

Hyoid trajectory analysis of sequential and discrete healthy swallows using Ultrasound Evaluation of Swallowing



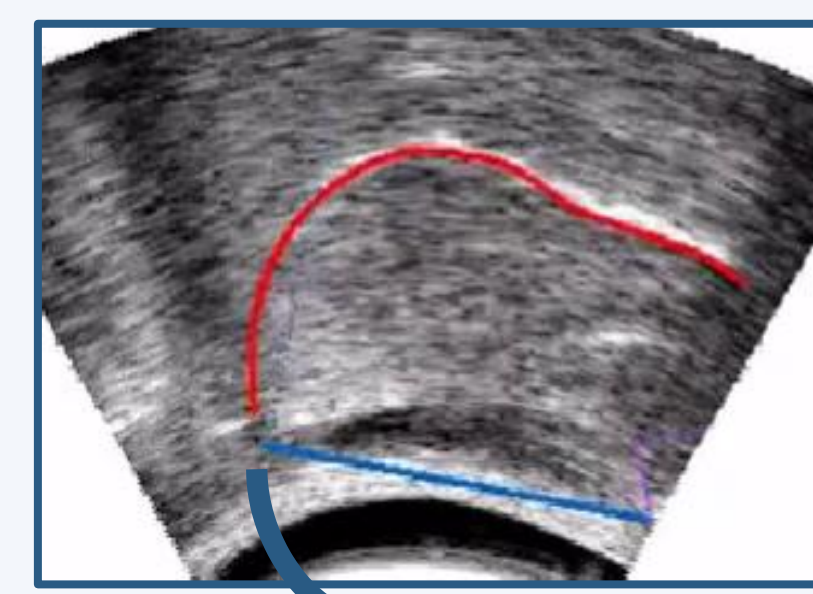
INTRODUCTION & AIM

Sequential swallowing (continuous) quantitative differences:
- reduced hyoid displacement
- reduced durations compared to Discrete (single) swallows.

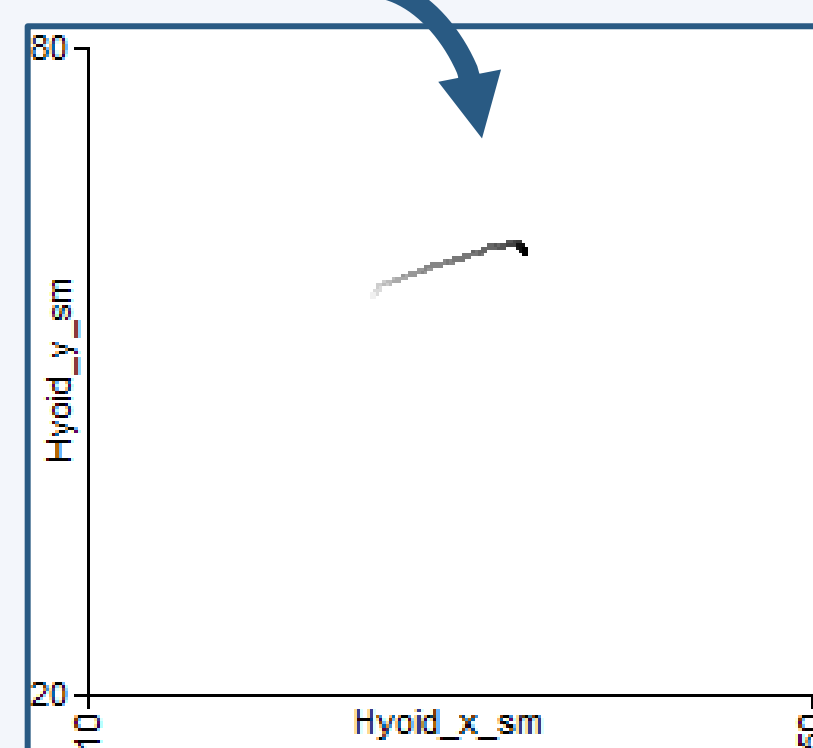
Does Sequential swallowing show qualitative differences in the overall trajectory of hyoid movement compared to Discrete swallowing?

Aim:
Evaluate if hyoid trajectory patterns are different in Sequential swallowing compared to Discrete, using a novel analysis with USES, adapting an established qualitative method for videofluoroscopy (Alves et al., 2022).

