# Calf Fatigue Recognition in Heel-lift Exercise Using Video Sequences of Body Sway

鳥取大学 Tottori University

T. Kamitani, M. Kojima, and M. Nishiyama, Tottori University, Japan

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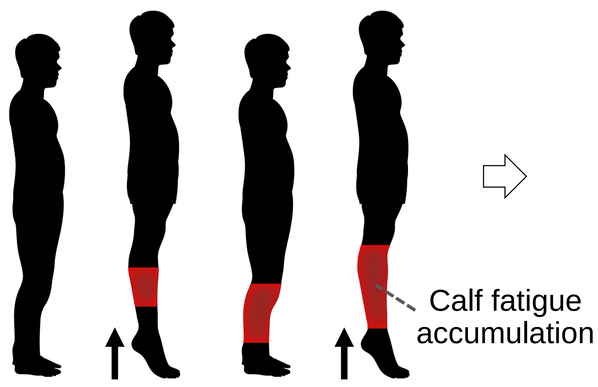
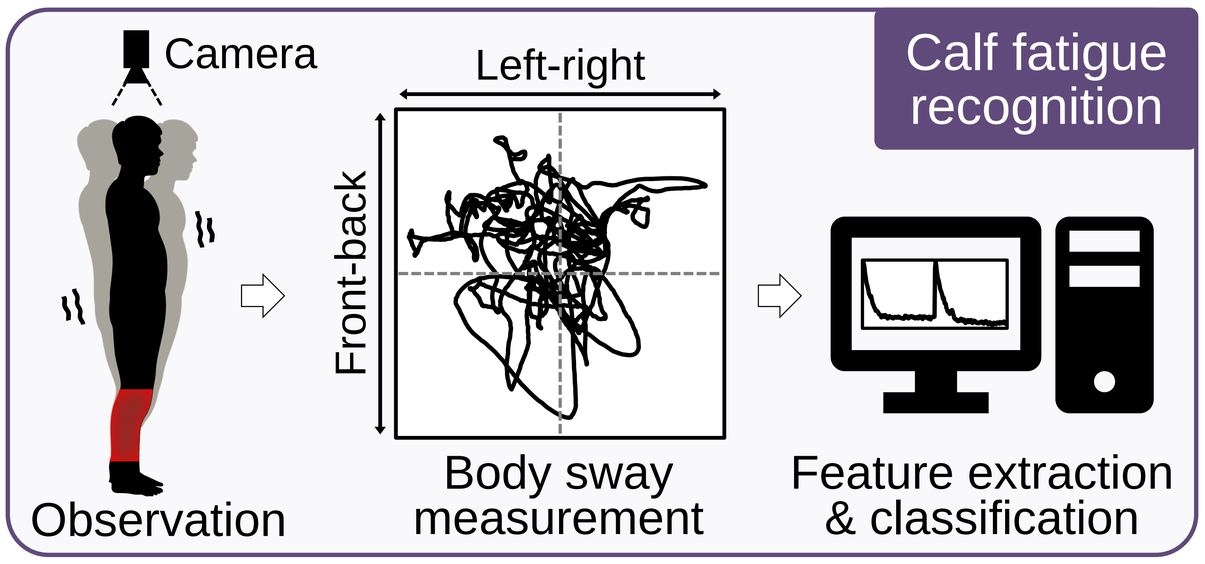
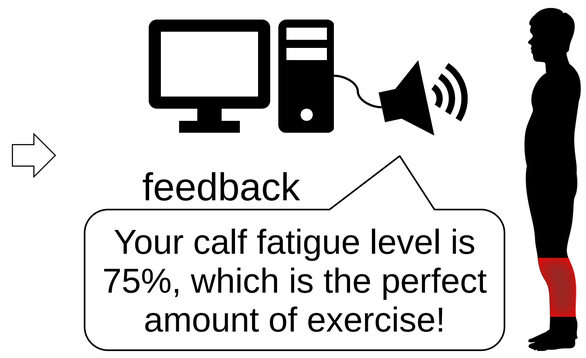
## Introduction

We aim to develop a system that provides feedback on the level of calf muscle fatigue after heel-lift exercise.




