Mechanical Modeling of Skinfold Compression

Kin 304W

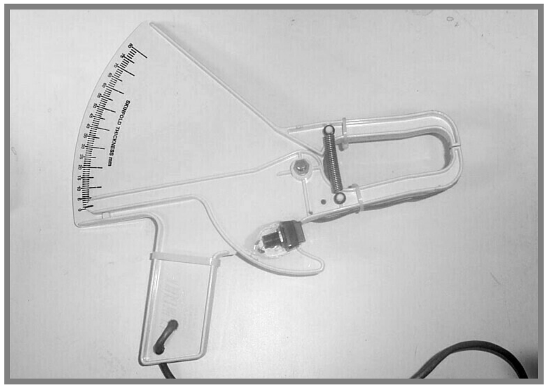
Week 10: July 10, 2012

Announcements

- Project Part II is due next Tuesday (July 17)
- Brett has office hours today (July 10) from 1-2 pm, K8619
- I still have a few marked Project Part I's - please pick them up from me at the break or end of class.

Skinfold Thickness Measurement

- Think back to Kin 142 when you measured skinfold thicknesses…
- Skinfolds are a compressed thickness of a double layer of skin plus adipose tissue
- Skinfold calipers have springs
- Measure in mm
- Caliper pressure is fixed: e.g. 10 g. mm^{-2}
- Skinfolds are held for 2 seconds and then a single measurement is recorded.



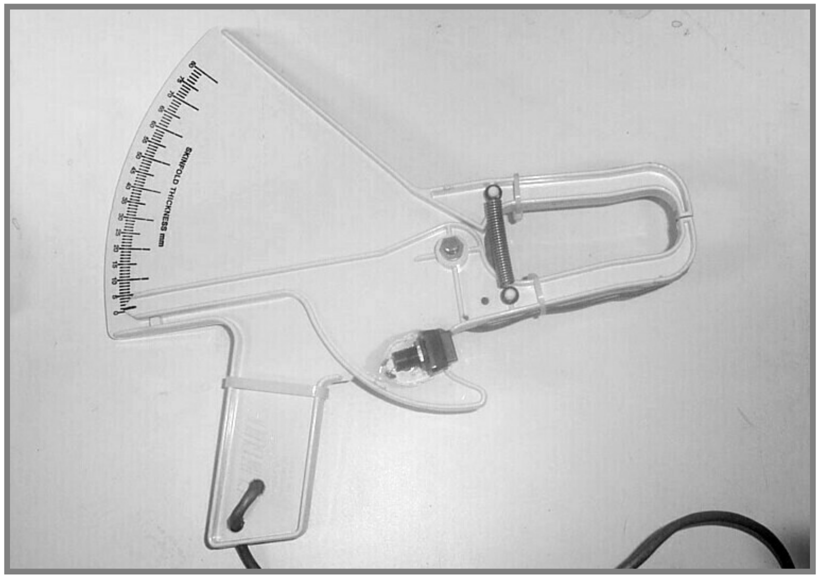
Skinfold Compressibility

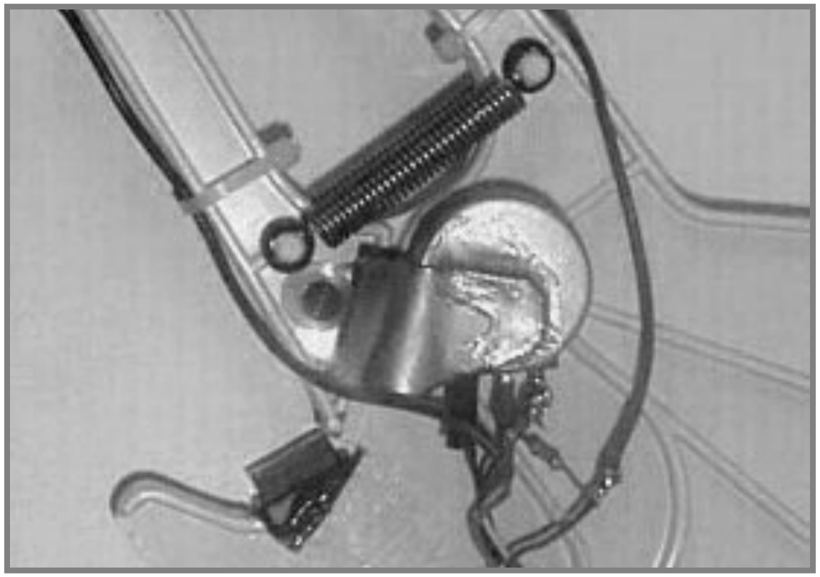
- Since skinfolds compress, thickness values actually vary over time.
- Compressibility varies:
  - from site to site
  - due to differences in skin thickness & tension
  - due to differences in adipose tissue composition
  - between sexes: skinfolds in women are more compressible than in men
  - with age, due to dehydration and changes in elastic properties of tissues
- Instead of recording a single skinfold measurement at the end of 2 sec, if we could record thickness continuously, we would see how it changes over time.

