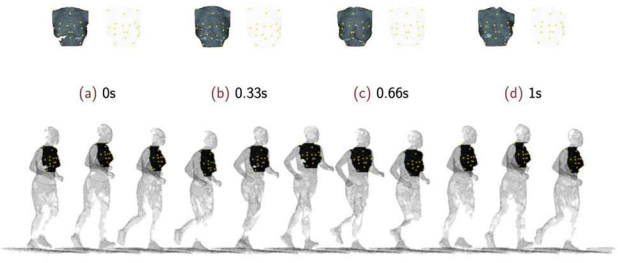
METHODS

In this paper, we utilised the 4D scanning technology to capture dynamic breast deformation in vivo during treadmill fast walking, offering **high spatial and temporal resolutions**, leading to a breast anthropometric dataset covering the dynamic deformation of the breast during treadmill fast walking.

- **Stage 1 Data collection** 4D scanning during treadmill fast walking.
- **Stage 2 Landmark lebelling** 18 anthropometric landmarks were labelled on the 4D scanning sequence.
- **Stage 3 Breast cropping** The breast area is automatically cropped out from the 4D scanning sequence.
- **Stage 4 Data analysis** The accumulated trajectory lengths of the landmarks were calculated as indicators of the breast regional deformation. They were them interpolated on the whole breast surface to illustrate the overall & directional deformation pattern.

(a) (b)

Figure 2. (a) The labelled anatomical landmarks. Landmarks on the clavicle, left breast, right breast, and rib cage bottom regions are represented as yellow, green, blue, and pink lines, respectively. (b) Spatial trajectories of different landmarks. Landmarks on the clavicle, left breast, right breast, and rib cage bottom regions are represented as yellow, green, blue, and pink lines, respectively.



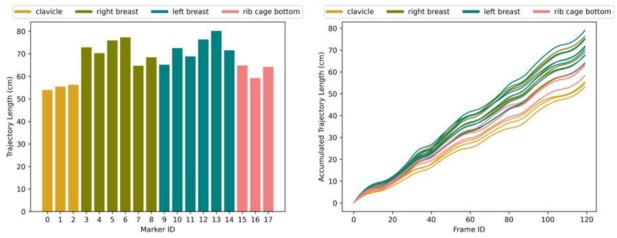
(a) 0s (b) 0.33s (c) 0.66s (d) 1s

(e) From left to right are frames of 0.0s, 0.1s, ..., 1.0s.

Figure 3. Breast area cropped out based on contour landmarks.

RESULTS

Based on this dataset, the **regional deformation intensity of the breast** was investigated, including overall deformation and directional displacement, respectively. The accumulated displacement is used as a measure of deformation intensity, revealing two patterns of breast deformation.

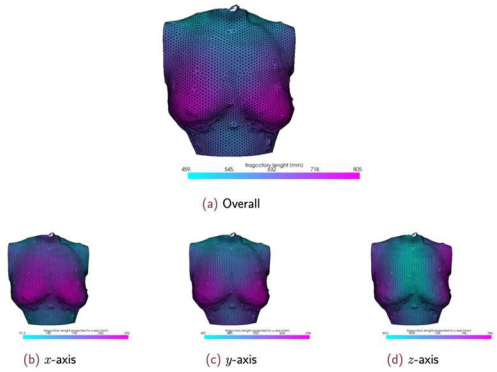


(a) (b)

Figure 4. Accumulated trajectory length: (a) accumulated trajectory length of different landmarks; (b) accumulated trajectory length of different landmarks across frames.

Overall Deformation Pattern

- The deformation intensity increases smoothly from the chest to nipple areas.
- Soft tissues are significantly more deformable than the rigid torso areas.



(a) Overall

(b) x-axis (c) y-axis (d) z-axis

Figure 5. Overall & directional displacement distribution of the whole breast area.

Directional Deformation Pattern

- The entire breast area and the chest area is subjected to large medial-lateral deformations (x-axis), while only the soft tissues of the breasts are subjected to obvious vertical deformation (y-axis).
- Both the lateral and vertical deformations are more pronounced on the front side of the body.
- In contrast, significant deformations in the forward and backward directions are observed on the side-parts of the torso.

DISCUSSION

Limitations:

- The dataset was constructed from a single participant, which may not be representative of the general population.
- The study focused on treadmill fast walking, which may not capture the full range of breast motion during other activities.
- When the movement involves large rotation, the accumulated displacement may not be an appropriate indicator of regional deformation intensity.

IMPACT STATEMENT

- This study demonstrates the potential of 4D scanning technology for capturing dynamic breast deformation patterns during physical activities.
- The results provide valuable insights into the complex nature of breast motion and deformation, which can inform the design of sports bras and other supportive garments.
- Future research could focus on expanding the dataset to include a larger sample size and a wider range of activities to further enhance our understanding of breast biomechanics.