Heel-lift exercises can load the calf muscles and improve poor blood circulation.



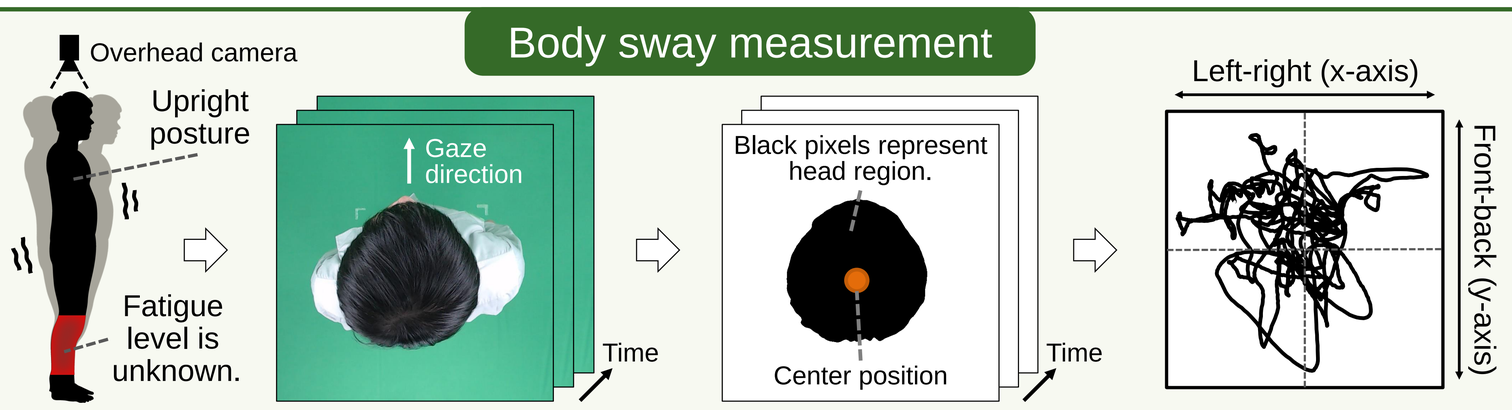




To provide valuable feedback, it is necessary to accurately recognize the calf fatigue level.

## Proposed method (Calf fatigue recognition)

We integrate medical knowledge on calf fatigue levels from previous analytical studies into the existing body sway feature extraction.

### Body sway measurement

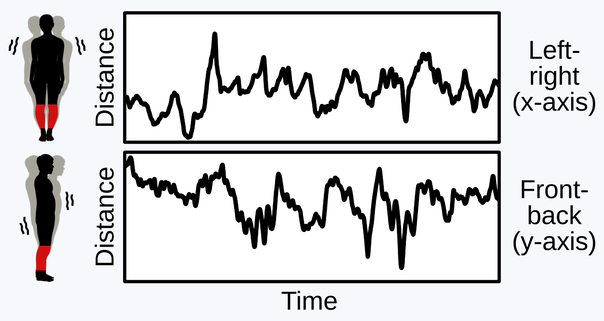



Acquisition of video sequences of body sway from a standing person

Estimation of head regions in video sequences

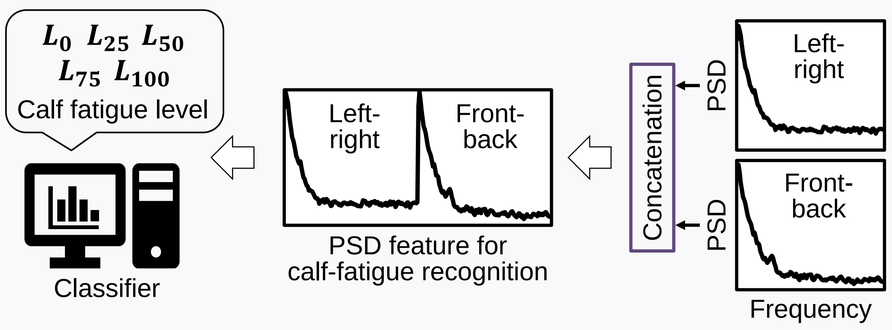
Calculation of center positions from head regions

