

Mechanisms of Injury and Countermeasures for EVA Associated Upper Extremity Medical Issues: Extended Vent Tube Study

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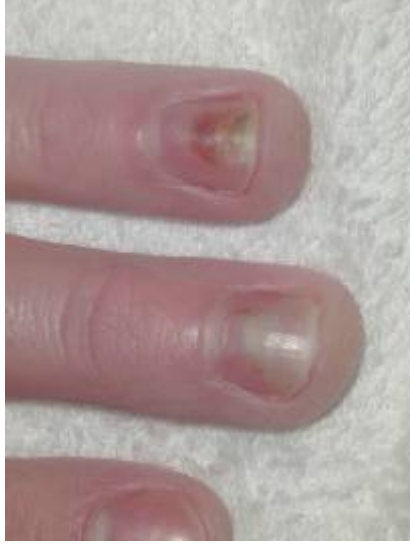
Presented by Rick Scheuring

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Issue

- During NBL training sessions a large amount of moisture accumulates in the glove due to the design because the liquid ventilation cooling garments do not extend completely into the hands and ventilation/cooling of the hand glove section is limited.
- Many astronauts develop subungual redness and fingernail pain following their NBL training sessions with subsequent onycholysis occurring over subsequent weeks (see example below):



- Various attempts have been made to reduce or avoid this problem, including trimming fingernails, taping the fingertips, or adding Dermabond medical grade superglue to the fingertip. An additional study using the product Hard as Nails found some positive effects as a countermeasure However, in general this remains a problem.

Issue (Concluded)

- Generally, six weeks is needed to recover tissue tensile strength, and an average of six months is needed for the injured nail to fully regrow.
- The EMU NBL schedule continues regular training sessions for the astronauts right up to the launch date of their assigned shuttle mission, thus resulting in a persistence of these injuries into the space flight and EVAs.
- Secondary infections following the development of onycholysis can also be seen.
- This problem of onycholysis is related to the Phase 6 gloves and did not occur with the use of the previous Series 4000 gloves. Recent evaluation appears to suggest that the thimble-like, semi-rigid “finger caps” of the restrainer component of the series 4000 gloves may have transmitted loads more uniformly throughout the fingertip, compared to the Phase 6 gloves which may concentrate the load at the fingernail and nail matrix.

Study Goal

- To determine the role that moisture plays in the injury to the fingers and fingernails during EVA training operations in the Neutral Buoyancy Laboratory
- Current Extravehicular Mobility Unit (EMU), with a PLSS) as configured in the NBL was used for all testing and a vent tube was extended down a single arm of the crewmember during the test; vent tube was moved between left and right arm to serve as experimental condition being investigated and the other arm served as control condition

Extended Vent Tube Configuration



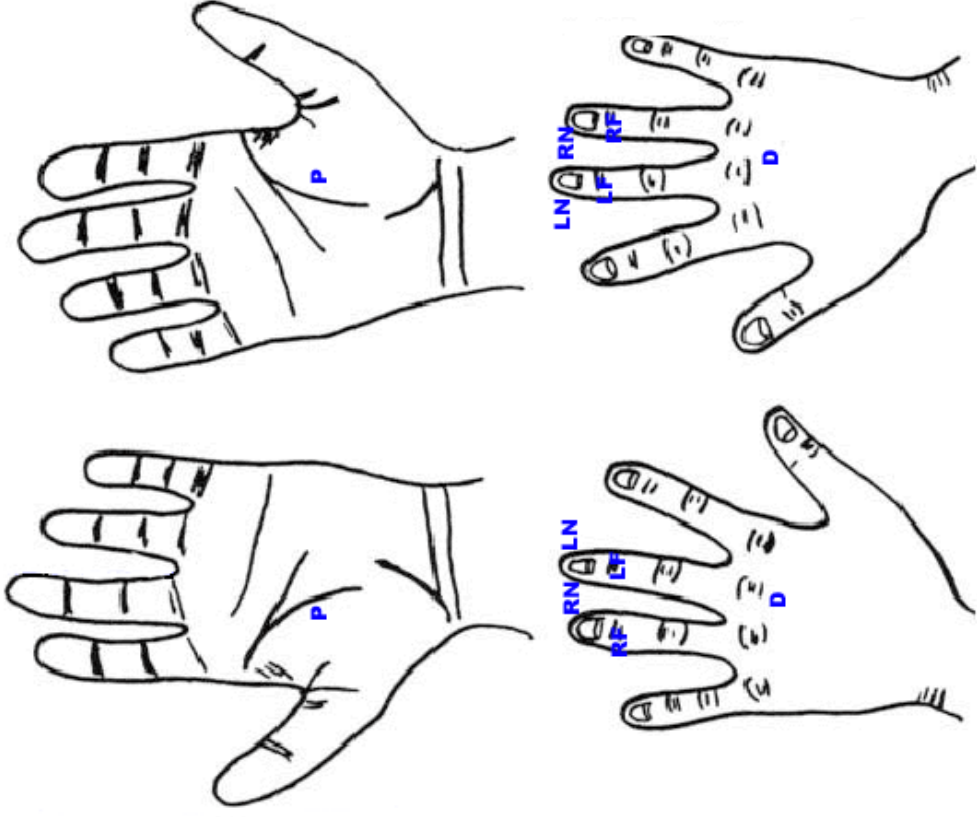
Glove Design



Delfin Moisture Measuring Meters

- **Moisture Meter (SC)** – hydration of skin surface via capacitance (proportional to water content)
 - 1 min contact
 - Feedback signal enables constant probe pressure
- **PikoMeter** - similar to SC but no pressure control
 - Quick response signal for reading
- **VapoMeter** – measures water loss from different surfaces (transepidermal water loss; TEWL)
 - Closed cylindrical chamber with sensors for relative humidity (RH%) and temperature
 - Signal for contact time
 - 16 to 20 seconds for calculation of TEWL from increase in RH%

Moisture Measure Points



Study Procedures

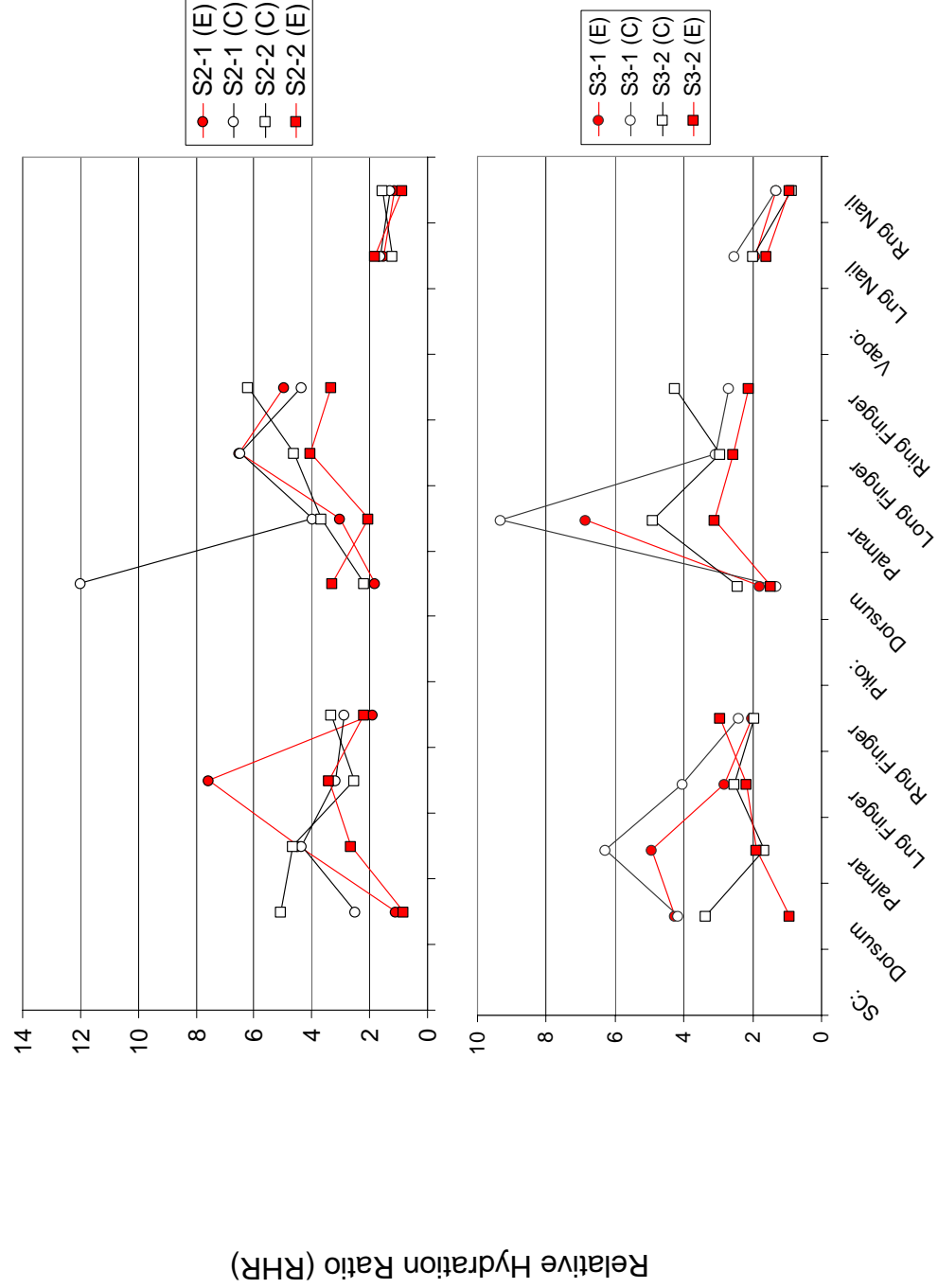
Pre and Post
EVA Sim:

- Questionnaire
- Moisture Measures
- Photos



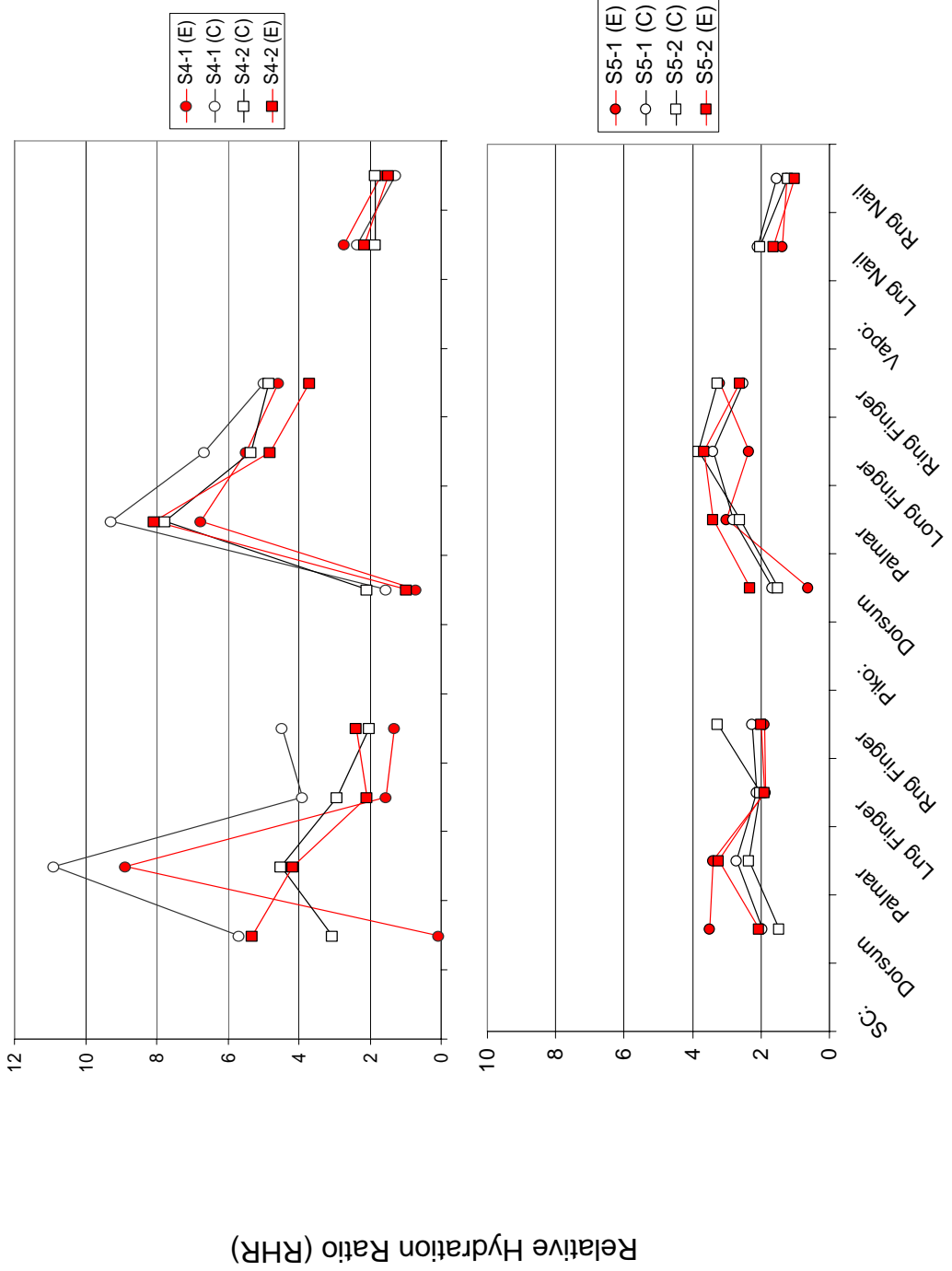
Moisture Data Summary:

S2 & S3 Runs



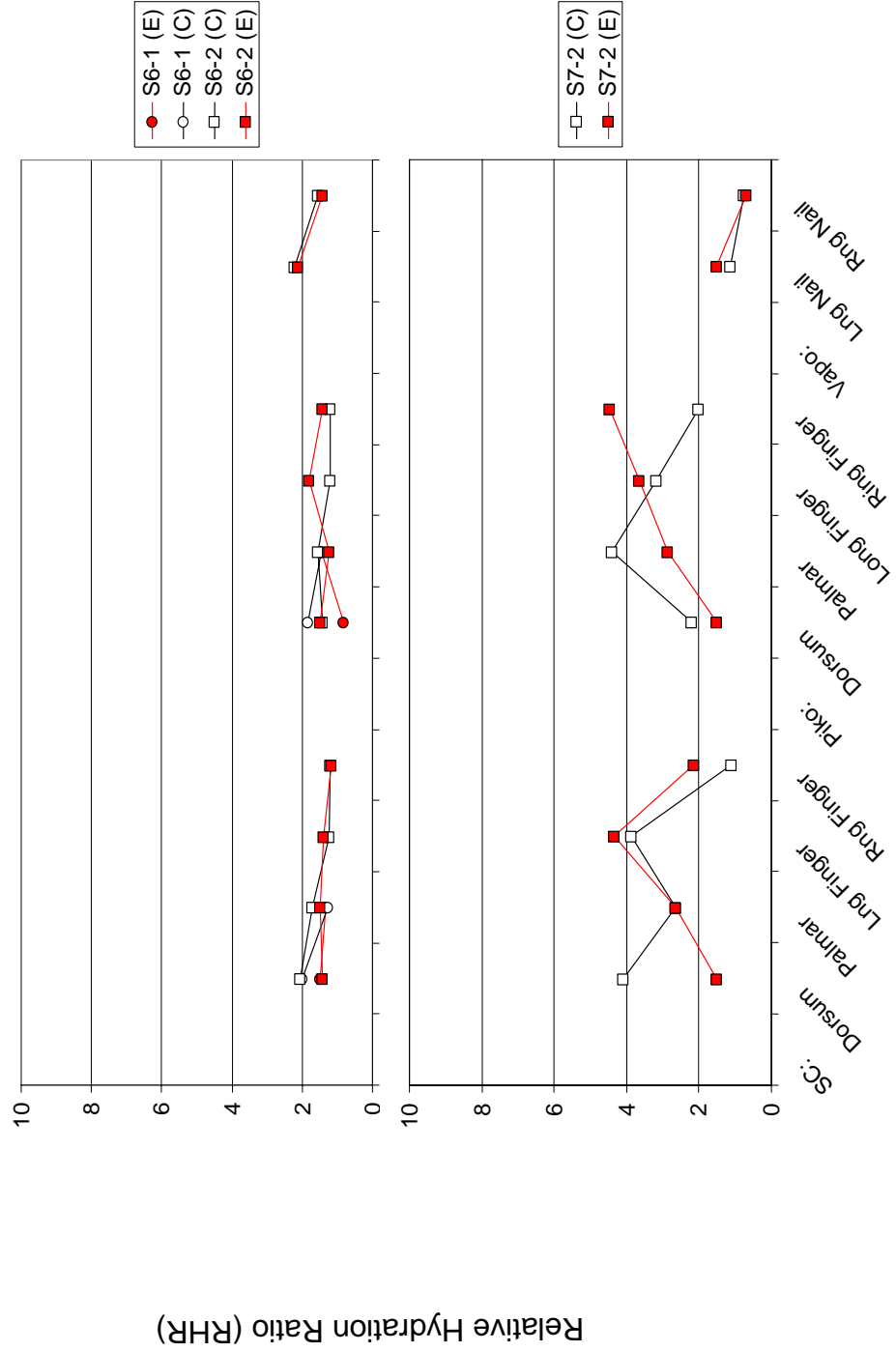
Moisture Data Summary:

S4 & S5 Runs



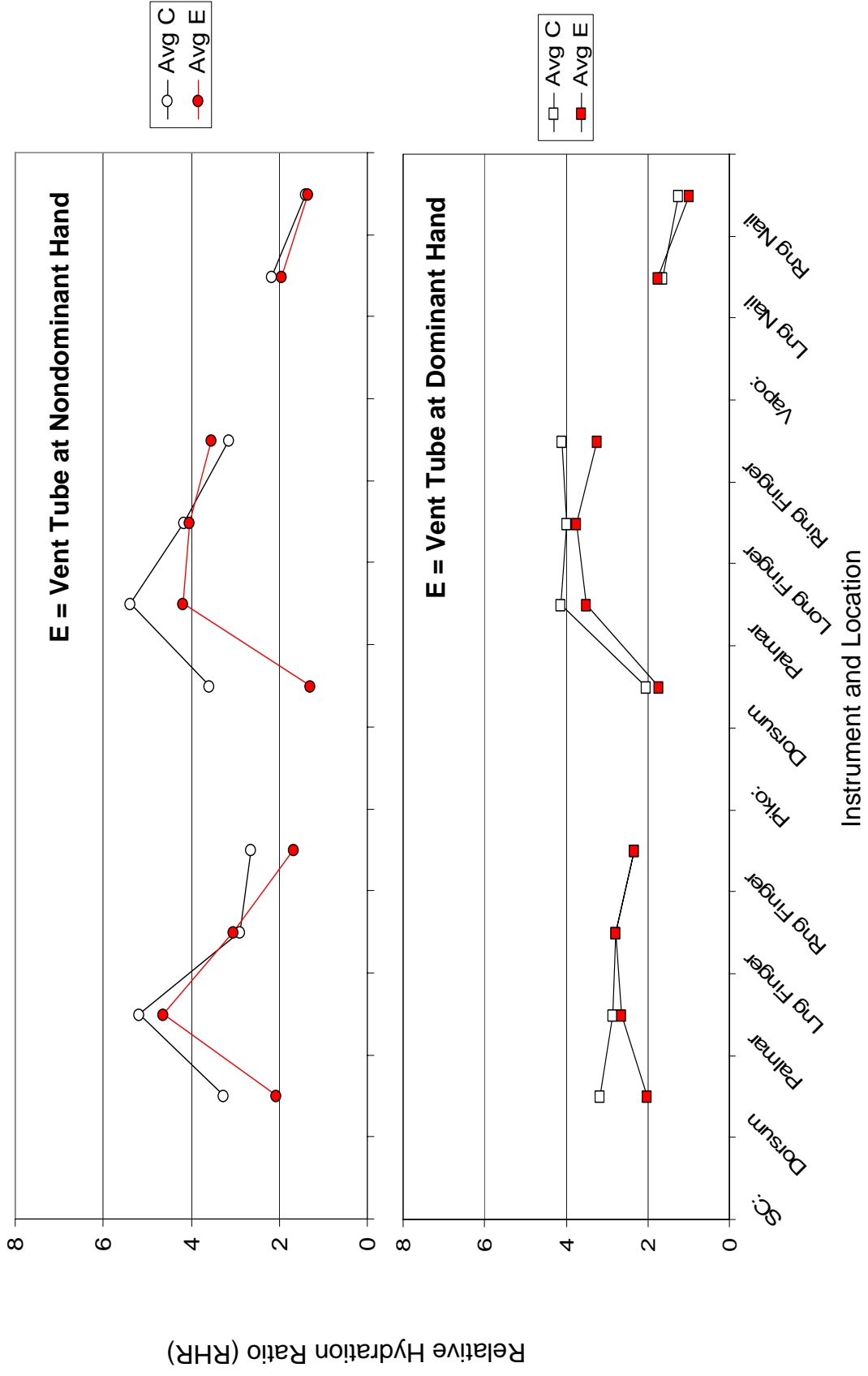
Instrument and Location

Moisture Data Summary: S6 & S7 Runs

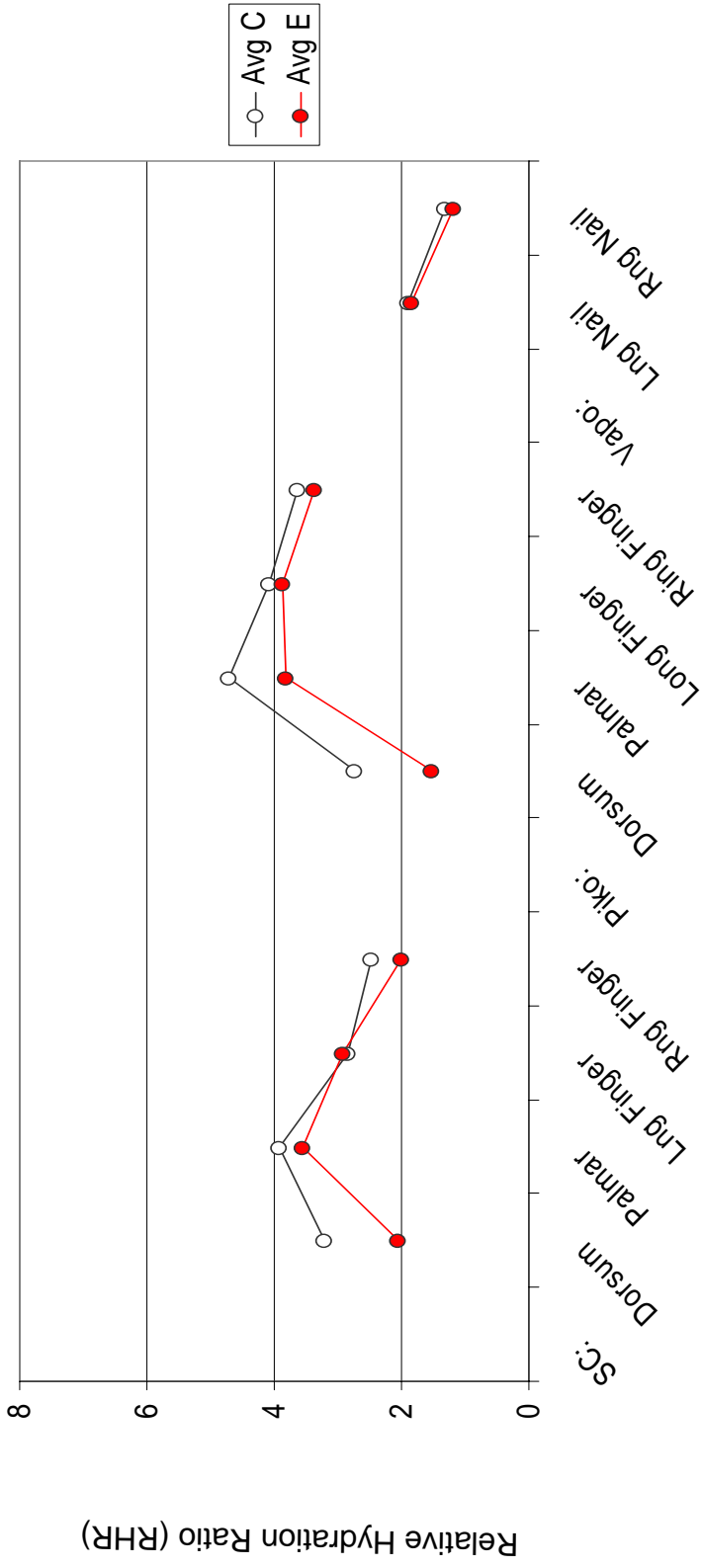


Instrument and Location

Moisture Data Summary: Avg by Vent Tube Location



Moisture Data Summary: Avg of All Runs



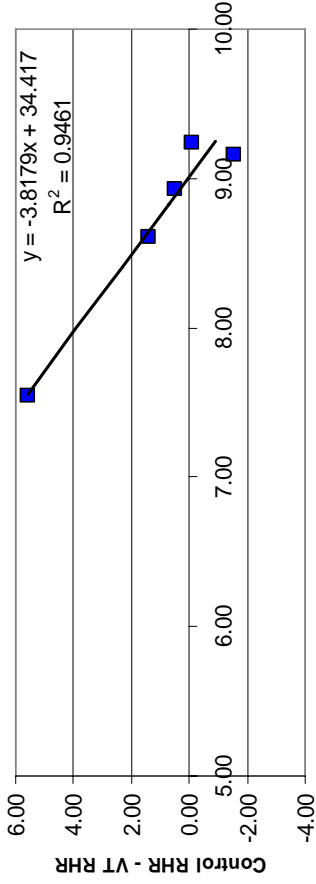
Instrument and Location

Moisture Data Statistics

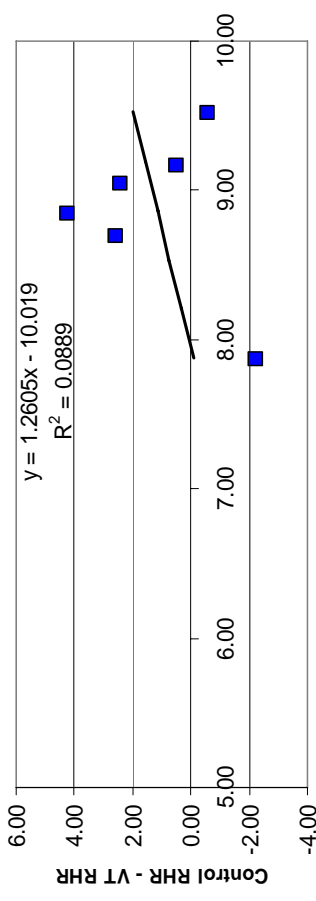
- Mann-Whitney U (Independently ordered samples; Vent tube hand vs. Control hand)
- For all runs
 - Dorsum, $p=.061$, $N=11$
 - Ring Finger, $p=.278$, $N=11$
- For Nondominant Hand (Vent tube on that hand)
 - Dorsum, $p=.251$, $N=5$
 - Ring Finger, $p=.094$, $N=5$
- For Dominant Hand (Vent tube on that hand)
 - Dorsum, $p=.200$, $N=6$
 - Ring Finger, $p=.754$, $N=5$

Moisture Differences, Hand Sizes, and Vent Tube Use

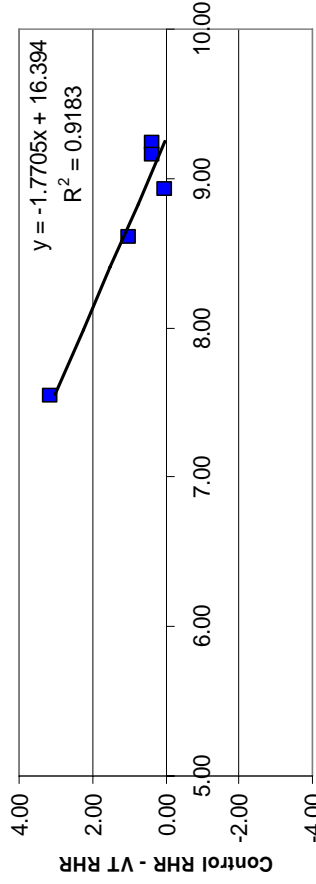
Dorsum RHR Difference vs. Nondominant Hand Size



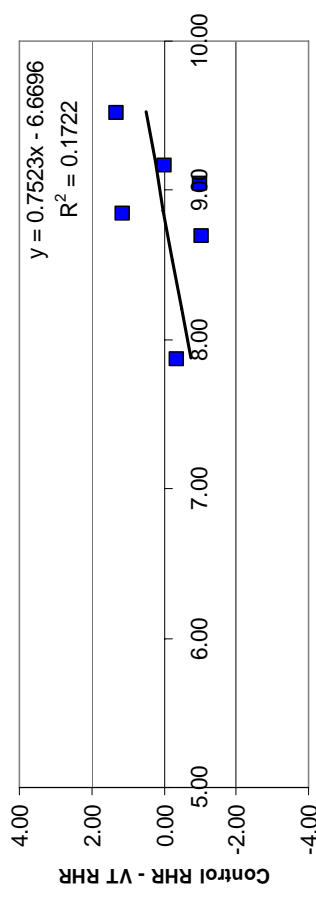
Dorsum RHR Difference vs. Dominant Hand Size



