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WHITE PAPER · PROSTHETICS & ORTHOTICS

Gait Analysis in Prosthetic Care

Population norms by amputation level, correlation with AMPPRO and PLUS-M, response to device adjustment, and long-term acclimation tracked with a smartphone

ONESTEP RESEARCH | OCTOBER 2024 | ONESTEP.CO/RESOURCES

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COVER LETTER

RE Gait Analysis in Prosthetic Care: Population Norms, Outcome-Measure Correlation, Device Adjustment and Long-Term Acclimation

Objective gait data for every fitting, adjustment and justification

Prosthetists have always read gait by eye. OneStep puts a number on it, in the clinic and at home, from the day of fitting through a year of acclimation.

400+	57	0.81	65
In-clinic walks tagged by CPOs	Patients, AKA and BKA	Peak r^2, gait vs. PLUS-M	Patients tracked long-term

Below-knee amputees mostly walk within healthy ranges; above-knee amputees often do not, especially in double support and cadence variability. Walk speed, stride length, double support and asymmetry track the two standard outcome measures of the field, AMPPRO and PLUS-M. And when a prosthetist changes a foot or fits a new socket, the gait change is visible on the same visit.

Where it fits in the O&P workflow

Fitting and adjustment

Record a walk before and after a component change. Clinically meaningful gains in speed, cadence and stride length appear immediately and document the value of the adjustment.

Medical necessity

Objective gait parameters alongside AMPPRO or PLUS-M scores give payers a quantified functional picture to support prosthetic prescriptions and K-level decisions.

Acclimation at home

Background walks collected passively over months show whether a patient is still improving, has plateaued, or needs to be seen again.

THE LONG VIEW

Acclimation to a prosthesis is not a six-week process. In patients tracked passively for up to a year, gait kept improving **long after supervised measurements stopped**. The phone in the pocket is the only instrument that sees that.

To learn how O&P practices use OneStep for fittings, documentation and follow-up, contact us at hello@onestep.co or through our contact form.

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The full white paper follows.

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Gait Analysis in Prosthetic Care

Population norms by amputation level, correlation with AMPPRO and PLUS-M, response to device adjustment, and long-term acclimation tracked with a smartphone

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ABSTRACT

Background. Gait analysis is critical to prosthetic care: it informs prosthetic fit, reveals movement patterns that may injure the residual limb, indicates fall risk and provides an objective measure of function and progress. Laboratory gait analysis is costly and infrequent, which limits its clinical use.

Objective. To characterize the gait of patients with lower-limb prostheses measured with OneStep's smartphone-based gait analysis: differences from healthy norms by level of amputation, correlation with the AMPPRO and PLUS-M outcome measures, response to device adjustment, and long-term acclimation measured passively at home.

Methods. Two datasets. In an orthotics and prosthetics (O&P) clinic, certified prosthetists/orthotists recorded over 400 in-clinic walks (January–June 2024) in patients with above-knee (AKA, n = 12) and below-knee (BKA, n = 45) amputation, tagged as pre- or post-adjustment; 14 patients also completed AMPPRO and PLUS-M within a week of measurement. Separately, 65 patients receiving prostheses through the Protez Foundation were followed with active and passive (background) walks, seven of them for four or more months.

Results. Most BKA patients had gait parameters within healthy ranges, whereas AKA patients more often fell outside them (double support abnormal in 41.7% vs 17.8%; cadence variability 25% vs 4.4%). Higher AMPPRO and PLUS-M scores correlated with lower double support, less stance asymmetry and greater speed, stride length and cadence (PLUS-M vs stride length $r^2 = 0.81$, vs double support $r^2 = 0.73$). Device adjustments produced immediate, clinically meaningful gait improvements in two case studies. In long-term follow-up, six of seven patients improved significantly in at least four gait parameters between first and last month with no significant declines, and acclimation continued for close to a year.

Conclusions. Smartphone gait analysis distinguishes amputation levels, aligns with established prosthetic outcome measures, gives immediate objective feedback on device adjustments and tracks acclimation over months, supporting fitting decisions and the justification of medical necessity.

