Customized Fetal Growth Modeling and Monitoring - A Statistical Process Control Approach

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Research Team

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Comment: Research report to be published June, 2014, in ***Quality Engineering.***

"Author's Accepted Manuscript" downloadable at ***ResearchGate***.

- **Q.:** How is *Quality Engineering* linked to *Fetal Growth*??
- **A.:**

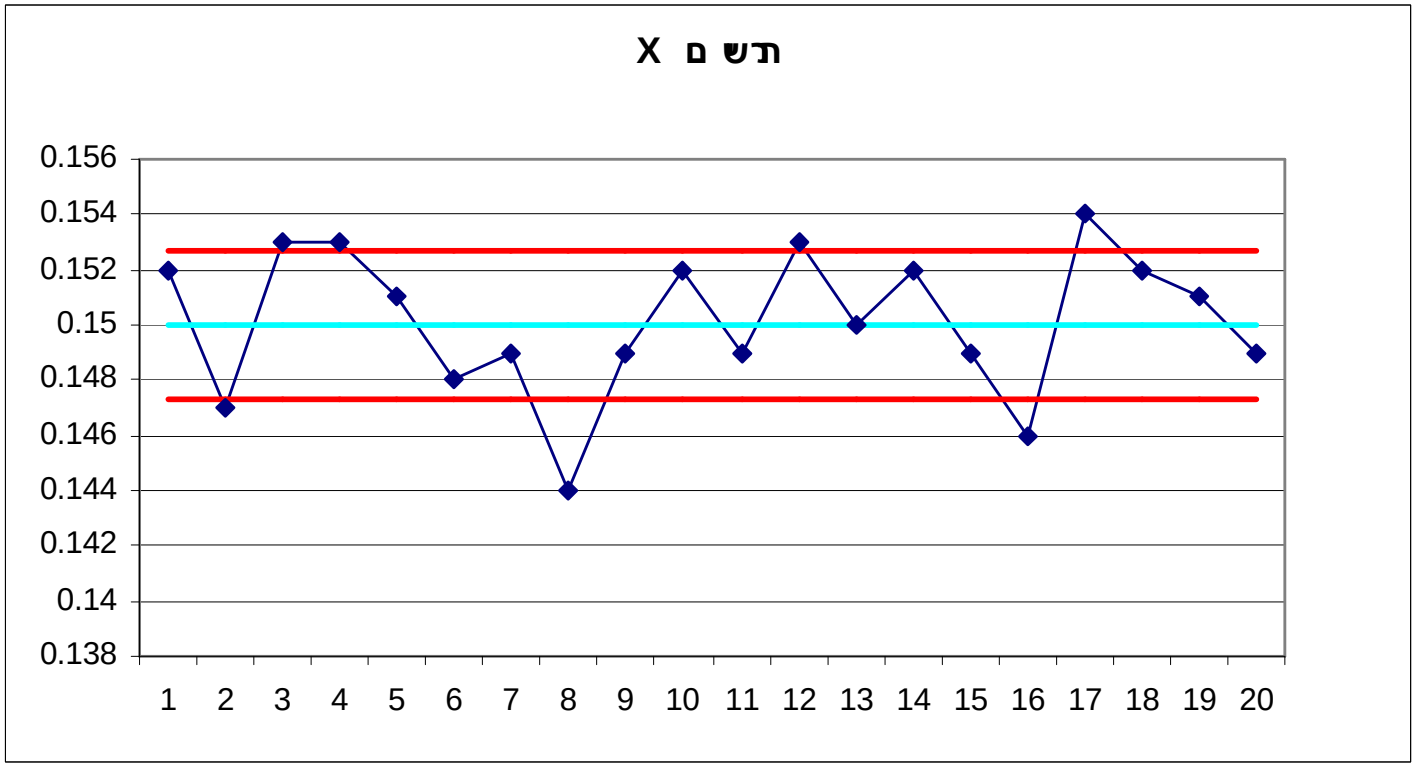
  * *Fetal Growth* is a process
  * *Quality Engineering* specializes in modeling and monitoring processes (to improve quality)

Two modes of monitoring a process

- Based on general knowledge of variation typical to that type of process ("population limits"):
  - Industry: "Specification limits" (Tolerances)
  - Fetal Growth: Boun. population centiles (Hadlcok's)
- Based on knowledge of variation typical to the monitored specific process:
  - Industry: "Control charts" (SPC; Shewhart, 1929)
  - Fetal growth: ??????

