DRGAIT: BIOMECHANICALLY GROUNDED VISUAL REASONING FOR INTERPRETABLE CLINICAL GAIT ANALYSIS

ABSTRACT

Current automated gait analysis for clinical applications often relies on black-box classifiers with limited interpretability. Although Vision-Language Models (VLMs) offer strong reasoning capabilities, applying them directly to gait videos can produce unsupported explanations, because they struggle to measure subtle geometric deviations from raw visual contexts. To address this, we introduce *DrGait*, a training-free agentic framework that shifts the VLM's role from a direct visual reasoner to a clinical planner. DrGait decouples semantic reasoning from geometric perception through a structured Triage-Verification-Synthesis (TVS) workflow. Given an input video and a set of basic spatiotemporal metrics, the DrGait agent first performs a heuristic triage to propose hypotheses on gait patterns, which are then verified by autonomously calling deterministic biomechanical tools that operate on reconstructed 3D mesh trajectories, segmented 2D pose tracks, and event-centered video evidence. Finally, a closed-loop mechanism recursively updates the agent's reasoning context based on the feedback. By anchoring VLM reasoning in verifiable geometric and temporal measurements, DrGait reduces hallucinations and improves gait classification, while generating transparent and interpretable clinical reports that greatly assist in clinician's diagnosis in practice.

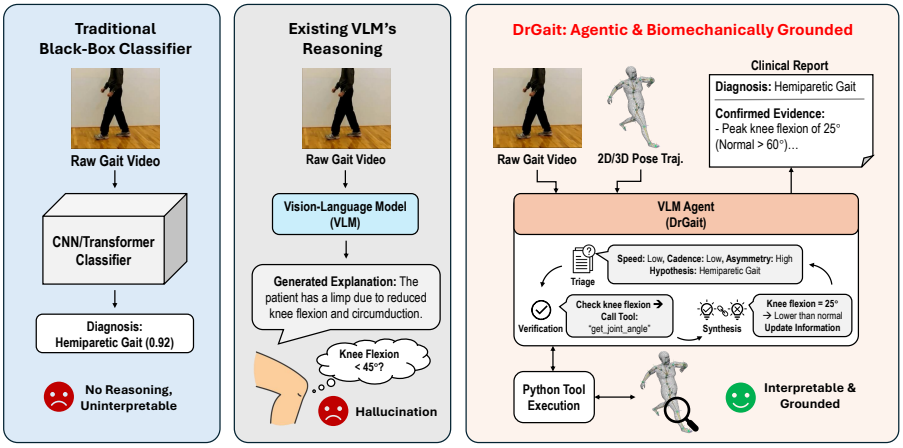


Figure 1: High-level comparisons between existing methods of gait analysis and DrGait

1 INTRODUCTION

Gait analysis [42; 25] is used in many clinical domains for assessment and rehabilitation, as gait deviations are associated with diseases such as stroke [2] and Parkinson's disease [21]. Traditionally, gait analysis relied on visual observations from trained professionals, but these judgments are subjective and difficult to standardize [24]. While quantitative methods using marker-based motion capture systems exist, their expense and complexity limit their use in many practical scenarios such as home rehabilitation monitoring and fall risk assessment for the elderly [26]. Low-cost camera systems offer another alternative, but their validity is usually limited to be low.

Computer vision can be used for automated and objective gait analysis, by extracting quantitative metrics such as skeleton models and Gait Energy Images (GEIs) from gait videos [1; 14]. For example, existing methods classify Parkinsonian gait stages [5], identify knee osteoarthritis from video-derived kinematics [3], and select gait parameters that distinguish multiple sclerosis from healthy controls using instrumented assessments [37]. However, these methods are limited to gait classification (e.g., identifying the "Parkinsonian gait") and cannot provide detailed reasoning about the pathological features underlying gait patterns. This lack of interpretability hinders their adoption in clinical practice, where understanding the reasons behind diagnosis is critical for disease management and treatment planning [30; 36].

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Vision-Language Models (VLMs) can provide such interpretability by generating natural language explanations for vision tasks [19; 22]. However, existing VLMs struggle to measure the subtle geometric deviations from raw visual contexts in gait videos, because their visual encoders are trained with 2D images and lack the capability of correctly perceiving gait characteristics in 3D space. As shown in Figure 1, a VLM might correctly identify a patient as "limping", but fails to distinguish whether that limp is caused by a deficit in ankle dorsiflexion or an increase in pelvic tilt. Consequently, the VLM reasoning in gait analysis usually contain hallucinations and are hence unreliable. Knowledge-augmented adaptation [39] and visual reasoning methods [6; 11; 33] improve interpretation, but the validity of their measurements for gait analysis remains unsatisfiable.

To address such deficiency in VLM reasoning, existing approaches either fine-tune the VLMs with datasets of specific clinical domains [39], or use advanced prompting techniques such as Visual Chain-of-Thought [6; 11; 33] to explicitly guide the reasoning steps. However, these methods still rely on the VLM's internal visual encoder, which fundamentally lacks the required geometric precision for measuring 3D human motions. Standard visual encoders such as CLIP-based Vision Transformers (ViTs) map 2D image patches into high-level semantic spaces, and compress the continuous spatial coordinates that are necessary for geometric measurements into discrete tokens. As a result, even if being retrained with large-scale 3D human motion data (e.g., Human3.6M [12] or AMASS [20]), these text-aligned encoders still suffer from severe numerical hallucinations when calculating the exact kinematic metrics, such as specific joint flexion angles or phase-specific temporal asymmetries.

In this paper, we made a fundamental shift: instead of improving the VLM's capability of visual perception of geometric measurements, we decouple such visual perception from VLM's reasoning in gait analysis. The VLM is only used for high-level task planning, and numerical measurements from pose, mesh and raw videos are done by specialized computational tools. We present **DrGait**, an agentic framework that manages a library of external biomechanical tools, including joint kinematics extractors, gait event detectors, pose-derived symmetry analyzers, etc. The VLM, then, decides the task flow of tool calling and uses these gait features for gait analysis reasoning, avoiding hallucinations due to visual inaccuracies and ensuring that reasoning is always biomechanically grounded.

DrGait emulates the structured workflow of human physicians through a three-step loop, including Triage, Verification, and Synthesis. 1) *Triage*: DrGait extracts pose or mesh representations from gait videos and calculates basic biomechanical features of gait, such as walking speed and cadence when available. These features are used by the VLM agent to narrow a broad set of pre-defined gait categories into a focused list of candidate hypotheses. 2) *Verification*: The VLM agent validates these hypotheses by calling external tools to extract physical measurements (e.g., joint angles, symmetry index, foot progression, or frontal-plane alignment) from the available geometric representation and event-centered video frames, and the workflow of tool calling is decided by VLM reasoning based on gait characteristics. For example, if the agent suspects a "foot drop" issue, it will call a tool to calculate the exact ankle angle at the moment the foot touches ground (i.e., initial contact). 3) *Synthesis*: the VLM agent cross-references the evidence extracted from measurements in Verification with established clinical guidelines, to evaluate the validity of candidate hypotheses and perform a differential diagnosis. If evidence contradicts the initial hypothesis, the agent updates its reasoning context, proposes new hypotheses, and plans a new set of tool calls. This loop continues until evidence supports the final assessment without unresolved verification conflicts.

To evaluate DrGait, we conduct extensive experiments on two clinical video datasets: GAVD [28] for general pathological gaits and ProGait [46] for prosthetic gait deviations. Rather than simple forced-choice classification, we task the VLM agent with identifying the correct condition from a comprehensive, open-ended list of clinical categories, and evaluate both the assessment accuracy and the semantic correctness of VLM reasoning. Our results demonstrate that DrGait significantly outperforms VLM baselines, improving the accuracy of gait classification by up to 32% and approaching the accuracy achieved by human experts. Human evaluations show that DrGait's transparent and tool-backed reports are highly trusted for providing clinical interpretability, being preferred by clinical professionals in 73.4% of cases on GAVD and 62.9% on ProGait.

2 Related Work

Video-based Gait Analysis: Traditional approaches use CNNs and transformers for gait classification [1; 14], but operate as uninterpretable "black boxes" [8]. To improve transparency, recent works connect human motion with LLMs [44; 35], but focus on gross action recognition rather than detailed reasoning about pathological deviations. Other efforts fine-tune LLMs to generate rationales for impairment scores [39; 40], but such fine-tuning is expensive and relies on the model's parametric

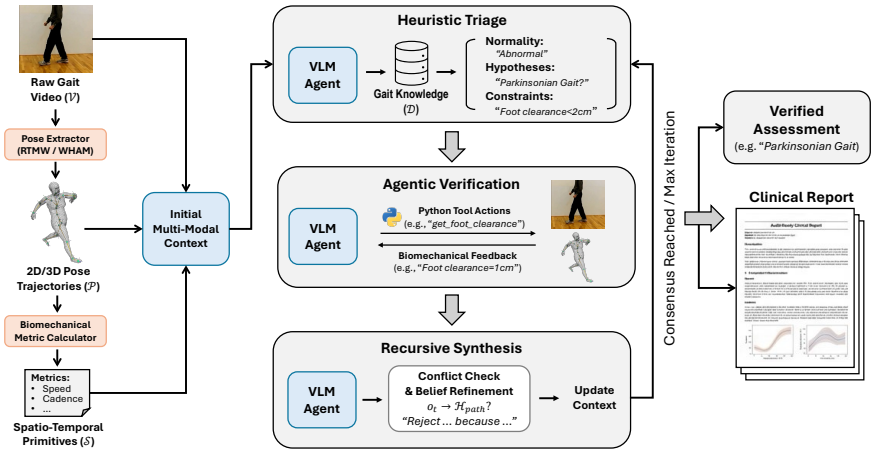


Figure 2: The overall paradigm of DrGait. To overcome VLMs' weakness of geometric measurements, DrGait replaces direct VLM inference with an iterative Triage-Verification-Synthesis (TVS) workflow. In *Triage*, the VLM agent translates multimodal contexts into candidate hypotheses and formal biomechanical constraints. In *Verification*, the VLM agent orchestrates external biomechanical tools to extract deterministic geometric evidence from mesh trajectories, segmented pose tracks, and event-centered frames. Finally, during *Synthesis*, a closed-loop mechanism recursively refines the agent's belief based on this empirical feedback until a verifiable clinical assessment is achieved.

memory, leaving it prone to hallucinations. DrGait avoids fine-tuning entirely, but instead utilizes pre-trained VLMs as active reasoning agents to retrieve verifiable physical data.

VLMs in Medicine: Specialized VLMs like Med-PaLM [38] and LLaVA-Med [16] demonstrated impressive capabilities in medical visual question answering (VQA) tasks. However, applying these VLMs directly to gait analysis exposes a critical limitation: standard text-aligned visual encoders (e.g., CLIP [27]) are optimized for macroscopic semantic understanding, compressing precise spatial measurements. Consequently, mapping raw videos directly to clinical assessment causes VLMs to hallucinate kinematic angles or temporal events. DrGait addresses this flaw by shifting the VLM's role from a direct visual reasoner to a higher-level clinical planner, delegating low-level spatial measurements to precise, deterministic mathematical tools.

Agentic AI and Tool-Use: To overcome the limitations of static memory in VLMs, agentic frameworks like Toolformer [32] and ReAct [45] empower LLMs to use external tools. While their reasoning structures have evolved from linear Chain-of-Thought [41] to complex topologies like Tree-of-Thoughts and Graph-of-Thoughts [4], they remain largely predefined and static. This rigidity is problematic for clinical gait analysis, where diagnostic workflows must dynamically adapt to patient-specific observations (e.g., an asymmetric limp requires a vastly different assessment pathway than a shuffling Parkinsonian gait). DrGait adapts the ReAct paradigm [45] into a dynamic Triage-Verification-Synthesis (TVS) loop, and continuously adjusts its reasoning trajectory by calling deterministic biomechanical tools and updating the context based on observations from tools' outputs.

Biomechanical Tools for Gait Analysis: Reliable clinical gait assessment depends on quantitative biomechanical parameters. Marker-based motion capture can reliably extract high-fidelity human meshes from monocular videos via 3D pose estimation (e.g., WHAM [34] and CLIFF [17]). Built upon these meshes, deterministic tools such as kinematic event detectors [31; 10] and ISB-standardized inverse kinematics [43] enable the calculation of joint angles and temporal milestones. Existing end-to-end AI methods typically attempt to learn these physical rules from scratch, but DrGait explicitly integrates these deterministic tools as callable functions, whose outputs are then returned to the VLM as auditable biomechanical evidence to bypass the VLM's geometric limitations.

3 METHOD

As shown in Figure 2, DrGait is a training-free agentic framework for clinical visual gait analysis, through an interactive, tool-augmented decision-making process. The VLM maintains an intermediate working context c_t and repeatedly performs stages of Triage, Verification, and Synthesis (TVS). This TVS reasoning loop serves as the fundamental structure of DrGait, and the differences across various clinical domains and tasks only enter through the input adapter, the injected domain-specific gait

knowledge base, and the available tool schemas. In this way, the clinical reasoning framework retains generic by itself, and allows the evidence representation to match tasks in different clinical domains.

3.1 Multi-Modal Input Context

Formally, the process by which a naive end-to-end VLM performs gait analysis can be framed as predicting a clinical assessment $y \in \mathcal{Y}$ from a raw input video sequence $V \in \mathcal{V}$ via $y = f_\theta(V)$. However, this unconstrained mapping is fundamentally ill-suited for biomechanical assessment, as it promotes implicit decision-making and increases the risk of clinical hallucinations. Instead, DrGait decouples this mapping by initializing an enriched multi-modal context state c_1. This starting context provides the VLM with both semantic and geometric scaffolding, which are defined as $c_1 = \{V, \mathcal{P}, \mathcal{S}, \mathcal{D}\}$ and comprise the following:

- **Visual Context (V):** The raw video sequence captures high-level cues such as patient effort, posture, assistive devices, prosthetic side, and visible limitations of the camera view.
- **Pose and Geometry State ($\mathcal{P}$):** The pose representation available for the given task. When monocular reconstruction is reliable, WHAM [34] provides 3D SMPL meshes and joint trajectories.
- **Spatiotemporal Primitives ($\mathcal{S}$):** Kinematic metrics extracted from $\mathcal{P}$. We detect swing and stance phases from foot motion in a body-oriented coordinate basis (Figure 3), then compute cadence, step length, stride length, step width, and support-time statistics. Segmented 2D trials use image-plane proxies normalized by body height or shoulder width and aggregated across same-plane segments.
- **Gait Knowledge ($\mathcal{D}$):** A task-specific clinical knowledge base injected into the prompt. Each entry defines an exact output label, an expected biomechanical pattern, possible causes, and prosthetic-category mappings (details in Appendix G). An human expert drafts each gait pattern, an LLM expands it into a structured entry, and the human expert then verifies it[1]. The VLM must choose labels from the knowledge base rather than inventing free-form diagnoses.

3.2 Task Formalization via Heuristic Triage

In *Triage* stage, the VLM acts as a semantic analyst over the starting context c_1. The goal is to identify a set of possible hypotheses of gait pattern (e.g., Antalgic, Hemiparetic, Parkinsonian gait, or a prosthetic alignment deviation). To achieve this without hallucination, the agent matches the initial visual and spatiotemporal context against the injected knowledge base $\mathcal{D}$. Guided by this knowledge, the agent's policy π generates a schema-constrained thought $\hat{a}_{task} \in \mathcal{L}$ that decomposes the assessment goal into a normality decision, a ranked hypothesis path, and explicit verification objectives. The first substep is a normal-vs-abnormal gate:

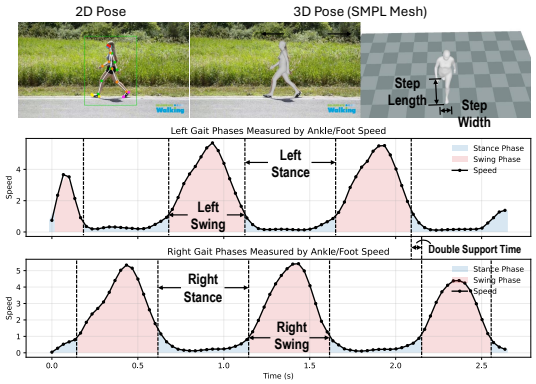


Figure 3: DrGait's detection of gait phases and extraction of kinematic metrics

$$g = (z, E_g, U_g) \sim \pi_g(g \mid c_1), \qquad z \in \{\texttt{normal}, \texttt{abnormal}, \texttt{uncertain}\}, \tag{1}$$

where z is the gate classification, E_g contains the visual or metric-grounded evidence used for the gate, and U_g records ambiguity that should be resolved downstream. The gate constrains the set of candidate hypothesis. Let h_{norm} be the normal-gait label, the implementation enforces:

$$\mathcal{H}_{path} \subseteq \begin{cases} \{h_{\text{norm}}\}, & z = \texttt{normal}, \\ \mathcal{H}_{all} \setminus \{h_{\text{norm}}\}, & z = \texttt{abnormal}, \\ \mathcal{H}_{all}, & z = \texttt{uncertain}. \end{cases} \tag{2}$$

In the `normal` case, $\mathcal{H}_{path}$ must contain exactly one normal hypothesis, but the agent still produces verification objectives to check subtle asymmetry, abnormal step width, small steps, stiff knee, sway, or posture. In the `abnormal` case, $\mathcal{H}_{path}$ contains only abnormal hypotheses. In the `uncertain`

[1]To expand the knowledge base to another clinical domain, no entries do not need to be rewritten from scratch. Instead, one only needs to provide new expert definitions, label mappings and validation.

case, the agent chooses the safest hypothesis path and uses verification objectives to resolve the uncertainty rather than prematurely declaring a conclusion. The full triage thought is therefore:

$$\hat{a}_{task} = (s, g, \mathcal{H}_{path}, \mathcal{C}_{bio}) \sim \pi(\hat{a} \mid c_1). \tag{3}$$

Here, $\mathcal{H}_{path} \subset \mathcal{H}_{all}$ is a confidence-ranked list of candidate labels from the injected knowledge base, and each element of $\mathcal{C}_{bio}$ specifies a biomechanical objective, the target hypotheses, priority, required observables, and decision rule (e.g., measuring ankle dorsiflexion at initial contact to confirm foot drop, or measuring foot progression angle to distinguish toe-in from circumduction). This thought updates the internal context to $c_2 = (c_1, \hat{a}_{task})$ before any complex computation begins.

3.3 Agentic Verification and Computation Tools

With the task thought injected into the context, the VLM transitions into a constrained planner. Governed by the accumulated context trajectory c_t from the Triage phase, the agent selects task-specific actions $a_t \in \mathcal{A}$. Each action is a schema-constrained call to an external tool $a_t \sim \pi(a_t \mid c_t)$.

To make the verification step easy to audit, we organize the executable tools by the type of clinical evidence they return as follows, and some examples of these tools and the geometric metrics they measure are shown in Figure 4. We keep the main text at the evidence-category level and defer function-level details to Appendix K.

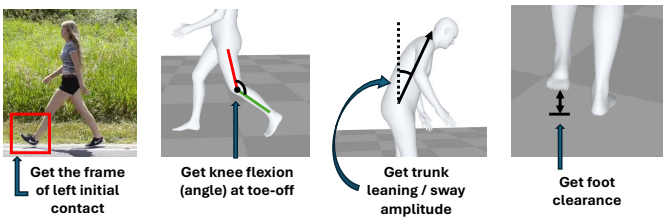


Figure 4: Examples of external biomechanical tools used in DrGait

1. **Event evidence.** Captures compact visual evidence at clinically meaningful gait events, such as initial contact, midstance, or toe-off.
2. **Joint motion evidence.** Quantifies phase-specific joint posture and range of motion to test claims such as stiff knee, excessive flexion, or limited ankle motion.
3. **Posture and balance evidence.** Measures trunk, pelvis, arm-swing, and body-center behavior to assess compensatory posture, instability, or reduced upper-body motion.
4. **Foot path and alignment evidence.** Characterizes foot clearance, lateral path deviation, foot orientation, whip direction, and lower-limb alignment for clearance, circumduction, base-width, and prosthetic-alignment hypotheses.
5. **Timing and symmetry evidence.** Summarizes bilateral timing and step asymmetries to evaluate whether one side contributes differently across the gait cycle.

Each tool call includes a rationale field (`why_used`) explaining which hypothesis or differential question it is meant to resolve. Verification is further restricted to one bounded round of function calling per iteration to prevent uncontrolled tool recursion. Executing a_t interacts with the geometric environment, and returns a deterministic observation feedback o_t containing targeted evidence, such that $o_t = \text{Execute}(a_t; \mathcal{P}, \mathcal{S}, V)$.

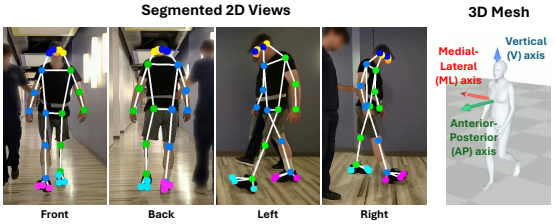


Figure 5: Visualizations of 2D and 3D contexts

This tool-based action step ensures the agent gathers deterministic measurements from external sources rather than hallucinating numerical values. For 3D contexts, anatomical measurements are computed in a stabilized body-oriented basis rather than raw world axes (Figure 5 - right). For segmented 2D contexts, the agent can request a clinically appropriate view: front/back for coronal-plane findings such as base width, pelvic drop, or varus/valgus alignment, and left/right for sagittal-plane findings such as knee flexion, foot clearance, or heel rise (Figure 5 - left). Outputs from 2D pose are explicitly treated as image-plane proxies, not calibrated 3D measurements. The observation is then appended to the state, updating the context to $c_{t+1} = (c_t, a_t, o_t)$.

3.4 Recursive Synthesis and Belief Refinement

The technical core of DrGait is its closed-loop reasoning mechanism. In the *Synthesis* stage, the agent evaluates the newly retrieved observation o_t against the active clinical hypotheses $\mathcal{H}_{path}$ and the verification objectives $\mathcal{C}_{bio}$. The output is structured to include each objective labeled as supported,

refuted, or inconclusive, and each hypothesis is labeled as confirmed, rejected, or inconclusive with a confidence score and explicit supporting/conflicting evidence. The specific fields of the synthesis outputs are as below and the full schema can be found in Appendix I.

- $\mathcal{C}_{bio}$: *"objective"* - biomechanical claim to verify; *"target hypotheses"* - related gait deviation candidates; *"status"* - [supported / refuted / inconclusive]; *"evidence"* - observations from tools.
- $\mathcal{H}_{path}$: *"category"* - gait deviation candidates; *"supporting evidence"* - $\mathcal{C}_{bio}$-grounded statements; *"conflicting evidence"* - contradiction; *"status"*: [confirmed / rejected / inconclusive]; *"confidence"*: confidence score of the conclusion.
- $SynthesisNotes$: A few sentences summarizing confirmed deviations, rejected distractors, contradictions, and remaining uncertainty.

To resolve conflicts or confirm the assessment, the agent generates a reasoning trace $\hat{a}_{syn} \in \mathcal{L}$. If the evidence contradicts a hypothesis, this thought acts as a belief refinement (e.g., *"Rejected Hemiparesis because unilateral circumduction is absent; shifting attention to Antalgic residuals"*) as $\hat{a}_{syn} \sim \pi(\hat{a} \mid c_{t+1})$. The context is recursively updated with this reasoning trace, such that $c_{t+2} = (c_{t+1}, \hat{a}_{syn})$, allowing dynamica adjustment of future tool calls. This synergistic loop of reasoning ($\hat{a} \in \mathcal{L}$) and acting ($a \in \mathcal{A}$) continues to update c_t until the biomechanical observations and clinical guidelines converge.

The loop terminates only when at least one hypothesis is marked `confirmed` and no inconclusive verification objective still targets a confirmed hypothesis. If the agent fails to satisfy this criterion after a given maximum number of iterations, DrGait returns the final synthesis produced, with unresolved conflicts or anomalous tool feedback explicitly preserved in the final report.

4 Experiments

4.1 Datasets, Baselines, and Evaluation Protocol

We evaluate DrGait on two clinical gait datasets. First, we use the GAVD dataset [28] to evaluate general pathological gait analysis. We include normal gait and five abnormal gait categories: *Antalgic, Myopathic, Cerebral Palsy, Parkinson's*, and *Stroke*. To avoid a simplistic forced-choice setup, the model predicts from an expanded clinical dictionary of 11 gait categories. Multiple fine-grained labels may map back to one dataset class, and distractor categories such as Ataxic Gait are also included. Complete mapping is available in Appendix H. After filtering unavailable videos, videos with diagnostic text leakage, severe occlusion/truncation, very short clips, and duplicates, the curated GAVD subset contains 134 gait videos from 102 subjects (27 normal and 107 abnormal videos; more details about class counts are in Appendix A). Each video is processed with RTMW [13] for 2D pose and WHAM [34] for 3D SMPL reconstruction.