METHOD: ANALYSIS



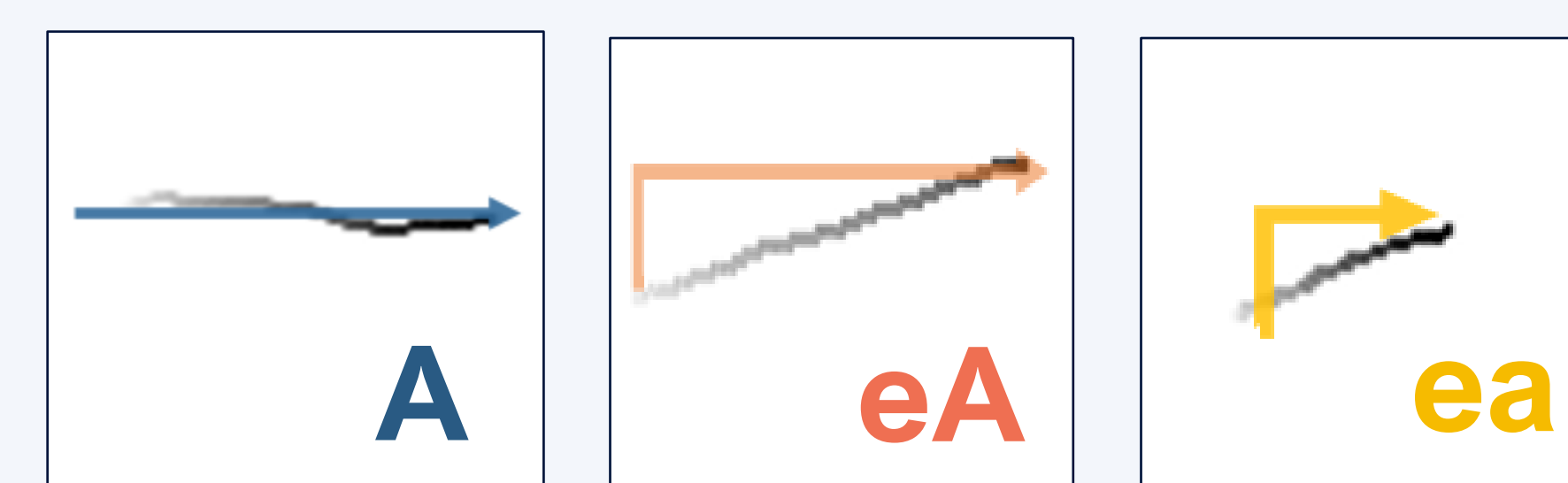
Each individual swallow analysed separately. Excursion phase only. XY reference axes fitted to ultrasound images.



USES automatically tracked hyoid position
➤ XY-axis graphs of hyoid trajectory over space/time (darker = more recent).

Trajectories qualitatively evaluated following Alves et al. (2022).

Alves et al. (2022) Patterns	Code	Description	Representation
H1	A	Anterior only	→
H2, H3	eA	short elevation, long Anterior	↗→
H4	Ea	long Elevation, short anterior	↗
H5	E	Elevation only	↑
H6	EA	long Elevation, long Anterior	↗→
H7	ea	short elevation, short anterior	↗