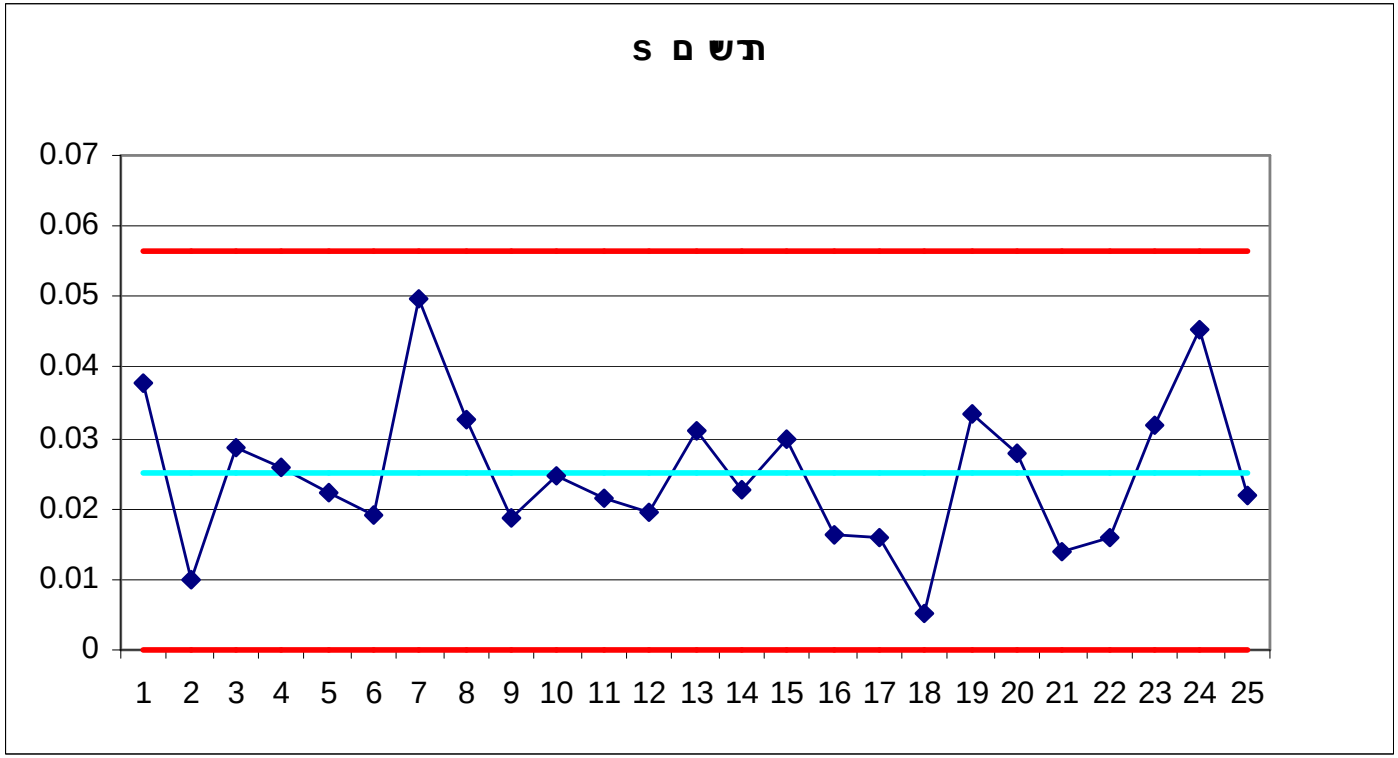
Example for Monitoring a Process

- Control Chart for the Average



Example for Monitoring a Process

- Example for Monitoring Variation (σ^2)



Two Recent Developments

- New definition of process stability (profile monitoring):

Process is **stable** if it behaves according to model and residuals have stable distribution (constant parameters);

- New modeling methodology:

Response Modeling Methodology (RMM; Shore, 2005);

Unique feature: “Continuous monotone convexity” (CMC), which grants flexibility in non-linear modeling.

