Hand Hygiene in the Biosafety Level-2 Lab: Is it a Matter of Training?

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Microbiological Containment

- Microbiological practices
- Safety equipment
- Facility safeguards

"The most important element of containment is strict adherence to standard microbiological practices and techniques."

BMBL, 5th ed. (p. 22)

Behaviors and Injury Prevention

Behavior and Injury Prevention

- "At-risk" behaviors
  - Mouth pipetting
  - Recapping needles
  - Hand to face contact
  - Picking up broken glass with hands
- "Safe" behaviors
  - Handwashing
  - Using pipetting devices
  - Safe sharps precautions
  - Using a mechanical device to pick up broken glass

Why Hand Hygiene?

- Small-diameter Aerosols
  - Inhalation hazard
    - < 5 µm penetrate to the alveoli
    - < 10 µm penetrate to bronchi
- "…the respirable component is relatively small and does not vary widely"

- Large-diameter Aerosols
  - Hand/skin contamination
  - Surface/fomite contamination
    - > 50 µm settle out quickly
- "…hand and surface contamination is substantial and varies widely"

BMBL, 5th ed. (p. 14)

Primary Routes of Transmission: Inhalation vs. Direct Contact

Comparison of 10 most common symptomatic laboratory-acquired infections (1979 – 2004)

Agent	No. of cases	No. of deaths
Mycobacterium tuberculosis	199	0
Arboviruses	192	3
Coxiella burnetii	177	1
Hantavirus	155	1
Brucella spp.	143	4
Hepatitis B virus	82	1
Shigella spp.	66	0
Salmonella spp.	64	2
Hepatitis C virus	32	1
Neisseria meningitidis	31	11

Adapted from Harding & Byers (2006, p. 55)

Why Hand Hygiene?

- Hand transmission most likely route of infection at BSL-2
  - Fingers, hands, & wrists are easily contaminated during laboratory procedures
  - Hand-to-face contact is common in the lab
  - Generally no barrier between hands and face

CDC (2007), Collins & Kennedy (1999), Evans (1990)

Hand Washing & Hand Disinfection

- Effective for removing/inactivating microbes
- Effectiveness varies depending on:
  - Agent used
  - Contact time
  - Surfaces covered
- Antiseptic handwashing & alcohol-based hand sanitizers are superior to traditional soap & water handwashing

CDC, (2002) *MMWR 51(RR-16)*

Behavioral Studies of Lab Workers

- Evans et al. (1990)
  - Observational study of 119 workers in 10 NIH labs
  - Focus: Universal precautions for blood and body fluids
  - Inappropriate behaviors identified in 40% (15/39) areas surveyed
    - At-risk behaviors included:
      - Handling specimens without gloves
      - Mouth pipetting
      - Spills resulting in skin contamination
      - Oral contact with contaminated items
      - Open bench sonicating
      - Hand braking of centrifuge rotors

Behavioral Studies of Lab Workers

- Alp, Haverkate, & Voss (2006)
  - Observational study of clinical lab workers
  - Focus: Hand hygiene behaviors and compliance with a no-jewelry policy (rings, wrist watches, bracelets)
  - Findings:
    - No-jewelry policy: 36.7% compliance rate (*n*=49)
    - Potential pathogens were cultured exclusively from skin underneath the offending accessories
    - End of shift hand hygiene compliance was 100% (*n*=37)

Behavioral Studies of Lab Workers

- Gaps in existing literature
  - Very few studies measure actual behavior
    - Limited to beliefs, perceptions, knowledge, attitudes
  - Intervention studies
    - Focus is primarily on training
    - Studies show change in knowledge over time, but the knowledge-behavior gap is not bridged
    - Studies are short-term (weeks/months vs. years)
  - Limited use/application of behavioral theory
    - Why do people do what they do?

- Why do laboratory workers take risks?
  - "Martyr-to-science" complex?
    - Wedum (1961), Phillips (1969)
  - Perception of risk is low?
    - Blayney & Eijnde (2005)
  - Inadequate training?