KEY POINTS

Question	Can smartphone-based gait analysis support prosthetic care, from fitting through long-term acclimation?
Findings	BKA gait mostly fell within healthy norms while AKA gait often did not; gait parameters correlated with AMPPRO and PLUS-M (r^2 up to 0.81); device adjustments changed gait measurably on the same visit; passive background walks showed improvement continuing for months in six of seven long-term patients.
Meaning	Objective gait data can inform component and fitting decisions, document their value, support medical-necessity justification and reveal acclimation that supervised assessment misses.

KEYWORDS lower limb amputation · prosthesis · AMPPRO · PLUS-M · K-level · gait variability · device adjustment · medical necessity · smartphone

About this edition. This paper consolidates OneStep's prosthetic research: the O&P clinic study (October 2024) and the long-term acclimation study with the Protez Foundation (November 2023), which this document supersedes.

1 Introduction

Gait assessment is a valuable tool for evaluating people who receive a lower limb prosthesis.[1] Measuring gait can help assess a patient's K-level, measure fall risk, track adjustment to a new prosthesis and indicate when an adjustment or intervention is needed.[1–3] It can also be used to fine-tune prosthetic fit and observe movement patterns that could injure the residual limb. Conventional gait analysis, however, requires specialized equipment and a

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visit to a gait lab, which limits how much data can be collected and therefore its clinical utility.

OneStep's FDA-listed gait analysis collects clinical-quality gait data anywhere with just a smartphone,[4–6] either as an actively recorded walk in the app or passively as background measurement when the patient walks with the phone in a pocket. This allows large amounts of gait data to be collected over weeks, months and years, showing long-term trends and alerting providers to changes that may warrant intervention.

This paper brings together two studies. The first, in an O&P clinic setting, asked how adjustments, components and fittings affect gait; how amputee gait differs from a healthy population; and how gait differs by level of amputation. The second followed patients who received prostheses through the Protez Foundation, which helps Ukrainians who lost limbs in the war acquire prosthetics in the United States, as they acclimated to a lower-limb prosthesis over months.

2 Methods

2.1 O&P clinic study

Certified prosthetists/orthotists (CPOs) were asked to use OneStep's gait analysis to inform decisions about adjustments, components and fittings. Over 400 walk measurements were collected in clinic from January to June 2024 in patients with lower-extremity prostheses, tagged by the CPO as pre- or post-adjustment. Gait parameters were compared with healthy population norms separately for above-knee (AKA, n = 12) and below-knee (BKA, n = 45) amputation. For 14 patients who also performed the Amputee Mobility Predictor with prosthesis (AMPPRO) and the Prosthetic Limb Users Survey of Mobility (PLUS-M), only gait measurements within a week of the assessment were included.

2.2 Long-term acclimation study

Sixty-five Protez Foundation patients had at least one recorded walk in OneStep's database as of October 31, 2023, recorded either consciously (in-app) or unconsciously (background, with the phone in a pants pocket during the day). The number of walks per patient ranged from one to well over 100 (Figure 1). Seven patients had at least 50 days of background recording over four or more months; for these, six parameters (cadence, double support, stride length, walk speed, stance asymmetry and velocity variability) were compared between the first and last month of data. Velocity variability, the stride-to-stride variability of walking speed, is of particular interest in the orthotic and prosthetic population.[2,3]