Ring Finger RHR Difference vs. Nondominant Hand Size

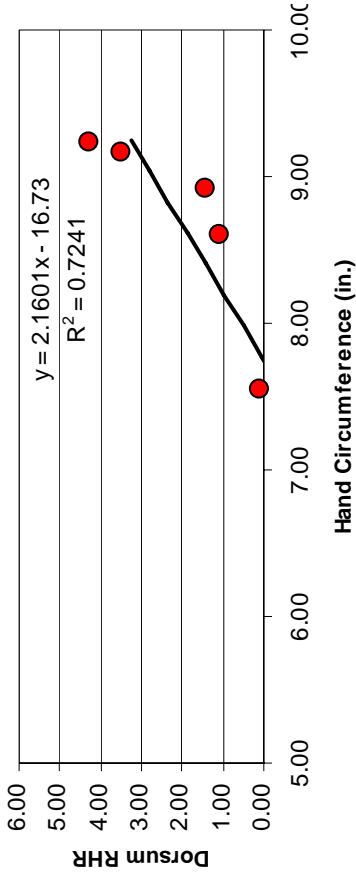


Ring Finger RHR Difference vs. Dominant Hand Size

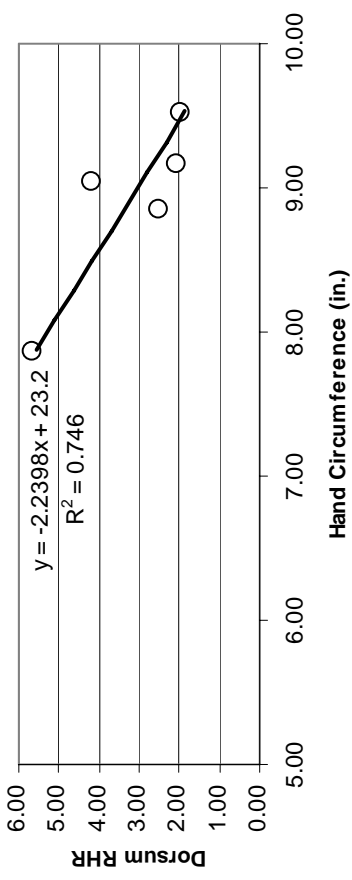


Dorsum RHRs, Hand Size, and Vent Tube Use

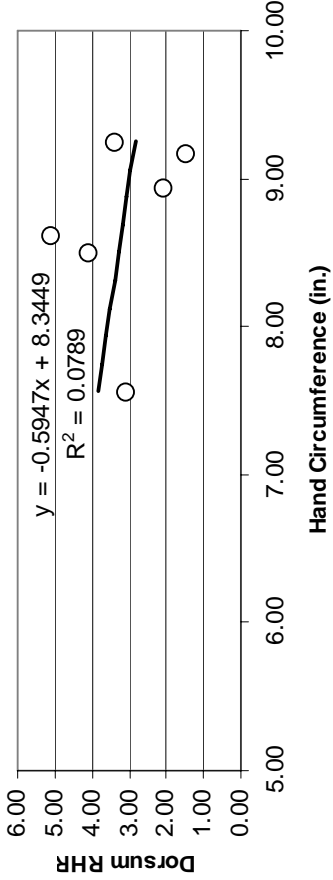
VT Dorsum RHR vs. Nondominant Hand Size



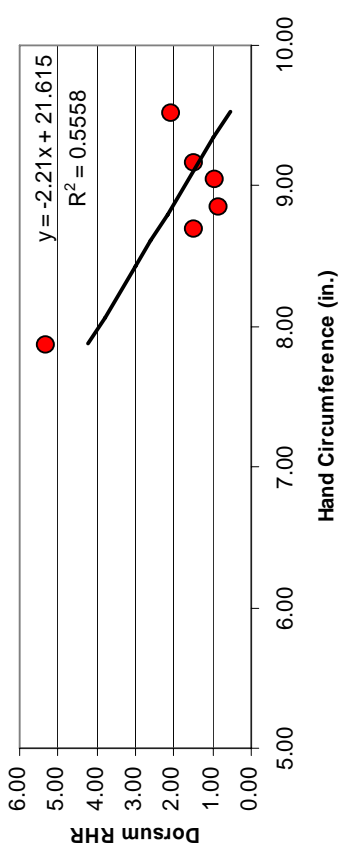
Control Dorsum RHR vs. Dominant Hand Size



Control Dorsum RHR vs. Nondominant Hand Size

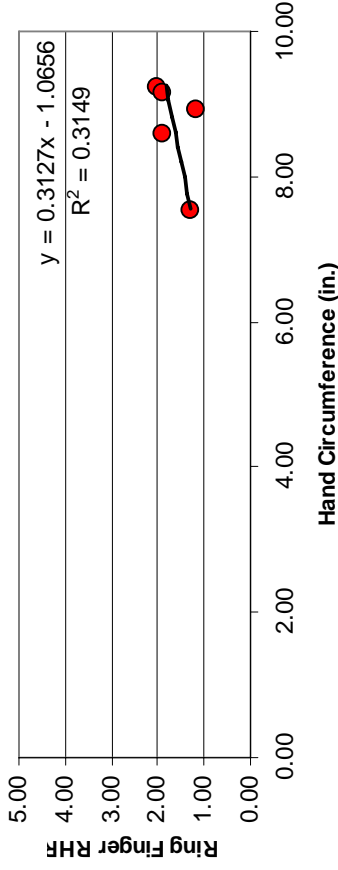


VT Dorsum RHR vs. Dominant Hand Size

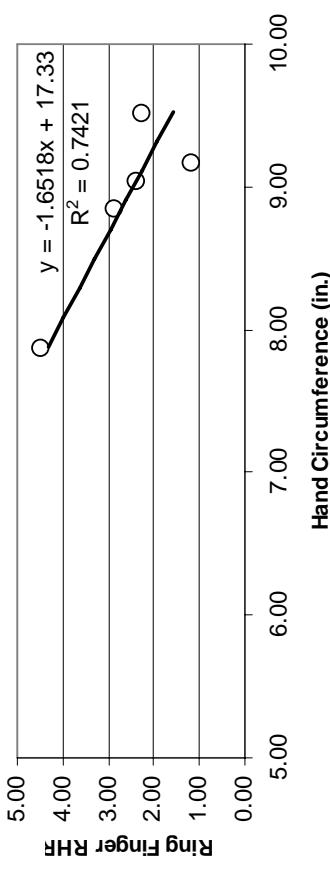


Ring Finger RHRs, Hand Size, and Vent Tube Use

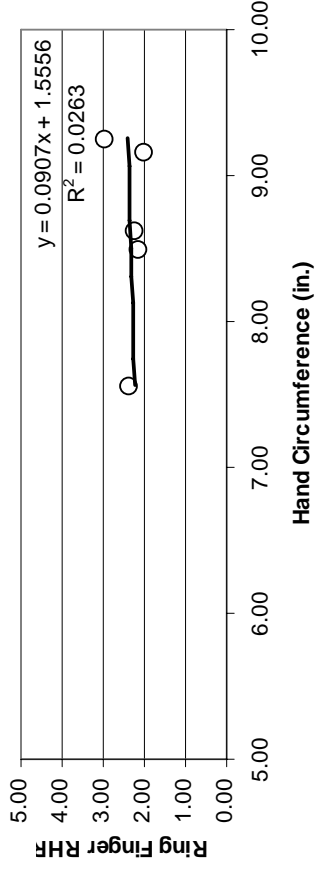
VT Ring Finger RHR vs. Nondominant Hand Size



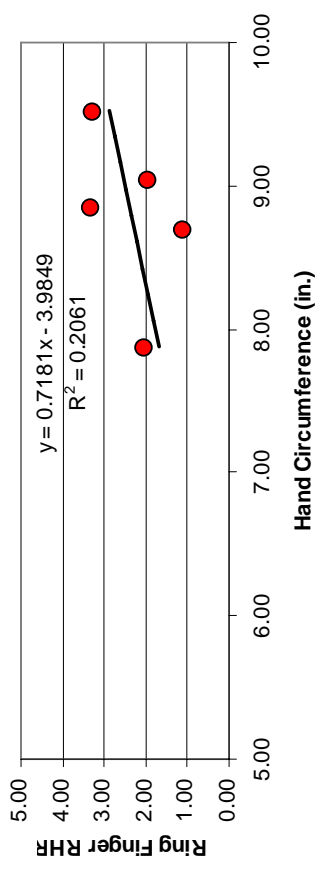
Control Ring Finger RHR vs. Dominant Hand Size



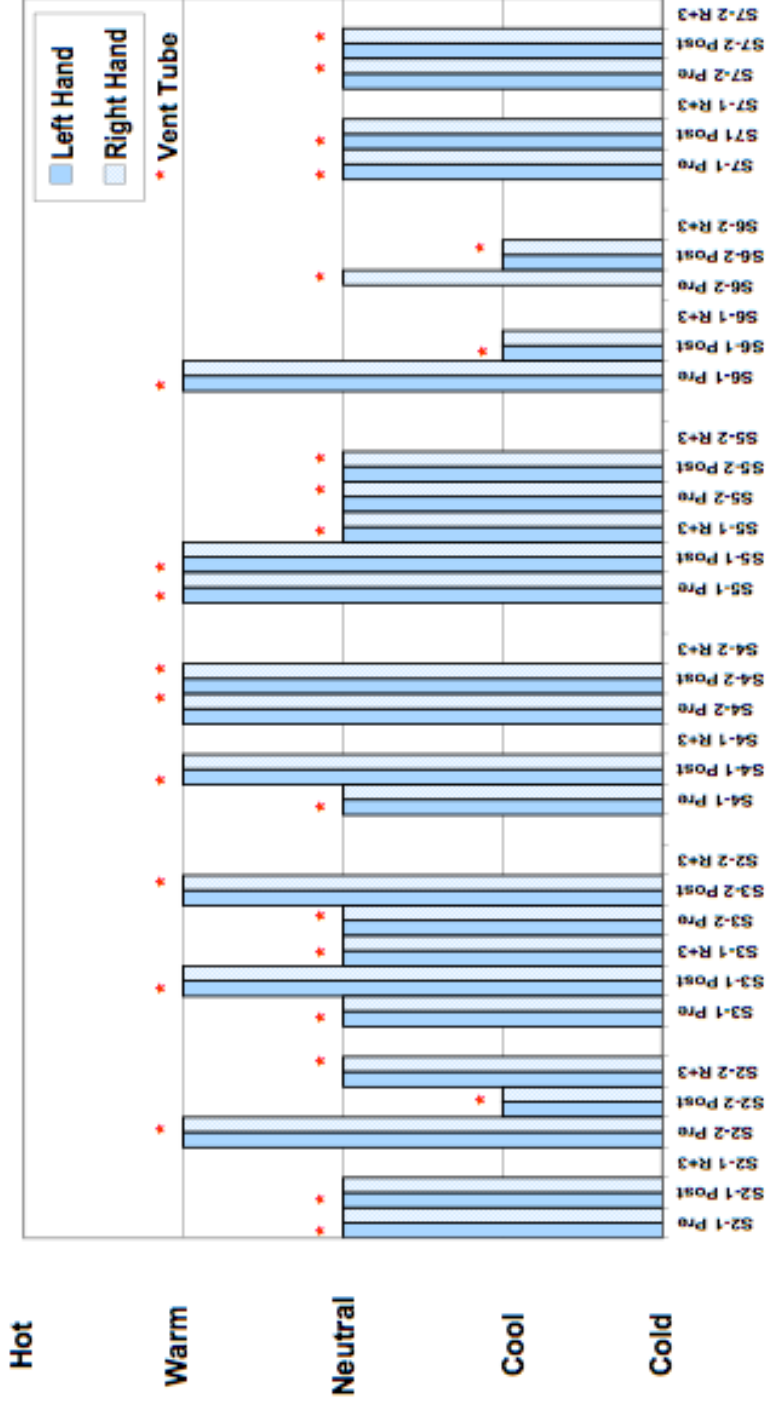
Control Ring Finger RHR vs. Nondominant Hand Size



