From Static Averages to Dynamic Models for Menstrual Phase Prediction: A Conceptual Model Integrating Cervical Mucus and Cycle Days

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Abstract

Problem statement: Current app-based fertile window predictions typically rely on simple back-calculation from average cycle length and the inferred end of the current menstrual phase. This approach ignores within-person variation in onset and duration of the fertile window, resulting in a high risk of misestimations. Established alternatives for ovulation detection often involve additional costs (e.g., LH tests, intravaginal sensors), are infeasible for at home use (e.g., urine tests, blood draws), or require strict daily adherence (e.g., basal temperature tracking) reducing their usability in practice. Cervical mucus (CM) characteristics are strongly associated with estrogen levels and change predictably around ovulation. CM is fast and easily observable and cost-free. However, CM can be influenced by external factors such as sexual intercourse or infections.

Solution: We propose a rule-based, dynamic prediction model that integrates between-person average menstrual phase lengths, within-person cycle variations, and CM observations to estimate current cycle phases with improved accuracy while remaining low-cost and user-friendly.

Methods & Theory: The statistical framework continuously updates predicted cycle phases by combining user-specific average cycle lengths with population-based averages of hormonal changes and CM observations. Model reliability was evaluated using synthetic data, demonstrating robust phase estimation. The next step involves validation with real user data and LH testing to assess accuracy and practical feasibility.

Conclusion & Significance: To our knowledge, this is the first conceptual model that jointly leverages average cycle phase lengths, intra-individual variability, and CM characteristics for dynamic menstrual phase prediction. This approach offers interpretable, individualized, and cost-free foundation for next-generation menstrual and fertility tracking applications.

Image



From left to right. **User Input** (yellow): *Mucus Entry*: none, sticky, creamy, egg white, watery; *Day in Cycle*: current cycle day (increments by +1 from previous day); *Cycle Length*: user's average cycle length (typically 23–35 days). **Classify Phase** (blue): Divide the individual average cycle length into five phases, i.e. Early Follicular (EF), Late Follicular (LF), Ovulation Phase(OV), Early Luteal (EL), Late Luteal (LL); *Phase Day Range*: allocate phase boundaries relative to the general average lengths of each phase, e.g., for a 28-day cycle: EF = 7 days, LF = 4 days, OV = 5 days, EL = 6 days, LL = 6 days; *Mucus Weights*: each mucus type has a phase-specific weight; *Relative Weight*: combines mucus-based weight (derived from *Mucus Entry* and its fit to the current day of cycle) and day-based likelihood (fitting of *Day in Cycle* into possible range of days of current phase). **Predicted Phase** (green): phase with highest score is returned as predicted cycle phase.

Recent Publications

Su, Hsiu-Wei; Yi, Yu-Chiao; Wei, Ting-Yen; Chang, Ting-Chang; Cheng, Chao-Min (2017): Detection of ovulation, a review of currently available methods. In Bioengineering & translational medicine 2 (3), pp. 238–246. DOI: 10.1002/btm2.10058.

Johnson, S., Marriott, L., & Zinaman, M. (2018). Can apps and calendar methods predict ovulation with accuracy?. Current Medical Research and Opinion, 34(9), 1587-1594.

Li, K., Urteaga, I., Shea, A., Vitzthum, V. J., Wiggins, C. H., & Elhadad, N. (2022). A predictive model for next cycle start date that accounts for adherence in menstrual self-tracking. Journal of the American Medical Informatics Association, 29(1), 3-11.

Francis, G., & Keay, N. (2024). Quantitative hormone analysis reveals sources of variability in the menstrual cycle. Women in Sport and Physical Activity Journal, 32(S1).

Stricker, R., Eberhart, R., Chevailler, M. C., Quinn, F. A., Bischof, P., & Stricker, R. (2006). Establishment of detailed reference values for luteinizing hormone, follicle stimulating hormone, estradiol, and progesterone during different phases of the menstrual cycle on the Abbott ARCHITECT® analyzer. Clinical Chemical Laboratory Medicine, 44(7), 883-887.

Fehring, R. J., Schneider, M., Raviele, K., & Barron, M. L. (2007). Efficacy of cervical mucus observations plus electronic hormonal fertility monitoring as a method of natural family planning. Journal of Obstetric, Gynecologic & Neonatal Nursing, 36(2), 152-160.

Najmabadi, S., Schliep, K. C., Simonsen, S. E., Porucznik, C. A., Egger, M. J., & Stanford, J. B. (2021). Cervical mucus patterns and the fertile window in women without known subfertility: a pooled analysis of three cohorts. Human Reproduction, 36(7), 1784-1795.

Biography

Elisa Palme is a Cognitive Scientist at the University of Osnabrück. She started her research on menstrual health and menstruation tracking apps during her Master's degree, focusing on well-being and menstrual symptoms. Her current research focuses on the relationship between language learning, hormonal changes and biological markers across the menstrual cycle and predicting changes across cycle phases. Her focus is to create scientific results with real-world applications. In addition to her academic work, she is a science communicator on the podcast *Kaleidoscience*. **Milad Rouygari** is a Cognitive Science Master's student and a research assistant at the University of Osnabrück. He developed a mathematical model for menstrual-cycle phases prediction to support hormone-informed learning. His interests span cognitive neuropsychology and applied research. Milad aims to bridge rigorous science and real-world practical impact, designing evidence-based tools that improve learning, accessibility, and well-being.

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Kommentiert [EP7]: idea: have rough process of how model calculates the phase

Kommentiert [EP8R7]: including division in 5 cycle phases that are matched to certain mucus (maybe similar to slides Milad created for cycle division), indicate flexible parts (EF, LF, OV) and stable part (EL, LL)

Kommentiert [MR9R7]: There is a preliminary graph

Kommentiert [MR1]: or their focus is finding the next cycle, or cycle length (I am not sure where it would be fine to add this info)

Kommentiert [MR2R1]: There is one recent source we could also use (if we have to match the 5 recent references :))

Kommentiert [EP3]: feedback pls

Kommentiert [MR4R3]: I like both the alternative wording

Kommentiert [EP5]: slightly cheated - refers to the validation for each day and possible mucus that were sensible - kind of synthatic data

Kommentiert [EP6]: please confirm that this is correct in this way