Postural-Change Detection Before and After Hemodialysis Using MediaPipe

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***Abstract*— This study aimed to evaluate changes in physical condition before and after hemodialysis using estimated joint angles in hemodialysis patients. The flexion angles of the elbow, knee, and hip joints were analyzed from captured images to assess potential changes in posture and motor control. The results indicated that the flexion angles increased or decreased depending on the subject, suggesting that hemodialysis may influence balance and muscle tone. However, limitations were noted in the accuracy of angle estimation due to the static posture during measurement and oblique camera positioning. Despite these constraints, the proposed method offers a simple approach for detecting physical changes associated with hemodialysis, indicating its potential for fall-risk assessment and real-time monitoring during hemodialysis sessions.**

Keywords: hemodialysis; postural-change detection; MediaPipe; joint-angle estimation, computer vision; fall-risk assessment; lightweight measurement method.

I. INTRODUCTION

Hemodialysis is the primary treatment for end-stage renal disease, and many patients worldwide undergo hemodialysis several times per week. After hemodialysis, patients often experience symptoms such as orthostatic hypotension and impaired balance due to rapid fluid shifts and reduced blood pressure. These symptoms frequently lead to post-dialysis unsteadiness [1]-[4], which is closely associated with an increased risk of falls. This is particularly concerning among elderly hemodialysis patients, as the incidence of falls in this population is significantly higher than that in non-dialysis older adults. Falls in hemodialysis patients may result in fractures, hospitalization, and an even worse long-term prognosis.

Given this background, early detection and assessment of post-dialysis unsteadiness are crucial for ensuring patient safety and improving quality of life. However, conventional methods for assessing unsteadiness often rely on subjective clinical observations or simple balance tests (e.g., the timed up-and-go test) [5][6], which may lack objectivity and reproducibility.

Our research group conducted a series of studies on the clinical application of gait analysis using MediaPipe [7]. For example, we demonstrated that the use of walking aids improved the gait trajectory and that this effect persisted for a certain duration even after the aid was removed [8]. Other studies explored technical considerations and error sources in pose estimation [9], quantitatively analyzed gait changes in patients with hemiparesis [10], and attempted to evaluate mobility during rehabilitation using MicroElectronic Mechanical System (MEMS) sensors [11]. These efforts contribute to the advancement of quantitative motion analysis using computer vision and highlight the clinical potential of machine-learning-based pose estimation.

Building on these findings, the present study focused on the postural behavior exhibited when stepping onto a weighing scale before and after hemodialysis. We developed a method using MediaPipe—a real-time pose-estimation

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library developed by Google that is capable of accurately extracting skeletal landmarks from video footage—to quantitatively assess the presence and degree of post-hemodialysis unsteadiness.

Stepping on a weighing scale requires maintaining balance over a small surface area, which can accentuate subtle changes in postural control. Therefore, assessing the trunk sway, body instability, and center-of-gravity shifts during this motion may be effective in detecting postural unsteadiness.

In the present study, we aimed to establish a new method for quantitatively evaluating post-dialysis unsteadiness by analyzing video-captured motion during weight measurement. This paper presents a preliminary examination of key body parts and motion patterns of interest, along with relevant quantitative indicators, and discusses future directions for clinical applications.

The remainder of this paper is organized as follows: Section II presents the experimental conditions. In Section III, we present the results of the calculation of posture indices and joint angles, which are the evaluation points. Section IV discusses the obtained results. Section V concludes the paper.

II. Experiments

A. Participants

Details regarding the participants are presented in Table I. The selection criteria for participants in this study were based on blood pressure fluctuations after dialysis, visual dizziness. This study was approved by the Ethics Committee of the Katori Omigawa Medical Center, Katori, Japan (No. 2024-3). Written informed consent was obtained from all participants prior to data collection. Here, of ESRD stands for End Stage Renal Disease, ABI stands for Ankle-Brachial Index, ΔDW stands for the change from the ideal Dry Weight when the body has an appropriate level of hydration, CG stands for Chronic Glomerulonephritis, and DM stands for Diabetes Mellitus.