➡ Need an output voltage to represent skinfold thickness

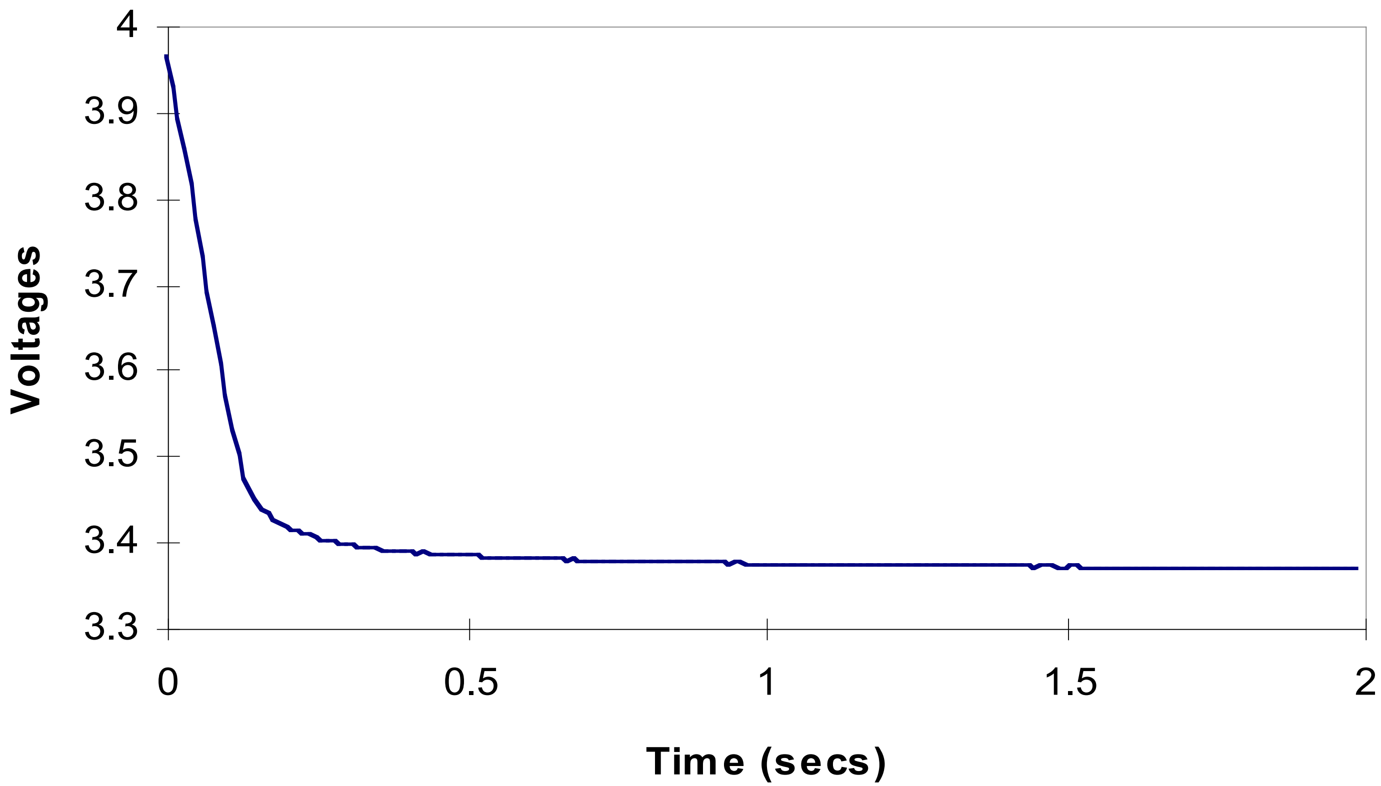
Inexpensive Acquisition of Dynamic Skinfold Data

1. Start with a **Slim Guide Skinfold Caliper**
2. Add a **Potentiometer** (transducer) to provide an analog signal (voltage) that varies with thickness
3. Connect the potentiometer to an **A/D board**
4. Control the A/D board with **Labview software**
5. Collect several trials of skinfold thickness data; save the data in a file you can read into **EXCEL**