Example: SPC-based Monitoring of an Ecological Process*

- **Modeling a nonlinear profile: Species richness (S) as function of Area (A)**

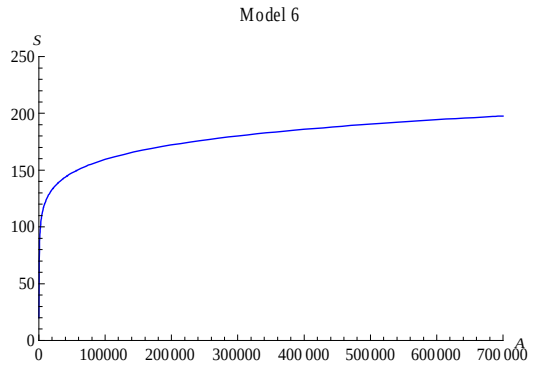
Model 6: Persistence function

Model: $S = (a)\ A^b \exp(-c/A)$

Covariate: A (area, [100,700000], km^2)

Response: S (Number of species, [20,250] units)

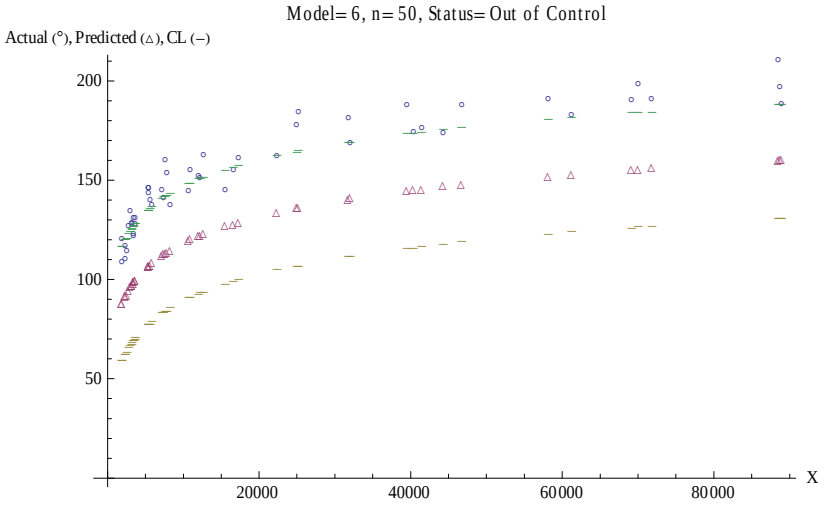
Parameters: a=45, b=0.11, c=132

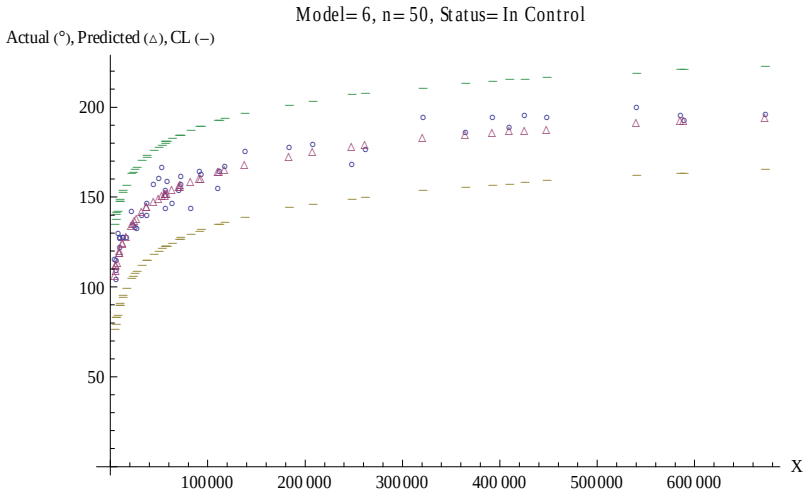


Source: Ulrich, W, Buszko, J. Self-similarity and the specie-area relation of Polish butterflies. *Basic and Applied Ecology* 2003. 4: 263–270.

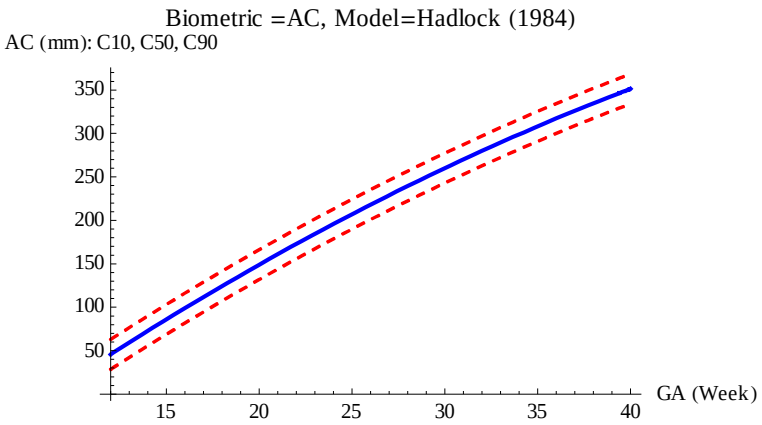
* **Example taken from:** Shore, H. (2013), Modeling and Monitoring Ecological Systems—A Statistical Process Control Approach. *Qual. Reliab. Engng. Int.*. doi: 10.1002/qre.1544