TABLE I. PARTICIPANT INFORMATION.

Subject	Age	Sex	Case of ESRD	ΔDW	ABI R	ABI L	Note
A	54	F	CG	4.2	1.10	1.17	BP reduced
B	62	M	Unknown	4.8	1.18	1.21	BP stable
C	78	M	DM	5.3	0.98	1.46	BP stable
D	51	M	DM	6.0	1.15	1.23	BP stable

B. Experimental Setup and Recording Conditions

As shown in Figure 1, the participants were recorded while standing still or shifting their posture on a body-weight scale. A consumer-grade video camera was placed approximately 2 m in front of the participants to capture their motion. Owing to spatial constraints in the clinical environment, the camera was positioned slightly above and to the left of each participant.

Figure 1. Experimental setup.

C. Data Acquisition and Skeletal Landmark Extraction

Video data were processed using the Pose module of MediaPipe. The analysis was conducted on a Jupyter Notebook using Python. MediaPipe extracted 3D skeletal landmarks (x, y, and z coordinates) for 33 body points. These coordinates, along with the overlaid visualization of the skeletal estimation, were saved in Comma-Separated Value (CSV) format for further analysis.

D. Postural Indices and Joint-Angle Computation

To evaluate changes in posture before and after hemodialysis, we defined a set of approximated joint angles (referred to as "approximated angles"), as illustrated in Figure 2. The following six metrics were used.

(1) The approximated Trunk Forward Tilt Angle (TFTA) was defined as the angle formed between the trunk axis (midpoints of the shoulders and hips) and lower-limb axis (midpoints of the hips and knees).

(2) The approximated Cervical Flexion Angle (CFA) was defined as the angle between the line connecting both shoulders and the nose and the line connecting the midpoint of both hips to the midpoint of the shoulders.

(3) The approximated Shoulder Abduction Angle (SAA_L of SAA_R) was calculated using the shoulder and elbow positions.

(4) Approximated Elbow Flexion Angle (EFA) was calculated as the angle formed by the wrist, elbow, and shoulder.

(5) The approximated Knee Flexion Angle (KFA) was calculated as the joint angle formed by the hip, knee, and ankle.

(6) The approximated Hip Flexion Angle (HFA) was defined as the angle between the extended trunk and lower-limb axis.

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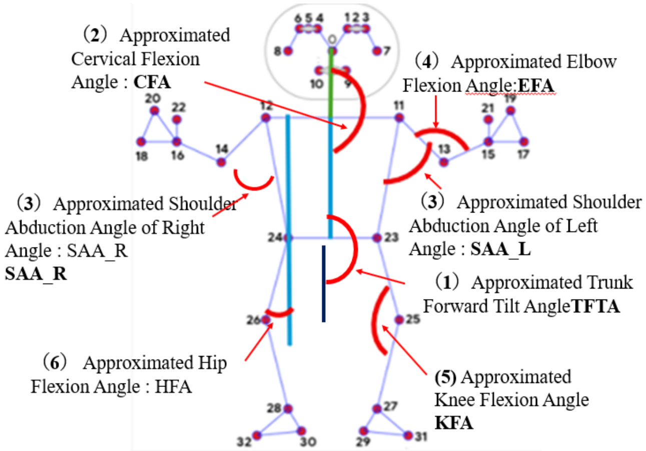


Figure 2. Definitions of the approximated angles.

Each angle was calculated using the following formula based on the inner product of two vectors *A* and *B*.