Second, we use the ProGait dataset [46] to evaluate prosthetic gait analysis using paired frontal and sagittal gait videos. Paired views are grouped into 138 trial-level samples from four transfemoral prosthesis users, and uses annotated straight-walking segments to construct front/back and left/right 2D pose contexts. ProGait evaluation reports general-category accuracy, top-3 general-category accuracy, and fine-grained deviation quality. The mapping between general category and fine-grained deviation is in Appendix G. Each predicted gait deviation is mapped to a general prosthetic gait category, and an LLM-as-a-judge scores semantic agreement with the human prosthetic annotation. This judge score rates the semantic similarity between DrGait's generated reports and human annotations from 1 (completely unrelated) to 5 (completely matched). Note that the dataset contains 4 trials without a scoreable broad label, and multiple deviations can coexist in these trials whereas top-1 scoring evaluates a single primary category; these metrics only partially capture the gait-assessment quality.

For the GAVD dataset, we compare against three baseline families: (1) task-specific human reference labels; (2) training-based gait recognition models, including Pose+PCA+SVM, Pose+LSTM, GaitBase [7], and GaitGL [18]; and (3) training-free VLM baselines, including Gemini-3-Flash, Gemini-3.1-Pro, GPT-5.4, and Qwen3.6-Plus. Our main DrGait configuration uses Gemini-3-Flash, and an additional experiment replaces the planner with Qwen3.6-Plus. For VLM baselines, we use direct zero-shot prompting with the same clinical reference dictionary. Training-based models fall back to a closed six-class GAVD classification task because no training data are available for the distractor classes in the expanded clinical dictionary, and are evaluated with 5-fold cross-validation. Their accuracy therefore cannot be directly compared with the open-dictionary VLM and DrGait settings. For the ProGait dataset, we evaluate training-free VLM baselines using the same direct zero-shot prompting protocol with paired video inputs. The complete system and user prompts used for baselines and DrGait are available in Appendix I and J.

Method	Abnormal (%) (Sensitivity)	Normal (%) (Specificity)	AUROC	Overall Accuracy (%)
Human Expert	98.9	100.0	0.995	99.2
Training-based				
Pose+PCA+SVM	82.1	18.2	0.501	69.4
Pose+LSTM	85.6	27.3	0.564	73.9
GaitBase [7]	87.3	45.5	0.784	78.4
GaitGL [18]	86.5	36.4	0.769	76.9
Training-free				
Gemini-3-Flash	51.4	**100.0**	0.757	61.2
Gemini-3.1-Pro	83.2	92.6	0.879	85.1
GPT-5.4	57.9	92.6	0.752	64.9
Qwen3.6-Plus	50.5	96.0	0.733	59.7
DrGait (Gemini-3-Flash)	**91.6**	99.3	**0.939**	**93.2**

Table 1: Accuracy of binary normality recognition on the GAVD dataset

Human protocols. Five human evaluators independently label the 134 GAVD videos and 138 ProGait cases using the same 11-category dictionary and canonical mapping, with dataset labels and model outputs hidden. They have no patient history, examination, or instrumented gait data, and do not discuss or adjudicate labels. This forced-choice reference is separate from report quality evaluation, in which each case is presented with three anonymous, randomly ordered reports alongside the video. System identities and ground truth are hidden. Appendix A gives the protocol and aggregation details.

Method	Antalgic (%)	Cerebral Palsy (%)	Myopathic (%)	Parkinson's (%)	Stroke (%)	Overall Accuracy (%)
Human Expert	68.3	18.6	24.4	90.4	88.8	53.7
Training-based						
Pose+PCA+SVM	9.1	25.0	6.9	0.0	7.7	10.3
Pose+LSTM	18.2	54.2	20.7	5.9	30.8	28.0
GaitBase [7]	36.4	41.7	27.6	35.3	38.5	36.4
GaitGL [18]	27.3	41.7	34.5	23.5	30.8	32.7
Training-free						
Gemini-3-Flash	36.4	4.2	3.5	29.4	50.0	22.4
Gemini-3.1-Pro	9.1	16.7	**24.1**	64.7	73.1	39.3
GPT-5.4	18.2	16.7	17.2	47.1	65.4	33.6
Qwen3.6-Plus	0.0	4.2	0.0	41.2	53.9	20.6
DrGait (Gemini-3-Flash)	**54.6**	**25.0**	18.8	**94.1**	**88.5**	**52.8**

Table 2: Accuracy of abnormal gait subtype classification on the GAVD dataset

4.2 Gait Classification Accuracy

On the GAVD dataset, we separate normal-vs-abnormal gait detection from abnormal gait subtype recognition after mapping fine-grained predictions back to the dataset categories. Table 1 reports binary normal-vs-abnormal gait recognition performance, and Table 2 reports accuracy among the five abnormal gait classes. DrGait with Gemini-3-Flash achieves 93.2% accuracy on normality recognition, largely outperforming all the baselines. Table 2 shows a similar advantage for DrGait: it reaches 52.8% overall accuracy, improving over Gemini-3-Flash by 30.4% and Gemini-3.1-Pro by 13.5%. The largest gains occur in clinically tool-sensitive categories such as Parkinson's (94.1%), Stroke (88.5%), and Antalgic gait (54.6%). An example case is provided in Appendix D.

The evaluations made by human experts reaches 99.2% binary accuracy and 53.7% abnormal-subtype accuracy, compared with DrGait's 93.2% and 52.8%. The subtype accuracies are close, but this comparison is limited to video judgments with a fixed label set and does not demonstrate clinical equivalence. The low accuracies in classifying cerebral-palsy and myopathic cases is because labels in these categories cover diverse and overlapping movement patterns [29; 23]. Unreliable pelvic/trunk estimates and missing clinical context may also make these categories difficult to distinguish [15; 9].

On the ProGait dataset, Table 3 shows that DrGait improves on most reported metrics. Gemini-3.1-Pro obtains the highest top-1 general-category accuracy (18.2%), but DrGait achieves the best top-3 accuracy and the best semantic agreement with human annotations. This suggests that tool-guided reasoning helps the generated prosthetic-gait report capture relevant deviations even when the exact broad category is not ranked first. An example case is provided in Appendix E.

Method	General Acc. (%)	Top-3 General Acc. (%)	LLM-Judge Score
Gemini-3-Flash	8.7	23.9	1.51
Gemini-3.1-Pro	**18.1**	27.5	1.68
GPT-5.4	5.1	14.5	1.44
Qwen3.6-Plus	7.3	24.6	1.62
DrGait (Gemini-3-Flash)	16.0	**32.6**	**1.98**

Table 3: Gait classification accuracy on the ProGait dataset

Methods	Diagnostic	Grounding	Usefulness	Overall	Best Win %
GAVD					
Gemini-3-Flash	2.85	2.58	2.10	2.51	11.0
Gemini-3.1-Pro	3.25	2.86	2.33	2.82	19.6
DrGait (Gemini-3-Flash)	**3.71**	**3.59**	**3.62**	**3.64**	**73.4**
ProGait					
Gemini-3-Flash	2.64	2.40	2.05	2.36	23.6
Gemini-3.1-Pro	2.53	2.35	2.07	2.32	27.5
DrGait (Gemini-3-Flash)	**3.43**	**2.86**	**2.61**	**2.76**	**62.9**

Table 4: Human evaluations, where scores are averaged across five human evaluators.

4.3 Human Evaluations on Interpretability

Gait classification accuracy does not capture whether a generated report is clinically useful or interpretable. We then conduct a human expert evaluation of report quality. For each sample, evaluators are shown three reports: one from Gemini-3.1-Pro baseline, one from Gemini-3-Flash baseline, and one from DrGait using Gemini-3-Flash. They rate each report on a 1-to-5 scale across three dimensions: diagnostic correctness, evidence grounding, and clinical usefulness, where 1 indicates worst and 5 indicates best. Evaluators also select the best overall report. These ratings assess report quality based on the video and do not validate disease diagnoses. We exclude missing fields when averaging each dimension and missing choices when calculating preference rates.

Table 4 reports the results from all five human evaluators. On the GAVD dataset, human evaluation shows that DrGait improves the overall report score to 3.71, compared with 2.85 for Gemini-3-Flash and 3.25 for Gemini-3.1-Pro. DrGait is selected as the best overall report in 73.4% of evaluations, compared with 11.0% for Gemini-3-Flash and 19.6% for Gemini-3.1-Pro. On the ProGait dataset, DrGait achieves the highest aggregate overall score (3.43) and best-overall selection rate (62.9%).The ProGait gains are strongest in evidence grounding, reflecting the value of tool-supported measurements for prosthetic-gait reports. Evaluation forms are included in Appendix F.

4.4 Efficiency and Cost Analysis

To evaluate the practical viability of deploying DrGait in real-world clinical settings, we analyze its computational efficiency, latency, and API costs compared to the zero-shot VLM baselines. This efficiency and cost analysis is based on the GAVD dataset. Results are summarized in Table 5 for VLM baselines and Table 6 for DrGait.

Metric	Gemini-3-Flash	Gemini-3.1-Pro
Total End-to-End Latency	**11.7s**	**14.1s**
Input Tokens	4,762	4,762
Output Tokens	197	196
Estimated API Cost (USD)	**$0.001**	**$0.012**

Table 5: Efficiency and cost per video on GAVD of the VLM baselines

Latency and Agentic Overhead: Operating as an autonomous agent naturally introduces a latency trade-off compared to single-shot inference. As shown in the baseline metrics, direct VLM evaluation processes a video in roughly 11.7 to 14.1 seconds. In contrast, DrGait requires an average end-to-end latency of 79.9 seconds (using Gemini-3-Flash) and 107.0 seconds (using Gemini-3.1-Pro).

The reasoning duration scales with case complexity. DrGait executes 1.06 to 1.23 TVS loops per video, heavily utilizing biomechanical tools (5.15 to 5.74 tool calls per round) to extract reliable kinematic evidence. Despite this overhead, a processing time of under two minutes is highly acceptable for asynchronous clinical assessment, especially given the substantial gains in transparency and diagnostic reliability.

Token Consumption and Cost-Performance Paradigm: Due to the inclusion of knowledge base, structured action schemas, and tool observation histories, DrGait consumes more tokens than baselines (averaging $\sim 23,000-27,000$ input tokens versus $\sim 4,700$). However, a closer analysis of API costs reveals a paradigm shift in cost-effectiveness. The Gemini-3.1-Pro baseline costs $\$0.012$ per GAVD video and reaches 85.1% binary accuracy and 39.3% subtype accuracy. DrGait powered by the smaller Gemini-3-Flash model costs slightly less at $\$0.011$ per video while reaching 92.4% binary accuracy and 51.4% subtype accuracy. This demonstrates a major advantage of DrGait: by offloading the heavy geometric perception to external tools, DrGait empowers a lightweight, low-cost VLM to surpass the raw capabilities of a larger direct VLM baseline.

Metric	DrGait Gemini-3-Flash	DrGait Gemini-3.1-Pro
Preprocessing Latency	50.2s	50.2s
LLM Agent Latency	29.7s	56.8s
Total End-to-End Latency	**79.9s**	**107.0s**
Reasoning Rounds	1.06	1.23
Tool calling	5.74/round	5.15/round
Input Tokens	23,385	26,900
Output Tokens	2,486	2,561
Estimated API Cost (USD)	**$0.011**	**$0.085**

Table 6: Efficiency and cost per video on GAVD of DrGait

Ablation	GAVD Normality Acc. (%)	GAVD Abnormal Acc. (%)	ProGait Top-3 Acc. (%)	ProGait LLM-Judge Score
None	93.2	52.8	32.6	1.98
No dictionary	—	41.3	16.7	—
Triage-only / no tools	91.8	44.9	13.1	1.30
One-pass / no recursion	91.0	43.9	34.1	1.84
No normality gate	85.1	33.6	35.5	1.75

Table 7: Results of ablation studies

4.5 Ablation Studies

We conduct ablation studies on tool-based verification, recursive refinement, and the normality gate. Table 7 shows that deterministic verification tools are the most important for fine-grained reasoning. Removing tools while keeping the triage stage preserves most of the GAVD normal-vs-abnormal accuracy (91.8% vs. 93.2%), indicating that global gait metrics and visual context are sufficient for coarse abnormality detection. However, the same ablation reduces GAVD subtype accuracy from 52.8% to 44.9%, ProGait top-3 accuracy from 32.6% to 13.1%, and the ProGait LLM-judge score from 1.98 to 1.30. This indicates that verification tools are the main driver of differential assessment and report grounding. Meanwhile, removing the dictionary also reduces the GAVD subtype accuracy by 7.9% and ProGait top-3 accuracy by 19.5%, indicating the usefulness of the knowledge base.

The one-pass variant, which performs verification without recursive refinement, behaves differently across datasets. On GAVD, recursion improves both normality accuracy (93.2% vs. 91.0%) and subtype accuracy (52.8% vs. 43.9%), suggesting that iterative belief updates help resolve ambiguous categories. On ProGait, the one-pass variant is slightly higher on top-3 accuracy and LLM-judge score (34.1% and 1.84), which suggests that many prosthetic cases are resolved by a single targeted verification round and additional refinement can introduce secondary-deviation evidence.

Besides, removing the normality gate largely hurts GAVD, reducing normality accuracy to 85.1% and abnormal-subtype accuracy to 33.6%. The gate therefore serves an important pruning role for the general pathological-gait setting, where normal and abnormal videos coexist. In contrast, ProGait consists mostly of prosthetic-deviation trials, so removing the gate increases top-3 category retrieval. Overall, tool verification is essential across tasks, recursion is most useful for GAVD-style differential assessment, and the normality gate is beneficial when normality itself is part of the decision.

Furthermore, we have evaluated the DrGait's performance when different VLMs are used as the backbone for task planning. We also realized that the external biomechanical tools used in DrGait are not always accurate, as pose, mesh, and gait-event errors can affect downstream measurements and gait classifications made by DrGait. We therefore ran a controlled sensitivity study to examine how these tools' errors may affect DrGait's performance. Results of these experiments are in Appendix B.

5 Conclusion

In this paper, we presented DrGait, a framework for clinically interpretable gait analysis. Through the Triage-Verification-Synthesis loop, a VLM forms clinically motivated hypotheses, verifies them with biomechanically grounded tools, and produces an evidence-backed report. DrGait improves the VLM's gait analysis capability by pairing VLMs with geometric tools that produce verifiable outputs.

AI USE STATEMENT

VLMs form the core planner, baseline, and semantic-judging components described in this paper. Generative AI also assists the expansion of expert-drafted knowledge entries, with expert verification of their final content. AI tools were used for implementation support, language editing, and manuscript formatting. The authors remain responsible for the final text, experimental claims, and artifacts.

ETHICS STATEMENT

This work analyzes the existing gait-video datasets and evaluates generated reports. Gait videos may contain identifying and health-related information. Their use and redistribution must respect the source datasets' access and consent conditions. Outputs may be misleading when pose estimates fail or when disease labels exceed what is visible in video. DrGait is intended to assist expert assessment, and should not independently determine diagnosis, treatment, or prosthetic adjustment.

REPRODUCIBILITY STATEMENT

The appendix provides prompts, schemas, tool definitions, label mappings, case traces, evaluation protocols, and additional analyses. We report the available experiment settings and aggregate results.

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A Dataset Details and Human-Evaluation Protocol

The curated GAVD evaluation set contains 134 videos from 102 subjects: 27 normal, 11 antalgic, 24 cerebral-palsy, 29 myopathic, 17 Parkinsonian, and 26 stroke videos. Predictions use the expanded 11-category dictionary and are mapped to dataset labels using Appendix H. Filtering removes unavailable items, duplicates, very short or severely truncated/occluded clips, and diagnostic text leakage.

The ProGait dataset contains 138 paired-view trials from four transfemoral prosthesis users: 35 rotational, 39 step/base-of-support, 12 step-length/timing, 12 knee, 10 prosthetic-length, 6 rollover/-clearance, 2 socket, 8 foot/ankle, 10 normal, and four without a scoreable broad label. Several deviations may coexist in one trial, so scoring against a single primary category only partially measures assessment quality.

For the GAVD human reference, evaluators independently watch each video and select a label from the fixed dictionary. Labels are normalized with the same canonical mapping as model predictions. Dataset labels, model outputs, patient history, examination, and instrumented gait measurements are hidden or unavailable, and there is no discussion or adjudication. The initial three evaluators have a physical-therapy background. The expanded results include two additional evaluators. This reference measures performance on the video-only task and cannot be used to infer general clinical diagnostic accuracy.

The separate report-quality study presents each case with its video and three anonymous, randomly ordered reports, generated by direct Gemini-3-Flash, direct Gemini-3.1-Pro, and DrGait with Gemini-3-Flash. System identities and ground truth are hidden. Evaluators score diagnostic correctness, evidence grounding, and clinical usefulness from 1 to 5 and select the best report. We exclude missing fields when averaging each dimension and missing choices when calculating best-report rates. Table 4 reports the combined five-evaluator results. Agreement is lower on ProGait, although DrGait is preferred more often than either baseline. The earlier three-evaluator agreement coefficients apply only to the initial group.

B More Experiments

B.1 Different VLM Backbones

For the VLM backbone being used as the task planner in DrGait, we replace Gemini-3-Flash with Qwen3.6-Plus, while preserving the TVS schemas, tools, and stopping rule, and evaluate the complete scoreable sets. Table 8 shows that DrGait improves over direct Qwen inference on all reported tasks. This experiment tests a single additional VLM backbone being used as the planner, on the same datasets. Other planners and clinical domains require further evaluation.

Dataset/task	Direct Qwen	DrGait with Qwen
GAVD binary	59.7%	93.3%
GAVD abnormal subtype	20.6%	47.8%
ProGait top-1	7.3%	13.2%
ProGait top-3	24.6%	34.3%

Table 8: Task accuracies using Qwen3.6-Plus

B.2 Impact of Biomechanical Tools' Errors

DrGait relies on calling the external tools to provide inputs for VLM reasoning. We realized that these external tools are not always accurate, as pose, mesh, and gait-event errors can affect downstream measurements and gait classifications made by DrGait. We therefore ran a controlled sensitivity study by perturbing 3D joints in the GAVD dataset and 2D keypoints in the ProGait dataset, using three random seeds while keeping DrGait's reasoning plans fixed. Clean and noisy synthesis used the same temperature-zero setting; the matched-clean values below are internal controls for measuring perturbation effects, not replacements for the complete-set results. We report results of using both Gemini-3-Flash and Qwen-3.6-Plus as the VLM backbone, in Table 9 and 10, respectively. By comparing these with the earlier results reported (Table 2 for the GAVD dataset and Table 3 for the ProGait dataset), we conclude that DrGait exhibited strong robustness against error propagation from the upstream external tools of 3D reconstruction and post estimation, due to its well articulated and clinically grounded reasoning pipeline. Especially with small perturbations on the 3D joints

or 2D keypoints on the gait, DrGait experienced the minimum degradation on its gait classification performance. Even when such perturbations increase to a high level, DrGait can still effectively restrain such performance drop with a reasonable level.

Noise	Gemini accuracy	Qwen accuracy	Gemini label retention	Qwen label retention	Gemini inconclusive
Clean	52.8	47.8	100.0	100.0	6.7
10 mm	50.7	44.8	96.3	88.9	11.7
25 mm	47.1	41.9	87.8	82.8	17.8
50 mm	43.1	34.2	81.4	76.7	22.6
100 mm	38.7	29.8	78.9	67.8	30.0

Table 9: GAVD 3D-joint sensitivity

Noise	Gemini top-1	Qwen top-1	Gemini label retention	Qwen label retention	Gemini abstention
Clean ($T = 0$)	16.0	13.2	100.0	100.0	2.4
1%	15.7	12.6	97.8	94.4	0.0
2%	15.5	11.8	94.4	93.7	0.0
5%	14.9	10.8	90.2	91.4	0.0
10%	14.7	10.3	87.8	88.9	0.0

Table 10: ProGait 2D-keypoint sensitivity. Noise is relative to body height.

C TVS LOOP ALGORITHM

The following algorithms, prompts, example outputs, and evaluation forms document the evaluated system. Recorded terms such as "confirmed" or "diagnosis" denote model outputs or internal schema fields, not independently established clinical diagnoses; illustrative recommendations require clinician review.

Algorithm 1: Current DrGait Triage-Verification-Synthesis (TVS) Loop

Input: visual input X (video(s) or keyframes), pose/geometry context $\mathcal{P}$, metrics $\mathcal{S}$, dictionary $\mathcal{D}$, toolset $\mathcal{A}$, max iterations N_{max}
Output: final synthesis S^*, final report R, audit trace $\mathcal{T}$
$\mathcal{T} \leftarrow [\,]$; $\eta \leftarrow \emptyset$; `converged` $\leftarrow$ FALSE;
Prepare model visual content from X (upload video views or attach ordered keyframes);
for $i \leftarrow 1$ **to** N_{max} **do**
  `/* Stage 1: schema-constrained triage */`
  Build triage context $c_i^{tri} \leftarrow (X, \mathcal{S}, \mathcal{D}, \eta)$;
  Generate and validate $T_i \sim \pi(\cdot \mid c_i^{tri})$ as `TriageResponse`;
  `/* T_i contains prosthetic side, normality gate, ranked H_path, and verification objectives C_bio */`
  `/* Stage 2: bounded deterministic verification */`
  Ask the agent for function calls $A_i \subseteq \mathcal{A}$ conditioned on T_i and η;
  $O_i \leftarrow [\,]$; $I_i \leftarrow [\,]$;
  foreach $a \in$ FIRSTK$(A_i, K = 10)$ **do**
    Execute a on $(\mathcal{P}, \mathcal{S}, X)$ using the declared tool schema;
    Store sanitized tool result, `why_used`, arguments, and compact summary in O_i;
    Collect bounded verification images in I_i when tools return event frames;
  end
  `/* Stage 3: differential synthesis */`
  Build compact synthesis context $c_i^{syn} \leftarrow (T_i, O_i, I_i, \mathcal{D}, \eta)$;
  Generate and validate $S_i \sim \pi(\cdot \mid c_i^{syn})$ as `SynthesisResponse`;
  `/* S_i labels each objective as supported/refuted/inconclusive and each hypothesis as confirmed/rejected/inconclusive */`
  Append (T_i, O_i, S_i) and token usage to $\mathcal{T}$;
  if `Converged(`S_i`)` **then**
    $S^* \leftarrow S_i$; `converged` $\leftarrow$ TRUE;
    Break;
  else
    $\eta \leftarrow$ `synthesis_notes(`S_i`)`;
    `/* Refinement notes are injected into the next triage/verification/synthesis pass */`
  end
end
if S^* *is not set* **then**
  $S^* \leftarrow$ synthesis output from the last completed iteration;
end
$R \leftarrow$ `final_report(`S^*`)`;
Write reasoning trace $\mathcal{T}$ and compact final report to disk;
Return $S^*, R, \mathcal{T}$, `converged`;

Function `Converged(`S`)`**:**
  $H_c \leftarrow \{h_{\text{cat}} \mid h \in S.H_{\text{path}},\ h_{\text{status}} = \texttt{confirmed}\}$;
  if $H_c = \emptyset$ **then**
    return FALSE;
  end
  if *any objective in* $S.C_{\text{bio}}$ *is* `inconclusive` *and targets a category in* H_c **then**
    return FALSE;
  end
  return TRUE;

D GAVD EXAMPLE CASE

Below is a complete reasoning trace of DrGait analyzing a GAVD video labeled as Myopathic Gait. This is a representative case in which the initial hypothesis is incorrect, but subsequent verification with biomechanical tools corrects the diagnosis.

DrGait initially favored Parkinsonian gait because the patient showed rapid, short steps and reduced arm swing. Tool verification overturned this interpretation: measured full hip/knee extension and lack of stooped posture refuted Parkinsonian rigidity, while wide base and rhythmic coronal trunk sway supported Waddling/Myopathic gait.