"Laboratory directors or principal investigators should train and retrain new staff to the point where aseptic techniques and safety precautions become second nature."

BMBL, 5th ed. (p. 15)

- Stimulus-Response Theory (20th century)
  - B.F. Skinner (1904 – 1990)

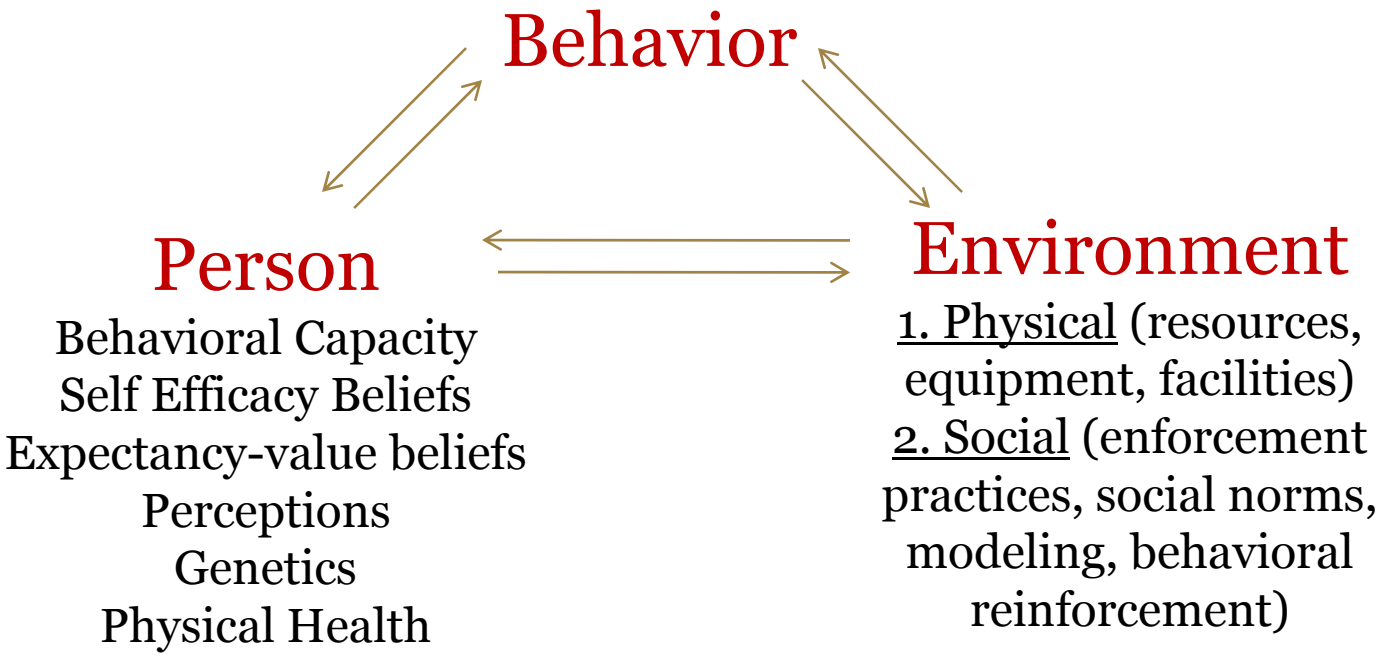
Stimulus (Antecedent Cue) → **Response** (Operant Behavior) → **Stimulus** (Contingent Reinforcement or Punishment)

Theoretical foundation for "Behavior-based Safety"

Theoretical Framework

Social Cognitive Theory (SCT)

Bandura 1986



Purpose

1. What is the observed frequency of handwashing (HW) among BSL-2 lab personnel before exiting the lab and before entering “clean” areas?
2. Is there a difference between the observed and self-reported frequency of HW among BSL-2 lab workers?
3. What is the relationship between SCT variables and BSL-2 lab workers’ HW practices, and which of these variables most strongly predict HW?
4. What is the quality of HW among BSL-2 lab workers?