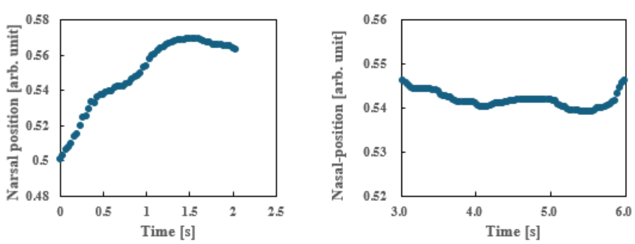
$$\theta = \cos^{-1}\left(\frac{\vec{A}\cdot\vec{B}}{\|\vec{A}\|\cdot\|\vec{B}\|}\right)$$

The vectors were derived from the coordinate data stored in the CSV files. Given that the video recordings were obtained from a slightly left upper oblique angle relative to the participant, all computed values were interpreted as approximate angles rather than as exact anatomical measurements.

III. EXPERIMENTAL RESULTS

A. Evaluation of Nasal Displacement (Sway)

Figure 3 illustrates an example of the nasal-position fluctuations of participant A when the participant stood on a weighing scale. Figures 3(1) and 3(2) correspond to the pre-dialysis and post-hemodialysis conditions, respectively. The recording time before hemodialysis was shorter because of simultaneous body-weight measurement. Although identical measurement durations would be ideal, no special instructions were provided to the participants, who followed their normal clinical procedures.

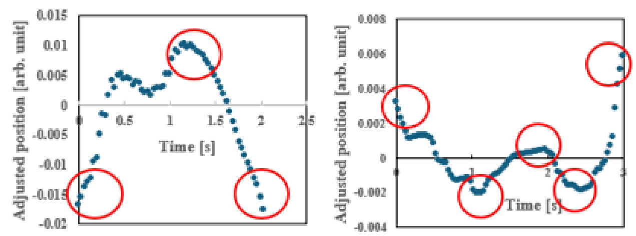


(1) (2)

Figure 3. Nasal position.

To remove the consistent directional drift, we applied a linear correction to the x-axis nasal-position data, adjusting the overall mean to zero. The corrected data are shown in Figure 4. The degree of nasal sway was calculated as the difference between the maximum positive and negative peaks. Red circles indicate the time points corresponding to these peaks. Additionally, if the values reached the measurement-range boundaries without forming clear peaks, they were counted as peak points. The numbers of transitions in the right and left directions are presented in Table II.

Before hemodialysis, all participants exhibited a consistent difference in the number of directional transitions between right and left movements. Hence, this index may be a useful quantitative indicator of postural changes related to hemodialysis.



(1) (2)

Figure 4. Adjusted nasal position.

TABLE II. NUMBER OF TRANSITIONS.

		Before	R-L	After	R-L
A	L	1	1	3	-1
	R	2		2	
B	L	1	1	2	0
	R	2		2	
C	L	2	1	3	0
	R	3		3	
D	L	1	1	2	1
	R	2		1	

Figure 5 shows the time-series differential analysis of the x-axis nasal position used to detect finer fluctuations. We assume that sign changes in the differential correspond to reversals in the direction of movement.

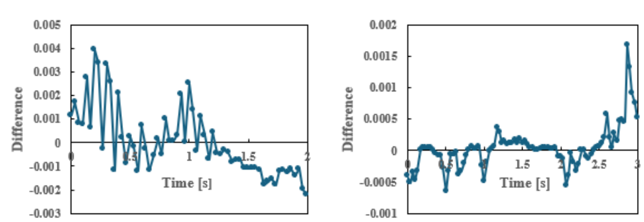


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Figure 5. Differential analysis of the x-axis nasal position.

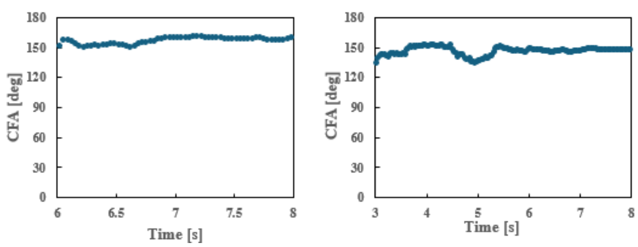
B. Approximated Trunk Forward Tilt Angle (TFTA)

As an example, the results for subject B, which showed a large difference, are described. The mean trunk tilt angle for Subject B before hemodialysis was 163°, whereas after hemodialysis, it decreased significantly to 136°, indicating increased forward leaning.