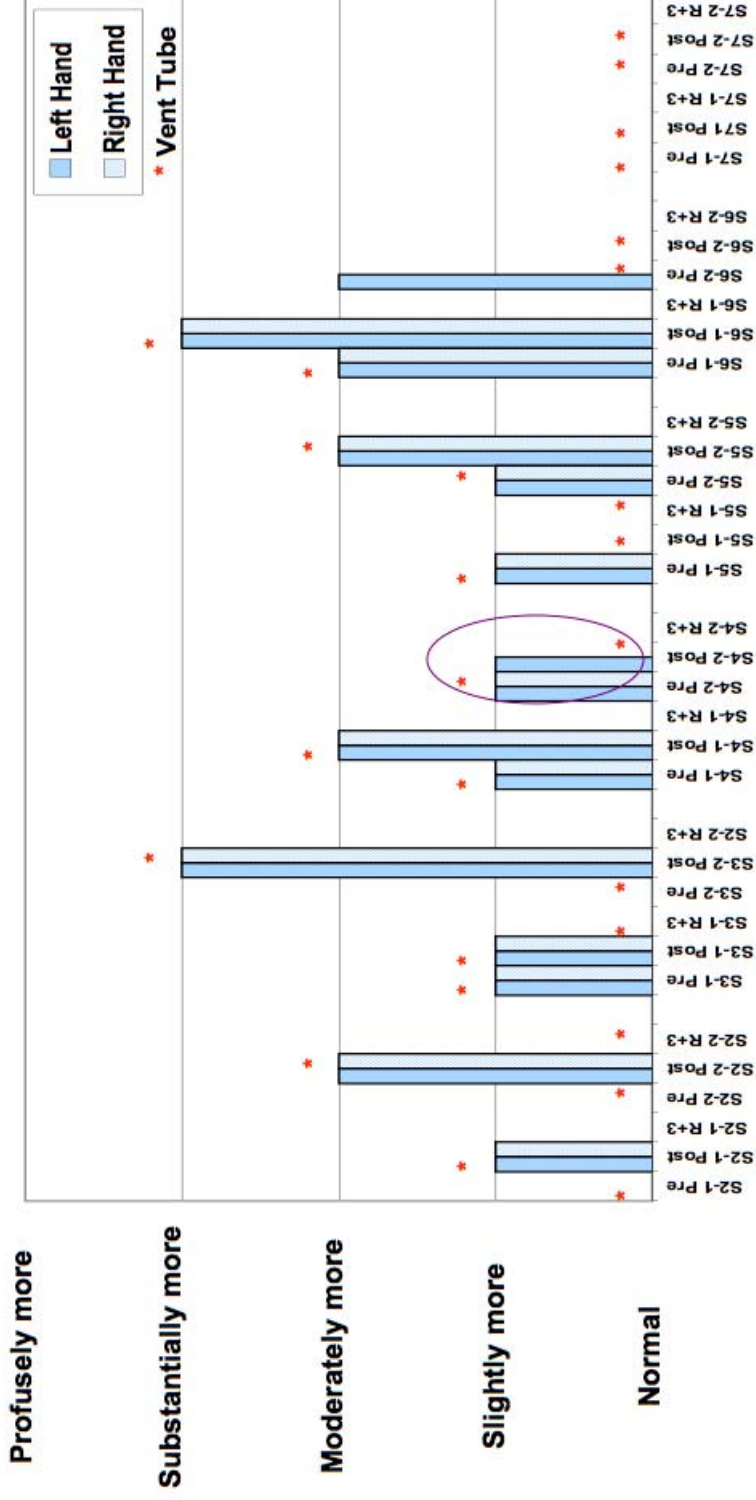
VT Ring Finger RHR vs. Dominant Hand Size



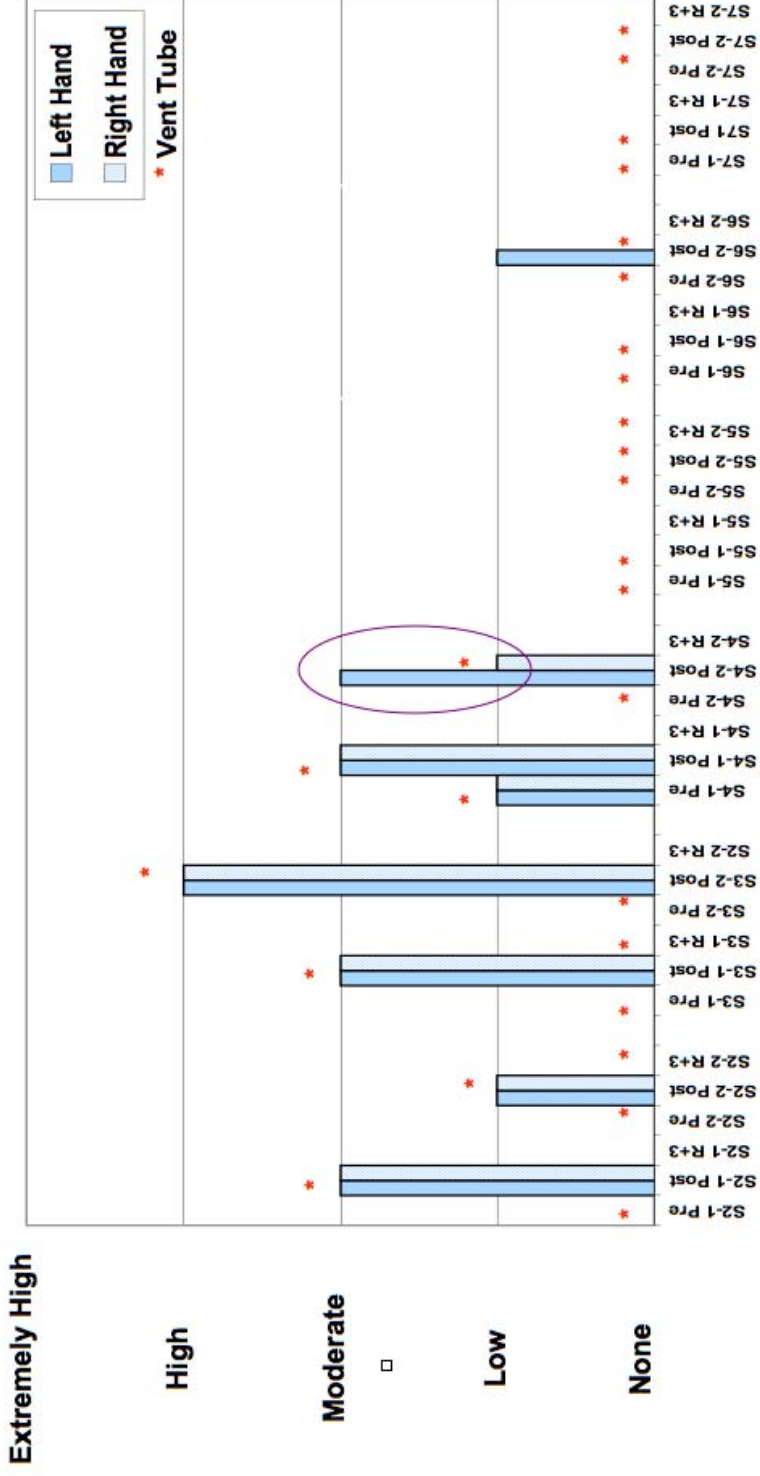
Questionnaire Data Summary: Level of Thermal Discomfort