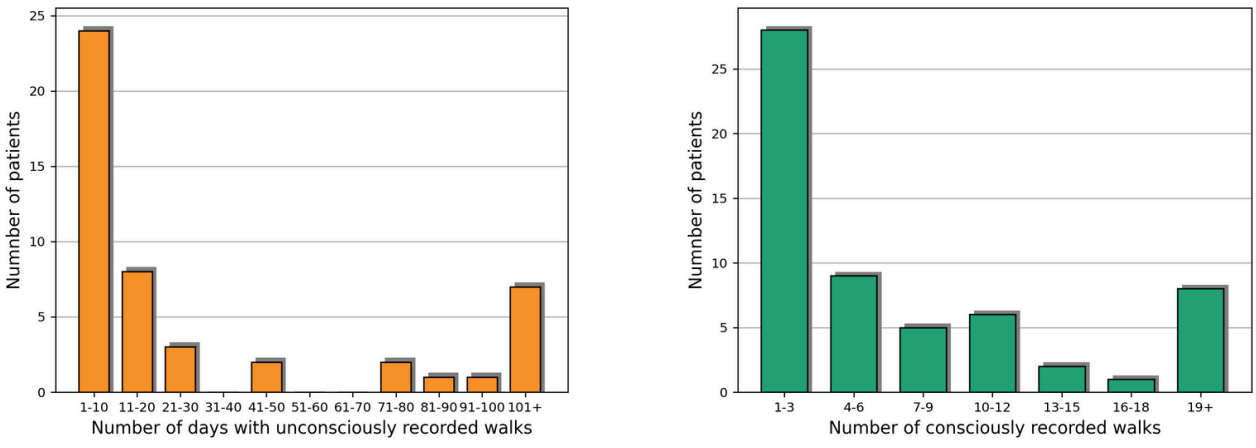


Figure 1. Walks recorded in the acclimation study. Distribution of the number of days with background (unconscious) walks (left) and of consciously recorded in-app walks (right) across 65 patients.

3 Population gait norms by level of amputation

Most patients with BKA had gait parameters within normal, healthy ranges, while patients with AKA tended to have more results outside population norms (Figure 2, Table 1). Greater gait variability typically indicates higher fall risk, instability and poorer balance or coordination. Walk speed variability was similar between groups, but AKA patients showed greater cadence variability than BKA patients.

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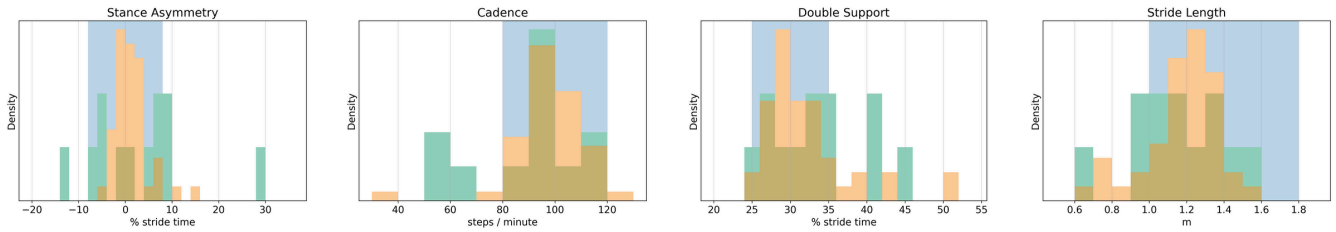


Figure 2. Patients with BKA are mostly within healthy gait ranges. Distributions of stance asymmetry, cadence, double support and stride length for AKA (green) and BKA (orange); brown marks the overlap. Healthy range in light blue.

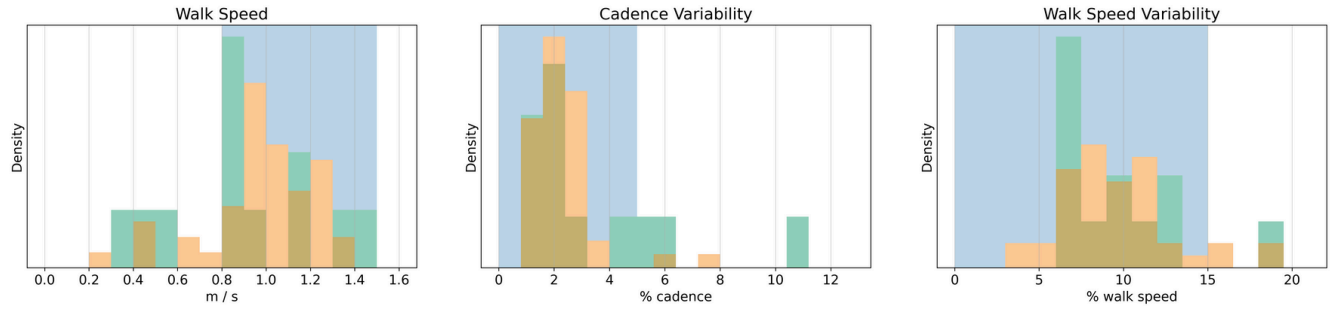


Figure 2 (continued). Walk speed, cadence variability and walk speed variability.