### Medical knowledge integration




Generation of time-series signals from center positions in x and y axes

### Feature extraction and classification



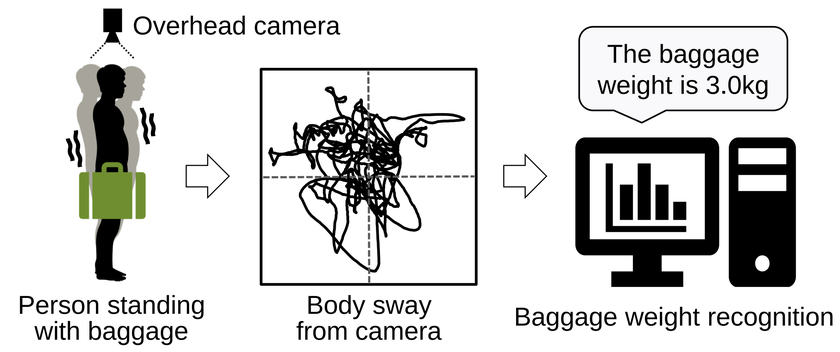

Classification of calf fatigue level based on PSD feature

Generation of PSD for each time-series signal

## Related works

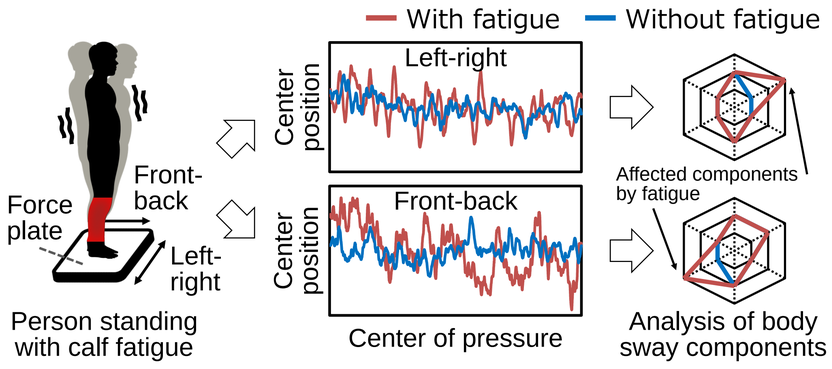
※1 Yamaguchi et al., GCCE'20
※2 Vuillerme et al., MSSE'02

An existing method measures body sway to recognize the weight of held baggage. ※1




We incorporated their technique for measuring body sway from video sequences.

Previous analytical studies show different traits between the front-back and left-right components depending on calf fatigue. ※2



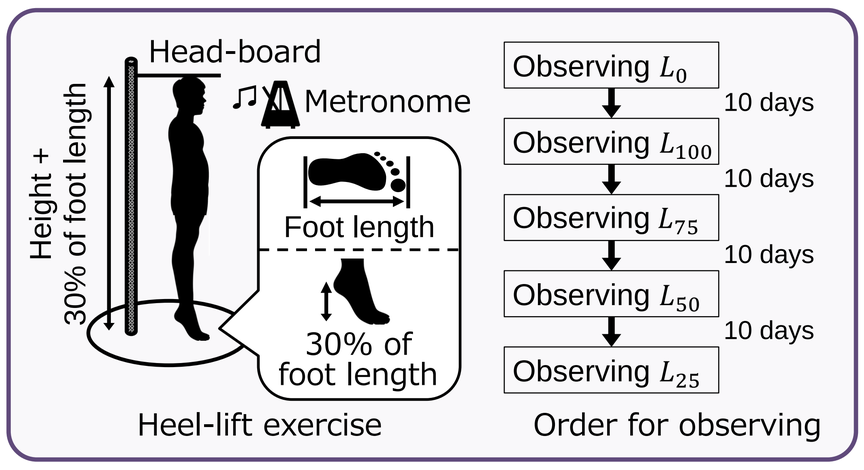

We integrated their idea of separating body sway into front-back and left-right components.