Although the median may suppress the effect of outliers more effectively than the mean, the difference between these two values was within the range of the measurement errors. Therefore, this study adopted the mean value for evaluation.

C. Approximated Cervical Flexion Angle (CFA)

Figure 6 shows an example of changes in the approximated cervical flexion angle for Subject B. (1) and (2) correspond to pre-dialysis and post-dialysis, respectively. The mean angle was 163° and 146° pre- and post-dialysis, respectively. This result suggests increases in forward head posture and cervical flexion, possibly indicating fatigue or changes in postural control after hemodialysis.



(1) (2)

Figure 6. CFA for subject B pre- and post-dialysis.

D. Approximated Shoulder Abduction Angle of Left and Right (SAA_L and SAA_R)

Figure 7 presents the results for SAA_L of Subject A, where (1) and (2) correspond to pre- and post-dialysis, respectively. A significant change in the left shoulder abduction angle was observed. As shown in Figures (1) and (2), the mean pre-dialysis angle was 14°, and the mean angle decreased to approximately 8° post-dialysis-a reduction of nearly 50%. In contrast, the right shoulder abduction angle for the same subject changed by <1°.

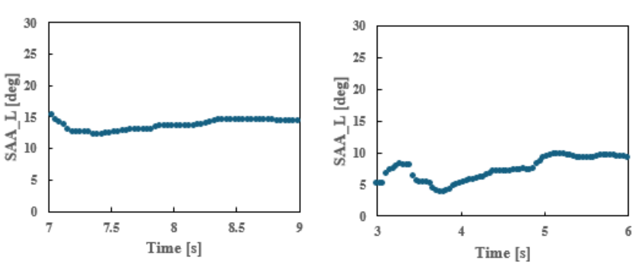


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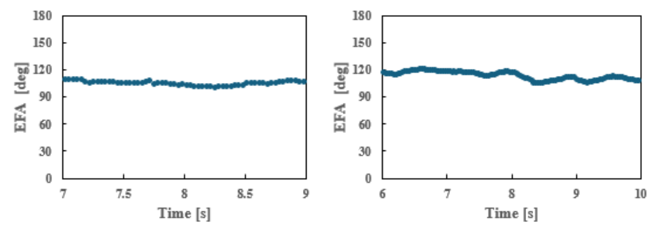
Figure 7. SAA_L for subject A pre- and post-dialysis.

Although not shown in the figure, Subject D exhibited the opposite trend, with a significant change in the right shoulder abduction angle, which decreased from approximately 30° to 15° after hemodialysis. These asymmetric changes may be influenced by not only individual differences in posture but also the oblique camera angle during data collection.

E. Approximated Elbow Flexion Angle (EFA)

Figure 8 shows the left elbow flexion angle for Subject C. (1) and (2) correspond to pre-dialysis and post-dialysis, respectively, as in the other figures. The angle increased from 105° before hemodialysis to 112° after hemodialysis. Although the absolute values were lower than those for Subjects A and D, the trend of increased flexion was consistent. In contrast, Subject B exhibited a slight decrease in flexion angle after hemodialysis.

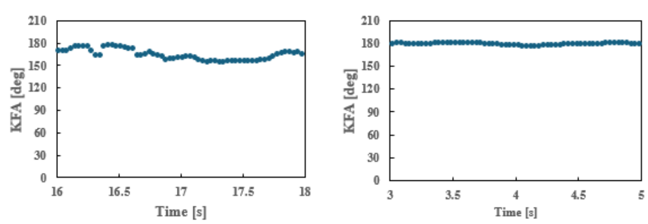


(1) (2)

Figure 8. EFA for subject C pre- and post-dialysis.