Dynamic Skinfold Compression

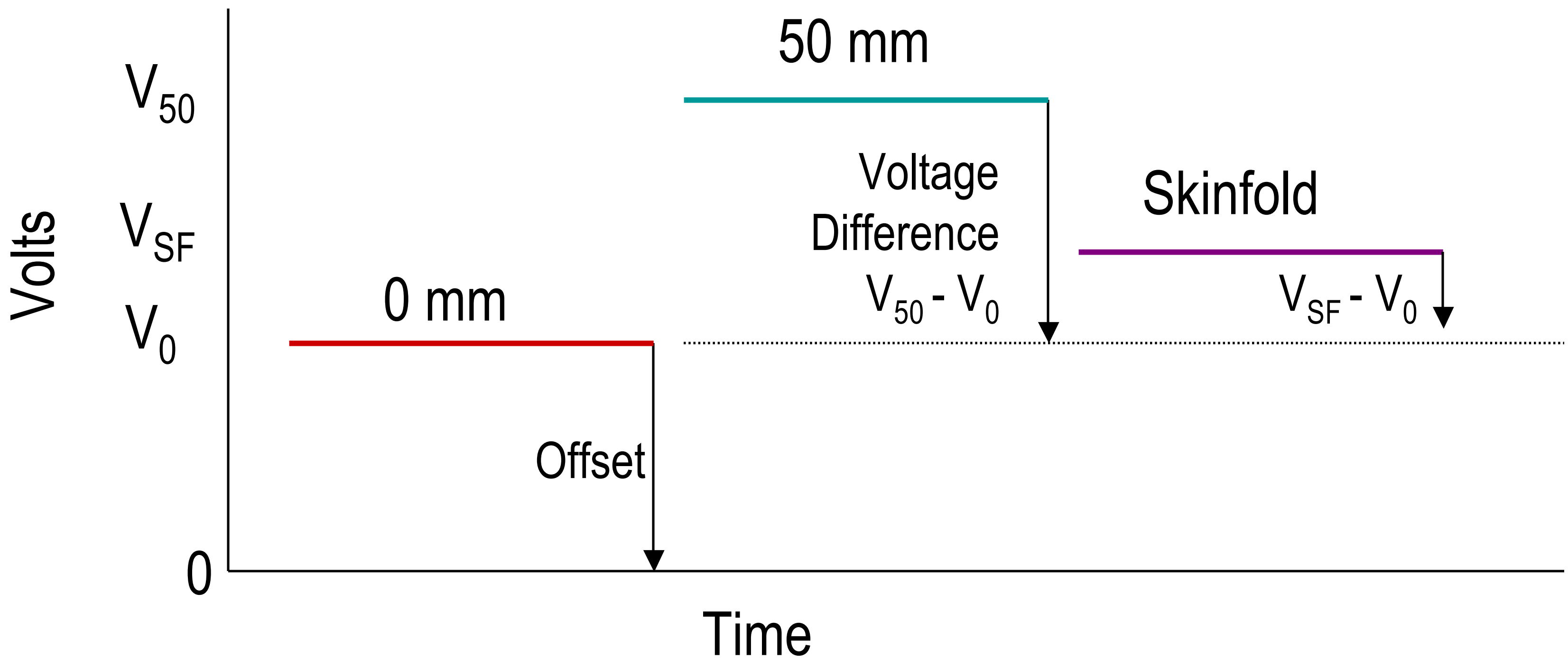


Data Collection

- Initially a calibration run is required
  - Establishes gain and offset used to convert volts of signal to mm of skinfold thickness
- Record 2 seconds of data
  - Long enough to monitor any meaningful changes in skinfold compression
- 100Hz (100 data points per second)
- 10 trials per skinfold