## Experiments

※3 Bilen et al., TPAMI'18
※4 Tran et al., ICCV'15
※5 Hochreiter et al., Neural Computation'97

### Five calf-fatigue level & heel-lift exercise

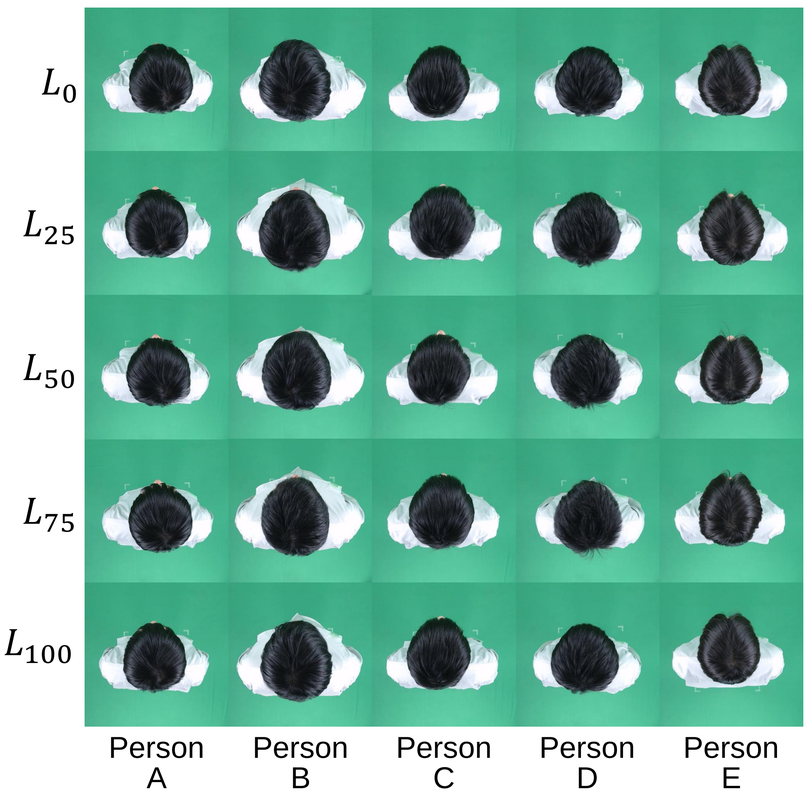
- $L_0$: Participants showed no calf fatigue.
- $L_{100}$ : Participants reached maximum heel lifts.
- $L_{25}$~$L_{75}$: Participants reached 25% to 75% of maximum heel lifts.




- Calf fatigue initialization: No vigorous exercise for 10 days.
- Heel lift height: 30% of each participant's foot length.
- Heel lift speed: 100 beats per minute.

### Dataset

※ A total of 20 individuals.




Calf fatigue differences were not easily visible in appearance.

### Results

Impact of integrating medical knowledge

| Medical knowledge | Ave. accuracy |
|---|---|
| **With (Ours)** | **32.3±7.8 %** |
| Without ※1 | 22.5±3.1 % |

- Using three classifier for average accuracy

Comparison with human action recognition

| Method | Best accuracy |
|---|---|
| **Ours** | **40.0±1.8 %** |
| DI ※3 | 20.1±2.1 % |
| C3D ※4 | 16.8±0.3 % |
| LSTM ※5 | 19.1±2.3 % |

- Classifier (ours/DI): Gradient boosting decision tree
- Dataset splitting: Leave-one-participants-out
- Evaluation metrics: First matching rate

Our method integrating medical knowledge achieved top accuracy.