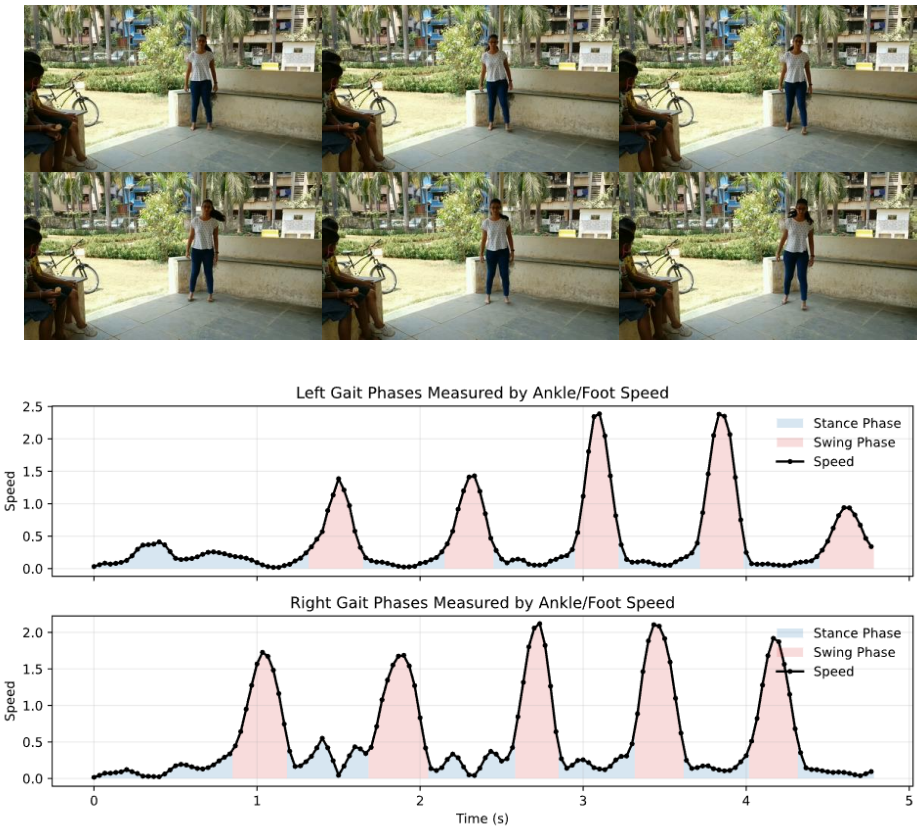


Figure 6: GAVD video example with gait phase detection graph


```
{
  "seq_id": "cljr6cam3003f3n6lzc4mo5ig",
  "video_file_name": "files/gbi6l5tkcq5d",
  "grounding_with_google_search": false,
  "initial_metrics": [
    "mean_cadence_steps_min": 134.0,
    "left_step_length_m": 0.23,
    "right_step_length_m": 0.224,
    "step_length_symmetry_index_pct": 2.63,
    "mean_step_width_m": 0.342,
    "body_sway_amplitude_deg": 9.56,
    "left_stance_phase_pct": 64.3,
    "right_stance_phase_pct": 60.6,
    "stance_time_symmetry_index_pct": 5.95,
    "total_double_support_time_pct": 24.3,
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    "right_step_length_std_m": 0.0408,
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            "evidence": [
            "Severely reduced step lengths (mean < 0.25m) indicating a
                ↪ shuffling pattern.",
            "Increased mean step width of 0.342m, which exceeds the
                ↪ normal threshold of 0.2m.",
            "High cadence of 134 steps/min suggests a rapid, short-
                ↪ stepping (festinating) pattern.",
            "Stance and step length symmetry indices are within normal
                ↪ limits (< 15%), suggesting a bilateral, symmetrical
                ↪ abnormality rather than a unilateral one."
            ],
            "uncertainty": [
            "Visual assessment of postural rigidity and arm swing is
                ↪ limited in the current view.",
            "Need to differentiate between the rhythmic wide-base sway of
                ↪  Waddling gait and the erratic instability of Ataxic
                ↪ gait."
            ]
          },
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            "category": "Parkinsonian (Festinating) Gait",
            "confidence": 0.7,
            "evidence": [
            "Mean step lengths of 0.23m and 0.224m are below the 0.30m
                ↪ threshold for shuffling.",
            "High cadence (134 steps/min) supports a festinating (
                ↪ involuntarily accelerating) pattern.",
            "Symmetrical timing (Stance SI 5.95%) is consistent with
                ↪ bilateral Parkinsonian rigidity."
            ],
            "uncertainty": [
            "Stooped posture and loss of arm swing (upper body rigidity)
                ↪ need visual confirmation or kinematic measurement."
            ]
          },
          {
            "id": 2,
            "category": "Waddling (Myopathic) Gait",
            "confidence": 0.5,
            "evidence": [
            "Increased mean step width (0.342m) is a key feature of the
                ↪ wide base used in myopathic gait.",
            "Symmetrical timing (Stance SI 5.95%) aligns with the
                ↪ bilateral nature of proximal muscle weakness."
            ],
            "uncertainty": [
            "Requires verification of rhythmic lateral trunk sway
                ↪ amplitude to differentiate from Parkinsonian rigidity."
            ]
          },
          {
            "id": 3,
            "category": "Ataxic (Cerebellar) Gait",
            "confidence": 0.3,
            "evidence": [
            "Increased mean step width (0.342m) suggests a compensatory
                ↪ base for instability.",
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            "Right step length variability (SD 0.0408m) shows some
                ↪ inconsistency."
            ],
            "uncertainty": [
            "Step width variability (SD 0.0219m) is relatively low, which
                ↪  may contradict the high variability typically seen in
                ↪ Ataxic gait."
            ]
          }
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            "objective": "Measure dynamic lateral trunk sway to
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                ↪ Parkinsonian) or erratic (Ataxic) trunk movement.",
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            "Waddling (Myopathic) Gait",
            "Ataxic (Cerebellar) Gait"
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            "priority": "high",
            "required_observables": [
            "get_postural_sway_amplitude"
            ],
            "decision_rule": "Large rhythmic sway supports Waddling;
                ↪ minimal/rigid sway supports Parkinsonian; high
                ↪ variability/staggering supports Ataxic."
          },
          {
            "id": 2,
            "objective": "Evaluate trunk and hip flexion angles to
                ↪ identify stooped posture.",
            "target_hypotheses": [
            "Parkinsonian (Festinating) Gait"
            ],
            "priority": "high",
            "required_observables": [
            "trunk_angle",
            "hip_flexion_at_mid_stance"
            ],
            "decision_rule": "Persistent flexion (angles significantly
                ↪ less than 180 degrees) throughout the cycle supports
                ↪ Parkinsonian gait."
          },
          {
            "id": 3,
            "objective": "Verify arm swing amplitude during gait.",
            "target_hypotheses": [
            "Parkinsonian (Festinating) Gait"
            ],
            "priority": "medium",
            "required_observables": [
            "arm_swing_range"
            ],
            "decision_rule": "Bilateral reduction in arm swing supports
                ↪ Parkinsonian rigidity."
          }
          ],
          "ruled_out_distractors": [
          "Hemiparetic (Hemiplegic) Gait",
          "Antalgic Gait",
          "Spastic Diplegic (Scissors) Gait"
          ],
          "triage_notes": "The subject exhibits a symmetrical, wide-based
              ↪ , short-stepping gait with high cadence. This pattern
              ↪ strongly suggests a hypokinetic (Parkinsonian) or
              ↪ proximal weakness (Waddling) profile. Verification will
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            ↪ focus on trunk sway characteristics and postural rigidity
            ↪ ."
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          "output_tokens": 1165,
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      "verification": {
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          "why_used": "Measuring dynamic coronal trunk sway to
              ↪ differentiate between rhythmic waddling (high sway) and
              ↪ rigid Parkinsonian (low sway) patterns.",
          "args": {
            "plane": "coronal",
            "segment": "trunk",
            "why_used": "Measuring dynamic coronal trunk sway to
                ↪ differentiate between rhythmic waddling (high sway) and
                ↪  rigid Parkinsonian (low sway) patterns."
          },
          "result_summary": "9.56"
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        {
          "tool": "get_postural_sway_amplitude",
          "why_used": "Evaluating sagittal trunk range to assess for
              ↪ rigid, stooped Parkinsonian posture versus dynamic sway
              ↪ .",
          "args": {
            "plane": "sagittal",
            "segment": "trunk",
            "why_used": "Evaluating sagittal trunk range to assess for
                ↪ rigid, stooped Parkinsonian posture versus dynamic sway
                ↪ ."
          },
          "result_summary": "4.21"
        },
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          "why_used": "Quantifying trunk posture at mid-stance to check
              ↪ for a stooped (flexed) position characteristic of
              ↪ Parkinsonian gait.",
          "args": {
            "segment": "trunk",
            "frame": 12,
            "plane": "sagittal",
            "why_used": "Quantifying trunk posture at mid-stance to check
                ↪  for a stooped (flexed) position characteristic of
                ↪ Parkinsonian gait."
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              ↪ angle. 0 or 180 degrees means the segment is aligned/
              ↪ straight with the reference axis; 90 degrees means
              ↪ perpendicular.\", \"plane\": \"sagittal\", \"pose_space
              ↪ \": \"world_3d\", \"reference_axis\": \"body vertical\",
              ↪ \"segment\": \"trunk\", \"view\": \"front\"}"
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          "tool": "get_peak_joint_angle",
          "why_used": "Checking for persistent hip flexion during stance
              ↪ to support a stooped Parkinsonian posture.",
          "args": {
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            "joint": "left_hip",
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            "why_used": "Checking for persistent hip flexion during
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            "plane": "sagittal"
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              ↪ \"}]"
        },
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          "why_used": "Checking for persistent hip flexion during stance
              ↪ to support a stooped Parkinsonian posture.",
          "args": {
            "plane": "sagittal",
            "joint": "right_hip",
            "phase": "right_stance",
            "why_used": "Checking for persistent hip flexion during
                ↪ stance to support a stooped Parkinsonian posture."
          },
          "result_summary": "[{\"max_angle\": 180.0, \"min_angle\":
              ↪ 167.78, \"pose_space\": \"world_3d\", \"view\": \"front
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          "why_used": "Assessing for bilateral reduction in arm swing, a
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            "why_used": "Assessing for bilateral reduction in arm swing,
                ↪ a hallmark of Parkinsonian rigidity.",
            "side": "left"
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          "why_used": "Assessing for bilateral reduction in arm swing, a
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          "args": {
            "why_used": "Assessing for bilateral reduction in arm swing,
                ↪ a hallmark of Parkinsonian rigidity.",
            "side": "right"
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              ↪ \": -15.82, \"view\": \"front\"}"
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          "tool": "get_peak_joint_angle",
          "why_used": "Checking for restricted knee flexion to
              ↪ differentiate Parkinsonian rigidity or Stiff-Knee Gait
              ↪ from Neuropathic/Normal flexion.",
          "args": {
            "plane": "sagittal",
            "why_used": "Checking for restricted knee flexion to
                ↪ differentiate Parkinsonian rigidity or Stiff-Knee Gait
                ↪ from Neuropathic/Normal flexion.",
            "joint": "left_knee",
            "phase": "left_swing"
          },
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              ↪ \"}]"
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          "tool": "get_joint_angle_at_event",
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              ↪  gait.",
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            "joint": "left_ankle",
            "why_used": "Checking for flat-foot strike or foot slap to
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                ↪ Parkinsonian gait.",
            "event": "left_initial_contact"
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              ↪ pose_space\": \"world_3d\", \"step_index\": 1, \"view\":
              ↪ \"front\"}, {\"angle\": 110.94, \"frame_num\": 97, \"
              ↪ pose_space\": \"world_3d\", \"step_index\": 2, \"view\":
              ↪ \"front\"}]"
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                ↪ Parkinsonian) or erratic (Ataxic) trunk movement.",
            "target_hypotheses": [
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            "Waddling (Myopathic) Gait",
            "Ataxic (Cerebellar) Gait"
            ],
            "status": "supported",
            "evidence": [
            "get_postural_sway_amplitude (coronal) measured 9.56 deg,
                ↪ which is relatively high for rigid Parkinsonian gait
                ↪ but within rhythmic sway ranges.",
            "get_postural_sway_amplitude (sagittal) measured 4.21 deg,
                ↪ suggesting limited anterior-posterior trunk movement."
            ]
          },
          {
            "id": 2,
            "objective": "Evaluate trunk and hip flexion angles to
                ↪ identify stooped posture.",
            "target_hypotheses": [
            "Parkinsonian (Festinating) Gait"
            ],
            "status": "refuted",
            "evidence": [
            "get_postural_angle (sagittal) found the trunk is only 7.13
                ↪ degrees from vertical, indicating a largely upright
                ↪ rather than stooped posture.",
            "get_peak_joint_angle for hips showed extension reaching 180
                ↪ degrees during stance, refuting persistent flexion."
            ]
          },
          {
            "id": 3,
            "objective": "Verify arm swing amplitude during gait.",
            "target_hypotheses": [
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            "Parkinsonian (Festinating) Gait"
            ],
            "status": "supported",
            "evidence": [
            "get_arm_swing_amplitude measured very low ranges (~7 deg for
                ↪  left, ~5 deg for right), supporting upper body
                ↪ rigidity."
            ]
          }
          ],
          "H_path": [
          {
            "id": 1,
            "category": "Parkinsonian (Festinating) Gait",
            "supporting_evidence": [
            "Severely reduced step lengths (< 0.25m) and high cadence
                ↪ (134 steps/min).",
            "Significant reduction in bilateral arm swing amplitude (~5-7
                ↪  deg)."
            ],
            "conflicting_evidence": [
            "Lack of stooped posture (trunk near 7 deg from vertical) and
                ↪  presence of full hip extension (180 deg) in stance."
            ],
            "status": "inconclusive",
            "confidence": 0.4
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          {
            "id": 2,
            "category": "Waddling (Myopathic) Gait",
            "supporting_evidence": [
            "Increased mean step width (0.342m).",
            "Presence of rhythmic lateral trunk sway (9.56 deg) and
                ↪ symmetrical timing (SI < 6%)."
            ],
            "conflicting_evidence": [
            "Very short step lengths and high cadence are more typical of
                ↪  Parkinsonian festination than pure myopathic gait."
            ],
            "status": "inconclusive",
            "confidence": 0.4
          },
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            "id": 3,
            "category": "Healthy (Normal) Gait",
            "supporting_evidence": [
            "High degree of temporal and spatial symmetry (SI < 10%).",
            "Full hip extension during stance phase."
            ],
            "conflicting_evidence": [
            "Pathologically short step lengths (0.23m) and significantly
                ↪ increased step width (0.342m) relative to height/
                ↪ normative data."
            ],
            "status": "rejected",
            "confidence": 0.1
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          ],
          "synthesis_notes": "The gait shows mixed features: Parkinsonian
              ↪ -like shuffling and reduced arm swing, but without the
              ↪ characteristic stooped posture or hip flexion. The wide
              ↪ base and lateral sway overlap with myopathic patterns,
              ↪ but the extreme cadence and short steps suggest a central
              ↪  neurological component. Further clinical assessment of
              ↪ tone and power is required.",
          "final_report": "The analysis identifies an abnormal gait
              ↪ pattern characterized by rapid, very short steps (
              ↪ shuffling) and a widened base of support, though a
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            ↪ definitive diagnosis is inconclusive. While the shuffling
            ↪  and reduced arm swing are consistent with a Parkinsonian
            ↪  pattern, the lack of a stooped posture and presence of
            ↪ significant lateral sway also suggest possible proximal
            ↪ weakness or myopathic influence. Recommended next step:
            ↪ Clinical neurological and musculoskeletal evaluation to
            ↪ assess for muscle tone, proximal hip strength, and
            ↪ balance control."
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          "normality_gate": {
            "classification": "abnormal",
            "evidence": [
            "Severely reduced step length (mean < 0.25m) suggesting
                ↪ shuffling gait.",
            "Increased mean step width (0.342m) exceeding the normal
                ↪ threshold of 0.2m.",
            "High cadence (134 steps/min) combined with short steps,
                ↪ indicating possible festination.",
            "Visually reduced bilateral arm swing and rigid trunk
                ↪ movement."
            ],
            "uncertainty": [
            "The wide base and lateral sway (9.56 deg) could suggest
                ↪ either a compensatory myopathic pattern or ataxic
                ↪ instability.",
            "While step length is short, step width variability (0.0219m)
                ↪  is relatively low, which may conflict with an ataxic
                ↪ diagnosis."
            ]
          },
          "H_path": [
          {
            "id": 1,
            "category": "Parkinsonian (Festinating) Gait",
            "confidence": 0.65,
            "evidence": [
            "Mean step length is significantly reduced (< 0.30m).",
            "High cadence (134 steps/min) often accompanies the '
                ↪ festination' (accelerating short steps) of Parkinsonian
                ↪  gait.",
            "Visual observation of reduced bilateral arm swing and rigid
                ↪ 'en bloc' movement."
            ],
            "uncertainty": [
            "Patient lacks the classic stooped posture (trunk flexion)
                ↪ and persists with a wide base, which is atypical for
                ↪ Parkinsonism."
            ]
          },
          {
            "id": 2,
            "category": "Waddling (Myopathic) Gait",
            "confidence": 0.5,
            "evidence": [
            "Increased mean step width (0.342m) to improve lateral
                ↪ stability.",
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            "Lateral trunk sway amplitude is measured at 9.56 degrees.",
            "Temporal symmetry is preserved (Stance SI < 15%), consistent
                ↪  with bilateral proximal weakness."
            ],
            "uncertainty": [
            "Myopathic gait typically presents with rhythmic swaying
                ↪ rather than the rapid, shuffling cadence seen here."
            ]
          },
          {
            "id": 3,
            "category": "Ataxic (Cerebellar) Gait",
            "confidence": 0.3,
            "evidence": [
            "Mean step width is > 0.30m (0.342m).",
            "Visual appearance of unsteadiness during initiation and
                ↪ turning."
            ],
            "uncertainty": [
            "Step length and width variability (SD) are relatively low,
                ↪ whereas cerebellar ataxia usually exhibits erratic
                ↪ placement (SD > 0.10m)."
            ]
          }
          ],
          "C_bio": [
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                ↪ persistent hip/knee flexion.",
            "target_hypotheses": [
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            "Crouch Gait"
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            "priority": "high",
            "required_observables": [
            "Max hip extension during stance",
            "Max knee extension during stance"
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            "decision_rule": "If max knee angle remains < 160 deg and
                ↪ hips are flexed throughout stance, it supports
                ↪ Parkinsonian or Crouch gait."
          },
          {
            "id": 2,
            "objective": "Measure dynamic trunk sway rhythm and amplitude
                ↪ .",
            "target_hypotheses": [
            "Waddling (Myopathic) Gait",
            "Ataxic (Cerebellar) Gait"
            ],
            "priority": "high",
            "required_observables": [
            "get_postural_sway_amplitude"
            ],
            "decision_rule": "Rhythmic, bilateral sway supports Waddling
                ↪ gait; erratic, unpredictable sway (high variability)
                ↪ supports Ataxic gait."
          },
          {
            "id": 3,
            "objective": "Confirm presence of foot slap or flat-foot
                ↪ strike.",
            "target_hypotheses": [
            "Parkinsonian (Festinating) Gait",
            "Neuropathic (Steppage) Gait"
            ],
            "priority": "medium",
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            "required_observables": [
            "Ankle angle at initial contact"
            ],
            "decision_rule": "Ankle angle near neutral or in
                ↪ plantarflexion at initial contact (lack of heel strike)
                ↪  supports Parkinsonian shuffling."
          }
          ],
          "ruled_out_distractors": [
          "Hemiparetic (Hemiplegic) Gait",
          "Antalgic Gait"
          ],
          "triage_notes": "The patient exhibits a shuffling pattern with
              ↪ high cadence and short steps, pointing toward
              ↪ Parkinsonian gait, yet maintains a wide base and lateral
              ↪ sway more typical of myopathic or ataxic conditions. The
              ↪ absence of significant temporal asymmetry rules out
              ↪ Antalgic and Hemiparetic patterns. Primary focus is
              ↪ distinguishing between a hypokinetic central disorder and
              ↪  proximal muscle weakness."
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          "output_tokens": 1165,
          "thought_tokens": 0
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      "verification": {
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          "why_used": "To distinguish between the rhythmic sway of
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          "args": {
            "why_used": "To distinguish between the rhythmic sway of
                ↪ Waddling gait and the erratic sway of Ataxic gait.",
            "segment": "trunk",
            "plane": "coronal"
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          "result_summary": "9.56"
        },
        {
          "tool": "get_postural_sway_amplitude",
          "why_used": "To check for sagittal instability or stooped
              ↪ posture related to Parkinsonian gait.",
          "args": {
            "why_used": "To check for sagittal instability or stooped
                ↪ posture related to Parkinsonian gait.",
            "segment": "trunk",
            "plane": "sagittal"
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          "result_summary": "4.21"
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          "tool": "get_peak_joint_angle",
          "why_used": "To determine if the patient maintains persistent
              ↪ knee flexion (Crouch/Parkinsonian) or achieves full
              ↪ extension.",
          "args": {
            "joint": "left_knee",
            "plane": "sagittal",
            "why_used": "To determine if the patient maintains persistent
                ↪  knee flexion (Crouch/Parkinsonian) or achieves full
                ↪ extension.",
            "phase": "left_stance"
          },
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      "result_summary": "[{\"max_angle\": 171.56, \"min_angle\":
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          ↪ \"}]"
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      "why_used": "To check for a stooped (flexed) hip posture
          ↪ characteristic of Parkinsonian gait.",
      "args": {
        "why_used": "To check for a stooped (flexed) hip posture
            ↪ characteristic of Parkinsonian gait.",
        "phase": "left_stance",
        "plane": "sagittal",
        "joint": "left_hip"
      },
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          ↪ \"}]"
    },
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      "why_used": "To verify the presence of a flat-foot strike or
          ↪ foot slap, supporting a shuffling/Parkinsonian pattern.",
      "args": {
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            ↪ foot slap, supporting a shuffling/Parkinsonian pattern
            ↪ .",
        "event": "left_initial_contact",
        "plane": "sagittal",
        "joint": "left_ankle"
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          ↪ \"front\"}, {\"angle\": 109.83, \"frame_num\": 74, \"
          ↪ pose_space\": \"world_3d\", \"step_index\": 1, \"view\":
          ↪ \"front\"}, {\"angle\": 110.94, \"frame_num\": 97, \"
          ↪ pose_space\": \"world_3d\", \"step_index\": 2, \"view\":
          ↪ \"front\"}]"
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      "why_used": "To quantify the reduction in arm swing, a key
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      "args": {
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        "why_used": "To quantify the reduction in arm swing, a key
            ↪ hallmark of Parkinsonian gait."
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          ↪ \": -18.73, \"view\": \"front\"}"
    },
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      "tool": "get_arm_swing_amplitude",
      "why_used": "To check for bilateral reduction in arm swing,
          ↪ supporting Parkinsonian vs unilateral hemiparesis.",
      "args": {
        "side": "right",
        "why_used": "To check for bilateral reduction in arm swing,
            ↪ supporting Parkinsonian vs unilateral hemiparesis."
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      "why_used": "To check for low foot clearance (shuffling) vs
          ↪ high steppage (Neuropathic/Ataxic).",
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            "objective": "Verify the presence of a stooped posture or
                ↪ persistent hip/knee flexion.",
            "target_hypotheses": [
            "Parkinsonian (Festinating) Gait",
            "Crouch Gait"
            ],
            "status": "refuted",
            "evidence": [
            "get_peak_joint_angle for the left hip showed a max extension
                ↪  of 180.0 deg, refuting persistent hip flexion.",
            "get_peak_joint_angle for the left knee showed a max
                ↪ extension of 171.56 deg, which is near full extension
                ↪ and refutes the 'persistent flexion' required for
                ↪ Crouch Gait or classic stooped Parkinsonian posture."
            ]
          },
          {
            "id": 2,
            "objective": "Measure dynamic trunk sway rhythm and amplitude
                ↪ .",
            "target_hypotheses": [
            "Waddling (Myopathic) Gait",
            "Ataxic (Cerebellar) Gait"
            ],
            "status": "supported",
            "evidence": [
            "get_postural_sway_amplitude in the coronal plane measured a
                ↪ significant 9.56 deg, supporting the lateral sway
                ↪ characteristic of Waddling gait.",
            "Triage metrics showed a wide step width (0.342m) and low
                ↪ variability (SD 0.0219m), which supports the rhythmic
                ↪ pattern of a Waddling gait over the erratic placement
                ↪ of Ataxic gait."
            ]
          },
          {
            "id": 3,
            "objective": "Confirm presence of foot slap or flat-foot
                ↪ strike.",
            "target_hypotheses": [
            "Parkinsonian (Festinating) Gait",
            "Neuropathic (Steppage) Gait"
            ],
            "status": "supported",
            "evidence": [
            "get_joint_angle_at_event for ankle at initial contact showed
                ↪  angles (~110 deg) indicating a flat-foot strike rather
                ↪  than a heel-first landing.",
```

```
            "get_foot_clearance (0.76m) was relatively low, though not
                ↪ extremely restricted, supporting a shuffling-type foot
                ↪ strike."
          ]
        }
        ],
        "H_path": [
        {
          "id": 1,
          "category": "Waddling (Myopathic) Gait",
          "supporting_evidence": [
          "Significant coronal trunk sway (9.56 deg) and wide step
              ↪ width (0.342m) are primary signs.",
          "Temporal symmetry (Stance SI < 15%) is consistent with
              ↪ bilateral proximal weakness."
          ],
          "conflicting_evidence": [
          "High cadence (134 steps/min) and flat-foot strike are more
              ↪ common in hypokinetic gaits than classic myopathy."
          ],
          "status": "confirmed",
          "confidence": 0.7
        },
        {
          "id": 2,
          "category": "Parkinsonian (Festinating) Gait",
          "supporting_evidence": [
          "High cadence (134 steps/min), extremely short steps (< 0.25m
              ↪ ), and flat-foot strike.",
          "Bilateral reduction in arm swing (approx 5-7 deg amplitude)
              ↪ ."
          ],
          "conflicting_evidence": [
          "Tool measurements confirmed full hip extension (180 deg) and
              ↪  near-full knee extension (171.6 deg), refuting the
              ↪ diagnostic stooped posture.",
          "Wide base (0.342m) is atypical for Parkinsonism."
          ],
          "status": "inconclusive",
          "confidence": 0.4
        },
        {
          "id": 3,
          "category": "Ataxic (Cerebellar) Gait",
          "supporting_evidence": [
          "Increased mean step width (0.342m)."
          ],
          "conflicting_evidence": [
          "Low step-to-step variability in width (SD 0.0219m) refutes
              ↪ the erratic placement required for ataxia."
          ],
          "status": "rejected",
          "confidence": 0.1
        }
        ],
        "synthesis_notes": "The gait exhibits a contradiction between
            ↪ hypokinetic features (high cadence, short steps, flat
            ↪ strike, low arm swing) and mechanical compensations (wide
            ↪  base, significant lateral sway). Tool results refute the
            ↪  stooped posture and sagittal rigidity of Parkinsonian
            ↪ gait, while the rhythmic wide base supports a myopathic
            ↪ or waddling pattern. Clinical assessment should focus on
            ↪ proximal pelvic strength versus bradykinesia.",
        "final_report": "The analysis concludes that the patient
            ↪ demonstrates a Waddling (Myopathic) Gait pattern,
            ↪ characterized by a significantly wide base (0.34m) and
            ↪ pronounced lateral trunk sway (9.56 deg). While some
            ↪ features like a high cadence and flat-foot strike
```

```
              ↪ resemble shuffling, the presence of full hip/knee
              ↪ extension and low step variability effectively rules out
              ↪ classic stooped Parkinsonian or Ataxic gaits. This
              ↪ pattern is often associated with proximal muscle weakness
              ↪  around the hips; a clinical assessment of pelvic girdle
              ↪ strength and a referral for physical therapy focusing on
              ↪ core and hip stabilization are recommended."
        },
        "token_usage": {
          "input_tokens": 10211,
          "output_tokens": 1182,
          "thought_tokens": 0
        }
      }
    }
    ],
    "converged": true,
    "num_iterations": 2,
    "token_usage_total": {
      "input_tokens": 46550,
      "output_tokens": 5516,
      "thought_tokens": 0
    },
    "final_synthesis": "The analysis concludes that the patient
        ↪ demonstrates a Waddling (Myopathic) Gait pattern, characterized
        ↪  by a significantly wide base (0.34m) and pronounced lateral
        ↪ trunk sway (9.56 deg). While some features like a high cadence
        ↪ and flat-foot strike resemble shuffling, the presence of full
        ↪ hip/knee extension and low step variability effectively rules
        ↪ out classic stooped Parkinsonian or Ataxic gaits. This pattern
        ↪ is often associated with proximal muscle weakness around the
        ↪ hips; a clinical assessment of pelvic girdle strength and a
        ↪ referral for physical therapy focusing on core and hip
        ↪ stabilization are recommended.",
    "trace_path": "outputs/eval/gavd/default/myopathic/
        ↪ cljr6cam3003f3n6lzc4mo5ig/reasoning_trace.json"
  }
```