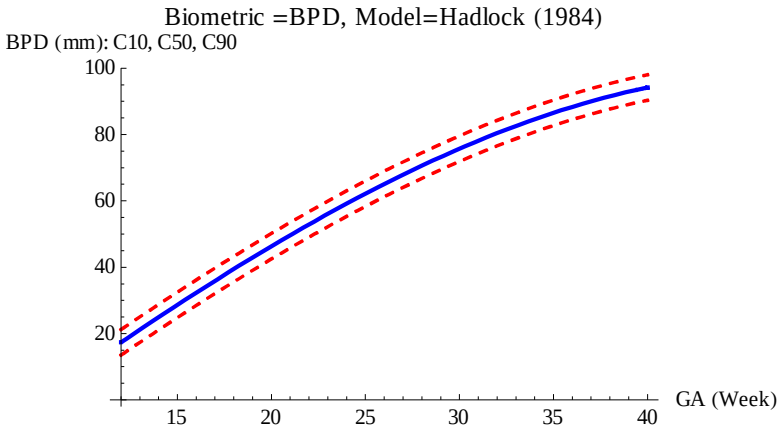
Scenario 2 (RMM ecological model): Change in Parameter “b” (from 0.11 to 0.13)

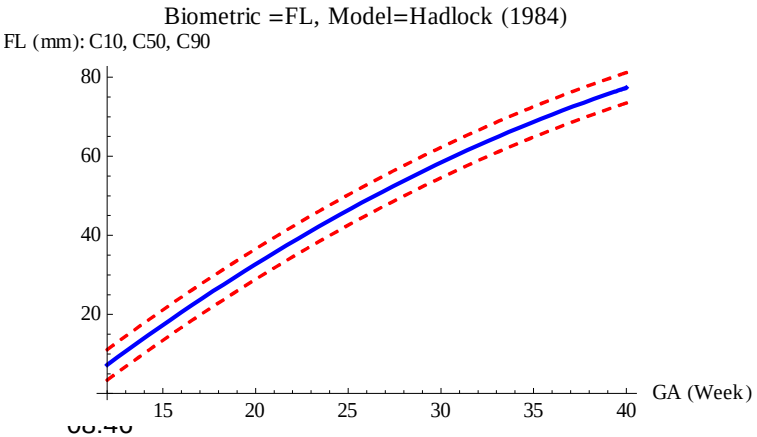


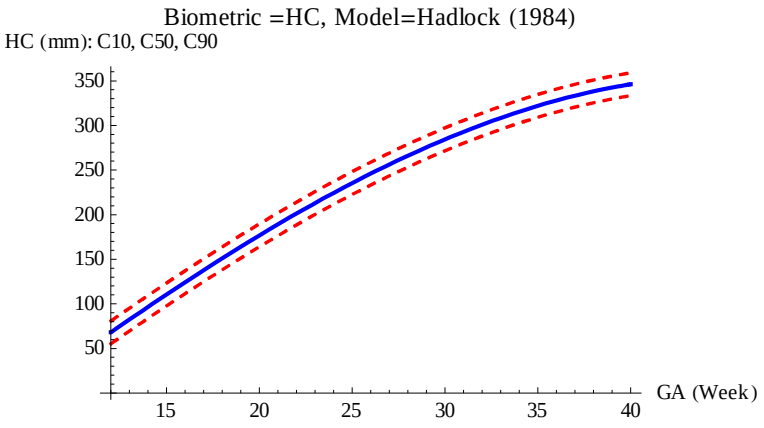


Monitoring with Hadlock's Limits (Fetal growth: specification limits..)