Parameter	AKA abnormal	BKA abnormal
Stance asymmetry	33.3% (4/12)	4.4% (2/45)
Cadence	25% (3/12)	6.7% (3/45)
Double support	41.7% (5/12)	17.8% (8/45)
Stride length	25% (3/12)	15.6% (7/45)
Speed	25% (3/12)	15.6% (7/45)
Cadence variability	25% (3/12)	4.4% (2/45)
Speed variability	8.3% (1/12)	8.9% (4/45)

Table 1. Share of patients with abnormal parameter values, by amputation level. For every parameter except speed variability, a larger share of AKA than BKA patients fell outside the healthy range.

4 Gait parameters versus outcome measures

The Amputee Mobility Predictor (AMP) measures the functional status of lower-limb amputees; AMPPRO is the version performed with a prosthesis. OneStep's gait data showed clear correlations with AMPPRO scores: higher scores went with lower double support, reduced stance asymmetry, higher speed, and longer stride length and cadence (Figure 3).

PLUS-M is a self-reported measure of mobility for adults with lower-limb amputation. The same pattern held, with stronger correlations: stride length $r^2 = 0.81$, double support $r^2 = 0.73$, walk speed $r^2 = 0.65$ (Figure 4). Correlating gait analysis with AMPPRO and PLUS-M gives clinicians a more robust view of a patient's functional mobility and lets them determine over time whether improvements in reported scores correspond to improved gait.

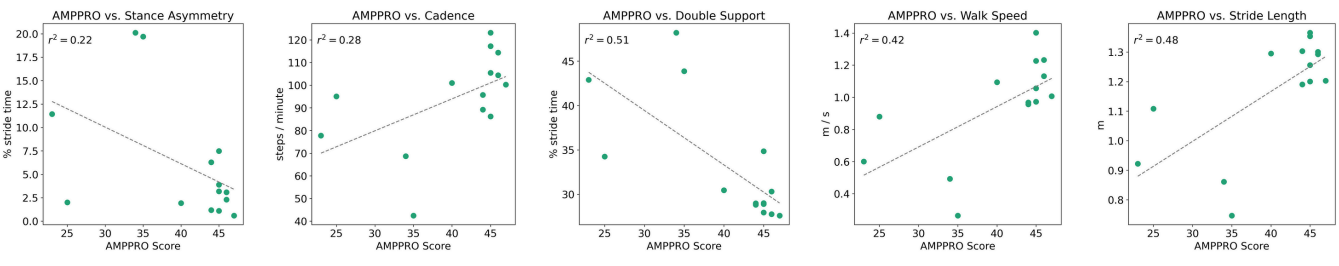


Figure 3. Gait parameters versus AMPPRO. Stance asymmetry ($r^2 = 0.22$), cadence (0.28), double support (0.51), walk speed (0.42) and stride length (0.48) against AMPPRO score, n = 14. Dotted line: linear fit.