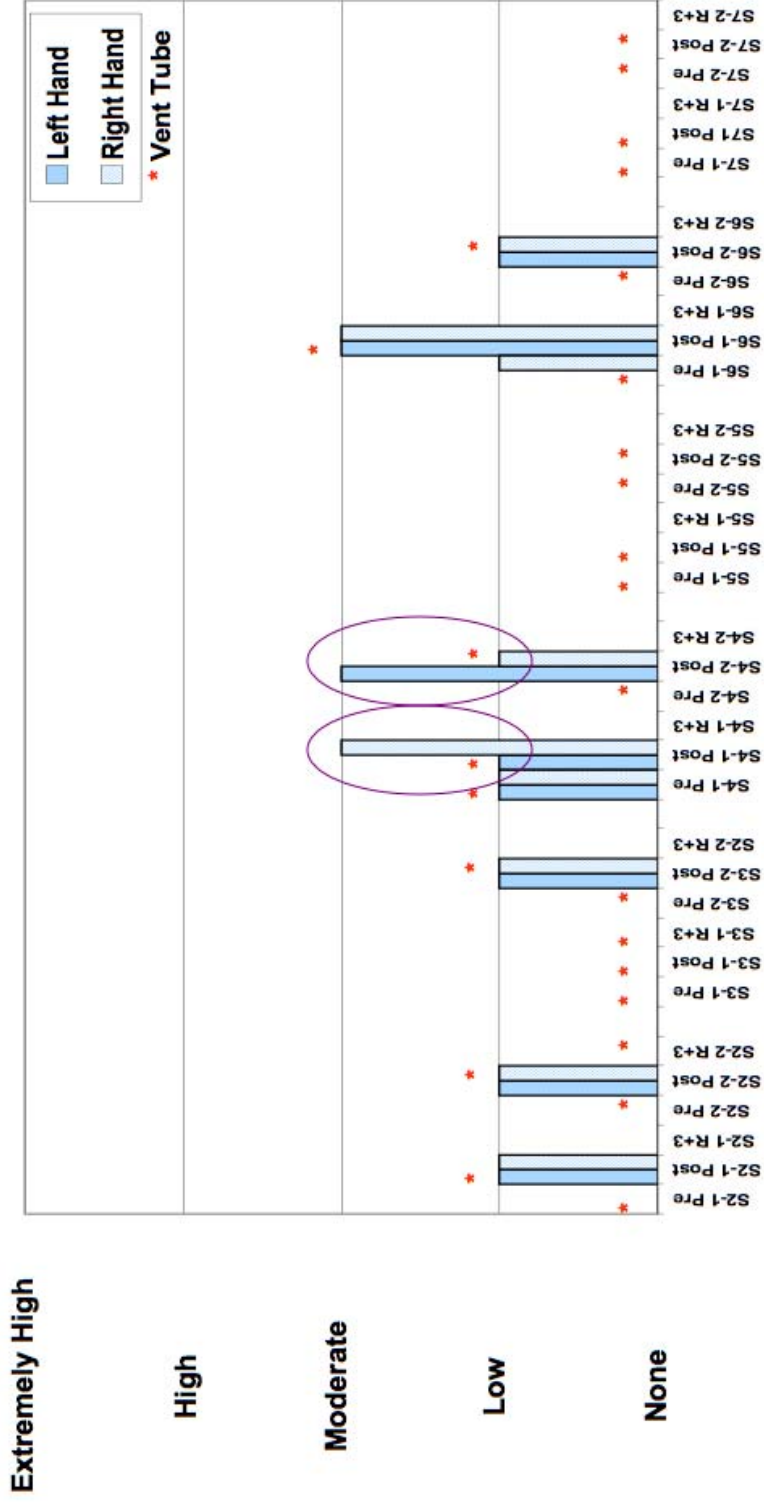
Questionnaire Data Summary: Level of Skin Moisture



Questionnaire Data Summary: Level of Hand Discomfort



Questionnaire Data Summary: Level of Nail Discomfort



Comfort Gloves in Use at NBL

Comfort Gloves	Subject	Estimated Relative Thickness
Nylon Tricot (coated with silver biocide)	1	1
Thin Spectra - Large	2, 3	2
Thin Spectra - Large Mod	6	2.5
PL-2 form Manzella		3
Thick Spectra	4, 7	4
Mod Spectra w/Back Hand Pads (MAX-10)	5	5

- Piko Dorsum RHR is correlated with comfort glove thickness for the nondominant hand in the control condition : Spearman R= -.865, p=.058
- Piko Dorsum RHR is highly correlated with comfort glove thickness for the nondominant hand in the vent tube condition: Spearman R= -1, p=.000
- Moisture Meter Dorsum RHR is correlated with comfort glove thickness for the dominant hand in the vent condition: Spearman R=+.883, p=.020

Summary

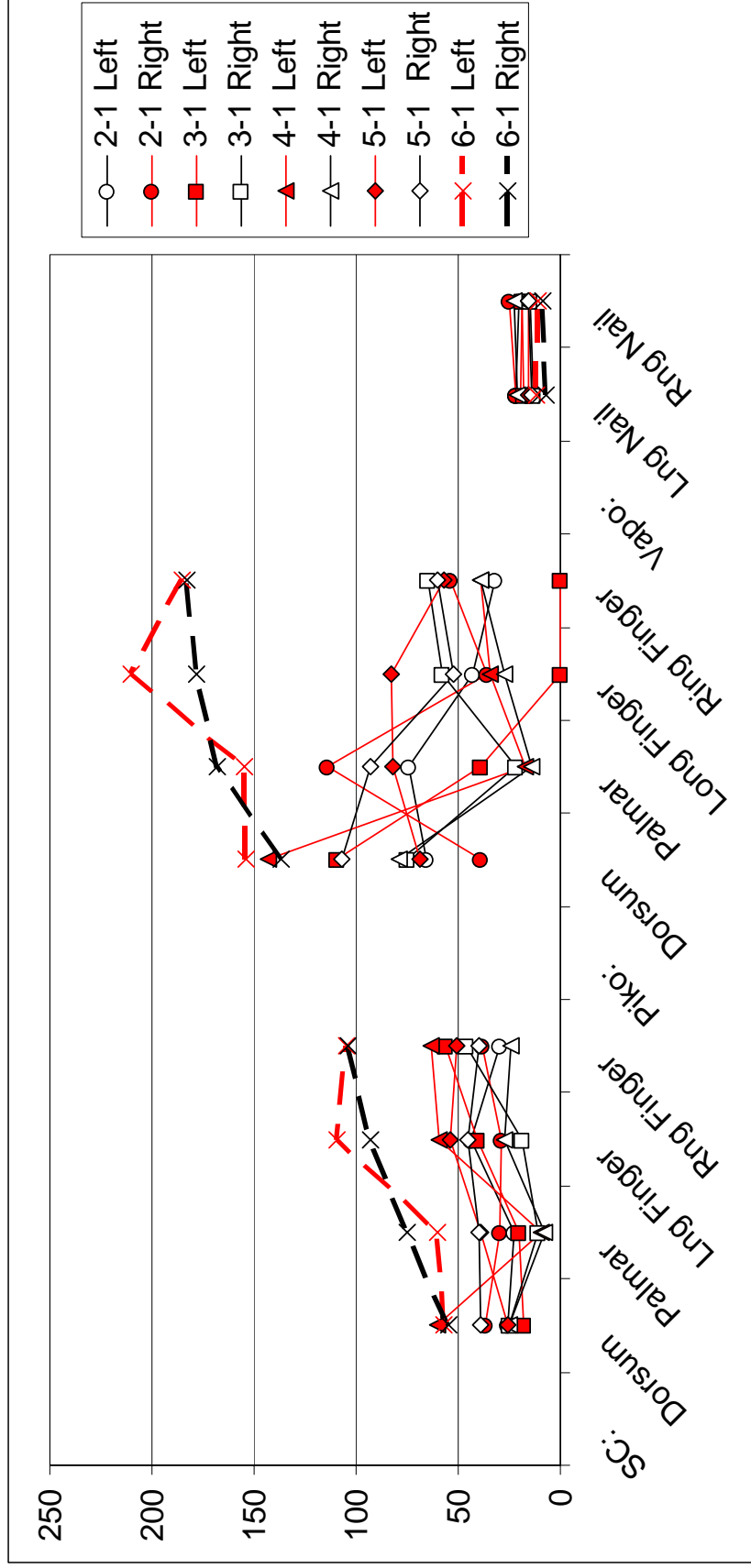
- 2 of 6 participants had symptoms alleviated on hand with vent tube (trend: $p=.121$)
- Moisture measures are more controlled and consistent with moisture meter as opposed to piko meter
- RHR at Dorsum and first Ring Finger joint tend to support hypothesis that extended vent tube improves moisture removal
- Extended vent tube tends to be more effective on non-dominant hand and the smaller hand
- Study Limitations
 - Glove fit interaction
 - Anthropometry interaction
 - Task interaction
- Vent Duct diffuser redesign could improve air flow distribution to hand and fingers
- Reducing hand/finger moisture via ventilation can reduce EVA training-associated symptoms in some crewmembers

Backup Charts

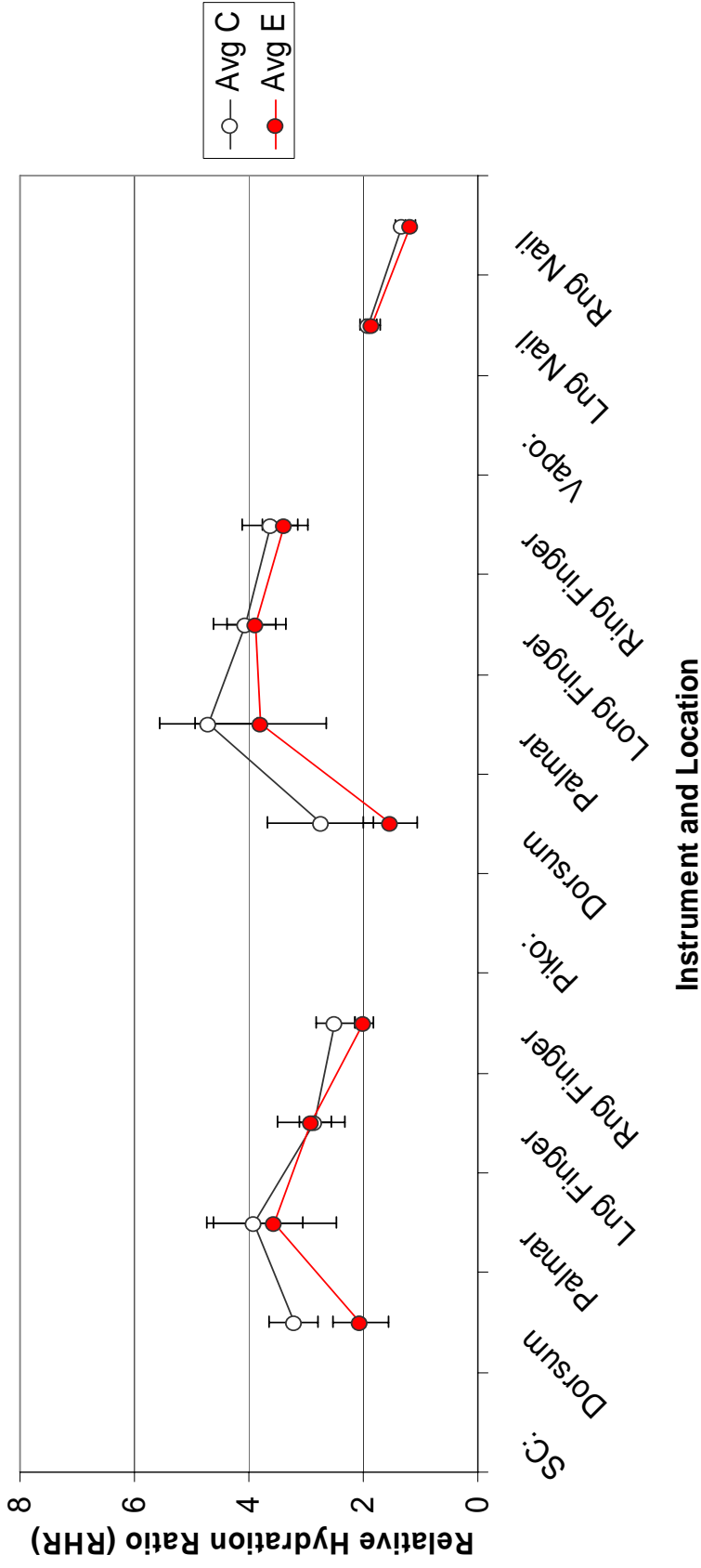
Moisture Data Summary:

Vent Tube	SC:	Dorsum	Palmar	Lng Finger	Rng Finger	Finger Piko:	Dorsum	Palmar	Long Finge	Ring Finge	Vapo:	Lng Nail	Rng Nail	Rng Tip
2- run "1"	S ₂ -1 (C)	5.08	4.65	2.52	3.33	3.33	2.20	3.66	4.60	6.19		1.20	1.56	
	S ₂ -1 (E)	0.84	2.67	3.41	2.21	2.21	3.31	2.06	4.06	3.33		1.82	0.88	
2- run 2	S ₂ -2(E)	1.11	4.48	7.57	1.88	1.88	1.80	3.04	6.50	4.94		1.51	1.13	1.85
	S ₂ -2 (C)	2.51	4.35	3.18	2.88	2.88	12.00	3.96	6.47	4.35		1.62	1.28	1.14
3- run 1	S ₃ -1 (E)	4.28	4.95	2.83	2.02	2.02	1.80	6.85				1.92	1.32	
	S ₃ -1 (C)	4.16	6.27	4.05	2.39	2.39	1.32	9.32	3.09	2.68		2.53	1.33	
3- run 2	S ₃ -2 (C)	3.38	1.68	2.54	1.96	1.96	2.44	4.90	2.94	4.26		1.97	0.87	
	S ₃ -2 (E)	0.94	1.90	2.18	2.96	2.96	1.49	3.12	2.55	2.11		1.61	0.92	
4- run 1	S ₄ -1 (E)	0.08	8.89	1.54	1.30	1.30	0.71	6.76	5.47	4.56		2.74	1.68	
	S ₄ -1 (C)	5.68	10.88	3.89	4.46	4.46	1.54	9.29	6.67	4.97		2.34	1.27	
4- run 2	S ₄ -2 (C)	3.06	4.50	2.92	2.03	2.03	2.09	7.78	5.35	4.83		1.87	1.86	
	S ₄ -2 (E)	5.30	4.15	2.10	2.39	2.39	0.96	8.08	4.79	3.69		2.14	1.48	
5- run 1	S ₅ -1 (E)	3.50	3.41	1.87	1.90	1.90	0.62	3.00	2.35	3.19		1.37	1.24	
	S ₅ -1 (C)	1.95	2.70	2.13	2.25	2.25	1.67	2.81	3.40	2.52		2.09	1.55	
5- run 2	S ₅ -2 (C)	1.48	2.36	2.03	3.27	3.27	1.51	2.62	3.82	3.27		2.04	1.22	
	S ₅ -2 (E)	2.07	3.22	1.90	1.98	1.98	2.31	3.39	3.67	2.62		1.65	1.02	
6- run 1	S ₆ -1 (E)	1.49	1.33				0.83	1.45						
	S ₆ -1 (C)	2.00	1.27				1.85	1.46						
6- run 2	S ₆ -2 (C)	2.05	1.71	1.25	1.19	1.19	1.42	1.54	1.21	1.19		2.21	1.56	1.14
	S ₆ -2 (E)	1.44	1.49	1.39	1.19	1.19	1.50	1.22	1.82	1.43		2.13	1.41	1.22
7- run 2	S ₇ -2 (C)	4.08	2.64	3.88	1.09	1.09	2.20	4.41	3.17	2.00		1.14	0.75	1.34
	S ₇ -2 (E)	1.50	2.65	4.33	2.15	2.15	1.52	2.87	3.64	4.47		1.51	0.68	1.20

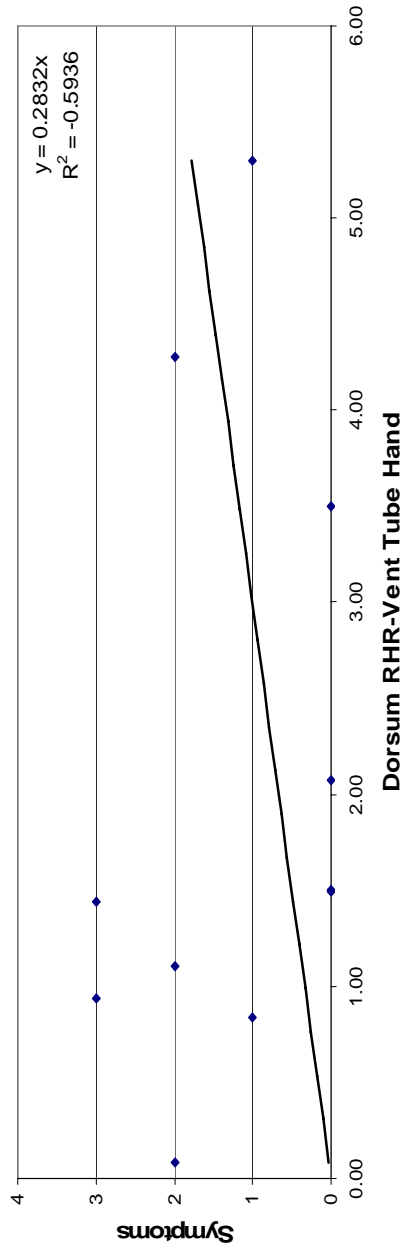
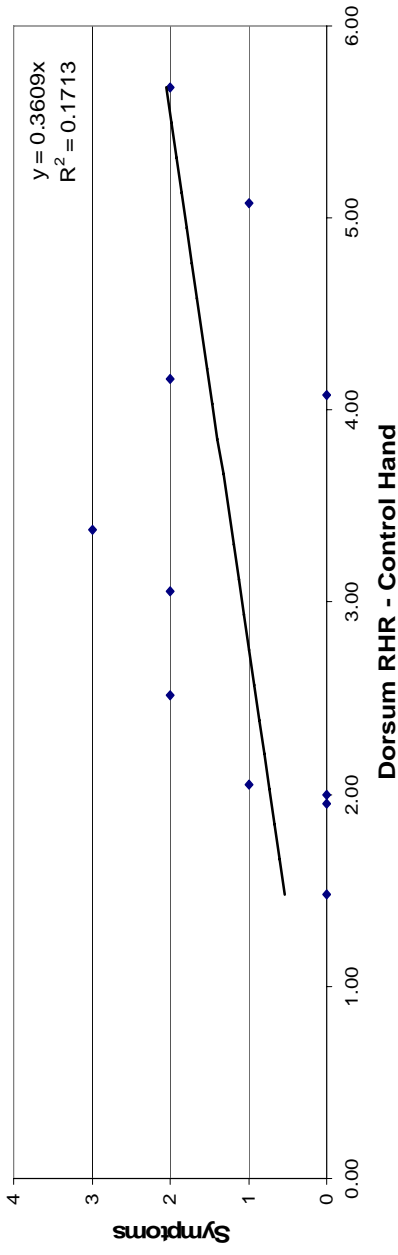
Pre-Run Moisture Measures (First Run)



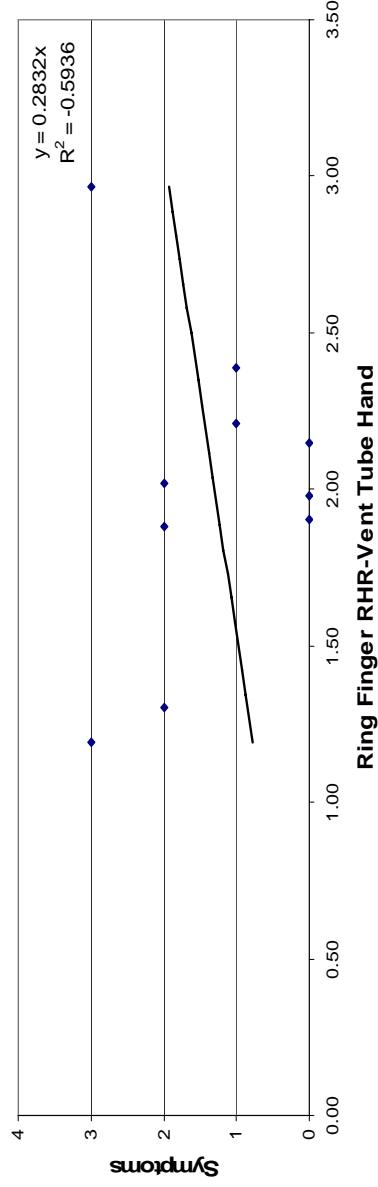
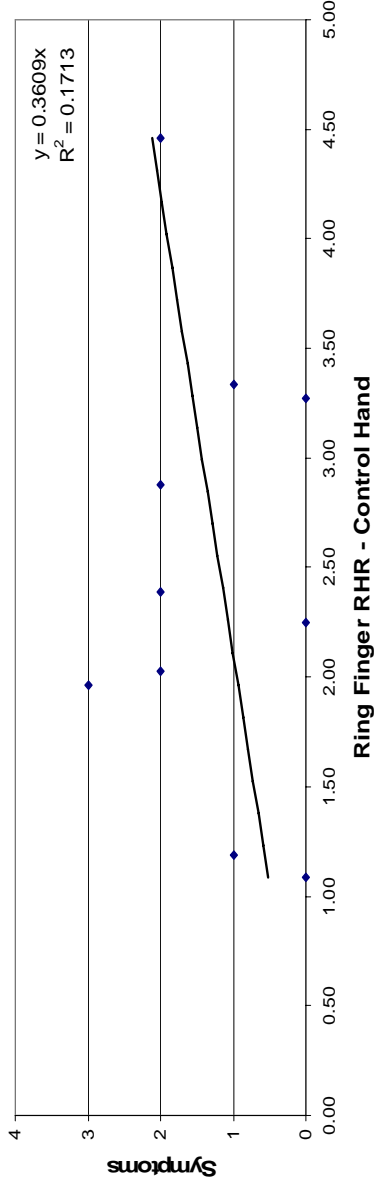
Average Moisture Data with Standard Error of the Mean