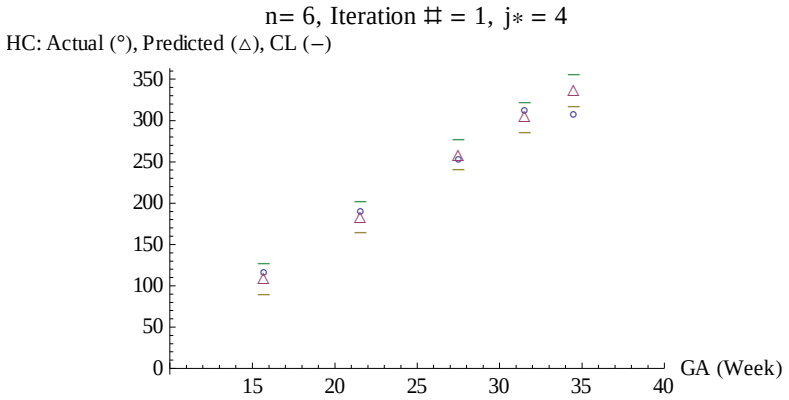


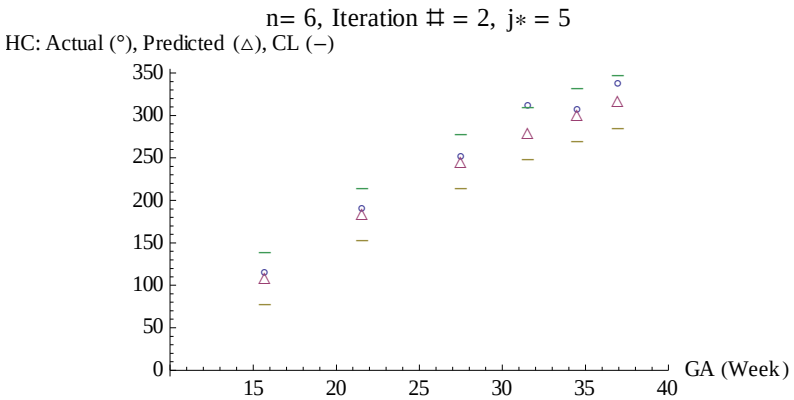
RMM modeling and SPC monitoring
(Shore *at al*., 2014)

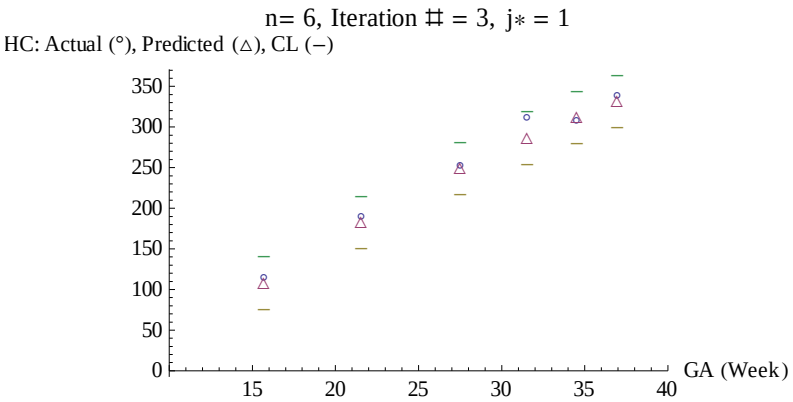
- **Phase 1 – Constructing monitoring scheme:**
  - **Growth trajectory is modeled by RMM**, based on available US measurements (minimally four);
  - **Two control charts:** For expected **median;** For **variation** around the median (**LAD**-Least absolute deviation).

- **Phase II – Monitoring:**
  - New US observation collected and compared to expected value;
  - If deviation is within median control limits and within LAD control limits – update control scheme parameters;
  - If observation outside these limits but within Hadlock's limits - seek medical advice;
  - If observation within control limits but outside Hadlock's limits – seek medical advice (of a different kind..)