Study Design

- 2-phase, cross-sectional study
  - Phase 1 (May – December 2009)
    - Informed consent
    - Behaviors measured by direct observation
      - Frequency of HW
      - Quality of HW
      - Rate of HFC
    - Situational factors measured
  - Phase 2 (December 2009 – January 2010)
    - Survey of participants beliefs, perceptions, & attitudes related to HH

Subjects & Setting

- Subjects
  - 93 participants (56% male, 44% female)
    - Research professors
    - Post-doctoral students
    - Research associates
    - Graduate students
    - Laboratory technicians
    - Medical doctors

Subjects & Setting

- Participating Labs (n = 21)
  - BSL-2 (17)
  - BSL-2+ (4)
- Staffing
  - Range 1 – 9 workers ($mean$ = 4.4/lab)
- Approved Agents
  - Viral only (14)
  - Bacterial and viral (4)
  - Bacterial only (2)
  - Bacterial and parasitic (1)

Measurement

- Instrumentation
  - Laboratory behavior observation tool (LBOT)
    - Developed from 2 existing tools
      - Handwashing assessment tool (HAT; Brock, 2002)
      - WHO HH assessment tool (Haas, 2007)
    - Standardized measurement tool
      - Amount of observation time
      - Procedure being performed
      - Agent in use
      - HH behaviors
      - Situational factors within labs

Measurement

- Biosafety level 2 behavior survey (BBS)
  - Demographic characteristics
  - Self-reported rate of HW
  - SCT constructs

Scale	Cronbach's alpha
Expectancy Belief scale 1	.63
Expectancy Belief scale 2	.79
Outcome Values	.78
Modeling	.92
Self Efficacy	.62
Behavioral Reinforcement	.93
Policy Enforcement	.74

Measurement

- Situational Factors
  - Measured at lab level
    - Time since last training
    - Training specifically on HW
    - Exit traffic from lab
    - Soap in lab
    - Paper towels in lab
    - Type of lab
    - HW policies written in SOPs

Measurement

- Dependent Variables
  - HW Compliance
    - # times washed/# opportunities
    - Attempted to observe 5 opportunities/subject
    - HW Opportunities included:
      - Before exiting BSL-2 lab (96%)
      - Before entering “clean” area within BSL-2 lab (4%)
  - HW Quality
    - Duration of scrubbing
    - Use of soap
    - Surfaces covered (dorsal, wrist, palm, interdigital)
    - Rinse
    - Drying (did subject use paper towel to turn off faucet?)
    - Hand sanitizer used