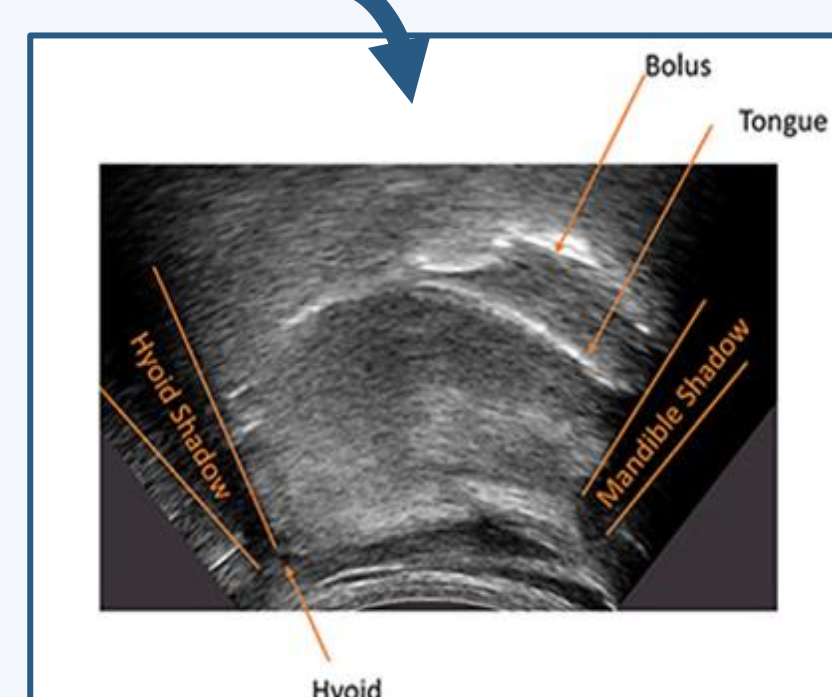
METHOD: DATA COLLECTION



USES: headset stabilised ultrasound imaging of tongue and hyoid

n = 8 (6F & 2M); normal swallowing

Water bolus (cup):
• Sequential - 100ml x1
• Discrete - 10ml x5



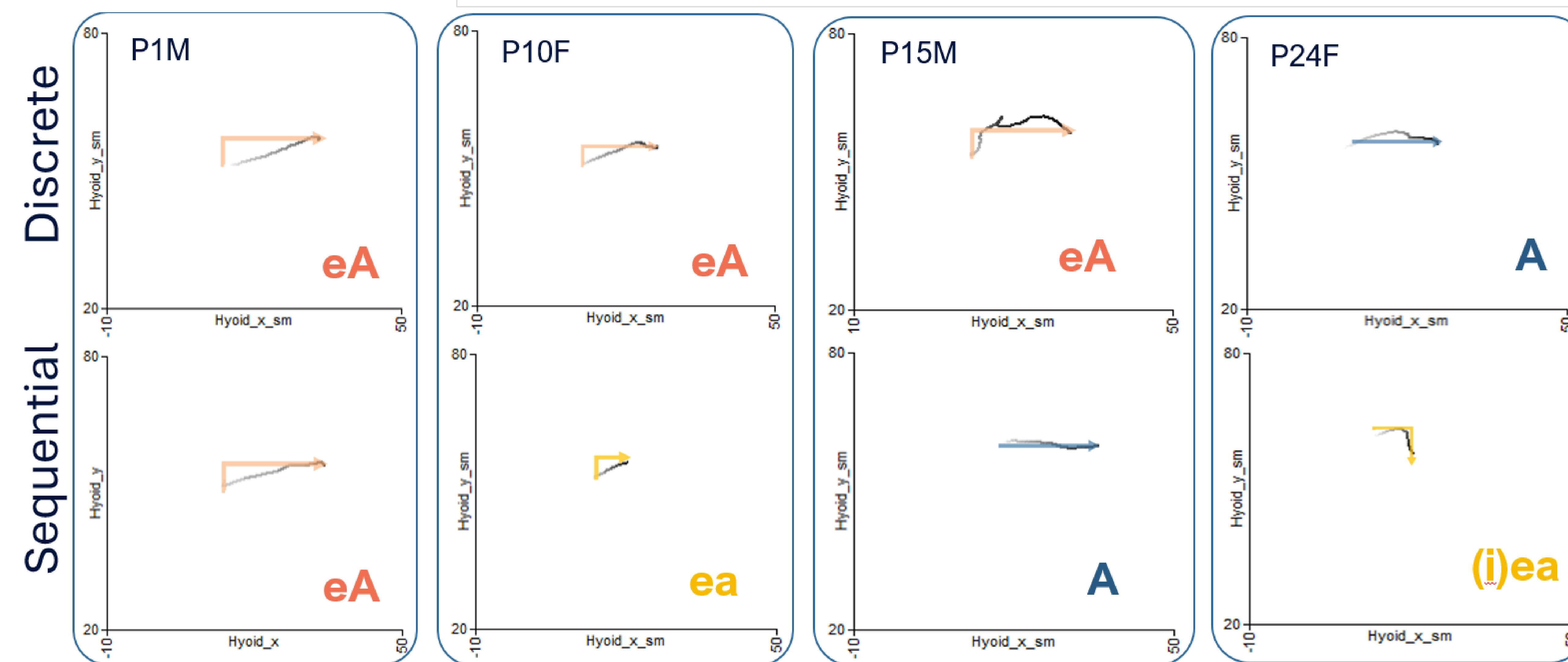
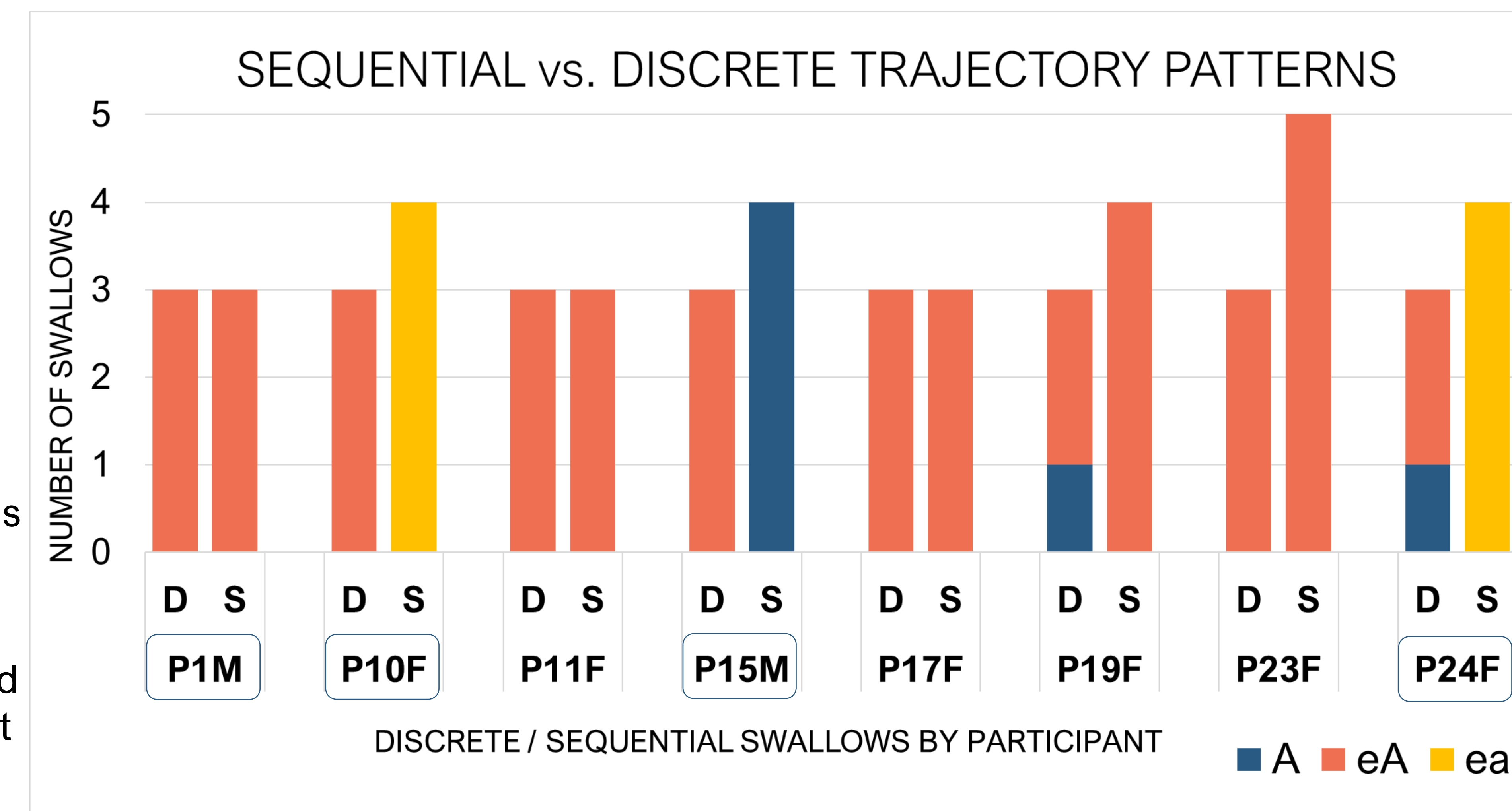
RESULTS