Three Examples (median control chart)

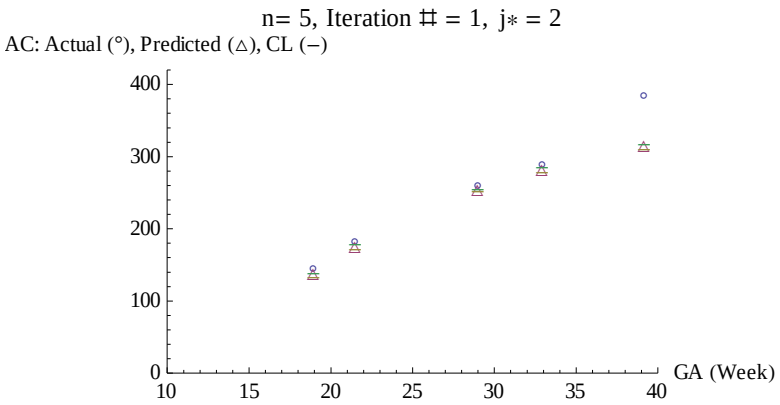


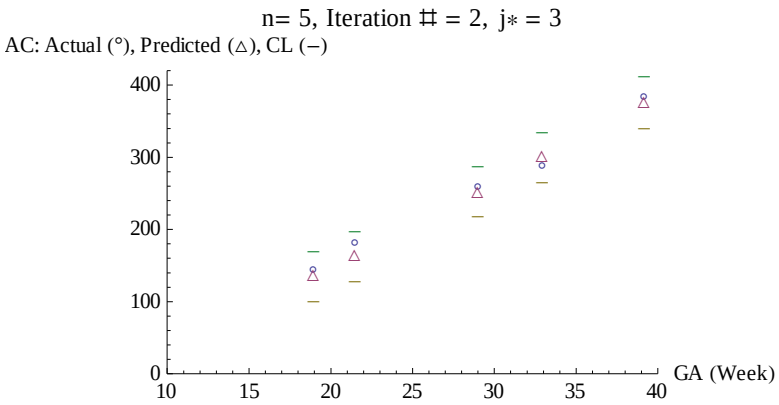




Example 1. Monitoring HC. Male with normal BW = 2930 grams. Close CLs.

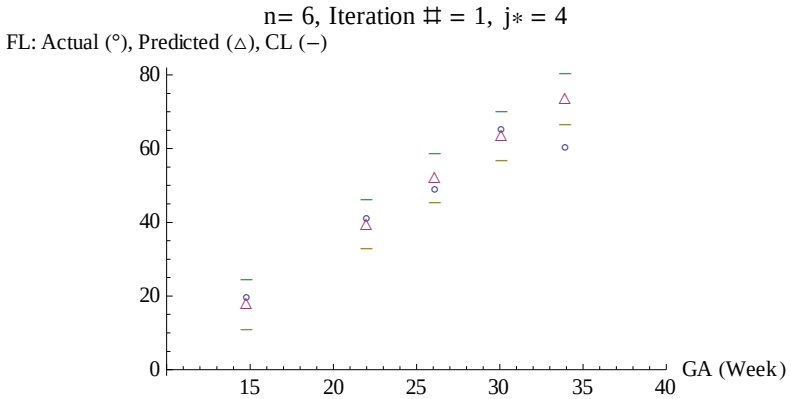
Three Examples (Cont'd)