F. Approximated Knee Flexion Angle (KFA)

Figure 9 illustrates the knee flexion angle for Subject D. (1) and (2) correspond to pre-dialysis and post-dialysis, respectively, as in the other figures. The pre-dialysis angle was 167°, and the angle increased to 180° after hemodialysis, indicating near-complete extension. Similar tendencies were observed in other participants, suggesting that detecting small changes in knee flexion may be challenging using this method.



(1) (2)

Figure 9. KFA for subject D pre- and post-dialysis.

G. Approximated Hip Flexion Angle (HFA)

Although hip flexion angle is typically assessed during gait, this study evaluated it in a static standing posture. Because of the short recording duration and oblique camera positioning, the accuracy was limited. Nevertheless, directional changes in the flexion angle were observed in

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two participants, potentially reflecting the physiological changes caused by hemodialysis. Future improvements in measurement precision and inclusion of dynamic assessments could enable a more detailed analysis.

A summary list of all calculation results is shown in Table III.

TABLE III. MEASURED VALUE FOR EACH EVALUATION ITEM.

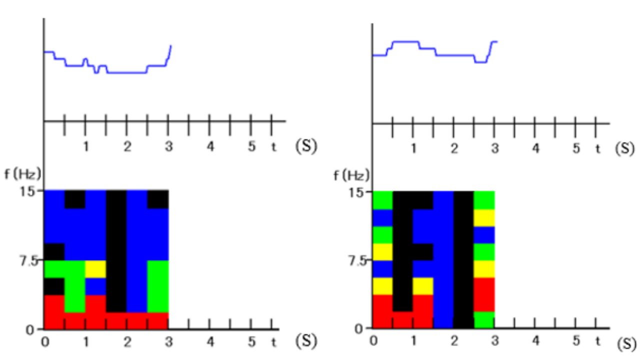
		nose	TFTA	CFA	SAA_Left	SAA_Right	EFA	KFA
		Dif	deg	deg	deg	deg	deg	deg
A	BFR	6.50E-02	161	147	14.3	19.3	100	166
	AFT	7.70E-03	177	137	7.70	13.1	118	140
	Ratio	0.11	1.10	0.93	0.54	0.68	1.18	0.84
B	BFR	7.20E-02	163	163	18.0	9.60	120	160
	AFT	5.60E-02	136	146	13.3	14.7	112	161
	Ratio	0.78	0.83	0.90	0.74	1.53	0.93	1.00
C	BFR	2.60E-02	165	156	20.3	30.3	105	149
	AFT	3.20E-02	165	152	23.5	26.8	112	149
	Ratio	1.23	1.00	0.97	1.16	0.88	1.07	1.00
D	BFR	4.30E-02	152	151	24.8	30.6	116	167
	AFT	4.10E-02	154	142	22.1	14.7	124	180
	Ratio	0.95	1.01	0.94	0.89	0.48	1.07	1.08

H. *Spectral Analysis of Knee Movement*

As part of the assessment of postural stability, we performed a time–frequency analysis of the x-axis (lateral) knee position data obtained via MediaPipe. Despite the short recording time, we applied a Discrete Fourier Transform (DFT) using a 1-s sliding window to obtain spectrograms capturing the temporal changes in frequency content.

The input data were extracted from 30-fps videos with the Nyquist frequency set to 15 Hz. The spectrograms were visualized with time on the horizontal axis and frequency on the vertical axis. The spectral magnitude (square root of the power spectrum) at each time–frequency point was color-coded using a five-level gradient: black (minimum), blue, green, yellow, and red (maximum).

Figure 10 shows an example for Subject A. (1) and (2) correspond to the left and right knees, respectively.



(1) (2)

Figure 10. Spectrogram.

IV. DISCUSSION

A. *Nasal Displacement (Sway)*

No special instructions were given to either the staff or participants regarding the measurement process. Consequently, there was variability in the timing of body-weight measurements and duration of video recording. This variability must be considered when comparing results, and standardization of measurement conditions is desirable for future studies.