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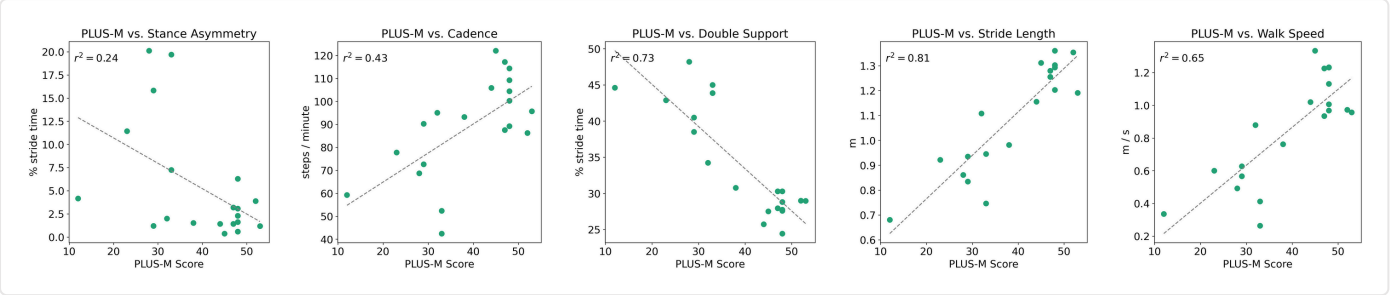


Figure 4. Gait parameters versus PLUS-M. Stance asymmetry (r^2 = 0.24), cadence (0.43), double support (0.73), stride length (0.81) and walk speed (0.65) against PLUS-M score.

5 Gait change after device adjustment

Two case studies show how CPOs can use gait data to evaluate adjustments and plan interventions (Figure 5).

Patient A, a woman in her early seventies with a right BKA and left foot amputation, received a new prosthesis and shoes. She recorded one walk with the old prosthesis and two with the new one in the same visit. Speed improved 0.1 m/s, cadence 9 steps/min, double support decreased 7 percentage points and stride length increased 9 cm, while stance asymmetry stayed stable (change under 1%).

Patient B, a man in his mid-fifties with a left BKA, received a new prosthetic foot. The first walk on the new foot showed some step-length asymmetry; the second showed significant improvement in velocity, stride length, cadence and step-length asymmetry. Speed improved 0.15 m/s, cadence 5 steps/min and stride length 10 cm; double support and stance asymmetry rose by about 2 points, below the threshold of clinical significance.

In both cases the gait parameters demonstrated clinically meaningful improvement, documenting the value of the adjustment. OneStep enabled immediate objective feedback to the device change, which can inform clinical decision-making.

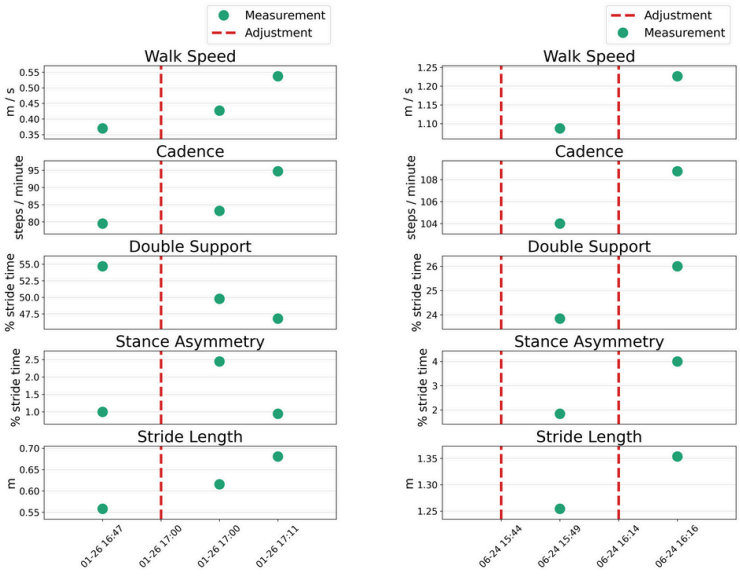


Figure 5. Pre- and post-adjustment gait parameters. Left: Patient A. Right: Patient B. Dashed red lines mark the adjustment; dots are individual walk measurements.

6 Long-term acclimation measured passively

In the seven Protez Foundation patients with at least four months of background data, unconscious gait tended to improve from the first to the last month of recording (Figure 6). Significant improvement was seen in at least four of six parameters in six of the seven patients, and no significant decline was seen in any patient. Walking speed in three patients was below the optimal range in the first month and within the normal range by the last month. Unconscious gait tracking can therefore meaningfully measure change over long periods in people with prosthetic limbs.