E PROGAIT EXAMPLE CASE

In this ProGait case, DrGait initially interpreted the prosthetic swing pattern as a Lateral Whip. Tool verification corrected the direction of the heel trajectory to a Medial Whip and confirmed a wide base of support through lateral-deviation metrics, while sagittal hip-extension measurements supported associated step-length asymmetry. The final diagnosis shifted to Abducted Gait / Increased Stride Width.


```
  {
    "seq_id": "outside/2_8_5",
    "video_file_name": {
      "frontal": "files/okqauavo7un3",
      "sagittal": "files/jl60ifv2d12k"
    },
    "grounding_with_google_search": false,
    "initial_metrics": [
      "sagittal_mean_cadence_steps_min": 48.0,
      "sagittal_apparent_step_length_symmetry_index_pct": 11.0,
      "sagittal_stance_time_symmetry_index_pct": 11.5,
      "sagittal_total_double_support_time_pct": 3.7,
      "sagittal_left_knee_angle_min_deg": 145.0,
      "sagittal_left_knee_angle_max_deg": 180.0,
      "sagittal_right_knee_angle_min_deg": 136.0,
      "sagittal_right_knee_angle_max_deg": 180.0,
      "frontal_mean_step_width_shoulder_width_std": 0.0935,
      "frontal_step_width_std_shoulder_width": 0.403,
      "frontal_mean_frontal_knee_angle_deg": 175.0,
```

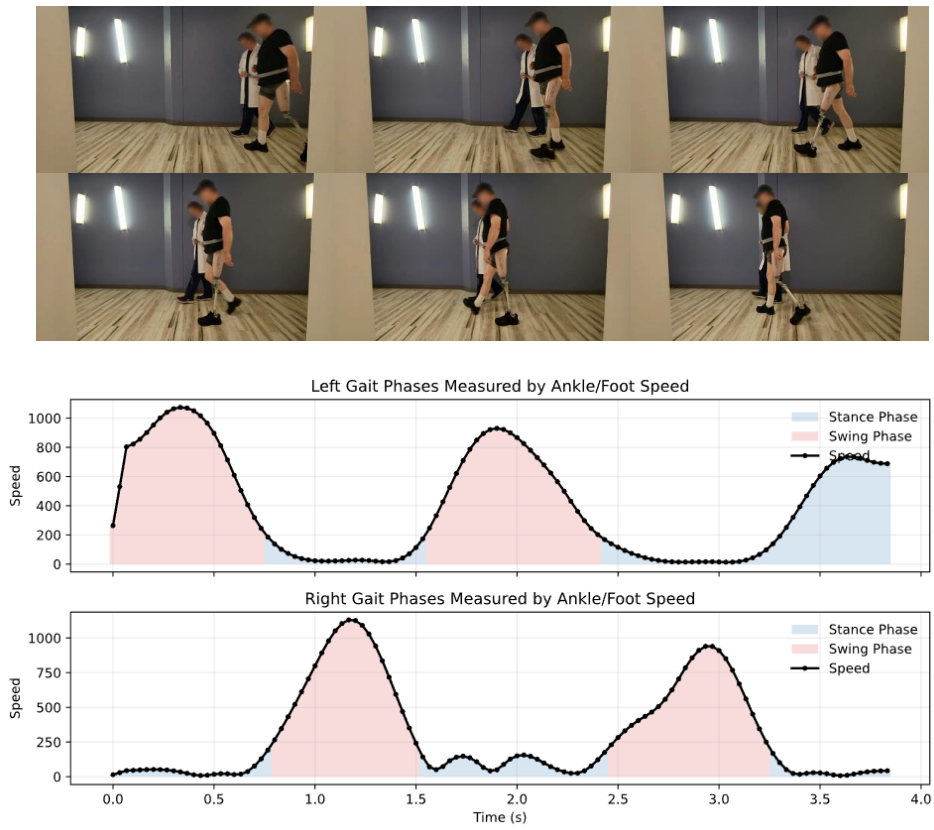


Figure 7: ProGait video example with gait phase detection graph


```
    ],
    "iterations": [
    {
      "iteration": 1,
      "triage": {
        "response_data": {
          "prosthetic_side": "right",
          "normality_gate": {
            "classification": "abnormal",
            "evidence": [
            "The user is walking with a manual belt-assist provided by
                ↪ the clinician, indicating significant gait instability
                ↪ .",
            "Visually apparent wide base of support (0.954 mean step
                ↪ width) and trunk shift toward the sound side.",
            "Significant step length asymmetry (11%) and stance time
                ↪ asymmetry (11.5%)."
            ],
            "uncertainty": [
            "Low mean cadence (48 steps/min) may exaggerate or mask
                ↪ certain timing-based deviations."
            ]
          },
          "H_path": [
          {
            "id": 1,
            "category": "Abducted Gait / Increased Stride Width",
            "general_category": {
              "code": 2,
              "name": "Step and Base of Support Deviations"
```

```
            },
            "confidence": 0.85,
            "evidence": [
            "Mean step width of 0.954 (nearly equal to shoulder width) is
                ↪  significantly higher than typical prosthetic gait
                ↪ norms.",
            "Frontal view shows the right prosthetic limb carried in a
                ↪ lateral position throughout stance and swing phases."
            ],
            "uncertainty": [
            "Manual belt-assist may be influencing the patient's lateral
                ↪ limb placement or balance strategy."
            ]
          },
          {
            "id": 2,
            "category": "Decreased Prosthetic Stance Time / Short
                ↪ Prosthetic Step",
            "general_category": {
              "code": 3,
              "name": "Step Length and Timing Issues"
            },
            "confidence": 0.75,
            "evidence": [
            "Stance time asymmetry (11.5%) indicates the patient is
                ↪ spending less time on the right prosthetic limb
                ↪ compared to the sound side.",
            "Sagittal view shows a quick, abbreviated stance phase on the
                ↪  right side followed by a rapid step-through of the
                ↪ left limb."
            ],
            "uncertainty": [
            "Asymmetry index of 11.5% is notable but requires stance-
                ↪ phase-specific time measurements to confirm the exact
                ↪ duration on the right limb."
            ]
          },
          {
            "id": 3,
            "category": "Lateral Trunk Lean",
            "general_category": {
              "code": 7,
              "name": "Socket Fit and Stability"
            },
            "confidence": 0.65,
            "evidence": [
            "Visual lean of the torso toward the right prosthetic side
                ↪ during the prosthetic stance phase in the frontal view
                ↪ ."
            ],
            "uncertainty": [
            "The clinician's manual gait-belt assist (holding the patient
                ↪ 's belt) directly interferes with the natural trunk and
                ↪  pelvic motion."
            ]
          }
          ],
          "C_bio": [
          {
            "id": 1,
            "objective": "Verify the lateral distance of the right foot
                ↪ center from the midline during mid-stance.",
            "target_hypotheses": [
            "Abducted Gait / Increased Stride Width"
            ],
            "priority": "high",
            "required_observables": [
            "Step width measurement",
```

```
            "Lateral foot displacement at mid-stance"
            ],
            "decision_rule": "Normalized step width significantly
                ↪ exceeding 0.40 shoulder widths consistently supports
                ↪ Abducted Gait."
          },
          {
            "id": 2,
            "objective": "Compare the duration of the right stance phase
                ↪ vs. left stance phase.",
            "target_hypotheses": [
            "Decreased Prosthetic Stance Time / Short Prosthetic Step"
            ],
            "priority": "high",
            "required_observables": [
            "Right stance time (seconds)",
            "Left stance time (seconds)"
            ],
            "decision_rule": "A stance time for the right side that is at
                ↪  least 10% shorter than the left side confirms the
                ↪ deviation."
          },
          {
            "id": 3,
            "objective": "Measure maximal trunk tilt angle in the frontal
                ↪  plane during right mid-stance.",
            "target_hypotheses": [
            "Lateral Trunk Lean"
            ],
            "priority": "medium",
            "required_observables": [
            "Trunk angle relative to vertical in frontal view"
            ],
            "decision_rule": "A lateral tilt of the trunk exceeding 5
                ↪ degrees over the prosthetic side supports the deviation
                ↪ , though clinician interference must be noted."
          }
          ],
          "ruled_out_distractors": [
          "Vaulting",
          "Circumduction",
          "Knee Instability (Excessive Knee Flexion)"
          ],
          "triage_notes": "The patient exhibits a highly unstable gait on
              ↪  the right prosthetic side, requiring manual assistance.
              ↪ The primary deviations are a wide base of support (
              ↪ Abducted Gait) and reduced loading time on the prosthesis
              ↪ . Clinician assistance via the gait belt introduces
              ↪ significant uncertainty regarding trunk and pelvic
              ↪ kinematics."
        },
        "token_usage": {
          "input_tokens": 26657,
          "output_tokens": 1146,
          "thought_tokens": 0
        }
      },
      "verification": {
        "tool_trace": [
        {
          "tool": "get_lateral_deviation",
          "why_used": "To measure the lateral displacement of the
              ↪ prosthetic foot during stance to verify Abducted Gait.",
          "args": {
            "view": "front",
            "why_used": "To measure the lateral displacement of the
                ↪ prosthetic foot during stance to verify Abducted Gait
                ↪ .",
```

```
            "joint": "right_foot",
            "phase": "right_stance"
          },
          "result_summary": "{\"aggregation\": \"mean_across_segments\",
              ↪ \"mean_max_lateral_deviation_norm\": 0.65, \"per_segment
              ↪ \": {\"front\": {\"interpretation\": \"2D image-plane
              ↪ lateral deviation proxy normalized by shoulder width; not
              ↪  centimeters\", \"max_lateral_deviation_norm\": 0.65, \"
              ↪ normalization\": \"shoulder_width\", \"pose_space\": \"
              ↪ image_2d\", \"scale_px\": 100.0, \"unit\": \"
              ↪ shoulder_width_fraction\", \"view\": \"front\"}}, \"
              ↪ segments\": [\"front\"]}"
        },
        {
          "tool": "calculate_symmetry_index",
          "why_used": "To confirm the magnitude of stance time asymmetry
              ↪ and verify the reduction in loading time on the right
              ↪ prosthetic limb.",
          "args": {
            "why_used": "To confirm the magnitude of stance time
                ↪ asymmetry and verify the reduction in loading time on
                ↪ the right prosthetic limb.",
            "metric_name": "stance_time"
          },
          "result_summary": "{\"aggregation\": \"mean_across_segments\",
              ↪ \"mean_symmetry_index_pct\": 11.39, \"per_segment\": {\"
              ↪ left\": 11.39}, \"segments\": [\"left\"]}"
        },
        {
          "tool": "get_postural_sway_amplitude",
          "why_used": "To quantify the range of trunk motion in the
              ↪ frontal plane to verify Lateral Trunk Lean, despite
              ↪ clinician assistance.",
          "args": {
            "view": "front",
            "plane": "coronal",
            "why_used": "To quantify the range of trunk motion in the
                ↪ frontal plane to verify Lateral Trunk Lean, despite
                ↪ clinician assistance.",
            "segment": "trunk"
          },
          "result_summary": "{\"aggregation\": \"mean_across_segments\",
              ↪ \"mean_amplitude_deg\": 13.9, \"per_segment\": {\"front
              ↪ \": 13.9}, \"segments\": [\"front\"]}"
        },
        {
          "tool": "get_postural_angle",
          "why_used": "To measure the static trunk tilt during right mid-
              ↪ stance for specific evidence of Lateral Trunk Lean.",
          "args": {
            "why_used": "To measure the static trunk tilt during right
                ↪ mid-stance for specific evidence of Lateral Trunk Lean
                ↪ .",
            "segment": "trunk",
            "frame": 10,
            "plane": "coronal",
            "view": "front"
          },
          "result_summary": "{\"aggregation\": \"mean_across_segments\",
              ↪ \"mean_angle_deg\": -2.28, \"per_segment\": {\"front\":
              ↪ {\"angle_deg\": -2.28, \"frame_num\": 10, \"
              ↪ interpretation\": \"Image-plane unsigned orientation
              ↪ angle. 0 or 180 degrees means the segment is aligned/
              ↪ straight with the reference axis; 90 degrees means
              ↪ perpendicular. This is not calibrated 3D posture.\", \"
              ↪ pose_space\": \"image_2d\", \"view\": \"front\"}}, \"
              ↪ segments\": [\"front\"]}"
        },
```

```
        {
          "tool": "get_gait_event_frame",
          "why_used": "To visually inspect the lateral position of the
              ↪ limb and trunk alignment at the peak of the prosthetic
              ↪ stance phase.",
          "args": {
            "event": "right_mid_stance",
            "why_used": "To visually inspect the lateral position of the
                ↪ limb and trunk alignment at the peak of the prosthetic
                ↪ stance phase."
          },
          "result_summary": "[{\"image_ref\": \"
              ↪ get_gait_event_frame_image_1\", \"frame_num\": 786, \"
              ↪ step_index\": 0, \"image_source\": \"raw_video\", \"view
              ↪ \": \"front\"}, {\"image_ref\": \"
              ↪ get_gait_event_frame_image_2\", \"frame_num\": 33, \"
              ↪ step_index\": 0, \"image_source\": \"raw_video\", \"view
              ↪ \": \"back\"}, {\"image_ref\": \"
              ↪ get_gait_event_frame_image_3\", \"frame_num\": 60, \"
              ↪ step_index\": 0, \"image_source\": \"raw_video\", \"view
              ↪ \": \"left\"}, {\"image_ref\": \"
              ↪ get_gait_event_frame_image_4\", \"frame_num\": 836, \"
              ↪ step_index\": 1, \"image_source\": \"raw_video\", \"view
              ↪ \": \"front\"}, {\"image_ref\": \"
              ↪ get_gait_event_frame_image_5\", \"frame_num\": 61, \"
              ↪ step_index\": 1, \"image_source\": \"raw_video\", \"view
              ↪ \": \"back\"}]"
        }
        ],
        "token_usage": {
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          "output_tokens": 287,
          "thought_tokens": 0
        }
      },
      "synthesis": {
        "response_data": {
          "C_bio": [
          {
            "id": 1,
            "objective": "Verify the lateral distance of the right foot
                ↪ center from the midline during mid-stance.",
            "target_hypotheses": [
            "Abducted Gait / Increased Stride Width"
            ],
            "status": "supported",
            "evidence": [
            "get_lateral_deviation: Measured a mean max lateral deviation
                ↪  proxy of 0.65 shoulder widths on the right side.",
            "Visual verification (frame 786): Shows the right prosthetic
                ↪ limb significantly lateral to the trunk midline during
                ↪ mid-stance."
            ]
          },
          {
            "id": 2,
            "objective": "Compare the duration of the right stance phase
                ↪ vs. left stance phase.",
            "target_hypotheses": [
            "Decreased Prosthetic Stance Time / Short Prosthetic Step"
            ],
            "status": "supported",
            "evidence": [
            "calculate_symmetry_index: Confirmed a stance time asymmetry
                ↪ of 11.39% favoring the sound side.",
            "Gait metrics: The total stance duration on the right side is
                ↪  notably shorter than the left, consistent with
                ↪ hesitant loading."
```

```
            ]
          },
          {
            "id": 3,
            "objective": "Measure maximal trunk tilt angle in the frontal
                ↪  plane during right mid-stance.",
            "target_hypotheses": [
            "Lateral Trunk Lean"
            ],
            "status": "inconclusive",
            "evidence": [
            "get_postural_angle: Found a negligible trunk tilt of -2.28
                ↪ degrees at frame 10.",
            "get_postural_sway_amplitude: Measured high sway amplitude of
                ↪  13.9 degrees, but the clinician's manual gait-belt
                ↪ assist prevents reliable isolated assessment of the
                ↪ patient's voluntary trunk lean."
            ]
          }
          ],
          "H_path": [
          {
            "id": 1,
            "category": "Abducted Gait / Increased Stride Width",
            "general_category": {
              "code": 2,
              "name": "Step and Base of Support Deviations"
            },
            "supporting_evidence": [
            "Normalized lateral foot deviation of 0.65 shoulder widths
                ↪ exceeds the triage threshold for abducted gait.",
            "Frontal view confirms the right limb is carried in an
                ↪ abducted position during both swing and stance."
            ],
            "conflicting_evidence": [
            ""
            ],
            "status": "confirmed",
            "confidence": 0.95
          },
          {
            "id": 2,
            "category": "Decreased Prosthetic Stance Time / Short
                ↪ Prosthetic Step",
            "general_category": {
              "code": 3,
              "name": "Step Length and Timing Issues"
            },
            "supporting_evidence": [
            "Verified 11.39% stance time asymmetry indicates the patient
                ↪ spends significantly less time on the right prosthesis
                ↪ .",
            "Visual assessment shows a rapid transition from right stance
                ↪  to sound-side heel strike."
            ],
            "conflicting_evidence": [
            ""
            ],
            "status": "confirmed",
            "confidence": 0.9
          }
          ],
          "synthesis_notes": "Abducted gait and decreased prosthetic
              ↪ stance time are confirmed as the primary deviations.
              ↪ While trunk sway was high, the clinician's manual assist
              ↪ makes it impossible to distinguish between a pathological
              ↪  lean and assisted stabilization. The wide base of
```

```
            ↪ support likely serves as a compensatory strategy for the
            ↪ observed instability.",
          "final_report": "The assessment identifies two primary
            ↪ deviations: Abducted Gait / Increased Stride Width and
            ↪ Decreased Prosthetic Stance Time / Short Prosthetic Step.
            ↪  The patient exhibits a significantly wide base of
            ↪ support (0.65 shoulder widths) and spends ~11% less time
            ↪ loading the right prosthesis compared to the sound side,
            ↪ indicating instability. Suggested Action: Review socket
            ↪ fit for medial wall discomfort and check the prosthetic
            ↪ limb length; evaluate the patient's balance confidence
            ↪ and consider socket adduction or linear foot position
            ↪ adjustments to normalize the base of support."
        },
        "token_usage": {
          "input_tokens": 37852,
          "output_tokens": 930,
          "thought_tokens": 0
        }
      }
    }
    ],
    "converged": true,
    "num_iterations": 1,
    "token_usage_total": {
      "input_tokens": 95239,
      "output_tokens": 2363,
      "thought_tokens": 0
    },
    "final_synthesis": "The assessment identifies two primary deviations:
      ↪  Abducted Gait / Increased Stride Width and Decreased
      ↪ Prosthetic Stance Time / Short Prosthetic Step. The patient
      ↪ exhibits a significantly wide base of support (0.65 shoulder
      ↪ widths) and spends ~11% less time loading the right prosthesis
      ↪ compared to the sound side, indicating instability. Suggested
      ↪ Action: Review socket fit for medial wall discomfort and check
      ↪ the prosthetic limb length; evaluate the patient's balance
      ↪ confidence and consider socket adduction or linear foot
      ↪ position adjustments to normalize the base of support.",
    "trace_path": "outputs/eval/progait/progait/outside/2_8_5/
      ↪ reasoning_trace.json"
  }
```


F HUMAN EVALUATION EXAMPLE

Listing 1: GAVD

```
Case 1
Video file: 1.mp4

Scoring scale: 1 = poor/incorrect, 3 = adequate/partially correct, 5 =
    ↪ excellent.
Fill in one number after each scoring prompt.

--------------------------------------------------------------------------
Report 1

Diagnostic Correctness (1-5): __
Evidence Grounding (1-5): __
Clinical Usefulness (1-5): __

Final prediction:
Hemiparetic (Hemiplegic) Gait

Final report:
```

```
The visual evidence strongly points to a right-sided hemiparetic gait.
    ↪ The concurrent presence of upper limb flexor synergy and lower limb
    ↪  circumduction clearly differentiates this from an antalgic or
    ↪ primarily biomechanical abnormality.

--------------------------------------------------------------------------
Report 2

Diagnostic Correctness (1-5): __
Evidence Grounding (1-5): __
Clinical Usefulness (1-5): __

Final prediction:
Healthy (Normal) Gait

Final report:
The subject demonstrates a baseline physiological walking pattern with
    ↪ normal symmetry and joint movement. No specific compensatory signs
    ↪ associated with pathological categories are observed, though
    ↪ clinical history remains unknown.

--------------------------------------------------------------------------
Report 3

Diagnostic Correctness (1-5): __
Evidence Grounding (1-5): __
Clinical Usefulness (1-5): __

Final prediction:
Waddling (Myopathic) Gait

Final report:
The analysis confirms a Waddling (Myopathic) Gait pattern. This
    ↪ conclusion is based on the significant, rhythmic lateral trunk sway
    ↪  (25.54$^\circ$) used to compensate for pelvic instability,
    ↪ alongside symmetrical timing and preserved knee motion. The gait is
    ↪  characteristic of bilateral proximal hip abductor weakness.
    ↪ Clinical follow-up with a physical therapist for hip girdle
    ↪ strengthening and a review of pelvic stability is recommended.

--------------------------------------------------------------------------
Overall

Best overall report (enter 1, 2, or 3): __
```