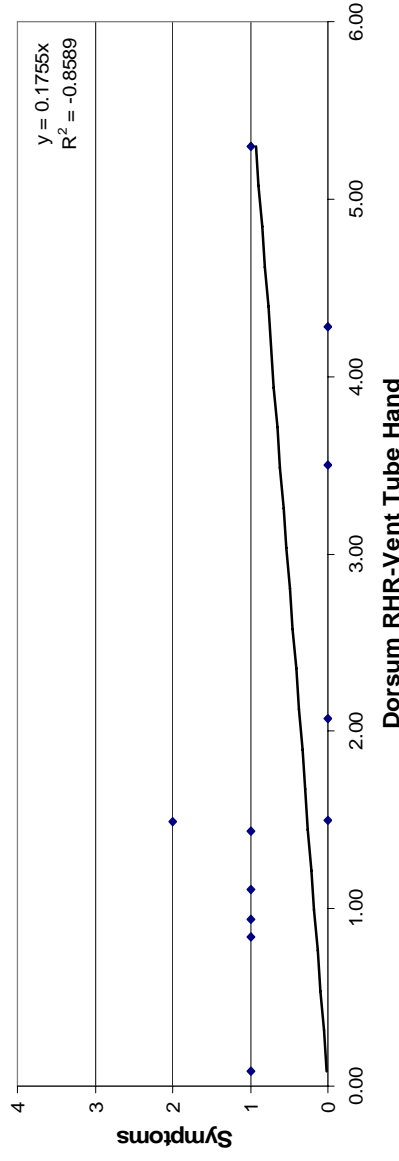
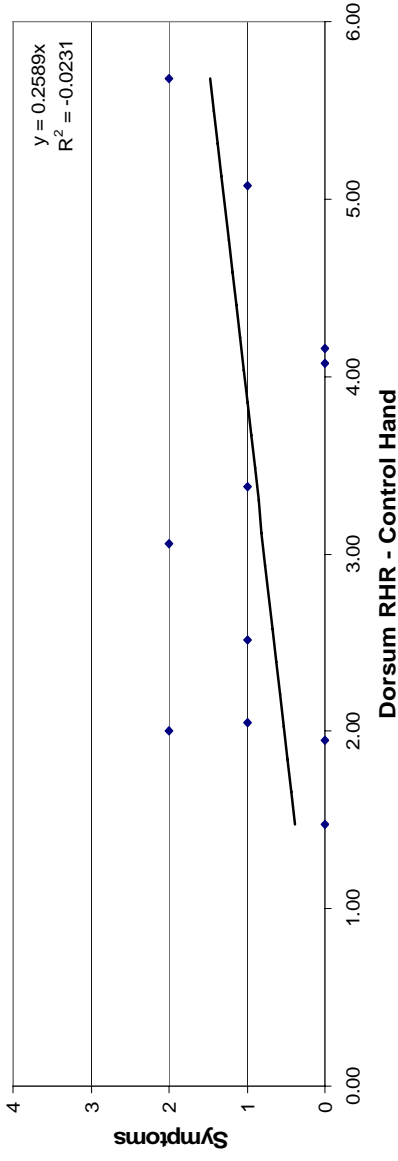
Hand Discomfort Ratings vs. Dorsum RHR



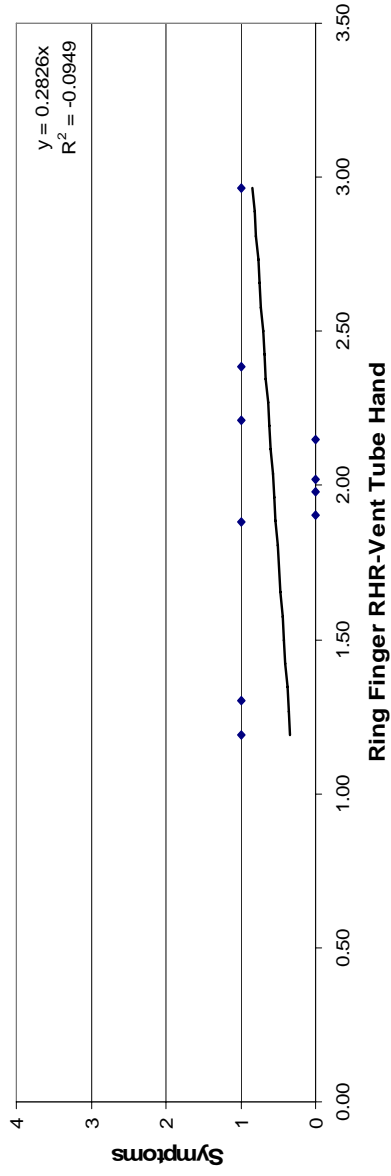
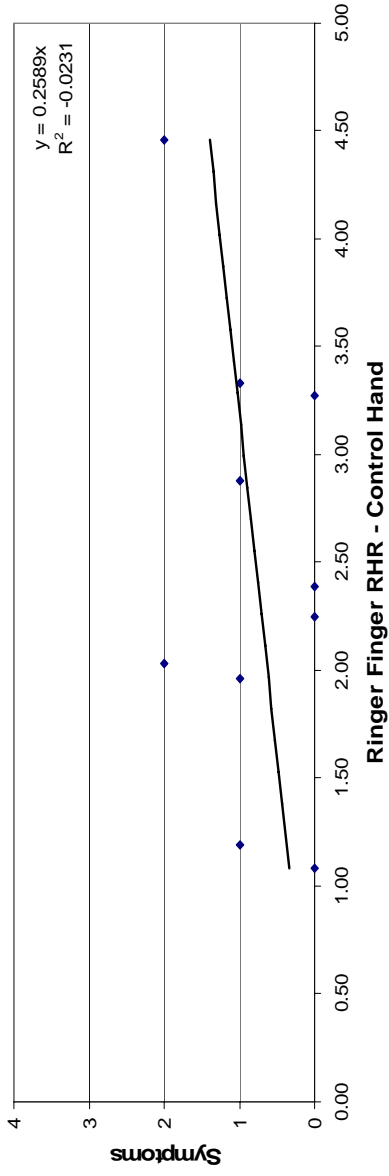
Hand Discomfort Ratings vs. Ring Finger RHR



Nail Discomfort Ratings vs. Dorsum RHR

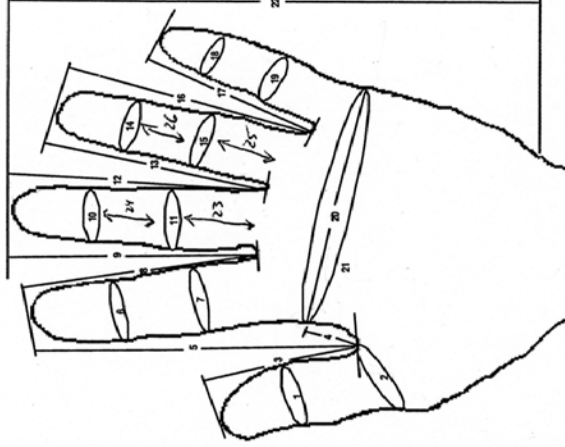


Nail Discomfort Ratings vs. Ring Finger RHR



Subject Hand Anthropomorphic Data

	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20	L21	L22
S6	2.795	3.74	2.165	0.866	4.724	2.362	2.756	3.189	3.701	2.323	2.835	3.701	3.268	2.205	2.638	3.543	2.559	2.047	2.362	3.898	9.173	7.953
S7	2.559	3.543	2.362	1.378	4.37	2.165	2.559	3.071	3.543	2.165	2.756	3.504	2.953	2.087	2.362	3.346	2.362	1.929	2.087	3.74	8.504	7.835
S3	2.756	2.953	2.402	1.102	5.039	2.323	2.756	3.15	3.583	2.323	2.835	3.661	2.992	2.126	2.52	3.701	2.638	2.008	2.362	3.937	9.252	8.031
S2	2.795	3.622	2.323	0.984	4.331	2.323	2.835	3.071	3.425	2.52	2.756	3.465	3.228	2.283	2.756	3.78	2.795	2.126	2.441	3.583	8.622	7.717
S5	2.835	2.835	2.437	0.906	4.311	2.283	2.638	3	3.122	2.283	2.677	3.437	2.874	2.087	2.559	3.122	2.374	2.047	2.362	3.587	9.173	7.449
S4	2.598	3.228	2.047	0.669	4.331	2.008	2.441	2.913	3.228	1.969	2.402	3.11	2.953	1.89	2.402	3.189	2.441	1.732	2.087	3.236	7.559	7.248
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22
S6	2.835	3.898	2.402	0.945	4.528	2.362	2.717	3.071	3.543	2.283	2.835	3.661	3.307	2.165	2.598	3.425	2.638	1.969	2.244	3.819	8.937	7.677
S7	2.638	3.583	2.52	1.299	4.528	2.205	2.559	2.756	3.54	3.543	2.283	2.795	3.504	3.031	2.126	2.598	3.425	2.362	2.205	3.543	8.701	7.874
S3	2.953	2.992	2.559	1.102	5.039	2.362	2.874	3.15	3.386	2.362	2.874	3.465	3.071	2.165	2.559	3.425	2.598	1.969	2.323	3.673	9.055	7.795
S2	2.835	3.78	2.362	1.024	4.528	2.362	2.795	3.11	3.622	2.402	2.874	3.622	3.307	2.244	2.717	3.543	2.795	2.087	2.362	3.622	8.858	7.717
S5	2.835	2.953	2.685	0.984	4.374	2.244	2.795	3	3.248	2.283	2.756	3.248	2.811	2.165	2.677	3.311	2.311	2.283	2.37	7.85	9.528	7.689
S4	2.52	3.465	2.165	0.787	4.291	2.165	2.559	2.913	3.268	2.087	2.48	3.228	2.992	1.929	2.402	3.268	2.323	1.732	2.087	3.343	7.874	7.343



Hand Circumference