Calibration

1. Hold caliper in 0mm position, record voltage (offset)
2. Hold caliper in 50mm position, record voltage

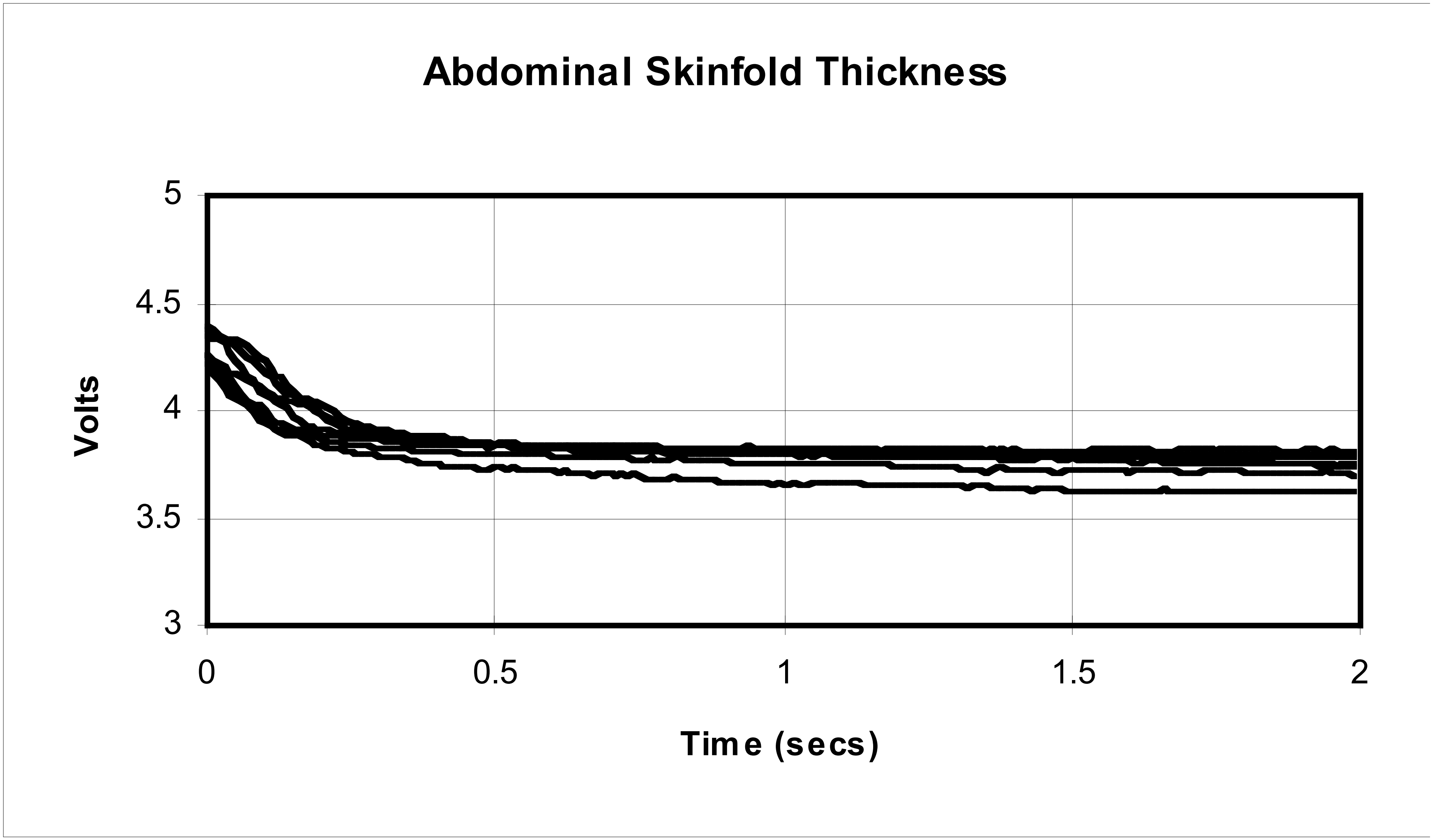


Gain (V/mm) = Voltage difference (V_{50} - V_0) / 50 mm

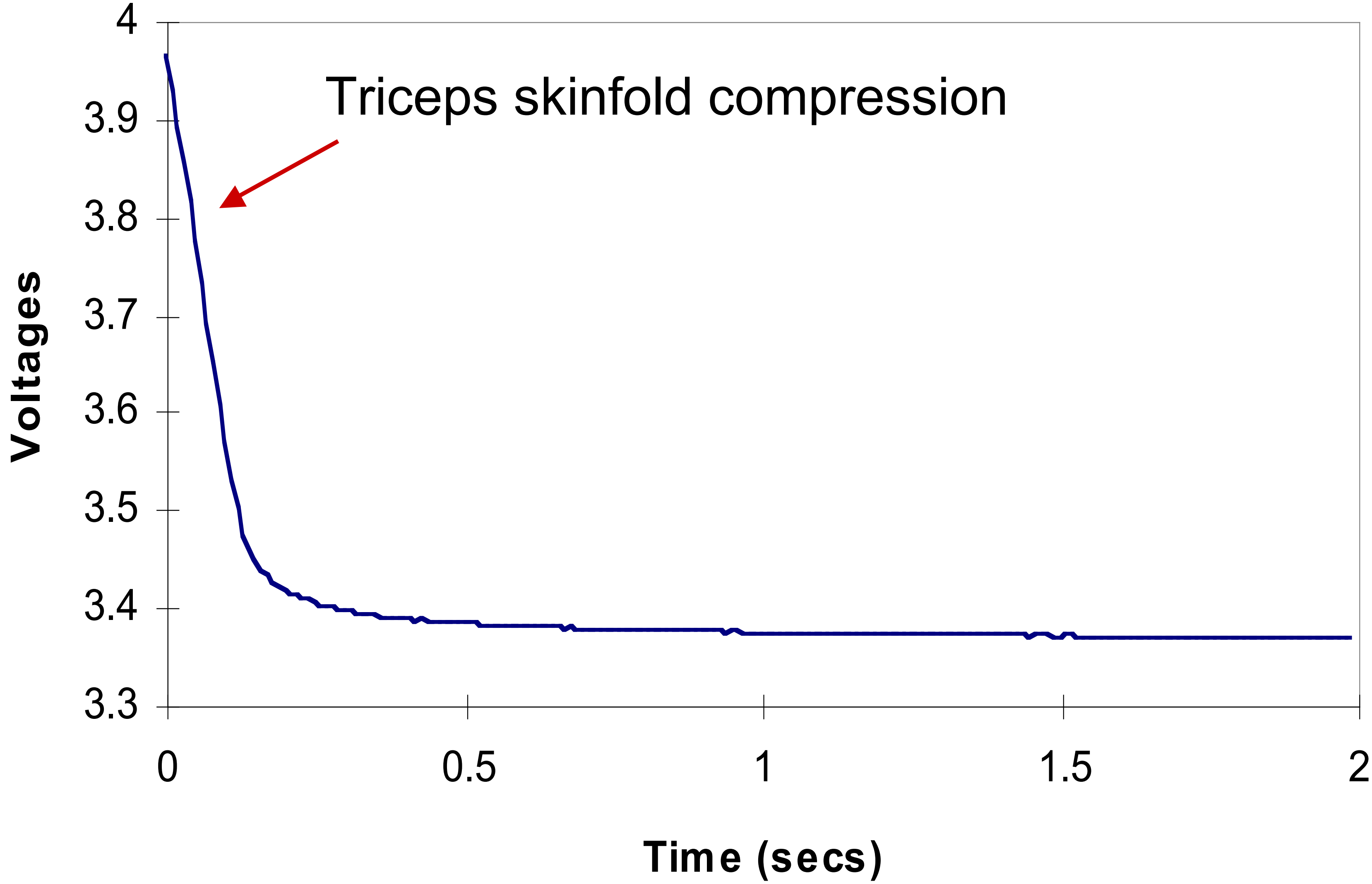
Skinfold thickness = (V_{SF} - V_0) / Gain

Calculate skinfold thickness if V_{50}=350 mV, $V_{0=}$150mV, and V_{SF}=200mV.