As shown in Table I, all participants exhibited the same number of lateral movements along the x-axis of the nose before hemodialysis. This suggests that pre-dialysis movements followed a consistent pattern and that the difference in movement count could serve as a quantitative indicator of postural sway or instability.

Without applying a linear correction to the nasal x-axis data, the observed movement tended to form a plateau (biased in a constant direction), making it difficult to define the motion boundaries. However, measuring the duration of such sustained bias may provide an alternative evaluation metric.

Moreover, the time-series differencing of nasal-position data can capture subtle movements. Applying the DFT to these differential data may allow the extraction of periodicity or distinctive frequency components, suggesting the potential for advanced sway analysis and quantitative assessment of individual differences.

B. *Estimated Cervical Flexion Angle*

Figure 6 illustrates the changes in the estimated cervical flexion angles. The results for Participant B indicated a decrease from a mean of 163° before hemodialysis to 146° after hemodialysis, implying an increase in cervical flexion. This may reflect a forward head posture or changes in neck alignment after hemodialysis, which may be associated with physical fatigue or altered postural control.

C. *Estimated Elbow Flexion Angle*

An increase in elbow flexion angle may suggest changes in muscle tone or improved body stability. In contrast to Participant B, these results highlighted the significance of individual variations. Furthermore, differences between the dominant and nondominant limbs, including the presence of a hemodialysis shunt, should be considered in future investigations.

D. *Estimated Knee Flexion Angle*

A trend toward full extension (approaching 180°) was observed. This may reflect muscle relaxation or changes in standing posture stability. However, measurement errors due to oblique camera angles rather than frontal views may have also contributed to this outcome.

E. *Estimated Knee Flexion Angle*

Although hip flexion is typically evaluated during gait, this study employed a brief static assessment with participants standing on a scale and the camera positioned obliquely. These conditions limit the precision of angle estimation. Nevertheless, the differences in flexion direction between the two participants suggested physical state changes induced by hemodialysis. High-precision measurements and evaluations during motion are expected to enable more detailed analysis in the future.

Table IV summarizes the evaluations at each estimated joint-angle point based on the results and discussion. Here, a change of 5% or more but less than 10% is indicated by the symbol ○, and a change of 10% or more is indicated by the symbol ◎. Because each participant's health status varies, correlations based on this will also be necessary.

The Intradialytic weight loss (%) were 4.2%, 4.8%, 5.3%, and 6.0% for Subjects A, B, C, and D, respectively. Although the present results focused on postural changes and did not directly reflect these fluid removal rates, a more accurate evaluation can be achieved by conducting a comprehensive analysis based on the indicators examined in this study, supplemented with individual physical function data and information such as medication.

F. Spectrogram

Because the spectral intensity corresponding to the passage of time is obtained, the variation in the frequency components can be obtained and used to improve the accuracy of the motion analysis by making some correspondence with the image. However, in this measurement, the upper frequency limit is set to 15 Hz every 0.5 s.

V. CONCLUSION

In this study, we evaluated the changes in the physical condition of patients before and after hemodialysis using the estimated joint angles (elbow, knee, and hip) as key indicators. A comparative analysis of these joint angles obtained via simple image processing revealed changes in the flexion angle (increase or decrease) in some participants after hemodialysis. These findings suggest that the observed angle variations may reflect changes in physical condition or postural instability associated with hemodialysis. However, limitations of this approach, including oblique camera placement and static assessment conditions, are evident. In future studies, it will be important to integrate more accurate sensor-based measurements with dynamic assessments to continuously evaluate individual changes before and after hemodialysis.

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TABLE IV. EVALUATION RESULTS.

		nose	TFTA	CFA	SAA_Left	SAA_Right	EFA	KFA
		Dif	deg	deg	deg	deg	deg	deg
A	Ratio ≧5% ○ ≧10% ◎	◎	◎	○	◎	◎	◎	◎
B		◎	◎	○	◎	◎	X	X
C		◎	X	X	◎	◎	X	X
D		○	X	○	◎	◎	X	○