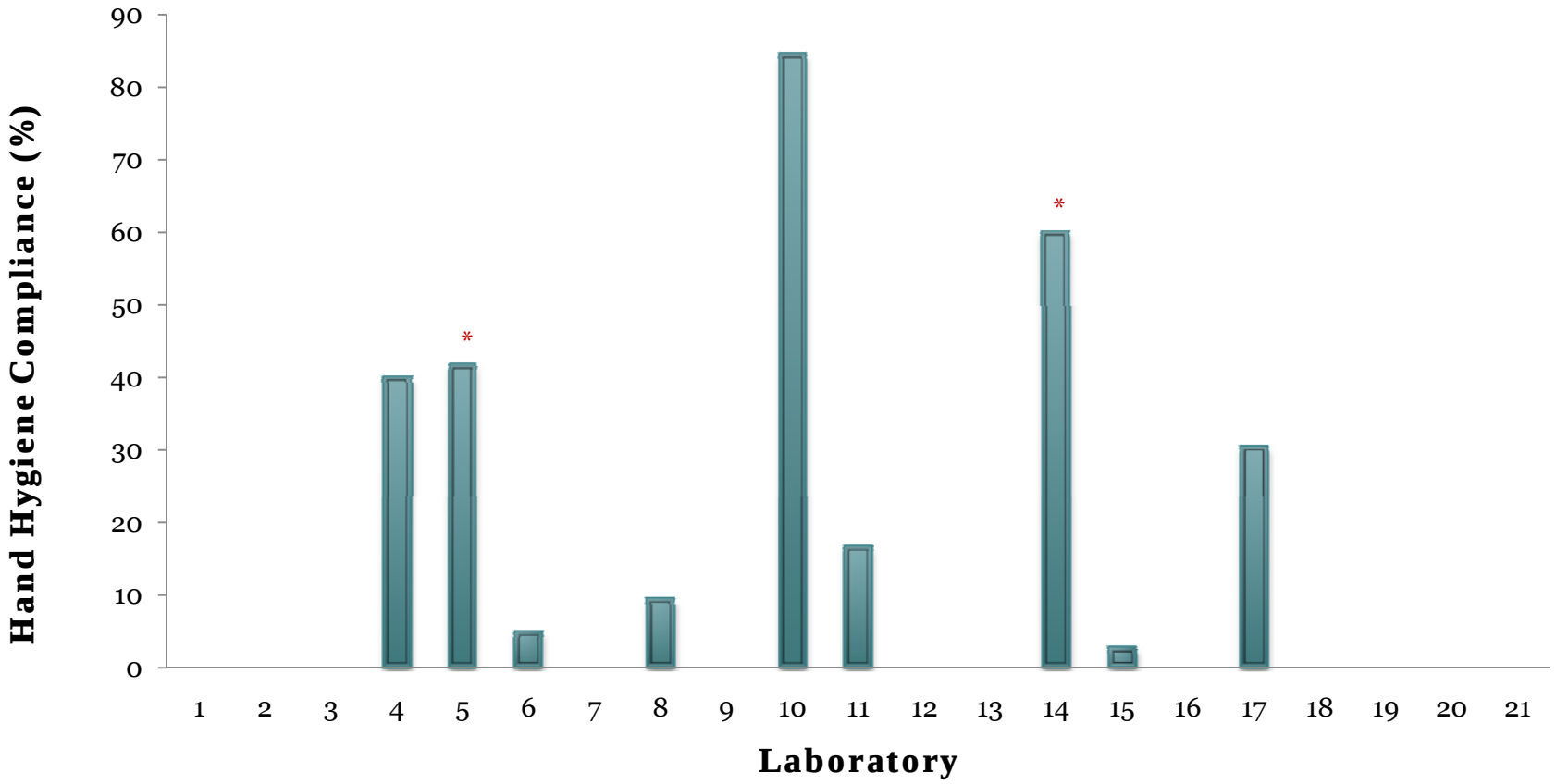
Analysis

- SPSS (version 15.0)
  - Univariate statistics
  - Correlations
  - Significance tests
- Microsoft Excel
  - Linear regression
- HLM 6.08
  - Hierarchical linear modeling of HW predictors

Results

- Overall HW Compliance
  - 118 hours of observation
  - 604 HW opportunities
  - 62 HW Events (1 w/hand sanitizer)
  - Overall compliance rate = 10.3%
- Compliance by lab
  - 336 opportunities in 12 labs with zero compliance
  - 268 opportunities in 9 labs: 3 – 85% compliance