Signal Averaging: 10 trials (100 Hz)



Can we model this phenomenon?

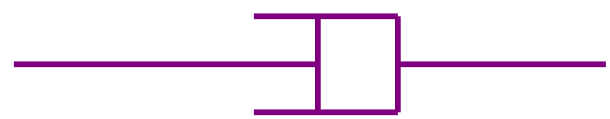


Mechanical Modeling

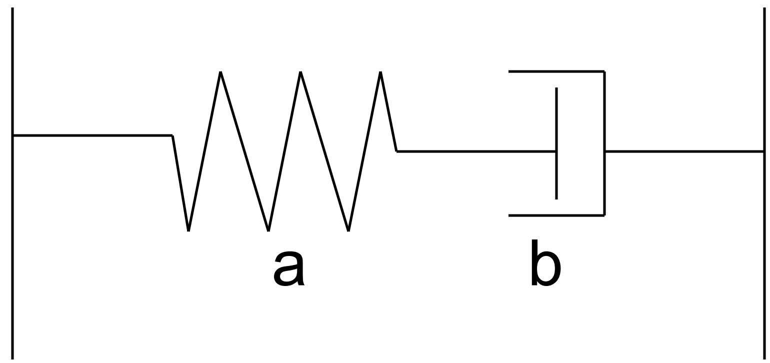
Skin and adipose tissue are viscoelastic; therefore, the mechanical response to loading involves both viscous and elastic (spring) components.