4 of 8 participants used same pattern for all swallows, Sequential and Discrete (eA).

Other 4: 10F, P15M, P19F, & P24F used different pattern for Sequential vs. Discrete.

No clear association between Discrete and Sequential patterns across those who switch for Sequential, but ea only in Seq.

Novel pattern sub-type identified in P24F: inverted ae (i)ea - short anterior, then short downwards.



CONCLUSIONS

Sequential swallowing can be qualitatively different to discrete swallows – consider assessing both.

Normal variation in hyoid trajectory patterns within and across individuals – consider in assessment/monitoring.

Future directions: Investigate trajectory differences in dysphagia

Hyoid trajectory analysis of sequential and discrete healthy swallows using Ultrasound Evaluation of Swallowing (extended version)



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INTRODUCTION & AIM

Hyoid movement plays key role in swallowing - airway protection and UES opening, and is frequently evaluated in clinical assessment.

- Holistic analysis of hyoid movement trajectory may reveal valuable insights:
- different hyoid trajectory patterns between specific dysphagia populations (Paik et al., 2008; Lee et al., 2021)
 - between-individual variability in hyoid trajectory patterns in discrete swallows (Alves et al., 2022)

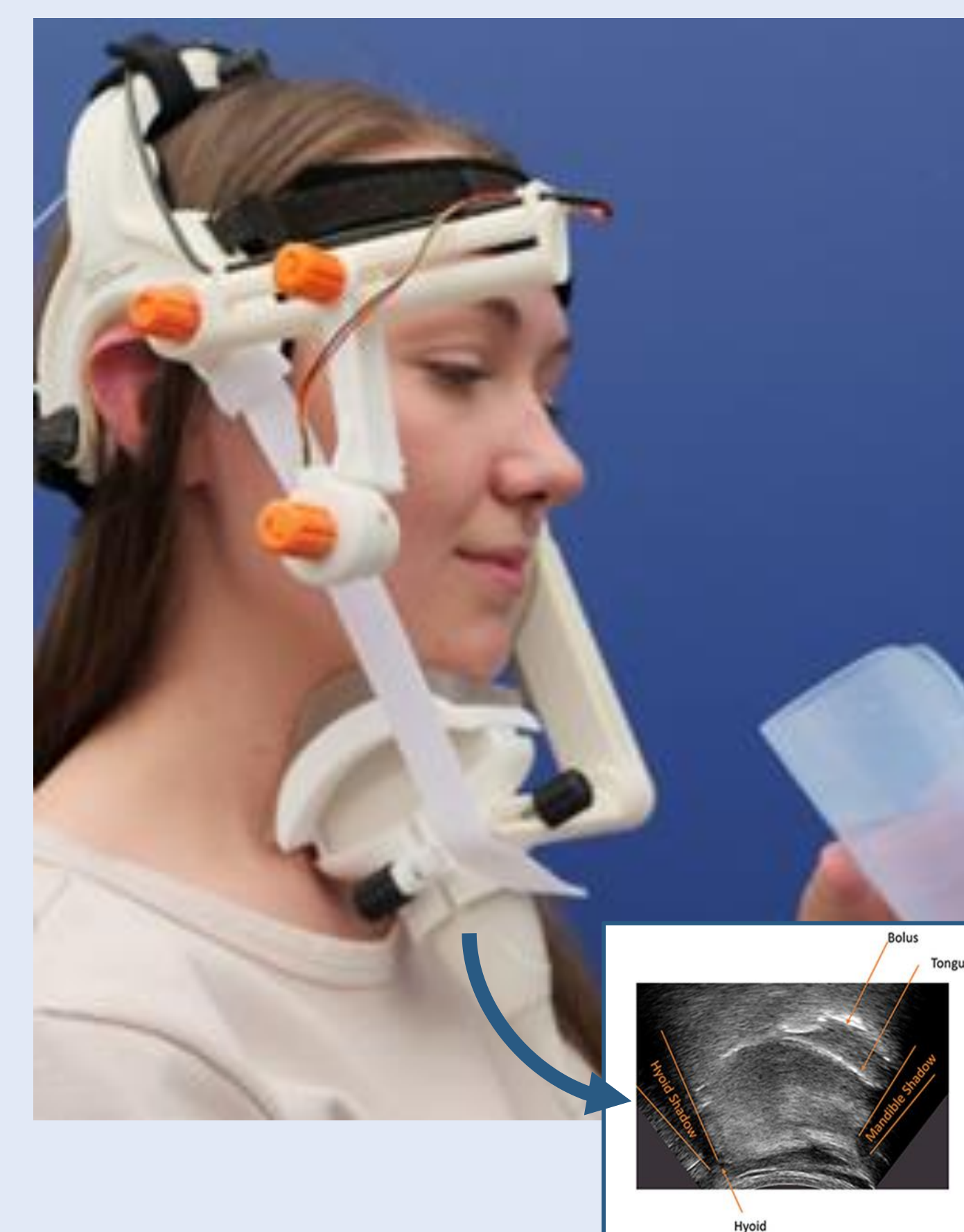
Sequential swallowing (continuous) is common in everyday life, and dysphagia assessments