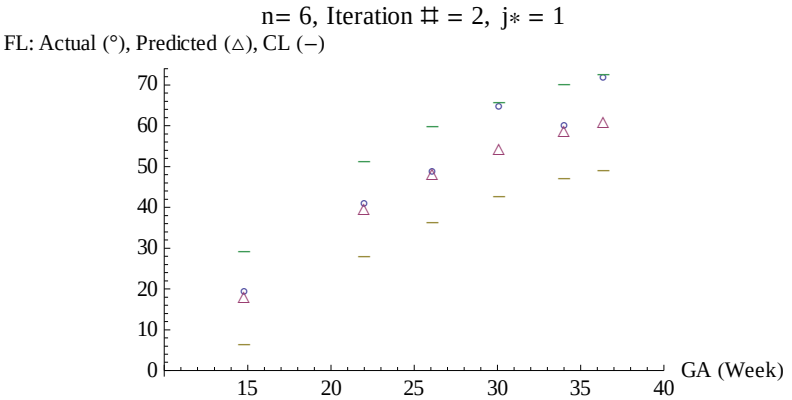


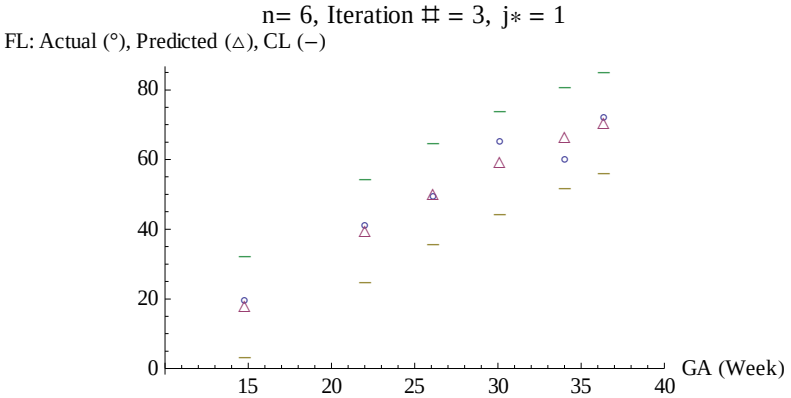


Example 2. Monitoring AC. Female with **HBW**, BW= 4010 grams. For model fitted with first four data points (first iteration), expected AC (fifth data point) is appreciably smaller than observed. Second iteration produces control limits more distant to accommodate the non-smooth growth pattern. This will show in a "jump" in the LAD control chart.

Three Examples (Cont'd)

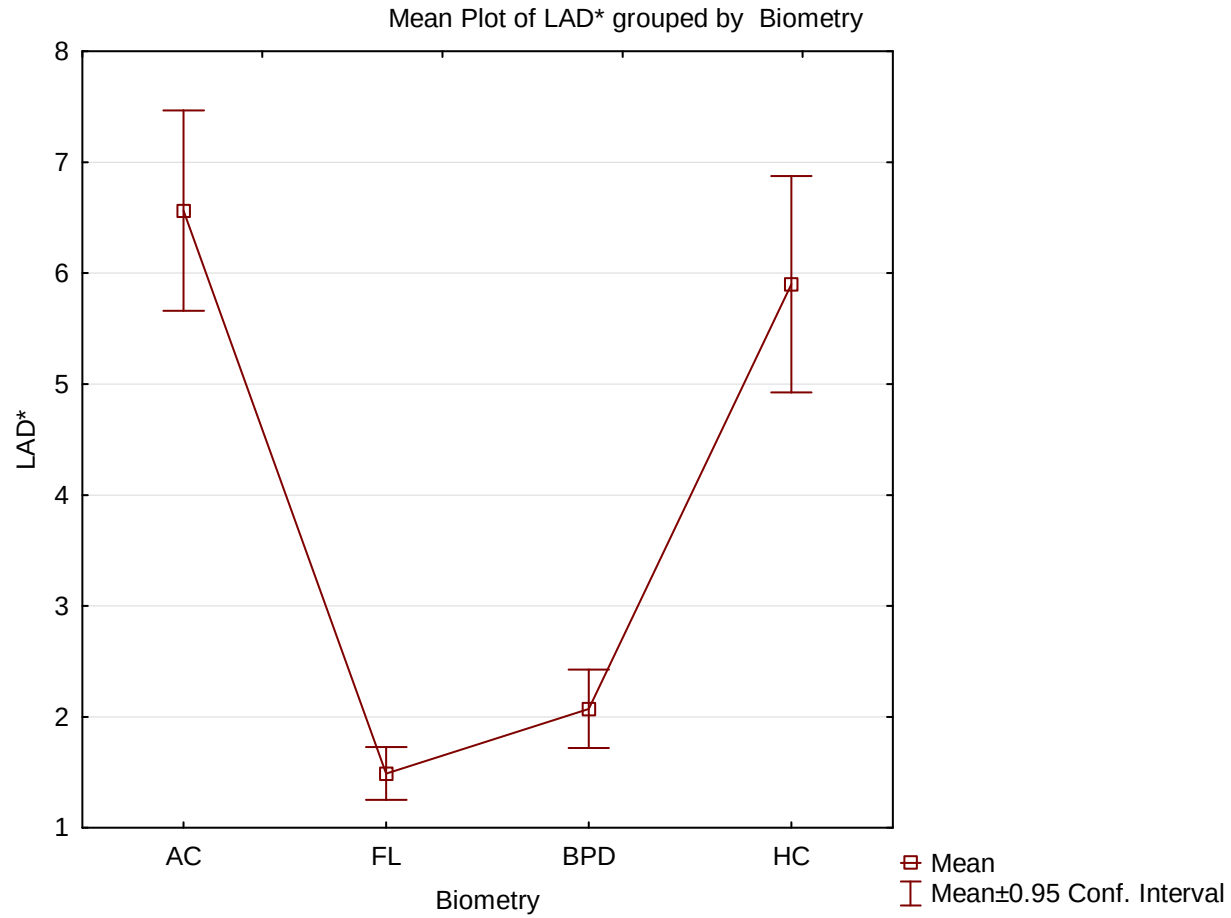






Example 3. Monitoring FL, Female with normal BW= 3460 grams. Three last points very volatile (relative to expected values across different iterations), resulting in large LAD* values that cause the CL to be far apart. Pregnancy with adverse prenatal outcome (GD).