G GAIT KNOWLEDGE BASE

Listing 2: GAVD

```
[
{
  "clinical_category": "Healthy (Normal) Gait",
  "description": "A baseline physiological walking pattern without
      ↪ neuromuscular or musculoskeletal deficits.",
  "key_patterns":[
  "Smooth, rhythmic, and functionally symmetrical walking pattern.",
  "Symmetry Index (SI) < 15% for stance and step length.",
  "NO assistive devices (canes) or medical braces.",
  "Mean step width is typically narrow relative to shoulder width.",
  "Knees flex normally during swing."
  ]
},
{
  "clinical_category": "Antalgic Gait",
  "description": "A protective gait adaptation caused by weight-bearing
      ↪ pain in the lower extremity, pelvis, or spine.",
```

```
  "key_patterns": [
  "Primary Sign: Severe temporal asymmetry with a notably shortened
      ↪ stance phase on the painful leg to minimize weight-bearing time
      ↪ .",
  "Absence of Hard Neurological Signs: The knee bends normally during
      ↪ swing and there is no circumduction or foot drop.",
  "Step length asymmetry: The step length is typically shortened on the
      ↪ unaffected side (due to rushing to get weight off the painful
      ↪ limb).",
  "Postural compensation: Arm swing and trunk movement may become
      ↪ asymmetrical to aid in balance and unweight the affected side."
  ]
},
{
  "clinical_category": "Hemiparetic (Hemiplegic) Gait",
  "description": "An asymmetrical pattern caused by unilateral upper
      ↪ motor neuron damage (e.g., Stroke, CP), often involving
      ↪ compensatory mechanics and assistive devices.",
  "key_patterns": [
  "Asymmetry: Severe spatial and temporal asymmetry is a core hallmark.
      ↪ Do not automatically misattribute this to Antalgic (pain-
      ↪ avoidance) gait.",
  "Assistive Devices: Presence of a unilateral cane/crutch is a strong
      ↪ indicator of hemiparesis, especially if used on the unaffected
      ↪ side to compensate for weakness and instability on the paretic
      ↪ side.",
  "Circumduction: The affected leg swings in a lateral arc.",
  "Compensatory Trunk Sway: Lateral trunk lean is frequently used to
      ↪ assist with foot clearance or balance.",
  "Kinematic Flexibility: While the affected knee often shows reduced
      ↪ swing flexion ('stiff knee'), preserved functional flexion does
      ↪ not rule out hemiparesis if circumduction or cane usage is
      ↪ present.",
  "Upper Limb Synergy: The affected arm is held in a static, flexed
      ↪ posture or demonstrates significantly reduced swing amplitude."
  ]
},
{
  "clinical_category": "Parkinsonian (Festinating) Gait",
  "description": "A hypokinetic gait pattern typical of Parkinson's
      ↪ disease, characterized by rigidity, bradykinesia, and postural
      ↪ instability.",
  "key_patterns": [
  "Festination & Shuffling: Severely reduced body-height-normalized step
      ↪ length with a flat-foot strike. The patient takes short, rapid
      ↪ steps that involuntarily accelerate (festination) to catch a
      ↪ forward-leaning center of gravity.",
  "Stooped Posture: The trunk, hips, and knees maintain a persistently
      ↪ flexed, rigid position throughout the entire gait cycle.",
  "Upper Body Rigidity: Bilateral loss of normal arm swing and trunk
      ↪ rotation, causing the patient to move and turn as a single rigid
      ↪ unit ('en bloc' turning).",
  "Initiation Deficits: Prone to 'freezing of gait' (FOG), where the
      ↪ patient experiences a sudden, temporary inability to initiate
      ↪ stepping, especially when starting or turning."
  ]
},
{
  "clinical_category": "Waddling (Myopathic) Gait",
  "description": "A bilateral compensated gait pattern caused by proximal
      ↪  pelvic girdle and hip abductor weakness.",
  "key_patterns": [
  "Rhythmic Sway (Bilateral Trendelenburg): Pronounced lateral trunk lean
      ↪  over the stance leg, alternating side-to-side with each step to
      ↪ compensate for pelvic drop.",
  "Wide Base: Increased shoulder-width-normalized step width to improve
      ↪ lateral stability and accommodate the shifting center of mass.",
```

```
  "Symmetrical Timing: Because the weakness is bilateral, stance and
      ↪ swing times remain largely symmetrical (Stance SI < 15%).",
  "Exclusion Criteria: Cannot be diagnosed/classified if the patient uses
      ↪  a unilateral cane, as the device artificially alters the
      ↪ bilateral sway dynamics."
  ]
},
{
  "clinical_category": "Ataxic (Cerebellar) Gait",
  "description": "An uncoordinated, unsteady gait caused by cerebellar
      ↪ dysfunction, lacking normal motor control.",
  "key_patterns": [
  "Erratic Placement: High normalized step-to-step variability in both
      ↪ step width and length.",
  "Wide Base: Increased shoulder-width-normalized mean step width to
      ↪ compensate for poor balance.",
  "Titubation: Irregular, unpredictable postural sway and staggering,
      ↪ unlike the rhythmic sway of a myopathic gait."
  ]
},
{
  "clinical_category": "Neuropathic (Steppage) Gait",
  "description": "A compensatory gait caused by lower motor neuron
      ↪ weakness of the ankle dorsiflexors (foot drop).",
  "key_patterns": [
  "High Steppage: Excessive hip and knee flexion during swing (knee angle
      ↪  drops < 90 deg) to lift the dropping foot clear of the ground.",
  "Foot Slap: Loss of normal heel strike; the foot lands flat or toes-
      ↪ first, often slapping the ground due to lack of eccentric
      ↪ dorsiflexor control.",
  "Orthotic Masking: If the patient wears an AFO, the foot drop and the
      ↪ compensatory high steppage are typically both eliminated."
  ]
},
{
  "clinical_category": "Trendelenburg Gait",
  "description": "A mechanically driven gait caused by unilateral
      ↪ weakness of the hip abductors (primarily gluteus medius).",
  "key_patterns": [
  "Uncompensated (Pelvic Drop): The pelvis drops significantly on the
      ↪ swing side when weight is borne on the weak stance leg.",
  "Compensated (Trunk Lean): The patient leans their trunk laterally over
      ↪  the weak stance leg to shift the center of mass and maintain
      ↪ balance.",
  "Differential: Driven entirely by biomechanical weakness, lacking the
      ↪ temporal asymmetry (rushed step) seen in pain-avoidance (Antalgic
      ↪ ) gaits."
  ]
},
{
  "clinical_category": "Spastic Diplegic (Scissors) Gait",
  "description": "A bilateral upper motor neuron pattern common in
      ↪ Cerebral Palsy, dominated by lower extremity hypertonia.",
  "key_patterns": [
  "Scissoring: Hip adductor spasticity causes a extremely narrow or
      ↪ negative step width, where the knees and feet cross the midline
      ↪ .",
  "Bilateral Stiff Knees: Extensor spasticity restricts normal knee
      ↪ flexion during swing.",
  "Equinus: Calf spasticity forces bilateral toe-walking and lack of heel
      ↪  strike."
  ]
},
{
  "clinical_category": "Sensory Ataxic (Stomping) Gait",
  "description": "An uncoordinated gait caused by a loss of
      ↪ proprioception (e.g., peripheral neuropathy, posterior column
      ↪ lesions).",
```

```
  "key_patterns": [
  "Stomping Impact: The patient strikes the ground heavily (foot slap/
      ↪ stomp) to maximize residual sensory feedback.",
  "Visual Dependence: The unsteadiness and erratic placement worsen
      ↪ dramatically in the dark or when the patient closes their eyes (
      ↪ positive Romberg sign equivalent).",
  "High Lift: Often accompanied by an exaggerated lifting of the legs due
      ↪  to uncertainty of spatial positioning."
  ]
},
{
  "clinical_category": "Crouch Gait",
  "description": "A pathological gait pattern common in spastic Cerebral
      ↪ Palsy, defined by excessive flexion across lower limb joints.",
  "key_patterns": [
  "Persistent Flexion: The hips and knees never fully extend during the
      ↪ stance phase (maximum knee angle remains < 160 deg).",
  "Excessive Ankle Dorsiflexion: Unlike jump gait, crouch gait is
      ↪ typically accompanied by excessive ankle dorsiflexion (calcaneus
      ↪ posture) during stance.",
  "Symmetry: Typically presents bilaterally and symmetrically.",
  "Energy Cost: Highly inefficient, leading to rapid fatigue due to
      ↪ continuous quadriceps activation required to prevent collapsing."
  ]
}
]
```

Listing 3: ProGait

```
[
{
  "deviation": "Pelvic Drop",
  "general_category": {
    "code": 5,
    "name": "Prosthetic Length Issues"
  },
  "annotation_aliases": [
  "Hip drop",
  "Prosthesis too short",
  "Stepping into a hole"
  ],
  "pattern": "The pelvis on the prosthetic side drops on initial contact
      ↪ as if 'stepping into a hole'.",
  "causes": {
    "patient_related": [
    "Contralateral hip abductor weakness"
    ],
    "prosthetic_related": [
    "Prosthetic limb too short",
    "Residual limb has shrunk relative to the socket",
    "Excessively compliant heel cushion or prosthetic heel keel"
    ]
  }
},
{
  "deviation": "Circumduction",
  "general_category": {
    "code": 6,
    "name": "Roll-Over and Clearance Issues"
  },
  "annotation_aliases": [
  "Circumduction gait",
  "Insufficient toe clearance",
  "Lateral arc during swing"
  ],
  "pattern": "The prosthetic limb travels in a lateral arch during the
      ↪ swing phase.",
```

```
  "causes": {
    "patient_related": [
    "Inability to adequately flex the knee on the prosthetic side",
    "Abduction contracture",
    "Weak hip flexors",
    "Lack of confidence in flexing the knee",
    "Habit gait pattern or using entire hip/pelvis to initiate gait",
    "Residual limb volume increase"
    ],
    "prosthetic_related": [
    "Prosthesis is physically or functionally too long",
    "Poorly suspended prosthesis",
    "Excessive knee friction",
    "Posterior TKA (Trochanter-Knee-Ankle) alignment"
    ]
  },
  "recommended_actions": [
  "Check socket fit",
  "Shorten prosthesis",
  "Externally rotate the prosthetic knee by adjusting the component
      ↪ inferior to the socket.",
  "Shorten the prosthesis to match the contralateral limb length and
      ↪ level the pelvis.",
  "Shorten the prosthesis to match the sound limb length and level the
      ↪ pelvis.",
  "Adjust prosthetic height"
  ]
},
{
  "deviation": "Hip Hike",
  "general_category": {
    "code": 6,
    "name": "Roll-Over and Clearance Issues"
  },
  "annotation_aliases": [
  "Hip hiking",
  "Clearance compensation"
  ],
  "pattern": "The ipsilateral hip rises during the prosthetic swing phase
      ↪  to clear the foot.",
  "causes": {
    "patient_related": [
    "Inability to adequately flex the knee on the prosthetic side",
    "Habit gait pattern",
    "Residual limb volume increase"
    ],
    "prosthetic_related": [
    "Prosthetic limb too long",
    "Poorly suspended prosthesis"
    ]
  }
},
{
  "deviation": "Vaulting",
  "general_category": {
    "code": 5,
    "name": "Prosthetic Length Issues"
  },
  "annotation_aliases": [
  "Prosthesis too long",
  "Vaulting gait due to an excessively long prosthesis",
  "Sound-side vaulting",
  "Vaulting gait due to excessive prosthetic length.",
  "Vaulting gait due to an excessively long prosthesis.",
  "Vaulting, secondary to excessive prosthetic length."
  ],
```

```
  "pattern": "Ankle plantar flexion and knee extension of the
      ↪ contralateral (sound) limb during the mid-stance phase to assist
      ↪ with prosthetic toe clearance.",
  "causes": {
    "patient_related": [
    "Gait habit or fear of catching the toe",
    "Improper initiation of hip flexors on residual limb",
    "Weak hip flexors on the residual limb"
    ],
    "prosthetic_related": [
    "Prosthetic limb too long (anatomic or functional)",
    "Poor suspension",
    "Excessive knee friction",
    "Posterior TKA alignment"
    ]
  },
  "recommended_actions": [
  "Shorten the prosthesis to match the contralateral limb length and
      ↪ ensure a level pelvis.",
  "Reduce the length of the prosthesis to match the contralateral limb
      ↪ and ensure a level pelvis.",
  "Reduce the prosthetic length to match the contralateral side, thereby
      ↪ leveling the pelvis.",
  "Reduce prosthetic length to match the contralateral limb and achieve a
      ↪  level pelvis."
  ]
},
{
  "deviation": "Abducted Gait / Increased Stride Width",
  "general_category": {
    "code": 2,
    "name": "Step and Base of Support Deviations"
  },
  "annotation_aliases": [
  "Abducted gait",
  "Too wide base of support",
  "Excessively wide base of support",
  "Wide step width",
  "Abducted gait resulting in an excessively wide base of support.",
  "Abducted gait, resulting in an excessively wide base of support.",
  "Abducted gait, characterized by an excessively wide base of support.",
  "The patient presents with an abducted gait, resulting in an
      ↪ excessively wide base of support.",
  "Excessively wide base of support, potentially due to excessive socket
      ↪ adduction.",
  "Wide base of support"
  ],
  "pattern": "The prosthetic limb is carried in an abducted position with
      ↪  a widened base of support throughout the swing and stance phase
      ↪ .",
  "causes": {
    "patient_related": [
    "Adaptation for medial compartment knee pain or residual limb pain",
    "Balance impairment, insecurity, or fear of falling",
    "Hip abduction contracture",
    "Weak hip flexors, abductors, or adductors"
    ],
    "prosthetic_related": [
    "Outset prosthetic foot",
    "Prosthesis physically or functionally too long",
    "Medial socket wall too high",
    "Lateral wall insufficient to stabilize the femur (loss of lateral
        ↪ containment)",
    "Excessive knee friction",
    "Excessive plantarflexion"
    ]
  },
  "recommended_actions": [
```

```
    "Adjust the socket into adduction by loosening the lateral set screw
        ↪ and tightening the medial set screw inferior to the socket.",
    "Adjust the socket into adduction by loosening the lateral set screw
        ↪ and tightening the medial set screw.",
    "Check socket fit and prosthesis length.",
    "Correct the prosthetic length",
    "Shift the socket laterally",
    "Perform socket abduction by loosening the lateral set screw and
        ↪ tightening the medial set screw."
    ]
},
{
    "deviation": "Toe Drag / Reduced Toe Clearance",
    "general_category": {
      "code": 6,
      "name": "Roll-Over and Clearance Issues"
    },
    "annotation_aliases": [
    "Insufficient toe clearance",
    "Toe drag",
    "Reduced toe clearance"
    ],
    "pattern": "The prosthetic toe drags or catches on the ground during
        ↪ the swing phase.",
    "causes": {
      "patient_related": [
      "Muscle weakness of the hip and/or knee flexors",
      "Fatigue",
      "Weak hip extensors",
      "Hip flexion contracture",
      "Toe lever load to unlock the knee does not occur"
      ],
      "prosthetic_related": [
      "Prosthetic limb too long",
      "Excessive plantar flexion of the prosthetic foot",
      "Inadequate suspension or pistoning",
      "Residual limb not fully seated in the socket",
      "Excessive knee friction",
      "Posterior TKA alignment"
      ]
    },
    "recommended_actions": [
    "Reduce swing flexion resistance"
    ]
},
{
    "deviation": "Drop Off (Premature Heel Rise)",
    "general_category": {
      "code": 6,
      "name": "Roll-Over and Clearance Issues"
    },
    "annotation_aliases": [
    "Drop off",
    "Premature heel rise",
    "Incomplete roll-over"
    ],
    "pattern": "Premature heel rise at the end of the stance phase, causing
        ↪  a quick 'drop off' onto the contralateral foot.",
    "causes": {
      "patient_related": [
      "Hip flexion contracture",
      "Knee flexion contracture",
      "Knee extensor weakness",
      "Hip extensor weakness"
      ],
      "prosthetic_related": [
      "Foot is too posterior (short toe lever arm)",
      "Foot keel is too soft",
```

```
    "Excessive dorsiflexion of the foot",
    "Excessive socket flexion"
    ]
  }
},
{
  "deviation": "Foot Slap",
  "general_category": {
    "code": 3,
    "name": "Step Length and Timing Issues"
  },
  "annotation_aliases": [
  "Early foot flat",
  "Foot slap"
  ],
  "pattern": "Rapid, uncontrolled plantarflexion of the foot immediately
     ↪ after initial heel contact.",
  "causes": {
    "patient_related": [
    "Poor eccentric dorsiflexion control (if observed on the intact lower
       ↪  limb)"
    ],
    "prosthetic_related": [
    "Posterior (plantar flexion) bumper is too soft",
    "Insufficient dampening of plantar flexion in a hydraulic ankle"
    ]
  }
},
{
  "deviation": "Inadequate Heel Off",
  "general_category": {
    "code": 6,
    "name": "Roll-Over and Clearance Issues"
  },
  "annotation_aliases": [
  "Incomplete roll-over",
  "Insufficient heel off",
  "Delayed roll-over"
  ],
  "pattern": "Insufficient heel rise at the end of the stance phase.",
  "causes": {
    "patient_related": [
    "Reduced confidence in putting weight through the toe of the
       ↪ prosthesis"
    ],
    "prosthetic_related": [
    "Foot is too anterior (long toe lever arm)",
    "Foot keel is too stiff"
    ]
  }
},
{
  "deviation": "Decreased Prosthetic Stance Time / Short Prosthetic Step
     ↪ ",
  "general_category": {
    "code": 3,
    "name": "Step Length and Timing Issues"
  },
  "annotation_aliases": [
  "Short prosthetic step",
  "Reduced prosthetic stance time"
  ],
  "pattern": "The total duration of the stance phase on the prosthetic
     ↪ limb is reduced, resulting in a short, quick step with the
     ↪ contralateral foot.",
  "causes": {
    "patient_related": [
    "Residual limb pain or discomfort",
```

```
    "Patient insecurity or poor balance",
    "Weak hip muscles",
    "Musculoskeletal pain in proximal structures"
    ],
    "prosthetic_related": [
    "Poorly fitting prosthetic socket",
    "Prosthetic foot alignment issues (e.g., toe lever too short)",
    "Unstable knee",
    "Excess socket flexion or ankle dorsiflexion",
    "Poor suspension"
    ]
  }
},
{
  "deviation": "Uneven Timing / Long Prosthetic Step",
  "general_category": {
    "code": 3,
    "name": "Step Length and Timing Issues"
  },
  "annotation_aliases": [
  "Asymmetric step length",
  "Uneven step length",
  "Long prosthetic step",
  "Uneven timing"
  ],
  "pattern": "Hesitation in gait timing from prosthetic mid-stance to
      ↪ sound side heel strike, causing the sound limb to take an
      ↪ unusually long step.",
  "causes": {
    "patient_related": [
    "Hip flexion contracture",
    "Pain on the sound limb side"
    ],
    "prosthetic_related": [
    "Excessive ankle plantarflexion",
    "Insufficient socket flexion",
    "Long or excessively stiff toe lever"
    ]
  }
},
{
  "deviation": "Knee Instability (Excessive Knee Flexion)",
  "general_category": {
    "code": 4,
    "name": "Knee Instability and Malalignment"
  },
  "annotation_aliases": [
  "Knee instability",
  "Excessive knee flexion",
  "Buckling"
  ],
  "pattern": "Excessive knee flexion on the prosthetic side in early
      ↪ stance; the knee tends to buckle, and the patient feels like they
      ↪  are 'walking downhill'.",
  "causes": {
    "patient_related": [
    "Knee flexion contracture",
    "Quadriceps weakness",
    "Weak hip extensors",
    "Short residual limb causing excessive play"
    ],
    "prosthetic_related": [
    "Excessive foot dorsiflexion",
    "Excessive socket flexion (forward tilt on pylon)",
    "Posterior translation of the foot/pylon (heel lever too long)",
    "Excessively hard heel cushion or prosthetic heel",
    "Knee axis of rotation is too anterior"
    ]
```

```
  }
},
{
  "deviation": "Knee Too Extended",
  "general_category": {
    "code": 4,
    "name": "Knee Instability and Malalignment"
  },
  "annotation_aliases": [
  "Hyperextended knee",
  "Knee hyperextension",
  "Knee too extended"
  ],
  "pattern": "Excessive knee extension during the stance phase; the
      ↪ patient feels like they are 'walking uphill'.",
  "causes": {
    "patient_related": [
    "Inadequate knee flexion range of motion or knee extension
        ↪ contracture",
    "Compensation for quadriceps weakness",
    "Compensation for hip flexion contracture"
    ],
    "prosthetic_related": [
    "Excessively compliant prosthetic heel cushion or forefoot keel too
        ↪ rigid",
    "Inadequate socket flexion",
    "Excessive plantar flexion of the prosthetic foot",
    "Anterior translation of the prosthetic foot/pylon (excess toe lever)
        ↪ "
    ]
  },
  "recommended_actions": [
  "Flex the socket",
  "Decrease ankle plantarflexion"
  ]
},
{
  "deviation": "Excessive Valgus Moment at the Knee",
  "general_category": {
    "code": 4,
    "name": "Knee Instability and Malalignment"
  },
  "annotation_aliases": [
  "Excessive valgus",
  "Knee valgus asymmetry",
  "Medial thrust",
  "Excessive knee valgus, potentially causing a medial whip at higher
      ↪ gait speeds."
  ],
  "pattern": "A medial thrust of the proximal socket is observed during
      ↪ the mid-stance phase.",
  "causes": {
    "patient_related": [
    "Short residual limb causing poor stabilization of the prosthetic
        ↪ socket",
    "Ligamentous instability"
    ],
    "prosthetic_related": [
    "Excessive lateral translation of the prosthetic pylon/foot",
    "Excessive valgus angulation at the prosthetic socket pylon junction
        ↪ ",
    "Socket too loose"
    ]
  },
  "recommended_actions": [
  "Reduce the knee valgus angle."
  ]
},
```

```
{
  "deviation": "Excessive Varus Moment / Lateral Shift",
  "general_category": {
    "code": 4,
    "name": "Knee Instability and Malalignment"
  },
  "annotation_aliases": [
  "Knee varus asymmetry",
  "Knee varus",
  "Varus deformity",
  "Lateral thrust"
  ],
  "pattern": "A lateral thrust of the proximal socket occurs in mid-
     ↪ stance phase.",
  "causes": {
    "patient_related": [
    "Inadequate balance",
    "Weak hip abductors",
    "Narrow gait base"
    ],
    "prosthetic_related": [
    "Excessive inset of the prosthetic foot",
    "Excessive abduction of the socket (brim tilted medially)",
    "Socket too loose",
    "Loss of frontal plane containment",
    "Short prosthesis"
    ]
  }
},
{
  "deviation": "Lateral Trunk Lean",
  "general_category": {
    "code": 7,
    "name": "Socket Fit and Stability"
  },
  "annotation_aliases": [
  "Lateral instability",
  "Compensated Trendelenburg",
  "Trunk lean"
  ],
  "pattern": "The trunk bends laterally over the prosthesis (compensated
     ↪ Trendelenburg) during the prosthetic stance phase.",
  "causes": {
    "patient_related": [
    "Weak hip abductors",
    "Pain at the distal lateral residual limb",
    "Gait habit or inadequate balance",
    "Short residual limb",
    "Abduction contracture"
    ],
    "prosthetic_related": [
    "Inadequate adduction of the socket",
    "Prosthesis too short",
    "Outset foot",
    "Medial wall too high causing pain",
    "Ineffective lateral socket containment"
    ]
  }
},
{
  "deviation": "Trunk Lordosis",
  "general_category": {
    "code": 7,
    "name": "Socket Fit and Stability"
  },
  "annotation_aliases": [
  "Socket fit issue",
  "Lumbar lordosis"
```

```
  ],
  "pattern": "Increased lumbar arch (hyperlordosis) observed during the
      ↪ stance phase.",
  "causes": {
    "patient_related": [
    "Compensation for tight hip flexors",
    "Weak hip extensors",
    "Weak abdominal/core muscles",
    "Gait habit"
    ],
    "prosthetic_related": [
    "Insufficient socket flexion",
    "Posterior wall promotes anterior pelvic tilt"
    ]
  }
},
{
  "deviation": "Forward Trunk Lean",
  "general_category": {
    "code": 7,
    "name": "Socket Fit and Stability"
  },
  "annotation_aliases": [
  "Forward trunk lean",
  "Stability compensation"
  ],
  "pattern": "The trunk leans forward significantly during the stance
      ↪ phase.",
  "causes": {
    "patient_related": [
    "Hip flexion contracture",
    "Lumbar pain aggravated by lumbar extension",
    "Compensation to prevent knee instability"
    ],
    "prosthetic_related": [
    "Knee is in an unstable alignment",
    "Stance control mechanism of the knee is insufficient"
    ]
  }
},
{
  "deviation": "External Rotation of Foot on Initial Contact",
  "general_category": {
    "code": 1,
    "name": "Rotational Deviations"
  },
  "annotation_aliases": [
  "Toe-out asymmetry",
  "Externally rotated foot",
  "External foot rotation"
  ],
  "pattern": "The prosthetic foot externally rotates immediately upon
      ↪ heel strike.",
  "causes": {
    "patient_related": [
    "Poor residual limb muscle control (decreased stability)",
    "Prosthesis improperly donned in external rotation"
    ],
    "prosthetic_related": [
    "Heel cushion or plantar-flexion bumper is too stiff",
    "Too much toe-out alignment built into the prosthesis"
    ]
  }
},
{
  "deviation": "Medial Whip",
  "general_category": {
    "code": 1,
```

```
    "name": "Rotational Deviations"
  },
  "annotation_aliases": [
  "Medial whip",
  "Externally rotated knee",
  "Externally rotated prosthetic knee"
  ],
  "pattern": "Abrupt medial movement of the prosthetic heel during the
      ↪ swing phase.",
  "causes": {
    "patient_related": [
    "Socket donned in external rotation",
    "Gait habit (external rotation of the hip at toe-off)",
    "Insufficient muscular activation"
    ],
    "prosthetic_related": [
    "External rotation of the knee, shank, or foot",
    "Socket too tight"
    ]
  },
  "recommended_actions": [
  "Internally rotate the prosthetic knee. Unscrew the component under the
      ↪  socket and rotate the knee.",
  "Internally rotate the prosthetic knee by adjusting the component
      ↪ inferior to the socket.",
  "Rotate the prosthetic knee internally relative to the socket and foot
      ↪ ",
  "Internally rotate the prosthetic knee by adjusting the component
      ↪ alignment under the socket.",
  "Internally rotate the prosthetic knee by adjusting the componentry
      ↪ inferior to the socket.",
  "Internally rotate the prosthetic knee by adjusting the rotational
      ↪ component located inferior to the socket."
  ]
},
{
  "deviation": "Lateral Whip",
  "general_category": {
    "code": 1,
    "name": "Rotational Deviations"
  },
  "annotation_aliases": [
  "Lateral whip",
  "Internally rotated knee",
  "Internally rotated prosthetic knee"
  ],
  "pattern": "Abrupt lateral movement of the prosthetic heel during the
      ↪ swing phase.",
  "causes": {
    "patient_related": [
    "Socket donned in internal rotation",
    "Gait habit (internal rotation of the hip at toe-off)"
    ],
    "prosthetic_related": [
    "Internal rotation of the knee, shank, or foot"
    ]
  },
  "recommended_actions": [
  "Externally rotate the prosthetic knee. Unscrew the component under the
      ↪  socket and rotate the knee.",
  "Externally rotate the prosthetic knee component.",
  "Externally rotate the prosthetic knee by loosening the proximal
      ↪ component adapter and rotating the knee unit.",
  "Externally rotate the prosthetic knee by adjusting the component under
      ↪  the socket.",
  "Externally rotate the prosthetic knee by adjusting the component
      ↪ inferior to the socket."
  ]
```

```
},
{
  "deviation": "Excessive Terminal Impact",
  "general_category": {
    "code": 3,
    "name": "Step Length and Timing Issues"
  },
  "annotation_aliases": [
  "Terminal impact",
  "Knee slam",
  "Terminal knee impact",
  "Hard terminal impact after swing extension"
  ],
  "pattern": "The prosthetic knee vigorously extends in terminal swing,
     ↪ causing the foot to visibly or audibly 'slam' into full extension
     ↪ .",
  "causes": {
    "patient_related": [
    "Vigorous hip flexion followed by strong hip extension",
    "Compensatory mechanism because the patient wants to feel the knee
       ↪ fully extend before loading weight"
    ],
    "prosthetic_related": [
    "Insufficient swing control/friction mechanism of the prosthetic knee
       ↪ ",
    "Excessive extension assist mechanism"
    ]
  },
  "recommended_actions": [
  "Reduce knee extension assist",
  "Increase knee extension resistance",
  "Reduce swing flexion resistance or decrease extension assist tension",
  "Reduce swing flexion resistance",
  "Reduce knee flexion resistance",
  "Reduce the knee extension assist or increase the knee extension
     ↪ resistance."
  ]
},
{
  "deviation": "Increased Knee Flexion (Excessive Heel Rise)",
  "general_category": {
    "code": 4,
    "name": "Knee Instability and Malalignment"
  },
  "annotation_aliases": [
  "Excessive knee flexion",
  "Excessive heel rise"
  ],
  "pattern": "The heel of the prosthesis rises much higher than the sound
     ↪  foot during pre-swing/toe-off.",
  "causes": {
    "patient_related": [
    "Excessive use of strong hip flexors to initiate swing phase,
       ↪ overpowering the knee unit",
    "Hip flexion contracture"
    ],
    "prosthetic_related": [
    "Insufficient stance control mechanism or knee friction",
    "Improper knee selection"
    ]
  }
},
{
  "deviation": "Inadequate Knee Flexion in Pre-Swing",
  "general_category": {
    "code": 4,
    "name": "Knee Instability and Malalignment"
  },
```

```
  "annotation_aliases": [
  "Insufficient knee flexion",
  "Inadequate knee flexion",
  "Stiff knee in pre-swing",
  "Insufficient swing phase flexion",
  "Insufficient swing flexion",
  "Persistent insufficient swing phase knee flexion."
  ],
  "pattern": "The prosthetic knee does not properly transition to swing
     ↪ phase, remaining too stiff at toe-off.",
  "causes": {
    "patient_related": [
    "Lack of confidence or training in the gait pattern needed to signal
       ↪ the prosthetic knee to switch from stance to swing",
    "Insufficient loading of the toe at the end of stance phase"
    ],
    "prosthetic_related": [
    "Excessive stability of the prosthetic knee"
    ]
  },
  "recommended_actions": [
  "Increase socket flexion, increase plantarflexion of the prosthetic
     ↪ foot, and/or reduce the flexion resistance in the prosthetic knee
     ↪  joint.",
  "Reduce knee flexion resistance by loosening the spring compression in
     ↪ the extension assist mechanism.",
  "Flex the socket and translate it anteriorly",
  "Lower the swing activation threshold of the prosthetic knee, ideally
     ↪ after addressing insufficient prosthesis length and socket
     ↪ flexion.",
  "reduce stance flexion resistance",
  "Reduce the friction resistance of the knee joint."
  ]
},
{
  "deviation": "Toe-In Asymmetry / Internally Rotated Foot",
  "general_category": {
    "code": 1,
    "name": "Rotational Deviations"
  },
  "annotation_aliases": [
  "Toe-in asymmetry",
  "Excessive toe-in",
  "Internally rotated foot",
  "Internal foot rotation",
  "Internally rotated prosthetic foot",
  "Internal rotation of the foot",
  "Excessive internal rotation of the prosthetic foot",
  "Excessive toe-in of the prosthetic foot",
  "Excessive toe-in alignment.",
  "Excessive toe-in.",
  "Too much toe-in",
  "Slight toe-in",
  "Too much toe-in coupled with slight inversion or supination"
  ],
  "pattern": "The prosthetic foot progresses with excessive toe-in or
     ↪ internal rotation relative to the sound side during stance or
     ↪ swing.",
  "causes": {
    "patient_related": [
    "Habitual internal hip rotation",
    "Prosthesis donned in internal rotation"
    ],
    "prosthetic_related": [
    "Too much toe-in alignment built into the foot, shank, knee, or
       ↪ socket",
    "Internal rotation of prosthetic components"
    ]
```

```
  },
  "recommended_actions": [
  "Externally rotate the prosthetic foot relative to the knee.",
  "Rotate the foot externally relative to the knee.",
  "Adjust the prosthesis to achieve an appropriate degree of toe-out.",
  "Externally rotate the prosthetic foot by loosening the tube clamp and
     ↪ adjusting its rotational position.",
  "Externally rotate the foot to match the contralateral limb's toe-out
     ↪ angle by loosening the tube clamp.",
  "Loosen the tube clamp and rotate the prosthetic foot externally to
     ↪ match the toe-out angle of the contralateral limb."
  ]
},
{
  "deviation": "Toe-Out Asymmetry / Externally Rotated Foot",
  "general_category": {
    "code": 1,
    "name": "Rotational Deviations"
  },
  "annotation_aliases": [
  "Toe-out asymmetry",
  "Excessive toe-out",
  "Externally rotated foot",
  "External foot rotation",
  "asymmetric toe-out",
  "Asymmetrical toe-out",
  "Toe-out",
  "Excessive toe-out."
  ],
  "pattern": "The prosthetic foot progresses with excessive toe-out or
     ↪ external rotation relative to the sound side during stance or
     ↪ swing.",
  "causes": {
    "patient_related": [
    "Habitual external hip rotation",
    "Prosthesis donned in external rotation"
    ],
    "prosthetic_related": [
    "Too much toe-out alignment built into the foot, shank, knee, or
       ↪ socket",
    "External rotation of prosthetic components"
    ]
  },
  "recommended_actions": [
  "Rotate prosthetic foot outward by 10-15 degrees",
  "rotate prosthetic foot outward by 10 deg",
  "Rotate the socket externally above the knee",
  "rotate foot outward underneath knee",
  "Externally rotate the prosthetic foot",
  "Correct the alignment by loosening the tube clamp and rotating the
     ↪ foot internally to match the toe-out angle of the sound side."
  ]
},
{
  "deviation": "Too Narrow Base of Support",
  "general_category": {
    "code": 2,
    "name": "Step and Base of Support Deviations"
  },
  "annotation_aliases": [
  "Too narrow base of support",
  "Base of support is too narrow",
  "Too narrow step width",
  "Excessively narrow base of support",
  "The base of support is too narrow.",
  "Excessively narrow step width",
  "Insufficient base of support width",
  "Insufficient base of support",
```