- Spring Component
  - Hooke's Law ($F = -kx$)
  - Spring Constant

- Viscous Component
  - Dashpot
  - Velocity dependent
  - Coefficient of viscosity



Simple Mechanical Model



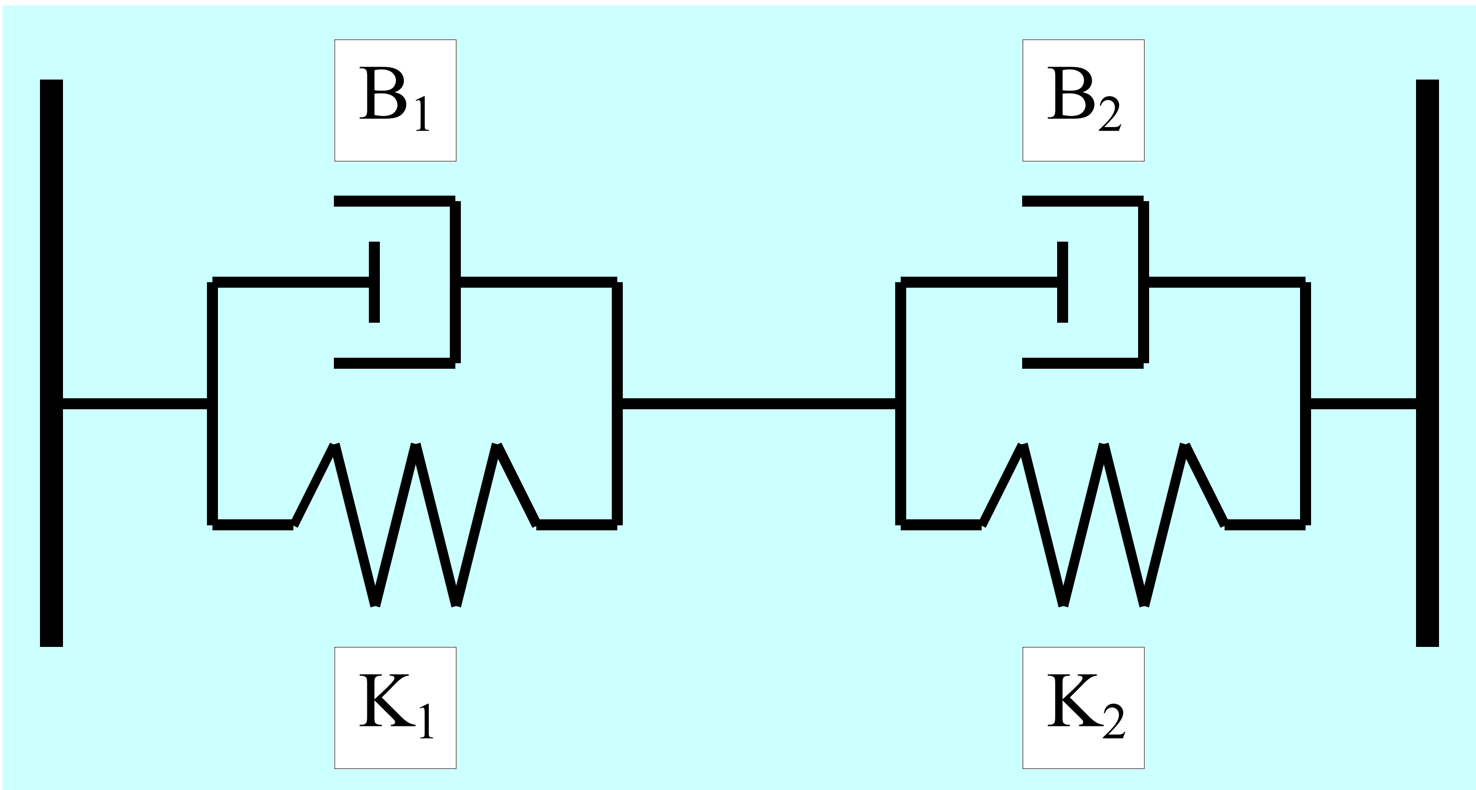
Viscous and Elastic Components in Series

$$Y = (F - bv) / a$$

where F=force, b = viscous coefficient, v=velocity, a = elastic coefficient

More Complex Mechanical Model

Two components of spring and dashpot in parallel



What mathematical equation describes this mechanical model?