Overall % Compliance by Lab



Observed vs. Self-reported Compliance

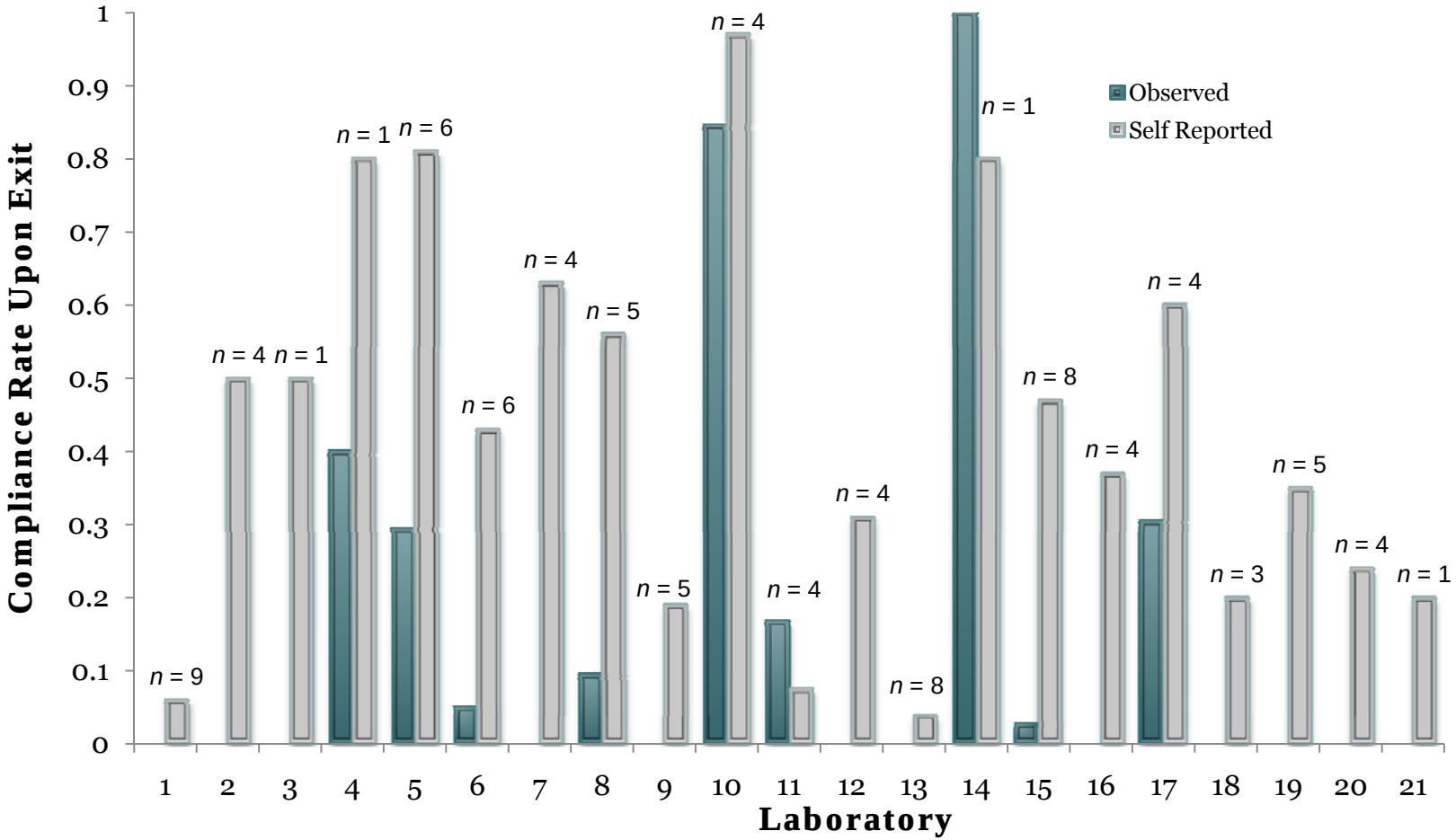
- Mean observed HW rate
  - Upon exit = 8.8%
  - Before entering clean areas (n=6) = 45.8%
- Mean self-reported HW rate
  - Upon exit = 39.5%
  - Before entering clean areas = 82%

- Correlation: $r = .47$, $P < .01$

HW Compliance by Job Title

	Postdoc/RA (*n* = 29)	Lab Tech (*n* = 26)	Prof/MD (*n* = 8)	Grad student (*n* = 30)
Years in Lab	8.9	7.1	14.5	4.9
Compliance Rate				
Overall	.13	.17	.04	.07
Upon Exit	.11	.15	.04	.05
SR Compliance				
Upon Exit	.38	.49	.36	.34

Observed vs. Self-reported Compliance



Compliance by Agent in use and Type of Lab

	Washed	Did Not Wash	Total	% Compliance
Agent in Use on Day of Observations				
Infectious (n = 51)	46	260	306	15.0
Potentially Infectious (n = 57)	11	217	228	4.8
Non-Infectious (n = 14)	5	65	70	7.1
Type of Lab				
BSL-2 (n = 17)	38	466	504	7.5
BSL-2+ (n = 4)	24	76	100	24.0