Means and CI of LAD* (variation measure)



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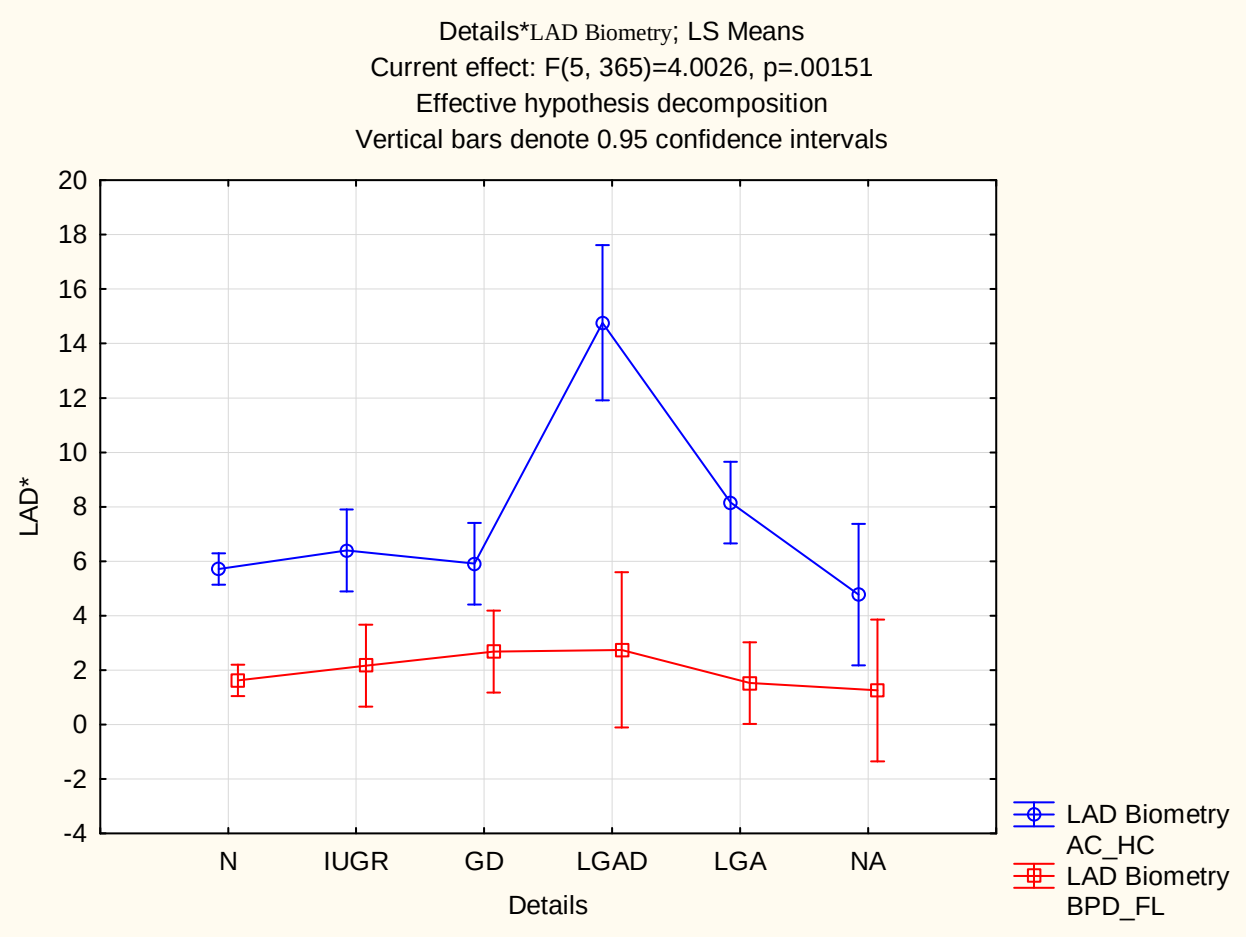
A profile of means (with 95% confidence intervals) for LAD* (N-Normal, NA-Not available)



Thank you

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Professor Haim Shore Blog