More Complex Mechanical Model

$$T_t = T_{initial} + F\left(\frac{1}{k1} - \left[\frac{e^{\frac{-k1t}{b1}}}{k1}\right]\right) + F\left(\frac{1}{k2} - \left[\frac{e^{\frac{-k2t}{b2}}}{k2}\right]\right)$$

T_t is thickness at time t

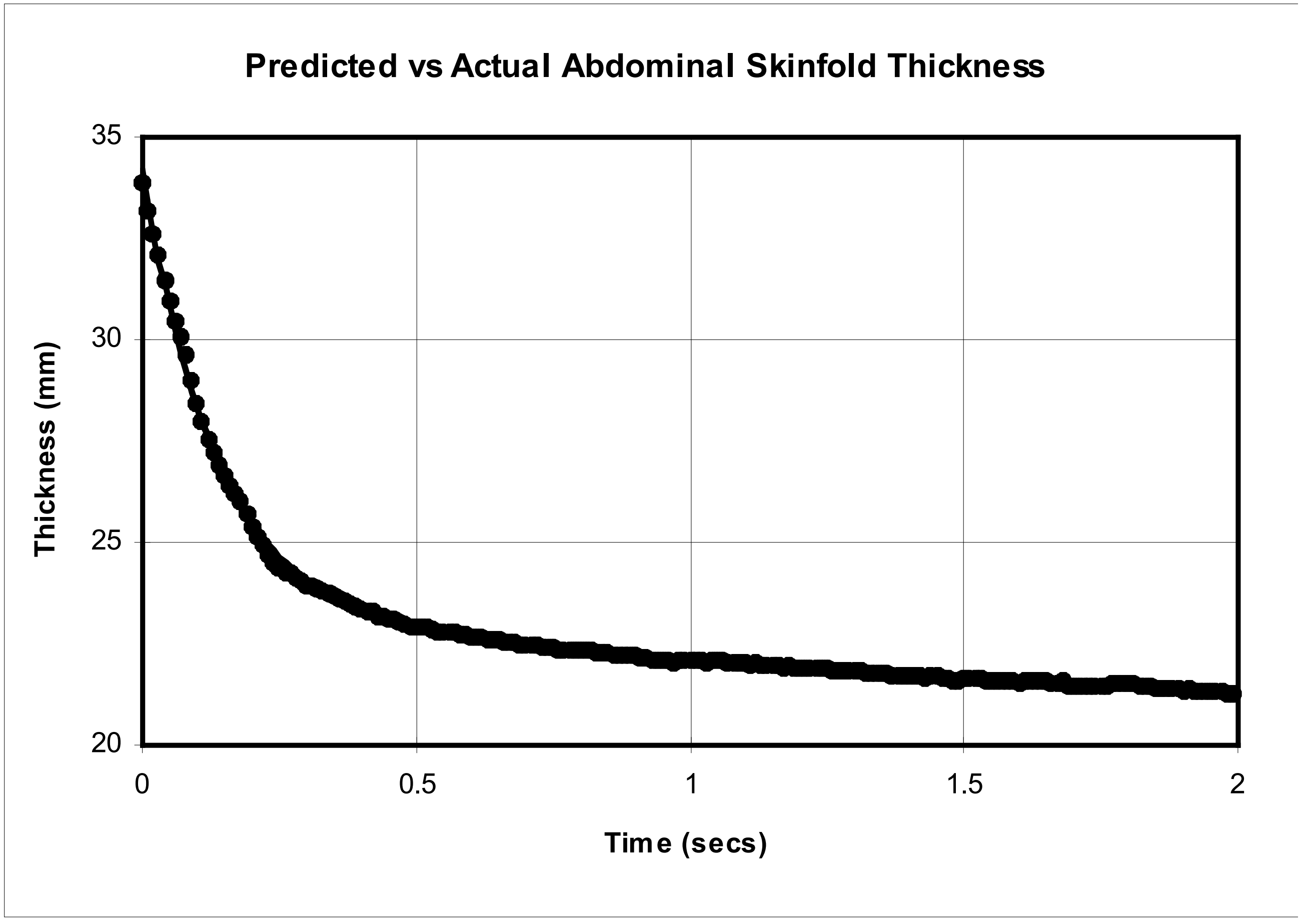
$T_{initial}$ is initial thickness

b_1 & b_2 are coefficients of viscosity

k_1 & k_2 are coefficients of elasticity

F is force (applied by skinfold caliper)

Criteria of Goodness of Fit to Real Data



Judge goodness of fit with sum of squared residuals and by shape of curve.