*X^2 (2, N=604) = 15.6, P < .001
**X^2 (1, N = 534) = 14.86, P < .001

Determinants of HW

- Correlations between HW and SCT predictors

Variable	Correlation Coefficient
Expectancy Belief Scale 1	.17
Expectancy Belief Scale 2	.39**
Modeling	.41**
Outcome Values	.27**
Self Efficacy	.28**
Perception of Safety Policies	.26*
Reinforcement	.38**

** P < 0.01
* P < 0.05

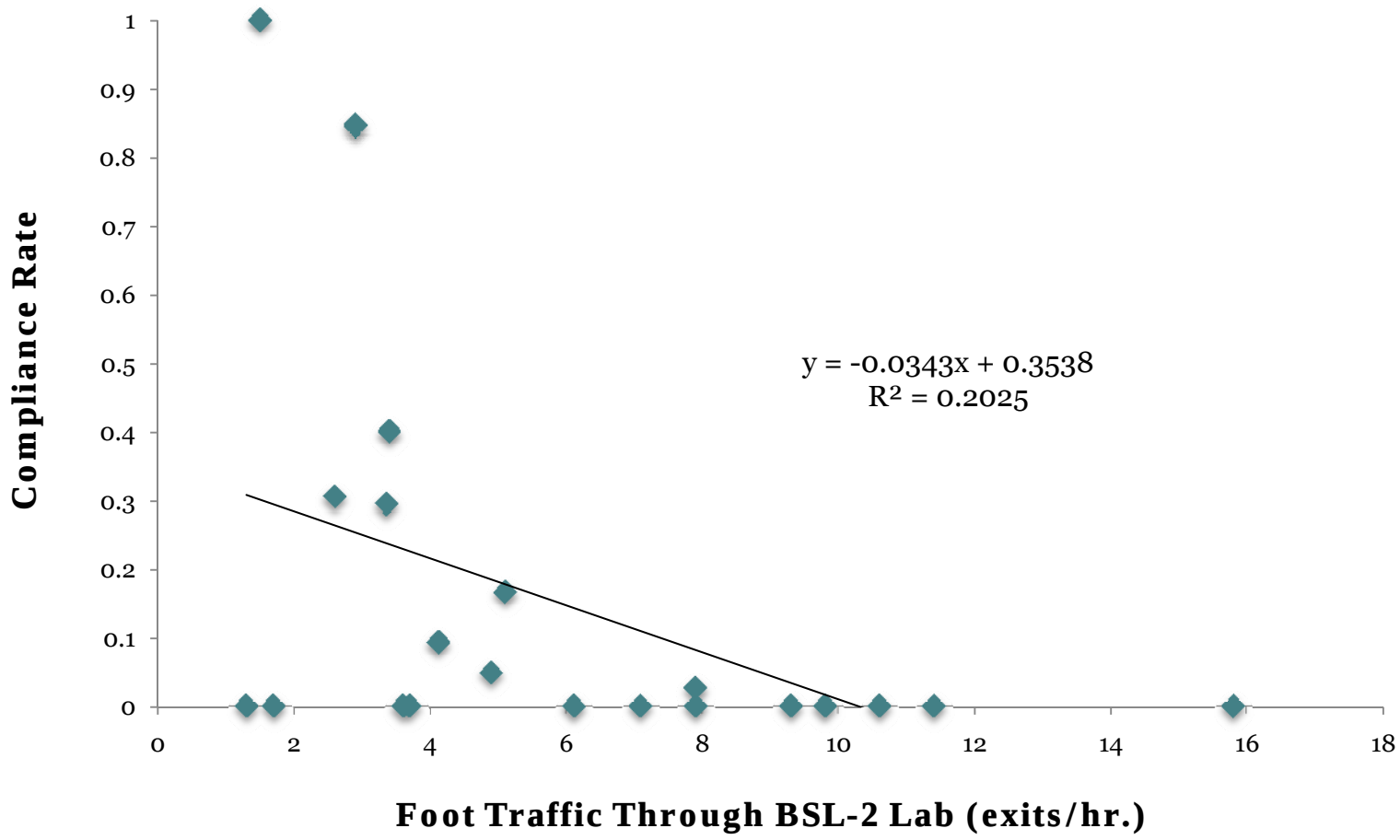
Determinants of HW

- Correlations between HW and situational factors

Variable	Correlation Coefficient
Safety Training	.18
Training on HW	.18
Exit Traffic	-.45*
Soap in Lab	.22
Paper Towels in Lab	.03
Type of Lab	.13
HW Policy in SOPs	.24

* $P < 0.05$

Relationship between HW compliance and exit traffic



Quality of HW

- 61 soap and water HW performed by 23 subjects (24.7%) from 9 labs
- 49 HW scored, 12 not scored (*n*=22)
- Average score = 11.3 (range = 2 – 18 points)
- Scrubbing 9 seconds or less (84% of cases)
- Soap use (92%)
- Lathering not visible to observer (51% of cases)
- Turned off faucet with bare hands (59% of cases)
- Foot operated (27%)
- Turned off with paper towel (14%)

Quality of HW by Gender and Job Title

	Time Scrubbing	Soap	Surfaces Covered	Rinse	Dry	Mean Score
Gender						
Female (*n*=8)	1.0	2.3	1.9	1.4	2.7	9.3
Male (*n*=14)	2.1	2.5	2.0	1.6	2.8	11.0
Job Title						
PostDoc/RA (*n*=10)	1.7	2.4	2.0	1.3	2.4	9.7
Lab Tech (*n*=6)	1.9	2.4	2.3	1.7	3.1	11.4
PI/MD (*n*=2)	1.0	2.0	1.0	1.5	3.0	8.5
GradStudent (*n*=4)	2.0	2.8	1.9	1.9	3.0	11.5

Duration of Scrubbing: < 5 sec. = 0; 5-9 sec. = 2; 10-14 sec. = 4; ≥ 15 sec. = 6
Soap: Soap not used = 0; Soap (lather not visible) = 2; Soap (lather visible) = 4
Surfaces Covered: One surface only = 0; Two surfaces = 2; Dorsal, wrist, palm, interdigital areas = 4
Rinse: No rinsing = 0; Partial = 1; All surfaces = 2