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  "Narrow base of support",
  "Excessively narrow base of support."
  ],
  "pattern": "The prosthetic and sound feet are placed too close to the
      ↪ walking midline, narrowing the base of support and risking
      ↪ contact between limbs.",
  "causes": {
    "patient_related": [
    "Habitual narrow walking base",
    "Balance strategy that places the prosthesis too close to midline"
    ],
    "prosthetic_related": [
    "Excessive inset or adduction alignment",
    "Socket or knee alignment that drives the prosthesis toward midline"
    ]
  },
  "recommended_actions": [
  "Increase knee valgus",
  "Adduct the socket by loosening the medial set screw and tightening the
      ↪  lateral set screw inferior to the socket.",
  "Increase knee valgus or shift the socket medially.",
  "Shift socket medially",
  "Adduct the prosthetic socket by loosening the medial set screw and
      ↪ tightening the lateral set screw. An alternative action is to
      ↪ perform a linear outset adjustment of the prosthetic foot.",
  "Adduct the socket. This is accomplished by loosening the medial set
      ↪ screw and tightening the lateral set screw inferior to the socket
      ↪ ."
  ]
},
{
  "deviation": "Leaning Pylon / Pylon Lean",
  "general_category": {
    "code": 2,
    "name": "Step and Base of Support Deviations"
  },
  "annotation_aliases": [
  "Leaning pylon",
  "Pylon lean",
  "Pylon alignment lean",
  "Leg axis misalignment, indicated by a leaning pylon.",
  "Leaning pylon persists."
  ],
  "pattern": "The prosthetic pylon visibly leans in the frontal plane
      ↪ during stance or progression, changing base width and cosmetic
      ↪ alignment.",
  "causes": {
    "patient_related": [
    "Balance compensation or habitual loading pattern"
    ],
    "prosthetic_related": [
    "Socket/pylon translation or angular alignment error",
    "Foot inset/outset mismatch"
    ]
  },
  "recommended_actions": [
  "Reduce knee valgus and/or translate the socket laterally.",
  "Further reduce knee valgus."
  ]
},
{
  "deviation": "Asymmetric Step Length",
  "general_category": {
    "code": 3,
    "name": "Step Length and Timing Issues"
  },
  "annotation_aliases": [
  "Uneven step length",
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  "Asymmetric step length",
  "Sound limb step shorter than prosthetic limb step",
  "Prosthetic step length is excessive",
  "The prosthetic foot is positioned too far anteriorly, leading to
     ↪ unequal step lengths."
  ],
  "pattern": "The prosthetic and sound side step lengths are visibly
     ↪ asymmetric outside of normal variation.",
  "causes": {
    "patient_related": [
    "Insufficient hip extension reserve",
    "Pain, weakness, or confidence limitations"
    ],
    "prosthetic_related": [
    "Socket flexion or foot alignment limits smooth progression over the
       ↪ prosthesis"
    ]
  },
  "recommended_actions": [
  "Increase socket flexion",
  "Translate the socket anteriorly",
  "Flex and shift the socket",
  "Flex the socket",
  "Decrease plantarflexion",
  "Translate the foot posteriorly via a linear adjustment."
  ]
},
{
  "deviation": "Early Foot Flat",
  "general_category": {
    "code": 3,
    "name": "Step Length and Timing Issues"
  },
  "annotation_aliases": [
  "Early foot flat",
  "Rapid foot flat"
  ],
  "pattern": "The prosthetic foot reaches foot-flat too early after
     ↪ initial contact.",
  "causes": {
    "patient_related": [
    "Cautious loading pattern"
    ],
    "prosthetic_related": [
    "Heel bumper or hydraulic plantarflexion resistance too soft",
    "Excessive plantarflexion alignment"
    ]
  },
  "recommended_actions": [
  "Reduce plantarflexion"
  ]
},
{
  "deviation": "Knee Varus Asymmetry",
  "general_category": {
    "code": 4,
    "name": "Knee Instability and Malalignment"
  },
  "annotation_aliases": [
  "Knee varus",
  "Varus deformity",
  "Knee varus asymmetry",
  "Reduce knee varus"
  ],
  "pattern": "The prosthetic knee or socket-pylon alignment presents
     ↪ excessive varus or bow-legged frontal-plane asymmetry.",
  "causes": {
    "patient_related": [
```

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    "Habitual narrow base or frontal-plane balance strategy"
    ],
    "prosthetic_related": [
    "Excessive varus alignment of knee/socket/pylon",
    "Socket/pylon shift used incorrectly to alter step width"
    ]
  },
  "recommended_actions": [
  "Reduce knee varus",
  "reduce varus angle",
  "Reduce the varus moment at the knee by shifting the socket laterally
     ↪ .",
  "Reduce knee varus by shifting the socket laterally."
  ]
},
{
  "deviation": "Externally Rotated Knee",
  "general_category": {
    "code": 4,
    "name": "Knee Instability and Malalignment"
  },
  "annotation_aliases": [
  "Externally rotated knee",
  "Knee externally rotated",
  "Rotate knee inward",
  "Excessive external rotation of the prosthetic knee.",
  "Prosthetic knee is excessively externally rotated."
  ],
  "pattern": "The prosthetic knee axis is externally rotated relative to
     ↪ the foot/ankle progression axis.",
  "causes": {
    "patient_related": [
    "Prosthesis donned in external rotation",
    "Habitual external rotation at toe-off"
    ],
    "prosthetic_related": [
    "External rotation of the prosthetic knee, shank, socket, or foot"
    ]
  },
  "recommended_actions": [
  "Internally rotate the prosthetic knee component."
  ]
},
{
  "deviation": "Prosthesis Too Short",
  "general_category": {
    "code": 5,
    "name": "Prosthetic Length Issues"
  },
  "annotation_aliases": [
  "Prosthesis is too short",
  "Prosthesis too short",
  "Leg length discrepancy",
  "Stepping into a hole",
  "Prosthesis is too short.",
  "Prosthesis is excessively short.",
  "Prosthetic side is too short.",
  "Prosthetic side is too short, causing a leg length discrepancy.",
  "Prosthesis is too short, creating a leg length discrepancy.",
  "Prosthesis is too short, resulting in a leg length discrepancy.",
  "Prosthesis is too short relative to the contralateral limb.",
  "Prosthetic limb is too short.",
  "Insufficient prosthetic length"
  ],
  "pattern": "The prosthetic limb is physically or functionally short,
     ↪ often producing pelvic drop, lateral trunk compensation, or a
     ↪ feeling of stepping into a hole.",
  "causes": {
```

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    "patient_related": [
    "Residual limb volume loss or incomplete seating changes effective
       ↪ length"
    ],
    "prosthetic_related": [
    "Prosthetic height set too low",
    "Socket fit or suspension reduces effective limb length"
    ]
  },
  "recommended_actions": [
  "Elongate the prosthesis to match the contralateral limb length and
     ↪ ensure a level pelvis.",
  "Lengthen the prosthesis to match the contralateral limb length and
     ↪ ensure a level pelvis.",
  "Extend shank pylon by 5 mm",
  "Lengthen the prosthetic shank by 5-10 mm",
  "Increase the overall length of the prosthesis to match the
     ↪ contralateral limb, thereby leveling the pelvis.",
  "Elongate the prosthesis to match the length of the contralateral limb,
     ↪  ensuring the pelvis is level."
  ]
},
{
  "deviation": "Prosthesis Too Long",
  "general_category": {
    "code": 5,
    "name": "Prosthetic Length Issues"
  },
  "annotation_aliases": [
  "Prosthesis is excessively long",
  "Prosthesis too long",
  "Excessively long prosthesis",
  "Shorten the prosthesis",
  "Prosthesis is excessively long.",
  "Excessive prosthetic length.",
  "Excessive prosthetic length causing slight circumduction."
  ],
  "pattern": "The prosthetic limb is physically or functionally long,
     ↪ forcing clearance compensations such as vaulting, circumduction,
     ↪ hip hike, or toe drag.",
  "causes": {
    "patient_related": [
    "Incomplete seating or suspension issues that make the prosthesis
       ↪ functionally long"
    ],
    "prosthetic_related": [
    "Prosthetic height set too high",
    "Excessive plantarflexion or stiff knee behavior increasing
       ↪ functional length"
    ]
  },
  "recommended_actions": [
  "Shorten the prosthesis to match the contralateral limb length and
     ↪ ensure a level pelvis.",
  "Shorten the shank segment by 5-10 mm.",
  "Shorten the prosthesis to match the height of the contralateral limb,
     ↪ thereby leveling the pelvis.",
  "Reduce the prosthetic length to match the contralateral limb and
     ↪ achieve a level pelvis.",
  "Reduce the length of the prosthesis to match the contralateral limb
     ↪ and achieve a level pelvis.",
  "Reduce the prosthesis length to match the contralateral limb and
     ↪ ensure a level pelvis."
  ]
},
{
  "deviation": "Incomplete Roll-Over",
  "general_category": {
```

```
    "code": 6,
    "name": "Roll-Over and Clearance Issues"
  },
  "annotation_aliases": [
  "Incomplete roll-over",
  "Incomplete rollover",
  "Insufficient roll-over",
  "Lack of confidence loading the prosthesis in late stance",
  "Disrupted swing initiation"
  ],
  "pattern": "Weight transfer over the prosthetic foot is incomplete or
      ↪ hesitant in late stance, disrupting smooth progression to pre-
      ↪ swing.",
  "causes": {
    "patient_related": [
    "Reduced confidence loading the prosthesis late in stance",
    "Habitual avoidance of toe loading"
    ],
    "prosthetic_related": [
    "Socket flexion/translation or foot alignment limits smooth roll-over
        ↪ ",
    "Toe lever too long or too stiff"
    ]
  },
  "recommended_actions": [
  "Flex and shift the socket anteriorly.",
  "Flex and shift the socket"
  ]
},
{
  "deviation": "Socket Too Wide in ML",
  "general_category": {
    "code": 7,
    "name": "Socket Fit and Stability"
  },
  "annotation_aliases": [
  "Socket too wide in ML",
  "Socket too wide mediolaterally",
  "Poor medial-lateral socket fit",
  "Socket mediolateral dimension is excessive",
  "Alignment is acceptable"
  ],
  "pattern": "The socket appears too wide in the medial-lateral dimension
      ↪ , allowing excess residual-limb or socket motion.",
  "causes": {
    "patient_related": [
    "Residual limb volume loss"
    ],
    "prosthetic_related": [
    "Socket fit too loose in the medial-lateral dimension"
    ]
  },
  "recommended_actions": [
  "Rectify the socket fit"
  ]
},
{
  "deviation": "Lateral Instability",
  "general_category": {
    "code": 7,
    "name": "Socket Fit and Stability"
  },
  "annotation_aliases": [
  "Lateral instability",
  "Loss of lateral containment",
  "Socket instability",
  "Lateral knee instability"
  ],
```

```
  "pattern": "The prosthetic socket or limb shows unstable lateral motion
      ↪  during stance, often reducing confidence and alignment control
      ↪ .",
  "causes": {
    "patient_related": [
    "Weak hip abductors or poor balance"
    ],
    "prosthetic_related": [
    "Insufficient lateral socket containment",
    "Socket too loose",
    "Incorrect pylon/foot translation"
    ]
  },
  "recommended_actions": [
  "Inset the socket (shift medially) for a transfemoral prosthesis",
  "Correct the varus alignment as previously described",
  "Correct varus alignment as previously described"
  ]
},
{
  "deviation": "Incongruity of Knee and Ankle Axes",
  "general_category": {
    "code": 8,
    "name": "Foot and Ankle Deviations"
  },
  "annotation_aliases": [
  "Incongruity of knee and ankle axes",
  "Knee and ankle axes incongruent",
  "Rotate knee inward and foot outward"
  ],
  "pattern": "The prosthetic knee and ankle/foot progression axes are
      ↪ visibly misaligned or rotationally incongruent.",
  "causes": {
    "patient_related": [
    "Habitual gait pattern or donning rotation"
    ],
    "prosthetic_related": [
    "Knee, shank, socket, or foot rotation set inconsistently"
    ]
  },
  "recommended_actions": [
  "Rotate knee inward and foot outward"
  ]
},
{
  "deviation": "Excessive Plantar Flexion",
  "general_category": {
    "code": 8,
    "name": "Foot and Ankle Deviations"
  },
  "annotation_aliases": [
  "Excessive plantar flexion",
  "Excessive plantarflexion"
  ],
  "pattern": "The prosthetic foot or ankle is excessively plantarflexed
      ↪ during stance or initial contact.",
  "causes": {
    "patient_related": [
    "Cautious loading pattern"
    ],
    "prosthetic_related": [
    "Foot set in excessive plantarflexion",
    "Plantarflexion bumper or hydraulic resistance mismatch"
    ]
  },
  "recommended_actions": [
  "Reduce plantarflexion"
  ]
```

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},
{
  "deviation": "Excessive Dorsiflexion",
  "general_category": {
    "code": 8,
    "name": "Foot and Ankle Deviations"
  },
  "annotation_aliases": [
  "Excessive dorsiflexion",
  "Foot set too dorsiflexed",
  "Excessive dorsiflexion of the prosthetic foot, resulting in the
      ↪ patient's inability to load the toe and a consequent loss of the
      ↪ push-off phase.",
  "Excessive dorsiflexion of the prosthetic foot, preventing the patient
      ↪ from loading the toe and resulting in a loss of the push-off
      ↪ phase."
  ],
  "pattern": "The prosthetic foot or ankle is excessively dorsiflexed,
      ↪ altering heel-off and roll-over.",
  "causes": {
    "patient_related": [
    "Compensatory loading pattern"
    ],
    "prosthetic_related": [
    "Foot set in excessive dorsiflexion",
    "Toe lever too short or keel too soft"
    ]
  },
  "recommended_actions": [
  "Induce plantarflexion of the prosthetic foot. This is achieved by
      ↪ loosening the anterior set screw and tightening the posterior set
      ↪  screw located superior to the ankle component.",
  "Increase plantarflexion of the prosthetic foot by loosening the
      ↪ anterior set screw and tightening the posterior set screw of the
      ↪ ankle component."
  ]
},
{
  "deviation": "Pronated or Everted Foot",
  "general_category": {
    "code": 8,
    "name": "Foot and Ankle Deviations"
  },
  "annotation_aliases": [
  "Pronated foot",
  "Everted foot",
  "Excessive foot eversion",
  "Initial contact on the medial border",
  "Pronated or everted foot",
  "Excessive foot eversion, causing the prosthesis to land on its medial
      ↪ border.",
  "Excessive foot eversion, causing the prosthesis to land on the medial
      ↪ border.",
  "Excessive foot eversion, causing the prosthesis to make initial
      ↪ contact on its medial border.",
  "Excessive foot eversion, causing the prosthesis to make initial
      ↪ contact on the medial border.",
  "Excessive foot eversion, causing initial contact on the medial border
      ↪ of the prosthetic foot.",
  "Excessive foot eversion, causing the prosthesis to contact the ground
      ↪ on its medial border."
  ],
  "pattern": "The prosthetic foot is excessively pronated or everted,
      ↪ sometimes contacting on the medial border at initial contact.",
  "causes": {
    "patient_related": [
    "Habitual foot-placement compensation"
    ],
```