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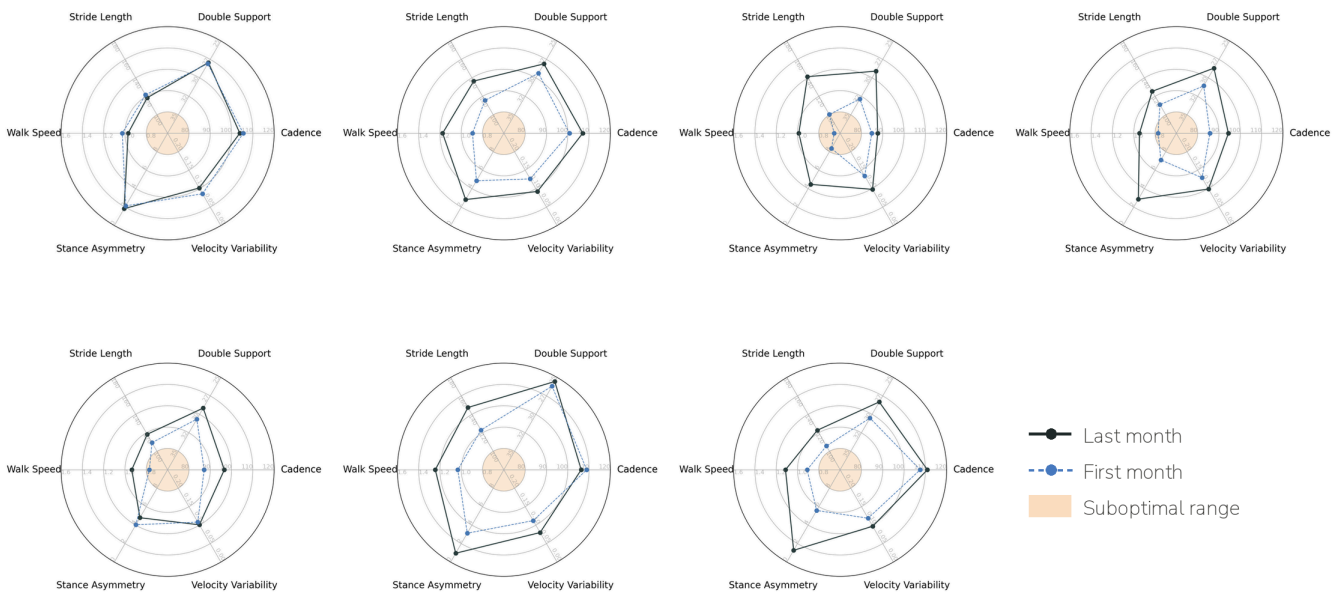


Figure 6. Long-term change in unconscious gait, seven patients. Each radar plot compares the first month (dashed blue) with the last month (solid black) of background data across cadence, double support, stride length, walk speed, stance asymmetry and velocity variability. The shaded centre marks the suboptimal range.

6.1 Case study: a year of acclimation

Patient C began measuring in December 2022 and recorded both in-app and background walks for five months, after which only background walks were captured. In-app walks improved steadily throughout the period they were recorded; background walks continued to improve for the rest of the year (Figure 7). Both measurement modes are informative, and acclimation to a prosthesis can continue for almost a full year.