- Sequential - hyoid's maximum displacement & durations reduced compared to Discrete (single) swallows (Chi-Fishman and Sonies, 2002)
- But, are Sequential swallow hyoid trajectory patterns different to Discrete?

Ultrasound Evaluation of Swallowing (USES) provides rapid automatic hyoid tracking (Ma and Wrench, 2022), allowing feasible, safe hyoid trajectory analyses, with no radiation exposure.

Aim: To evaluate whether hyoid trajectory patterns are different in Sequential swallowing compared to Discrete swallowing, using a novel analysis with USES, adapting an established qualitative method for videofluoroscopy (Alves et al., 2022).

METHOD: DATA COLLECTION



USES:

- Pocket-sized Micro-ultrasound system in standard B-mode, connected to a Windows laptop
- 2-5MHz 60mm convex probe
- UltraFit headset to stabilise probe in midsagittal submental position
- Customised acoustic gel pad
- Side-mounted camera to record bolus delivery

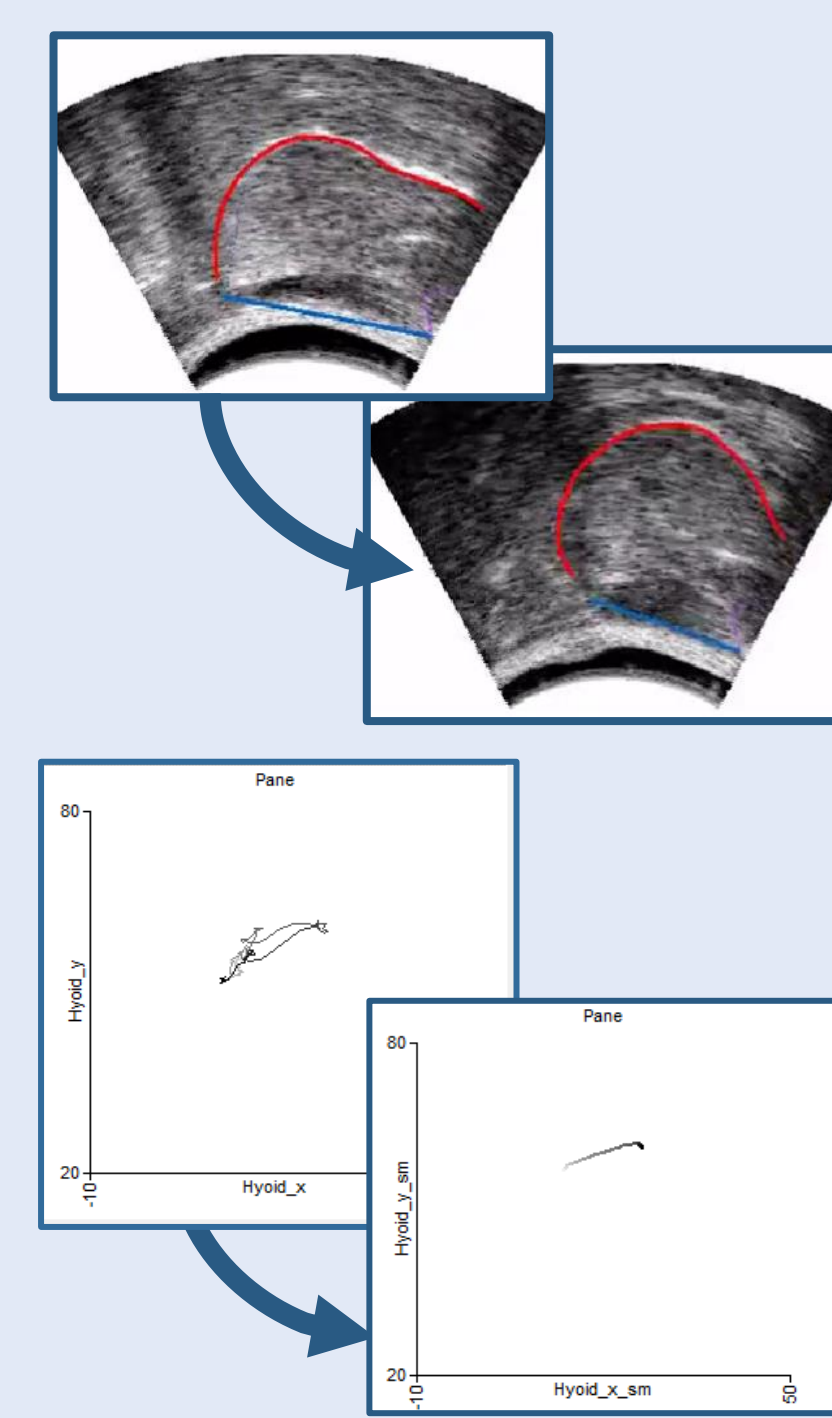
Participants:

- Subset of 8 participants with normal swallowing (6 females, 2 males)
- All with motor pattern in which hyoid returned to rest position between each sequential swallow

Water bolus from cup:

- Sequential - 100ml x1
- Discrete - 10ml x5

METHOD: DATA ANALYSIS



First/last Discrete swallows were excluded, only Sequential swallows between first swallow and end of bolus delivery were included. Participants coded F or M for sex.

XY reference axes fitted to ultrasound images. (Articulate Instruments Ltd).

DeepLabCut with MobileNet1.0 network:

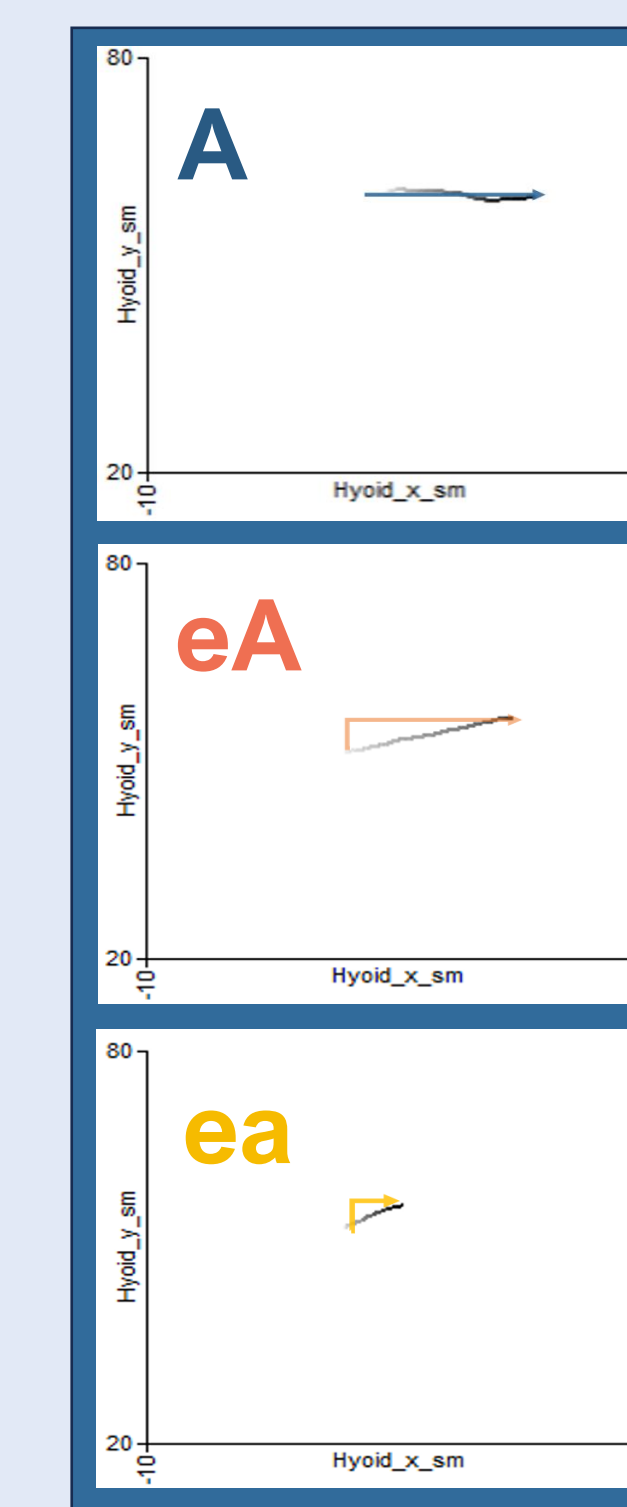
- automatically tracked hyoid position throughout swallowing
- XY-axis charts representing hyoid trajectory over space/time (darker = more recent).

Trajectory of the excursion phase for each Sequential/Discrete swallow was analysed individually, qualitatively evaluated following Alves et al. (2022).