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    "prosthetic_related": [
    "Foot inversion/eversion alignment error",
    "Ankle or foot component set in excessive eversion"
    ]
  },
  "recommended_actions": [
  "Invert the prosthetic foot by loosening the lateral set screw and
      ↪ tightening the medial set screw superior to the ankle component
      ↪ .",
  "Supinate or invert the foot.",
  "Loosen the lateral set screw and tighten the medial set screw superior
      ↪  to the foot.",
  "Invert the foot. Loosen the lateral set screw and tighten the medial
      ↪ set screw superior to the ankle component.",
  "Perform a foot inversion alignment adjustment. Loosen the lateral set
      ↪ screw and tighten the medial set screw located superior to the
      ↪ ankle component.",
  "Invert the foot by loosening the lateral set screw and tightening the
      ↪ medial set screw superior to the ankle component."
  ]
},
{
  "deviation": "Normal Gait",
  "general_category": {
    "code": 9,
    "name": "Normal Gait"
  },
  "annotation_aliases": [
  "Normal gait",
  "No action needed",
  "Optimized gait",
  "Acceptable gait",
  "Natural",
  "Natural gait",
  "Natural gait pattern",
  "Patient's gait is consistent with their established pattern."
  ],
  "pattern": "No clinically meaningful prosthetic gait deviation is
      ↪ supported by the available visual and metric evidence.",
  "causes": {
    "patient_related": [],
    "prosthetic_related": []
  },
  "recommended_actions": [
  "No action needed",
  "Knee fine-tuning to be determined outside of the parallel bars",
  "Consider fine-tuning the prosthesis after an extended accommodation
      ↪ period.",
  "Observe further",
  "Further observation is recommended",
  "No intervention required"
  ]
},
{
  "deviation": "Input Not Suitable for Analysis",
  "general_category": {
    "code": 0,
    "name": "Input Not Suitable for Analysis"
  },
  "annotation_aliases": [
  "Input not suitable for analysis",
  "No action can be determined",
  "Provided text not suitable for gait analysis"
  ],
  "pattern": "The input does not contain enough valid gait-analysis
      ↪ information to assign a prosthetic gait deviation.",
  "causes": {
    "patient_related": [],
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    "prosthetic_related": []
  },
  "recommended_actions": [
  "No action can be determined"
  ]
},
{
  "deviation": "Inconclusive Frontal Plane Alignment Assessment",
  "general_category": {
    "code": 99,
    "name": "Inconclusive or Unscorable Gait Assessment"
  },
  "annotation_aliases": [
  "Assessment of frontal plane alignment (varus/valgus) was inconclusive
     ↪ ",
  "Recommend re-evaluation with a camera providing a direct frontal plane
     ↪  view"
  ],
  "pattern": "The available view is insufficient to assess the intended
     ↪ frontal-plane alignment change, such as varus or valgus.",
  "causes": {
    "patient_related": [],
    "prosthetic_related": []
  },
  "recommended_actions": [
  "Recommend re-evaluation with a camera providing a direct frontal plane
     ↪  view"
  ]
},
{
  "deviation": "Excessive Socket Adduction / Valgus Gait",
  "general_category": {
    "code": 2,
    "name": "Step and Base of Support Deviations"
  },
  "annotation_aliases": [
  "Excessive socket adduction (valgus gait)",
  "Excessive socket adduction (valgus gait), causing initial foot contact
     ↪  on the medial border with the pylon exhibiting a medial lean.",
  "Excessive socket adduction, resulting in a valgus gait with medial
     ↪ foot contact and a medially inclined pylon.",
  "Excessive socket adduction resulting in a valgus gait pattern, causing
     ↪  the foot to land on its medial border and the pylon to lean
     ↪ medially.",
  "Excessive socket adduction, resulting in a valgus gait pattern with
     ↪ medial pylon leaning.",
  "Excessive socket adduction (valgus gait), resulting in a wide base of
     ↪ support.",
  "Excessive socket adduction (valgus gait) resulting in a wide base of
     ↪ support.",
  "Excessive socket adduction, valgus gait",
  "Excessive socket adduction",
  "Excessive adduction of the socket.",
  "Medially inclined pylon",
  "Pylon exhibiting a medial lean"
  ],
  "pattern": "The socket is excessively adducted, producing a valgus gait
     ↪  pattern, medial pylon lean, medial foot contact, or abnormal
     ↪ base width.",
  "causes": {
    "patient_related": [
    "Compensatory frontal-plane loading pattern"
    ],
    "prosthetic_related": [
    "Socket adduction alignment is excessive",
    "Socket/pylon/foot alignment produces a valgus gait pattern"
    ]
  },
```

```
  "recommended_actions": [
  "Abduct the socket by loosening the lateral set screw and tightening
      ↪ the medial set screw.",
  "Abduct the socket. This is achieved by loosening the lateral set screw
      ↪  and tightening the medial set screw on the pyramid adapter
      ↪ inferior to the socket.",
  "Abduct the socket by loosening the lateral set screw and tightening
      ↪ the medial set screw at the socket adapter.",
  "Induce foot eversion by loosening the medial set screw and tightening
      ↪ the lateral set screw at the ankle adapter.",
  "Induce foot dorsiflexion by loosening the posterior set screw and
      ↪ tightening the anterior set screw at the ankle adapter.",
  "Introduce a slight amount of socket abduction by loosening the lateral
      ↪  set screw and tightening the medial set screw of the pyramid
      ↪ adapter."
  ]
},
{
  "deviation": "Foot Inversion / Supinated Foot",
  "general_category": {
    "code": 8,
    "name": "Foot and Ankle Deviations"
  },
  "annotation_aliases": [
  "Foot inversion",
  "Inverted foot",
  "Supinated foot",
  "Associated foot inversion and plantarflexion.",
  "Slightly inverted foot causing the prosthesis to land on its lateral
      ↪ border.",
  "Slight foot inversion causing initial contact on the lateral border of
      ↪  the prosthetic foot.",
  "Slight foot inversion at initial contact, causing the prosthesis to
      ↪ land on its lateral border.",
  "Too much toe-in coupled with slight inversion or supination",
  "Initial contact on the lateral border of the prosthetic foot",
  "Excessive foot inversion, causing initial contact on the lateral
      ↪ border of the prosthetic foot."
  ],
  "pattern": "The prosthetic foot is excessively inverted or supinated,
      ↪ often contacting on the lateral border at initial contact.",
  "causes": {
    "patient_related": [
    "Habitual inverted foot placement or toe-in compensation"
    ],
    "prosthetic_related": [
    "Foot/ankle component set in excessive inversion or supination",
    "Socket/foot alignment drives lateral-border initial contact"
    ]
  },
  "recommended_actions": [
  "Toe-out and foot eversion or pronation",
  "Abduct the socket by loosening the lateral set screw and tightening
      ↪ the medial set screw at the socket adapter.",
  "Induce foot eversion by loosening the medial set screw and tightening
      ↪ the lateral set screw at the ankle adapter.",
  "Induce foot dorsiflexion by loosening the posterior set screw and
      ↪ tightening the anterior set screw at the ankle adapter.",
  "Adjust the foot into eversion. Loosen the medial set screw and tighten
      ↪  the lateral set screw located superior to the ankle component.",
  "Correct for foot inversion by loosening the medial set screw and
      ↪ tightening the lateral set screw above the ankle."
  ]
},
{
  "deviation": "Asymmetric Knee Flexion Angles",
  "general_category": {
    "code": 8,
```

```
    "name": "Foot and Ankle Deviations"
  },
  "annotation_aliases": [
  "Asymmetric knee flexion angles"
  ],
  "pattern": "The prosthetic and contralateral knees show asymmetric
      ↪ flexion angles that affect swing or stance mechanics.",
  "causes": {
    "patient_related": [
    "Activity-level or confidence mismatch affecting knee use"
    ],
    "prosthetic_related": [
    "Swing flexion/extension resistance settings are too high or
        ↪ otherwise mismatched"
    ]
  },
  "recommended_actions": [
  "Lower swing flexion resistance"
  ]
},
{
  "deviation": "Abducted and Externally Rotated Prosthetic Knee",
  "general_category": {
    "code": 4,
    "name": "Knee Instability and Malalignment"
  },
  "annotation_aliases": [
  "Prosthetic knee is abducted and externally rotated.",
  "Abducted and externally rotated prosthetic knee",
  "Prosthetic knee is abducted and externally rotated"
  ],
  "pattern": "The prosthetic knee is malaligned in abduction and external
      ↪  rotation relative to the limb progression line.",
  "causes": {
    "patient_related": [
    "Habitual rotated or abducted limb progression"
    ],
    "prosthetic_related": [
    "Knee component rotation and linear alignment are incorrect"
    ]
  },
  "recommended_actions": [
  "Internally rotate the knee component to correct for the external
      ↪ rotation.",
  "Shift the knee joint medially via a linear adjustment to address the
      ↪ abduction, which is an embedded design feature.",
  "Internally rotate the knee to address the external rotation. To
      ↪ correct the abduction, perform a medial linear shift of the knee
      ↪ joint. Addressing the knee joint alignment is a prerequisite for
      ↪ correcting the overall abducted gait."
  ]
}
]
```


H GAIT CATEGORY MAPPING FOR GAVD

- **Normal:** Healthy (Normal) Gait
- **Antalgic:** Antalgic Gait
- **Stroke:** Hemiparetic (Hemiplegic) Gait
- **Parkinson's:** Parkinsonian (Festinating) Gait
- **Myopathic:** Waddling (Myopathic) Gait, Trendelenburg Gait
- **Cerebral Palsy:** Spastic Diplegic (Scissors) Gait, Crouch Gait, Spastic Paraparetic Gait, Hemiparetic (Hemiplegic) Gait

I DRGAIT PROMPT TEMPLATES

Listing 4: System Prompt for GAVD

```
You are the reasoning module in a Triage-Verification-Synthesis (TVS)
    ↪ gait-analysis pipeline.

You can be invoked for different stages:
- TRIAGE: first decide normal-vs-abnormal gait, then propose the initial
    ↪ hypothesis path and measurable verification objectives.
- VERIFICATION: use deterministic tools to confirm/refute objectives and
    ↪ hypotheses.
- SYNTHESIS: integrate verified evidence into a final, transparent
    ↪ conclusion.

Global policy:
- Never invent numerical values, thresholds, or measurements.
- Ground quantitative claims in provided metrics and/or tool outputs.
- Do NOT use a single evidence to rule out a hypothesis.
- Joint angles are measured in degrees where 180 degree is fully extended
    ↪  (straight).

Tool policy:
- When tools are available, call tools for measurable biomechanical
    ↪ claims.
- Use only declared tools and keep each call purposeful.

Output policy:
- Follow the stage-specific output schema requested in the user prompt.
- During TRIAGE, do not jump directly to differential diagnosis before
    ↪ the normality gate.
- Return only valid JSON when a schema is requested.
- Do not output extra prose outside the requested format.
```

Listing 5: Triage User Prompt for GAVD

```
Stage: TRIAGE

Analyze the attached walking video and perform TVS triage.

Quantitative metrics:
{metrics_table}

Task:
1) First perform a normality gate: decide whether the gait is `normal`, `
    ↪ abnormal`, or `uncertain`.
2) Then propose the initial candidate hypotheses `H_path` according to
    ↪ that gate.
3) Propose explicit biomechanical verification objectives `C_bio` for
    ↪ downstream tool execution, focused on visual or numerical
    ↪ uncertainty.

Constraints:
- Candidate labels must come from the injected gait knowledge dictionary.
- Use category names exactly as listed in the dictionary.
- Use BOTH visual signs and provided metrics.
- Rhythm caution: High variation in step_length may indicate a lack of
    ↪ rhythm, but it may also come from problematic metric measurements.
    ↪ Do not use it alone to confirm or rule out any hypothesis.
- The `normal` hypothesis category is exactly `Healthy (Normal) Gait`.
- If the normality gate is `normal`, `H_path` MUST contain exactly one
    ↪ entry: `Healthy (Normal) Gait`. Do not include abnormal
    ↪ alternatives in `H_path`.
- If the normality gate is `abnormal`, `H_path` should contain only
    ↪ abnormal candidate categories; do not include `Healthy (Normal)
    ↪ Gait`.
```

```
- If the normality gate is `uncertain`, choose the safest initial
    ↪ hypothesis path based on current evidence, and use `C_bio` to
    ↪ verify the uncertainty before escalation.
- Even when `H_path` contains only `Healthy (Normal) Gait`, `C_bio` must
    ↪ still include tool-check objectives to inspect visual or numerical
    ↪ uncertainty, such as subtle asymmetry, step width/variability,
    ↪ small steps, stiff knee, circumduction, sway, or posture.
- MEASURING SWAY: To verify Waddling or Ataxic gaits, you MUST use `
    ↪ get_postural_sway_amplitude` to measure the dynamic range. Do not
    ↪ use single-frame angles.
- Do not invent numerical values, thresholds, or measurements.

Return format:
- Return valid JSON only.
- Use this exact top-level schema:
{
  "normality_gate": {
    "classification": "normal|abnormal|uncertain",
    "evidence": [
    "visual or metric-grounded evidence used for the normal-vs-abnormal
        ↪ gate"
    ],
    "uncertainty": [
    "visual or numerical ambiguity that should be checked downstream"
    ]
  },
  "H_path":[
  {
    "id": 1,
    "category": "exact clinical category string from injected knowledge
        ↪ dictionary",
    "confidence": 0.0,
    "evidence":[
    "metric-grounded or visual sign",
    "metric-grounded or visual sign"
    ],
    "uncertainty":[
    "missing cue, conflicting metric, or ambiguity"
    ]
  }
  ],
  "C_bio":[
  {
    "id": 1,
    "objective": "biomechanical claim to verify",
    "target_hypotheses": ["category_a", "category_b"],
    "priority": "high",
    "required_observables":[
    "what to measure from tools (angles, asymmetry, etc.)"
    ],
    "decision_rule": "what outcome would support vs refute target
        ↪ hypotheses"
  }
  ],
  "ruled_out_distractors":[
  "optional: dictionary categories considered but excluded after triage"
  ],
  "triage_notes": "1-3 sentences summarizing differential logic and main
      ↪ uncertainty"
}
- `H_path` must contain 1-5 entries with confidence in [0,1] and non-
    ↪ increasing by rank.
- If `normality_gate.classification` is `normal`, `H_path` must contain
    ↪ exactly one entry and its category must be `Healthy (Normal) Gait`.
- `C_bio` must contain 1-10 objectives; `priority` must be one of: high,
    ↪ medium, low.

{extra_context_block}
```

Listing 6: Verification User Prompt for GAVD

```
Stage: VERIFICATION

Run TVS verification for this gait case.

Instructions:
- Use declared function tools to verify the triage objectives and key
    ↪ differential points.
- Prioritize high-priority objectives first.
- This stage allows only one tool-calling round.
- Each function call must include why_used, explicitly stating which
    ↪ differential diagnosis it aims to resolve (e.g., 'Measuring step
    ↪ width to differentiate Ataxic vs. Hemiplegic').

{extra_context_block}
```

Listing 7: Synthesis User Prompt for GAVD

```
Stage: SYNTHESIS

Use the full TVS conversation (triage hypotheses, verification tool calls
    ↪  and results) to produce the recursive synthesis.

Instructions:
- First summarize the verification objectives in `C_bio` using only the
    ↪ tool results already in context.
- In each `C_bio[*].evidence` item, briefly state which tool produced the
    ↪  evidence and what key result supports, refutes, or leaves the
    ↪ objective inconclusive.
- Then determine `H_path` status from the `C_bio` evidence.
- Explicitly identify contradictions between triage claims and tool-
    ↪ grounded findings.
- Do not invent measurements; cite only values/observations present in
    ↪ prior context.
- If evidence is insufficient or conflicting, state this clearly.
- The response should be extend from last triage output. Do not invent
    ↪ new triage hypotheses or verification objectives. Focus on
    ↪ synthesizing the existing information.
- `H_path` may contain 1-5 entries with confidence in [0,1] and non-
    ↪ increasing by rank.
- Write `final_report` as the user-facing conclusion: state the final
    ↪ gait-category conclusion, briefly explain why the decision was made
    ↪ , and include a concise suggested action or next step to address
    ↪ the gait finding. Keep the action general and evidence-grounded,
    ↪ such as clinical follow-up, targeted gait training, strength/
    ↪ balance work, assistive-device review, or additional assessment
    ↪ when uncertainty remains.

Return format:
- Return valid JSON only.
- Use this exact schema:
{
  "C_bio":[
  {
    "id": 1,
    "objective": "biomechanical claim to verify",
    "target_hypotheses":["category_a", "category_b"],
    "status": "supported|refuted|inconclusive",
    "evidence": ["tool name + key result and interpretation", "..."]
  }
  ],
  "H_path":[
  {
```

```
    "id": 1,
    "category": "exact clinical category string from injected knowledge
        ↪ dictionary",
    "supporting_evidence":["C_bio-grounded statement", "..."],
    "conflicting_evidence": ["contradiction or empty list item if none"],
    "status": "confirmed|rejected|inconclusive",
    "confidence": 0.0
  }
  ],
  "synthesis_notes": "1-3 sentences summarizing new findings,
      ↪ contradictions, and remaining uncertainty. This will be added to
      ↪ the conversation context for next iteration.",
  "final_report": "User-facing final conclusion, brief rationale for the
      ↪ decision, and concise suggested action or next step."
}

{extra_context_block}
```

Listing 8: System Prompt for ProGait

```
You are the reasoning module in a Triage-Verification-Synthesis (TVS)
    ↪ prosthetic gait-analysis pipeline.

You can be invoked for different stages:
- TRIAGE: decide whether a prosthetic gait deviation is supported, then
    ↪ propose candidate deviations and measurable verification objectives
    ↪ .
- VERIFICATION: use deterministic tools to confirm/refute objectives and
    ↪ candidate deviations.
- SYNTHESIS: integrate verified evidence into a final, transparent
    ↪ conclusion.

Global policy:
- Candidate labels must be exact `deviation` strings from the injected
    ↪ prosthetic gait deviation dictionary.
- Use dictionary `general_category` and `annotation_aliases` as label-
    ↪ selection context.
- Use `recommended_actions` only as action-wording guidance after a
    ↪ deviation is supported; do not use them as labels or evidence.
- Assign one to three deviations. If no meaningful deviation is supported
    ↪ , assign `Normal Gait` alone. If the input is unusable or
    ↪ unscorable, use the corresponding dictionary label.
- Never invent numerical values, thresholds, measurements, or prosthetic
    ↪ side labels.
- Ground quantitative claims in provided metrics and/or tool outputs.
- Treat paired frontal/sagittal videos as complementary 2D views, not
    ↪ calibrated 3D reconstruction. Treat normalized 2D distance metrics
    ↪ as image-plane proxies.
- State uncertainty when prosthetic side, camera view, phase visibility,
    ↪ or evidence quality is limited.
- Observe gait by phase and use prosthetic/sound-side asymmetry as
    ↪ supporting evidence, not as a standalone diagnosis.

Tool policy:
- When tools are available, call tools for measurable biomechanical
    ↪ claims.
- Use only declared tools and keep each call purposeful.
- If a tool accepts `view`, use front/back for frontal-plane claims and
    ↪ left/right for sagittal-plane claims when a single segment is
    ↪ needed.

Output policy:
- Follow the stage-specific output schema requested in the user prompt.
- Return valid JSON only when a schema is requested.
- Do not output extra prose outside the requested format.
```

Listing 9: Triage User Prompt for ProGait

```
Stage: TRIAGE

Analyze the attached ProGait prosthetic walking trial and perform TVS
    ↪ triage.
The trial may include paired frontal and sagittal videos of the same
    ↪ walking trial.

Quantitative metrics:
{metrics_table}

Task:
1) Before the normality gate, determine `prosthetic_side` as anatomical `
    ↪ left`, `right`, `bilateral`, or `uncertain`.
2) Decide whether the trial is `normal`, `abnormal`, or `uncertain`.
3) Propose the initial candidate deviations in `H_path` according to that
    ↪  gate.
4) Propose explicit biomechanical verification objectives `C_bio` for
    ↪ downstream tool execution, focused on visual or numerical
    ↪ uncertainty.

Constraints:
- Candidate labels must come from the injected prosthetic gait deviation
    ↪ dictionary.
- Use `deviation` names exactly as listed in the dictionary.
- Use each entry's `general_category` and `annotation_aliases` as label-
    ↪ selection context.
- Do not use causes, interventions, or general categories as labels
    ↪ unless they are explicit dictionary deviations.
- Use both visual signs and provided metrics when relevant.
- For paired-view inputs, use frontal evidence for frontal-plane signs
    ↪ and sagittal evidence for sagittal-plane signs.
- Treat ProGait 2D distance metrics as normalized image-plane proxies,
    ↪ not calibrated 3D quantities.
- Do not use `Healthy (Normal) Gait`; use `Normal Gait` for ProGait
    ↪ normal cases.
- If `normality_gate.classification` is `normal`, `H_path` must contain
    ↪ only `Normal Gait`.
- If `normality_gate.classification` is `abnormal`, `H_path` should
    ↪ contain only supported prosthetic deviations.
- If `normality_gate.classification` is `uncertain`, choose the safest
    ↪ initial hypothesis path based on current evidence and use `C_bio`
    ↪ to verify the uncertainty.
- For special unscorable cases, use the corresponding dictionary label.
- `H_path` must contain 1-3 entries with confidence in [0,1] and non-
    ↪ increasing by rank.
- Assign multiple deviations only when each has distinct evidence.
- If a deviation is view-dependent, identify which view supports it or
    ↪ include the view limitation in `uncertainty`.
- Base `prosthetic_side` on visible prosthetic components, prosthetic-
    ↪ side mechanics, or explicit view evidence. Use `uncertain` if the
    ↪ anatomical side cannot be determined reliably.
- Do not invent numerical values, thresholds, prosthetic side, or
    ↪ measurements.

Return format:
- Return valid JSON only.
- Use this exact top-level schema:
{
  "prosthetic_side": "left|right|bilateral|uncertain",
  "normality_gate": {
    "classification": "normal|abnormal|uncertain",
    "evidence": [
    "visual or metric-grounded evidence used for the normal-vs-deviation
        ↪ gate"
    ],
    "uncertainty": [
```

```
    "prosthetic-side ambiguity, view limitation, missing phase, or
       ↪ conflicting cue"
    ]
  },
  "H_path":[
  {
    "id": 1,
    "category": "exact deviation string from injected prosthetic gait
       ↪ deviation dictionary",
    "general_category": "code and name from this dictionary entry",
    "confidence": 0.0,
    "evidence":[
    "phase-specific visual sign or metric-grounded sign",
    "phase-specific visual sign or metric-grounded sign"
    ],
    "uncertainty":[
    "missing cue, conflicting metric, uncertain side, or limited camera
       ↪ view"
    ]
  }
  ],
  "C_bio":[
  {
    "id": 1,
    "objective": "biomechanical claim to verify",
    "target_hypotheses": ["deviation_a", "deviation_b"],
    "priority": "high",
    "required_observables":[
    "what to inspect or measure from tools"
    ],
    "decision_rule": "what outcome would support vs refute the target
       ↪ hypotheses"
  }
  ],
  "ruled_out_distractors":[
  "optional: dictionary deviations considered but excluded after triage"
  ],
  "triage_notes": "1-3 sentences summarizing prosthetic side, leading
     ↪ deviations, differential logic, and main uncertainty"
}
- `C_bio` must contain 1-10 objectives; `priority` must be one of: high,
   ↪ medium, low.