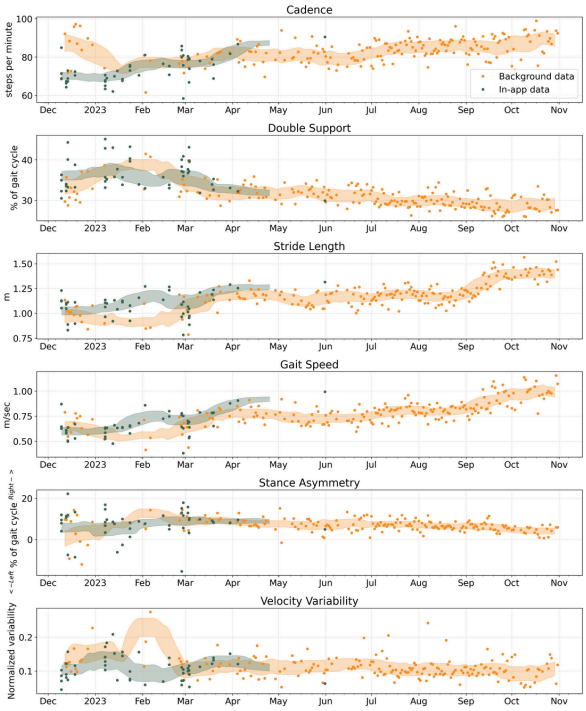


Figure 7. Patient C. Cadence, double support, stride length, gait speed, stance asymmetry and velocity variability over eleven months. Green: in-app walks; orange: background walks. Bands show the trend.

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6.2 Case study: two kinds of change

Patient D began recording in-app walks in April 2023 and showed very fast, sharp improvement in the first weeks, likely the initial period of learning to walk with the new prosthesis. The patient then stopped recording conscious walks but background recording began, showing slow, steady improvement over the following six months, most noticeably in stride length and gait speed but also in double support and cadence (Figure 8). The conscious data reflects the change that occurred as the patient learned to ambulate over a short period; the unconscious data reflects the slower progress as the body adjusted over weeks and months.

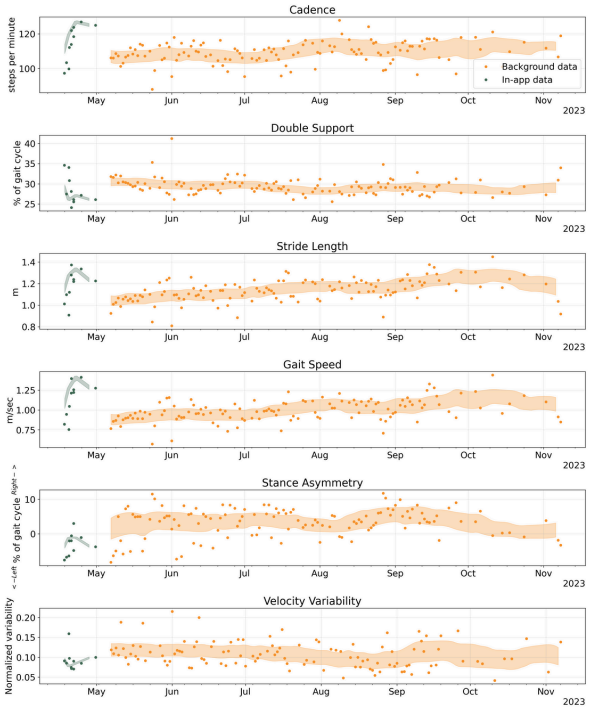


Figure 8. Patient D. Six gait parameters over seven months. Green: in-app walks (first weeks only); orange: background walks.

7 Discussion

OneStep data distinguished amputation levels: the gait of most BKA patients fell within population norms while many AKA patients fell outside them, with greater variability, especially in cadence, which may indicate higher fall risk, instability and poorer balance. Gait parameters correlated clearly with both AMPPRO and PLUS-M, so tracking gait alongside outcome measures lets clinicians monitor progress, evaluate interventions and check whether improvements in reported scores correspond to improved gait.

The adjustment case studies show that OneStep can be used effectively in an O&P setting: with objective data collected in the visit, CPOs can confirm that a fitting or component change is optimal for the patient. The acclimation data adds the dimension of time. Unconscious measurement allows gait to be collected over months with no effort from the patient, revealing continued improvement, or its absence, long after supervised measurements stop, and informing when adjustments and other interventions are needed.

8 Conclusion

OneStep provides valuable tools to track a patient's progress with their prosthesis over time, aid clinical decision-making in the clinic and help improve care between visits. Objective gait data, correlated with the field's standard outcome measures, also strengthens the justification of medical necessity for prosthetic prescriptions.

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