Drying: Did not dry = 0; Dried, turned off faucet with hands = 2; Dried, used paper towel to turn off faucet or foot operated = 4
*Maximum score = 20

Conclusions

- Rate and quality of HW is suboptimal
- BSL-2 containment may be routinely and pervasively violated by poor HW behaviors
- This study supports the need for research on the behavioral aspects of biological safety

Conclusions

- Self-reported compliance is not a reliable metric for use in future studies
- Direct observation is the “gold standard” for measuring hand hygiene in the healthcare setting, and should be used in the laboratory setting

Conclusions

- Space utilization and occupancy rates in BSL-2 labs may significantly influence workers' HW behaviors
- Risk assessments should consider the location of equipment and the number of workers in the lab
- Alcohol-based hand sanitizers may be appropriate for routine hand decontamination when supported by risk assessment

Future Research

- Apply lessons learned in the healthcare setting to the laboratory
  - Intervention studies are needed, but time should not be wasted on duplicating failed experiments
  - Multi-faceted rather than single-shot approaches
    - Top-down management support
    - Performance feedback
    - Interdisciplinary support
    - Participation by lab workers in program development
    - Alcohol-based hand sanitizer if supported by risk assessment

Future Research

- Need for studies focused on the development of valid and reliable instruments for measuring psychosocial variables
- Development of novel methods for measuring HH compliance
- Measurement of biological indicators of worker exposure

"Equipping a laboratory with the finest safety devices does not insure against all possible laboratory infections. Equipment is no substitute for safe technique…"

Reitman & Wedum, 1956