Alves et al. (2022) Patterns	Code	Description	Representation
H1	A	Anterior only	→
H2, H3	eA	short elevation, long Anterior	↗
H4	Ea	long Elevation, short anterior	↖
H5	E	Elevation only	↑
H6	EA	long Elevation, long Anterior	↗
H7	ea	short elevation, short anterior	↘

Reliability:

Intra-rater: 100% re-rated following 2 week interval.
Inter-rater: 35% of trajectories (3/8 participants) re-rated.



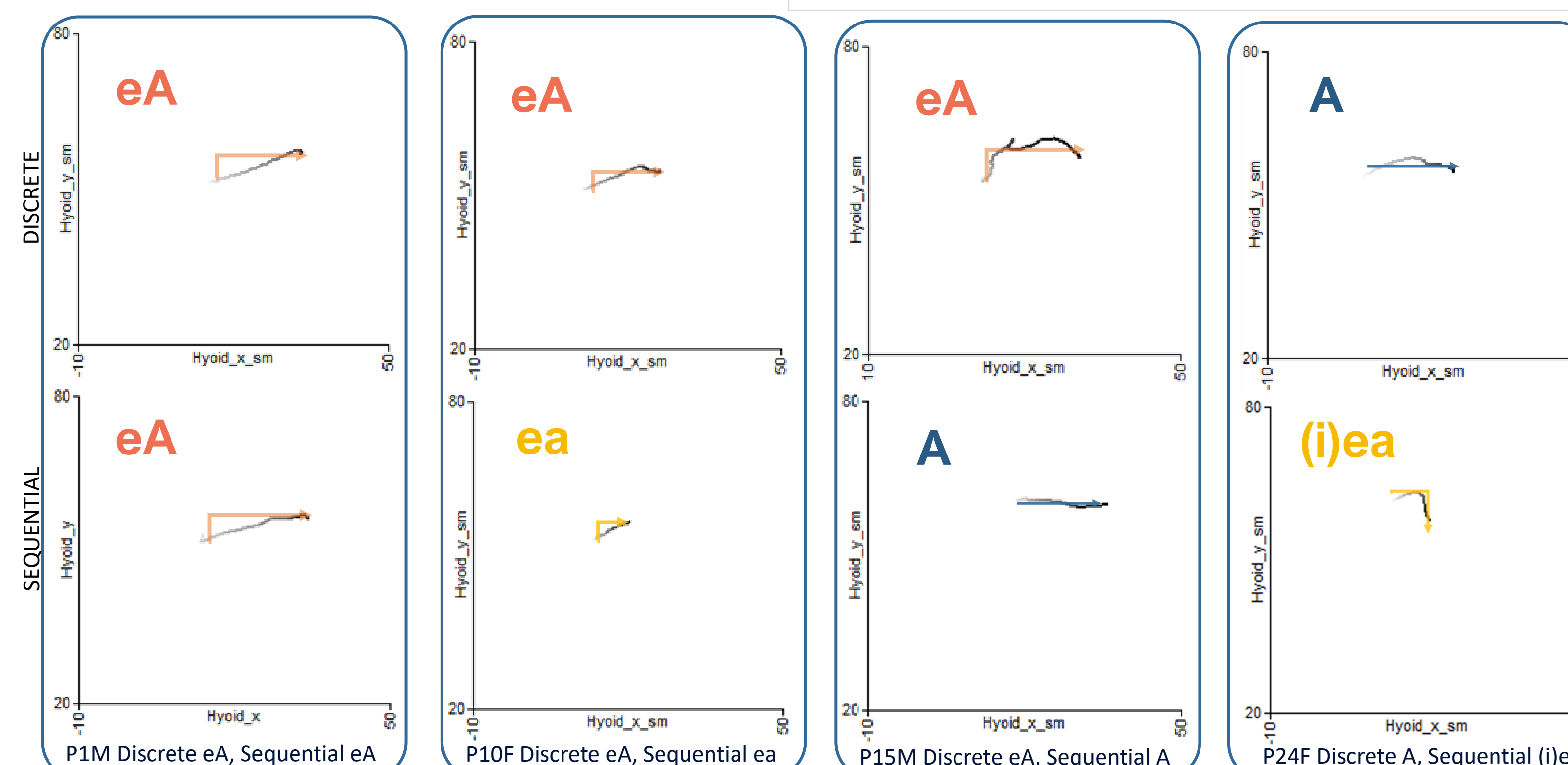
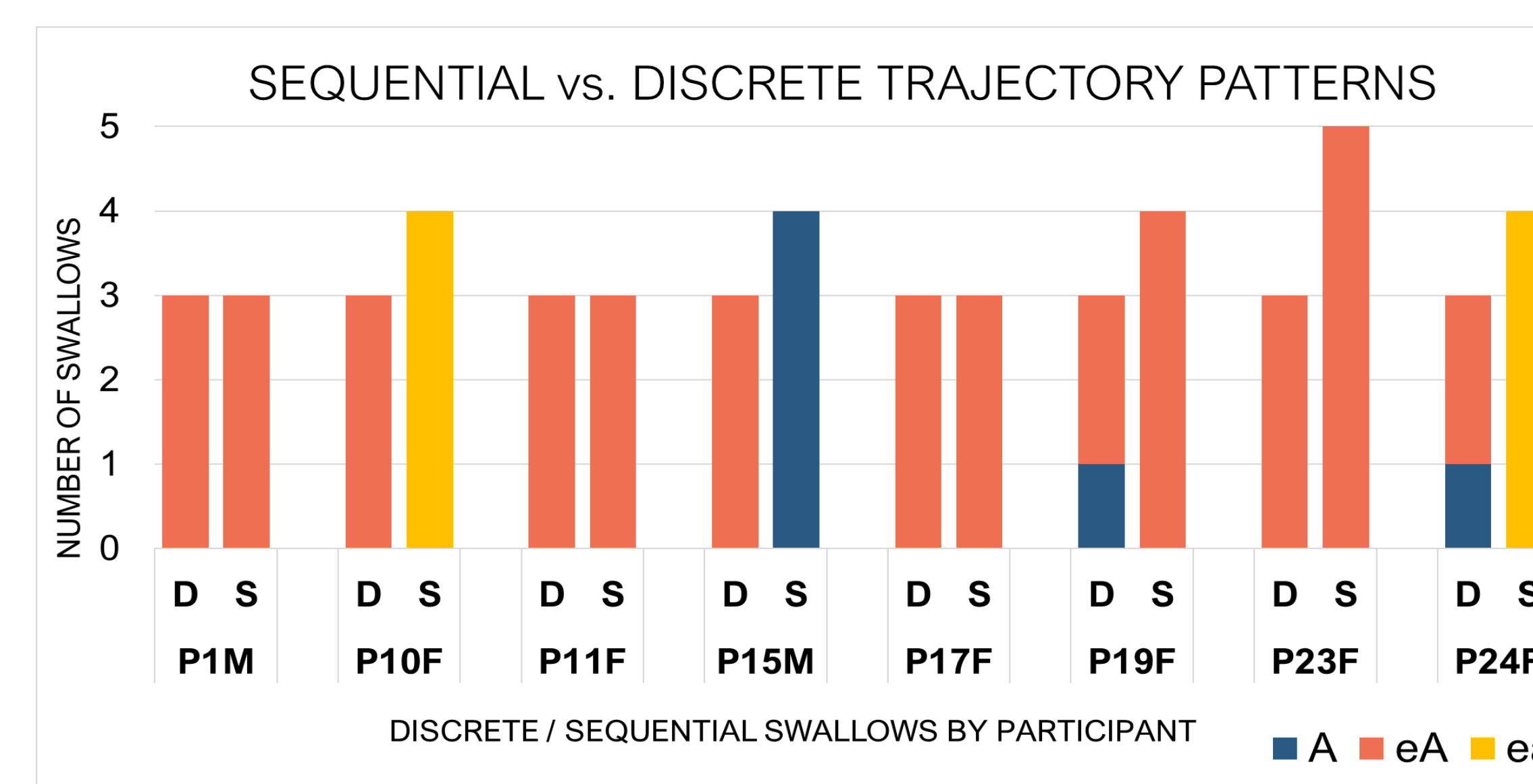
RESULTS