{extra_context_block}
```

Listing 10: Verification User Prompt for ProGait

```
Stage: VERIFICATION

Run TVS verification for this ProGait case.

Instructions:
- Use declared function tools to verify the triage objectives and the key
   ↪  differential points between candidate prosthetic gait deviations.
- Prioritize high-priority objectives first.
- This stage allows only one tool-calling round.
- Each function call must include `why_used`, explicitly stating which
   ↪ biomechanical uncertainty it aims to resolve.
- Match each tool call to the observable needed for the objective.
- If a tool accepts `view`, use front/back for frontal-plane claims and
   ↪ left/right for sagittal-plane claims when a single segment is
   ↪ needed.
- Interpret ProGait 2D distance outputs as normalized image-plane proxies
   ↪ , not calibrated centimeters/meters.
- If tool evidence contradicts triage, report the contradiction clearly.
- If the available tools cannot directly verify a deviation, use the
   ↪ closest observable and state the limitation.
```

```
{extra_context_block}
```

Listing 11: Synthesis User Prompt for ProGait

```
Stage: SYNTHESIS

Use the full TVS conversation (triage hypotheses, verification tool calls
    ↪  and results) to produce the recursive synthesis for ProGait.

Instructions:
- First summarize the verification objectives in `C_bio` using only the
    ↪ tool results already in context.
- In each `C_bio[*].evidence` item, briefly state which tool produced the
    ↪  evidence and what key result supports, refutes, or leaves the
    ↪ objective inconclusive.
- Then determine `H_path` status from the `C_bio` evidence. Keep each
    ↪ final hypothesis `general_category` aligned with the dictionary
    ↪ entry.
- Confirm one to three final prosthetic gait deviations; use exact `
    ↪ deviation` names from the injected dictionary.
- Use dictionary `general_category` and `annotation_aliases` as label-
    ↪ selection context.
- Use `recommended_actions` as concise action guidance only after the
    ↪ corresponding deviation is supported, without over-prescribing
    ↪ exact hardware turns.
- Explicitly identify contradictions between triage claims and tool-
    ↪ grounded findings.
- Do not invent measurements; cite only values/observations present in
    ↪ prior context.
- For paired ProGait trials, integrate frontal and sagittal evidence as
    ↪ complementary 2D views. Do not present normalized metrics as
    ↪ calibrated 3D distances.
- If evidence is insufficient or conflicting, state this clearly and keep
    ↪  confidence modest. If all abnormal hypotheses are weak or refuted,
    ↪  confirm `Normal Gait` alone rather than inventing deviations.
- The response should extend from the last triage output. Do not invent
    ↪ new triage hypotheses or verification objectives.
- Write `final_report` as the user-facing conclusion: list the final
    ↪ deviation label(s), briefly explain the evidence, and provide
    ↪ concise suggested action or follow-up.

Return format:
- Return valid JSON only.
- Use this exact schema:
{
  "C_bio":[
  {
    "id": 1,
    "objective": "biomechanical claim to verify",
    "target_hypotheses":["deviation_a", "deviation_b"],
    "status": "supported|refuted|inconclusive",
    "evidence": ["tool name + key result and interpretation", "..."]
  }
  ],
  "H_path":[
  {
    "id": 1,
    "category": "exact deviation string from injected prosthetic gait
        ↪ deviation dictionary",
    "general_category": "code and name from this dictionary entry",
    "supporting_evidence":["C_bio-grounded statement", "..."],
    "conflicting_evidence": ["contradiction or empty list item if none"],
    "status": "confirmed|rejected|inconclusive",
    "confidence": 0.0
  }
  ],
```

```
  "synthesis_notes": "1-3 sentences summarizing confirmed deviations,
      ↪ rejected distractors, contradictions, and remaining uncertainty
      ↪ .",
  "final_report": "User-facing final conclusion with one to three
      ↪ prosthetic gait deviation labels, brief rationale, and concise
      ↪ suggested action for each confirmed deviation."
}
- `H_path` must contain 1-3 entries with confidence in [0,1] and non-
    ↪ increasing by rank.

{extra_context_block}
```

Listing 12: LLM Judge System Prompt for ProGait

```
You are an impartial evaluator for prosthetic gait-analysis reports.

Your job is to compare a model-generated conclusion against the human
    ↪ ProGait annotation. The human annotation is the reference.

Scoring:
- 1: The conclusion is semantically unrelated to or contradicts the human
    ↪  annotation.
- 2: The conclusion has only a small overlap with the human annotation.
- 3: The conclusion partially matches the main annotation but misses
    ↪ important elements or adds notable unsupported claims.
- 4: The conclusion mostly matches the annotation, with minor omissions,
    ↪ wording differences, or harmless extra detail.
- 5: The conclusion completely matches, covers, or clearly paraphrases
    ↪ the human annotation.

Judge semantic overlap, not exact wording. Consider the annotated gait
    ↪ deviation, recommended action, and reason, but weigh the gait-
    ↪ deviation match most heavily. Extra claims not supported by the
    ↪ annotation should lower the score when they change the conclusion.

Return valid JSON only.
```

Listing 13: LLM Judge User Prompt for ProGait

```
Evaluate how well the VLM analysis conclusion semantically matches the
    ↪ human ProGait annotation.

Sequence: {seq_id}
Camera view(s): {camera_view}

Human annotation JSON:
{human_annotation_json}

VLM predicted deviation labels:
{predicted_deviations_json}

VLM analysis report:
{analysis_report}

Return valid JSON with this schema:
{
  "score": 1,
  "rationale": "concise reason for the score",
  "matched_points": [
  "annotation point covered by the VLM conclusion"
  ],
  "missed_points": [
  "annotation point missing or contradicted by the VLM conclusion"
  ],
  "unsupported_or_extra_points": [
```

```
  "VLM claim not supported by the annotation"
  ]
}
```

J BASELINE PROMPT TEMPLATES

Listing 14: System Prompt for GAVD Baseline

```
You are an expert of visual gait analysis for clinical purposes.

You should reason from visual evidence in the given video and the
    ↪ injected gait knowledge dictionary.

Policy:
- Do not use external tools.
- Do not assume or invent quantitative biomechanical measurements.
- If evidence is ambiguous, state uncertainty explicitly.
- Keep the output concise, clinically coherent, and grounded in visible
    ↪ cues.
```

Listing 15: User Prompt for GAVD Baseline

```
Analyze the attached walking video and provide one direct diagnostic
    ↪ hypothesis from visual evidence only.

Task:
1) Propose one hypothesis in `H_path`.
2) Provide concise notes describing your reasoning and uncertainty.

Constraints:
- Candidate labels must come from the injected gait knowledge dictionary.
- Use category names exactly as listed in the dictionary.
- Do not use external tools or assumed measurements.
- Do not invent numerical values, thresholds, or biomechanical metrics.

Return format:
- Return valid JSON only.
- Use this exact top-level schema:
{
  "H_path": [
  {
    "id": 1,
    "category": "exact clinical category string from injected knowledge
        ↪ dictionary",
    "confidence": 0.0,
    "evidence": [
    "visual sign",
    "visual sign"
    ],
    "uncertainty": [
    "ambiguity, missing cue, or contradiction"
    ]
  }
  ],
  "notes": "1-3 sentences summarizing differential logic and main
      ↪ uncertainty"
}
- `H_path` must contain exactly 1 entry with confidence in [0,1].

{extra_context_block}
```

Listing 16: System Prompt for ProGait Baseline

```
You are an expert in visual prosthetic gait analysis.

Reason from visual evidence in the given video input(s) and the injected
    ↪ prosthetic gait deviation dictionary. Inputs may include paired
    ↪ frontal and sagittal videos of the same trial.

Policy:
- Candidate labels must be exact `deviation` strings from the injected
    ↪ dictionary.
- Use each dictionary entry's `general_category` and `annotation_aliases`
    ↪  as label-selection context.
- Treat `recommended_actions` as action guidance only, not labels or
    ↪ evidence.
- Assign one to three gait deviations. If no meaningful deviation is
    ↪ visible, assign `Normal Gait` alone. If the input is unusable or
    ↪ unscorable, use the corresponding dictionary label.
- Do not output causes, interventions, or general categories as labels
    ↪ unless they are explicit dictionary deviations.
- Do not use external tools.
- Do not assume or invent quantitative biomechanical measurements.
- Use frontal and sagittal views as complementary 2D evidence when both
    ↪ are present.
- If the prosthetic side or camera view is ambiguous, state uncertainty
    ↪ explicitly.
- Keep the output concise, clinically coherent, and grounded in visible
    ↪ gait-phase cues.
```

Listing 17: User Prompt for ProGait Baseline

```
Analyze the attached prosthetic walking video input(s) and assign one to
    ↪ three gait deviations from visual evidence only.
If both frontal and sagittal videos are attached, treat them as paired
    ↪ views of the same trial.

Task:
1) Propose one to three deviations in `H_path`.
2) Provide concise notes describing prosthetic side, gait-phase evidence,
    ↪  differential logic, and uncertainty.

Constraints:
- Candidate labels must come from the injected prosthetic gait deviation
    ↪ dictionary.
- Use `deviation` names exactly as listed in the dictionary.
- Use each entry's `general_category` and `annotation_aliases` as label-
    ↪ selection context.
- Treat `recommended_actions` as action wording guidance only; do not use
    ↪  them as labels or as evidence.
- If no meaningful deviation is visible, assign `Normal Gait` alone. If
    ↪ the input is unusable or unscorable, use the corresponding
    ↪ dictionary label.
- Do not use causes, interventions, or general categories as labels
    ↪ unless they are explicit dictionary deviations.
- Do not use external tools or assumed measurements.
- Use frontal and sagittal views as complementary 2D evidence when both
    ↪ are present.
- Do not invent numerical values, thresholds, prosthetic side, or
    ↪ biomechanical metrics.
- Assign multiple deviations only when each has distinct visual evidence.
- Prefer phase-specific evidence: initial contact, loading response,
    ↪ midstance, terminal stance, pre-swing, swing, or terminal swing.

Return format:
- Return valid JSON only.
- Use this exact top-level schema:
{
  "H_path": [
  {
```

```
    "id": 1,
    "category": "exact deviation string from injected prosthetic gait
       ↪ deviation dictionary",
    "general_category": "code and name from this dictionary entry",
    "confidence": 0.0,
    "evidence": [
    "phase-specific visual sign",
    "phase-specific visual sign"
    ],
    "uncertainty": [
    "prosthetic-side ambiguity, limited camera view, missing phase, or
       ↪ contradiction"
    ]
  }
  ],
  "notes": "1-3 sentences summarizing prosthetic side, leading deviation(
     ↪ s), differential logic, and main uncertainty"
}
- `H_path` must contain 1-3 entries with confidence in [0,1] and non-
   ↪ increasing by rank.

{extra_context_block}
```

K TOOL DECLARATIONS

Listing 18: GAVD Tools

```
[
{
  "name": "get_gait_event_frame",
  "description": "Return up to 5 raw video RGB frames at exact gait-event
     ↪  frames from complete gait cycles only. Each entry includes one
     ↪ base64 JPEG in `frame` plus frame metadata.",
  "parameters": {
    "type": "object",
    "properties": {
      "event": {"type": "string", "enum": VALID_EVENT_TOKENS},
      "step_index": {"type": "integer"},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
           ↪ call.",
      },
    },
    "required": ["event", "why_used"],
  },
},
{
  "name": "get_joint_angle_at_event",
  "description": "Get joint angle at specified gait event from complete
     ↪ gait cycles only. Cross-side combinations are allowed (e.g.,
     ↪ left_knee at right_initial_contact).",
  "parameters": {
    "type": "object",
    "properties": {
      "joint": {
        "type": "string",
        "enum": VALID_ANGLE_JOINT_TOKENS,
        "description": "Sided joint token, e.g. left_knee.",
      },
      "plane": {"type": "string", "enum": ["default", "sagittal", "
         ↪ coronal", "transverse"]},
      "event": {"type": "string", "enum": VALID_EVENT_TOKENS},
      "why_used": {
        "type": "string",
```

```
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["joint", "plane", "event", "why_used"],
  },
},
{
  "name": "get_peak_joint_angle",
  "description": "Get overall max/min joint angles in complete-cycle
      ↪ portions of a gait phase. Cross-side combinations are allowed (e.
      ↪ g., left_knee during right_stance).",
  "parameters": {
    "type": "object",
    "properties": {
      "joint": {
        "type": "string",
        "enum": VALID_ANGLE_JOINT_TOKENS,
        "description": "Sided joint token, e.g. left_knee.",
      },
      "plane": {"type": "string", "enum": ["sagittal", "coronal", "
          ↪ transverse"]},
      "phase": {"type": "string", "enum": VALID_PHASE_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["joint", "plane", "phase", "why_used"],
  },
},
{
  "name": "get_postural_angle",
  "description": "Get the unsigned body-oriented posture angle of pelvis
      ↪ or trunk at ONE specific frame. For trunk, this is the angle
      ↪ between the trunk segment and body vertical in the requested
      ↪ plane. 0 or 180 degrees means aligned/straight with the reference
      ↪  axis; 90 degrees means perpendicular. WARNING: Do not use this
      ↪ to measure dynamic rhythmic sway (like Waddling). Use
      ↪ get_postural_sway_amplitude for dynamic range.",
  "parameters": {
    "type": "object",
    "properties": {
      "segment": {"type": "string", "enum": ["pelvis", "trunk"]},
      "plane": {"type": "string", "enum": ["sagittal", "coronal"]},
      "frame": {"type": "integer"},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call."
      }
    },
    "required":["segment", "plane", "frame", "why_used"]
  }
},
{
  "name": "get_arm_swing_amplitude",
  "description": "Get signed shoulder arm-swing extrema over complete
      ↪ gait cycles for one side in the body-oriented sagittal plane.
      ↪ Returns max_angle_deg as anterior swing (positive) and
      ↪ min_angle_deg as posterior swing (negative).",
  "parameters": {
    "type": "object",
    "properties": {
      "side": {"type": "string", "enum": ["left", "right"]},
      "why_used": {
        "type": "string",
```

```
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["side", "why_used"],
  },
},
{
  "name": "get_foot_clearance",
  "description": "Get minimum foot clearance from complete-cycle portions
      ↪  of the requested phase, normalized by body height.",
  "parameters": {
    "type": "object",
    "properties": {
      "phase": {"type": "string", "enum": VALID_PHASE_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["phase", "why_used"],
  },
},
{
  "name": "get_lateral_deviation",
  "description": "Get maximum lateral deviation of a sided lower-limb
      ↪ joint from complete-cycle portions of the requested phase,
      ↪ normalized by shoulder width. Cross-side combinations are allowed
      ↪  (e.g., left_foot during right_stance).",
  "parameters": {
    "type": "object",
    "properties": {
      "joint": {"type": "string", "enum": VALID_LATERAL_JOINT_TOKENS},
      "phase": {"type": "string", "enum": VALID_PHASE_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["joint", "phase", "why_used"],
  },
},
{
  "name": "get_vertical_com_displacement",
  "description": "Get total vertical COM displacement normalized by body
      ↪ height, restricted to complete gait cycles.",
  "parameters": {
    "type": "object",
    "properties": {
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["why_used"],
  },
},
{
  "name": "get_postural_sway_amplitude",
  "description": "Get the dynamic range of motion (Max Angle - Min Angle)
      ↪  of the trunk or pelvis over complete gait cycles. Essential for
      ↪ diagnosing Waddling (coronal sway), Ataxic instability, or
      ↪ Trendelenburg compensations.",
  "parameters": {
    "type": "object",
```

```
    "properties": {
      "segment": {"type": "string", "enum": ["pelvis", "trunk"]},
      "plane": {"type": "string", "enum": ["sagittal", "coronal"]},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call."
      }
    },
    "required": ["segment", "plane", "why_used"]
  }
},
{
  "name": "calculate_symmetry_index",
  "description": "Calculate bilateral symmetry index in percent for
      ↪ step_length, stance_time, or swing_time.",
  "parameters": {
    "type": "object",
    "properties": {
      "metric_name": {"type": "string", "enum": ["step_length", "
          ↪ stance_time", "swing_time"]},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call."
      }
    },
    "required": ["metric_name", "why_used"]
  }
},
]
```

Listing 19: ProGait Tools

```
[
{
  "name": "get_gait_event_frame",
  "description": "Return up to 5 raw video RGB frames at exact gait-event
      ↪  frames from complete gait cycles only. In segmented 2D contexts,
      ↪  set view to one of front, back, left, or right when the
      ↪ requested evidence is segment-specific. Each entry includes one
      ↪ base64 JPEG in `frame` plus frame metadata.",
  "parameters": {
    "type": "object",
    "properties": {
      "event": {"type": "string", "enum": VALID_EVENT_TOKENS},
      "step_index": {"type": "integer"},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["event", "why_used"],
  },
},
{
  "name": "get_joint_angle_at_event",
  "description": "Get joint angle at specified gait event from complete
      ↪ gait cycles only. In image-based 2D contexts, this returns an
      ↪ image-plane angle from the selected view rather than calibrated 3
      ↪ D rotation; ankle angles use the average of toe and little-toe
      ↪ landmarks when explicit foot joints are not available. Cross-side
      ↪  combinations are allowed (e.g., left_knee at
      ↪ right_initial_contact).",
  "parameters": {
    "type": "object",
```

```
    "properties": {
      "joint": {
        "type": "string",
        "enum": VALID_ANGLE_JOINT_TOKENS,
        "description": "Sided joint token, e.g. left_knee.",
      },
      "plane": {"type": "string", "enum": ["default", "sagittal", "
          ↪ coronal", "transverse"]},
      "event": {"type": "string", "enum": VALID_EVENT_TOKENS},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["joint", "plane", "event", "why_used"],
  },
},
{
  "name": "get_peak_joint_angle",
  "description": "Get overall max/min joint angles in complete-cycle
      ↪ portions of a gait phase. In image-based 2D contexts, this
      ↪ returns image-plane extrema from the selected view rather than
      ↪ calibrated 3D rotation; ankle angles use the average of toe and
      ↪ little-toe landmarks when explicit foot joints are not available.
      ↪  Cross-side combinations are allowed (e.g., left_knee during
      ↪ right_stance).",
  "parameters": {
    "type": "object",
    "properties": {
      "joint": {
        "type": "string",
        "enum": VALID_ANGLE_JOINT_TOKENS,
        "description": "Sided joint token, e.g. left_knee.",
      },
      "plane": {"type": "string", "enum": ["sagittal", "coronal", "
          ↪ transverse"]},
      "phase": {"type": "string", "enum": VALID_PHASE_TOKENS},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["joint", "plane", "phase", "why_used"],
  },
},
{
  "name": "get_postural_angle",
  "description": "Get the unsigned body-oriented posture angle of pelvis
      ↪ or trunk at ONE specific frame. For trunk, this is the angle
      ↪ between the trunk segment and body vertical in the requested
      ↪ plane. 0 or 180 degrees means aligned/straight with the reference
      ↪  axis; 90 degrees means perpendicular. WARNING: Do not use this
      ↪ to measure dynamic rhythmic sway (like Waddling). Use
      ↪ get_postural_sway_amplitude for dynamic range.",
  "parameters": {
    "type": "object",
    "properties": {
      "segment": {"type": "string", "enum": ["pelvis", "trunk"]},
      "plane": {"type": "string", "enum": ["sagittal", "coronal"]},
      "frame": {"type": "integer"},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
```

```
        "description": "One-sentence biomechanical reason for this tool
            ↪ call."
      }
    },
    "required":["segment", "plane", "frame", "why_used"]
  }
},
{
  "name": "get_arm_swing_amplitude",
  "description": "Get signed shoulder arm-swing extrema over complete
      ↪ gait cycles for one side. In segmented 2D contexts, use the view
      ↪ that best represents sagittal-plane arm motion when available.",
  "parameters": {
    "type": "object",
    "properties": {
      "side": {"type": "string", "enum": ["left", "right"]},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["side", "why_used"],
  },
},
{
  "name": "get_foot_clearance",
  "description": "Get minimum foot clearance from complete-cycle portions
      ↪  of the requested phase, normalized by body height. In image-
      ↪ based 2D contexts the result is an image-plane proxy.",
  "parameters": {
    "type": "object",
    "properties": {
      "phase": {"type": "string", "enum": VALID_PHASE_TOKENS},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["phase", "why_used"],
  },
},
{
  "name": "get_lateral_deviation",
  "description": "Get maximum lateral deviation of a sided lower-limb
      ↪ joint from complete-cycle portions of the requested phase,
      ↪ normalized by shoulder width. In image-based 2D contexts the
      ↪ result is an image-plane proxy. Cross-side combinations are
      ↪ allowed.",
  "parameters": {
    "type": "object",
    "properties": {
      "joint": {"type": "string", "enum": VALID_LATERAL_JOINT_TOKENS},
      "phase": {"type": "string", "enum": VALID_PHASE_TOKENS},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["joint", "phase", "why_used"],
  },
},
{
```

```
  "name": "get_foot_progression_angle",
  "description": "Estimate foot progression/orientation from heel-to-toe
      ↪ landmarks during a complete-cycle phase. In image-based 2D
      ↪ contexts this is an image-plane proxy for toe-in/toe-out and
      ↪ should be compared side-to-side or with event frames.",
  "parameters": {
    "type": "object",
    "properties": {
      "side": {"type": "string", "enum": ["left", "right"]},
      "phase": {"type": "string", "enum": ["stance", "swing", "full_cycle
          ↪ "]},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["side", "why_used"],
  },
},
{
  "name": "get_whip_direction",
  "description": "Estimate whether the heel moves medially or laterally
      ↪ during swing using complete-cycle heel trajectory. Use for medial
      ↪ /lateral whip hypotheses and confirm abruptness with event frames
      ↪  when needed.",
  "parameters": {
    "type": "object",
    "properties": {
      "side": {"type": "string", "enum": ["left", "right"]},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["side", "why_used"],
  },
},
{
  "name": "get_knee_ankle_axis_alignment",
  "description": "Estimate frontal-plane knee-to-ankle axis alignment
      ↪ during a complete-cycle phase. Use for varus/valgus, pylon lean,
      ↪ and knee/ankle axis incongruity hypotheses.",
  "parameters": {
    "type": "object",
    "properties": {
      "side": {"type": "string", "enum": ["left", "right"]},
      "phase": {"type": "string", "enum": ["stance", "swing", "full_cycle
          ↪ "]},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["side", "why_used"],
  },
},
{
  "name": "get_vertical_com_displacement",
  "description": "Get total vertical body-center displacement normalized
      ↪ by body height, restricted to complete gait cycles. In image-
      ↪ based 2D contexts the result is an image-plane proxy.",
  "parameters": {
```

```
    "type": "object",
    "properties": {
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call.",
      },
    },
    "required": ["why_used"],
  },
},
{
  "name": "get_postural_sway_amplitude",
  "description": "Get the dynamic range of motion (Max Angle - Min Angle)
      ↪  of the trunk or pelvis over complete gait cycles. In segmented 2
      ↪ D contexts, use the view that best represents the requested
      ↪ anatomical plane.",
  "parameters": {
    "type": "object",
    "properties": {
      "segment": {"type": "string", "enum": ["pelvis", "trunk"]},
      "plane": {"type": "string", "enum": ["sagittal", "coronal"]},
      "view": {"type": "string", "enum": PROGAIT_SEGMENT_VIEW_TOKENS},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call."
      }
    },
    "required": ["segment", "plane", "why_used"]
  }
},
{
  "name": "calculate_symmetry_index",
  "description": "Calculate bilateral symmetry index in percent for
      ↪ step_length, stance_time, or swing_time. In multiview 2D contexts
      ↪ , left/right segment apparent step-length and timing metrics are
      ↪ averaged when available.",
  "parameters": { "type": "object",
    "properties": {
      "metric_name": {"type": "string", "enum": ["step_length", "
          ↪ stance_time", "swing_time"]},
      "why_used": {
        "type": "string",
        "description": "One-sentence biomechanical reason for this tool
            ↪ call."
      } },
    "required": ["metric_name", "why_used"]
  } }, ]
```