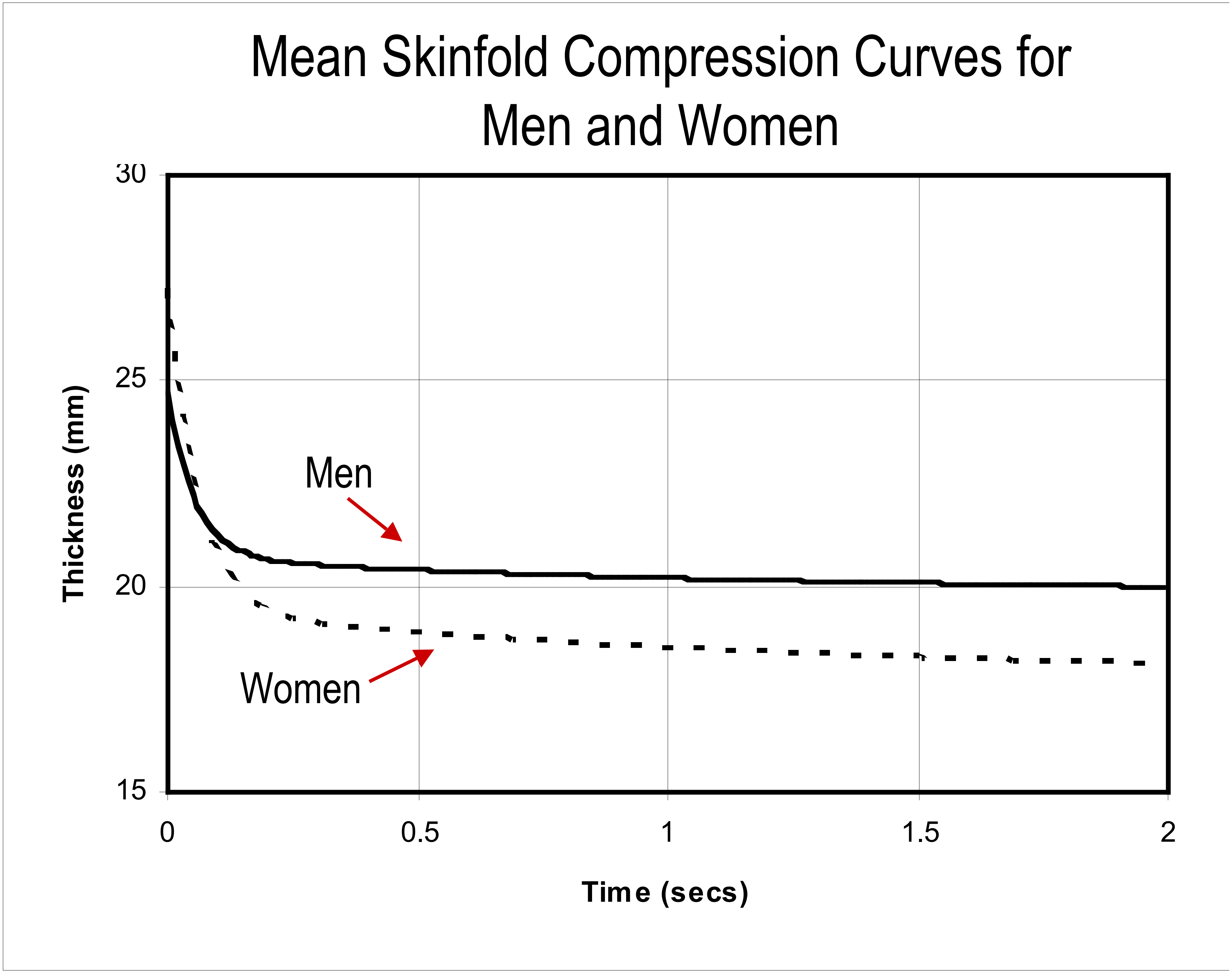
Sex Differences in Model Parameters

Table 1: Means and standard errors of mean for values of model coefficients k_1, k_2, b_1, b_2 and Tinit for females (n=8) and males (n=8) all three skinfold sites combined.

		k_1	k_2	b_1	b_2	Tinit
Female	**Mean**	-1.275	-6.276	-0.077	-7.738	27.255
	S.E.M.	0.251	0.970	0.010	1.672	3.684
Male	**Mean**	-2.499*	-11.362*	-0.135*	-14.59*	24.692
	S.E.M.	0.883	3.618	0.039	5.796	7.807

* = significantly different from Female mean using independent T-test ($p<0.05$).

Source: Ward R, Rempel R, Anderson GS. Modeling dynamic skinfold compression. Am J Hum Biol. 1999;11(4):531-537.



Mean Skinfold Compression Curves for Men and Women
Thickness (mm)
30
25
20
15
0
0.5
1
1.5
2
Time (secs)
Men
Women