Only **A**, **eA**, and **ea** were observed.

4 of 8 participants used same pattern for all swallows, both Sequential and Discrete (**eA**).

Other 4 of 8: P10F, P15M, P19F, & P24F used a different pattern for Sequential than Discrete.

Reliability:
inter-rater: 94.7%.
Intra-rater: 88%.



- **ea** exclusive to Sequential

- no clear association between Discrete and Sequential patterns across those who switch for Sequential

- novel pattern subtype was identified in P24F: inverted ae (**(i)ea**) - short anterior followed by short downwards movement

DISCUSSION & CONCLUSIONS

Qualitative analysis shows that some people (4/8) use different hyoid trajectory patterns during Sequential swallowing compared to Discrete swallows.

Trajectory patterns can be efficiently evaluated using USES and qualitative analyses.

Unlike Alves et al. (2022) videofluoroscopy study (n=67), this study found use of >1 pattern within individuals - within-individual variability in both Discrete and Sequential.

Variability:

- sequential swallowing behaviours can be considerably different to discrete
- hyoid is capable of multiple movement patterns
- all appropriate for safe, normal swallowing.
- Ultrasound/USES valuable in assessing normal variability

One pattern (ea) occurred only in sequential. May be well-suited to task demands of sequential, consistent with quantitative findings (Chi-Fishman and Sonies, 2002).

Novel pattern findings:

- Inverted ea in one individual
- anterior only pattern (A) in one male in sequential - pattern not observed in males' discrete swallows in Alves et al.

Both findings possibly unique to sequential, due to elevated outset/start position adopted between cyclical sequential swallows.

Clinical implications:

- Sequential swallowing can be qualitatively different to discrete swallows - emphasises need to assess both.
- Normal variation in hyoid trajectory patterns within and across individuals - consider in assessment/monitoring

Future directions:

- Investigate trajectory differences in clinical groups - PD
- May offer novel method of evaluating the complex coordination of oral and pharyngeal stages in sequential swallowing.

Project website:
swallow-vision.com

References

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