Measurements and Data Collection

Research Methods

S. M. Munsaka, PhD
Department of Biomedical Sciences
School of Health Sciences
The University of Zambia

24th February 2020

Measurement

Used with permission

Meridith Blevins, MS
Department of Biostatistics
Vanderbilt Institute for Global Health

Why Measurement?

- Measurements supply the numbers used in statistical analysis.

- No matter how profound the theoretical formulations, how sophisticated the design, and how elegant the analytic techniques, researchers cannot compensate for **poor measures**.

- We will discuss the *role* of measurement, and the *types* of measurement.

Types of Measurements (Variables)

- **Categorical (Nominal)**
  - Mutually exclusive and exhaustive
  - No particular order
  - E.g. profession, Disease condition, Sex
    - Binary (dichotomous): two outcomes
      - E.g. Sex; male and female, HIV status; Positive and negative

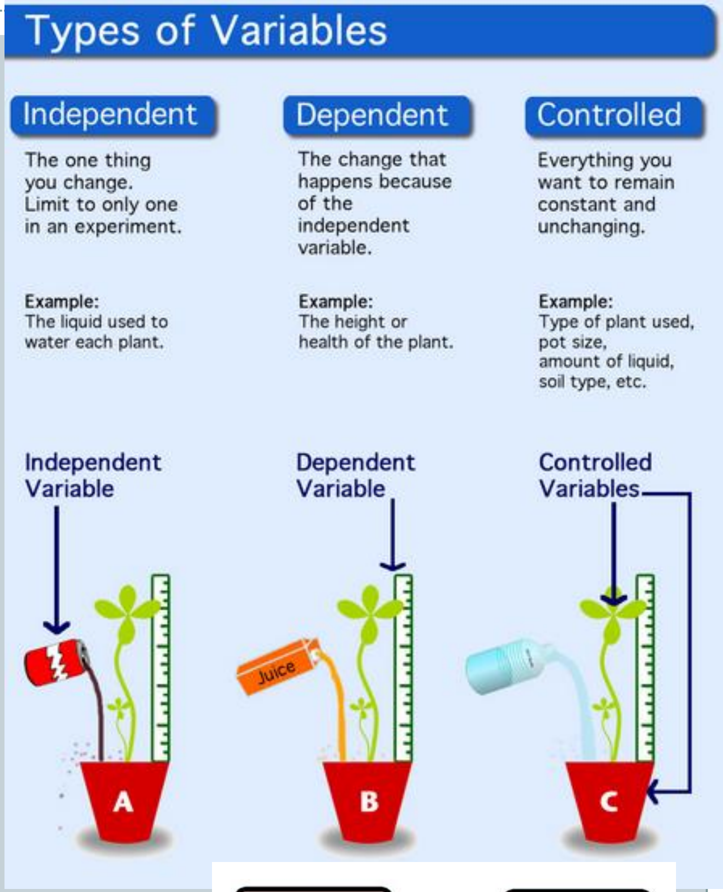
- **Ordinal**
  - Categorical measurements (variables) that can be ordered
    - E.g. severity of symptoms, age ranges

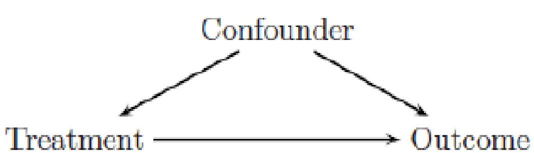
- **Continuous (interval)**
  - Numerical variable with many possible values, no upper limit
  - Has the most statistical information
    - E.g. age, blood pressure, blood glucose levels, CD4, viral load etc

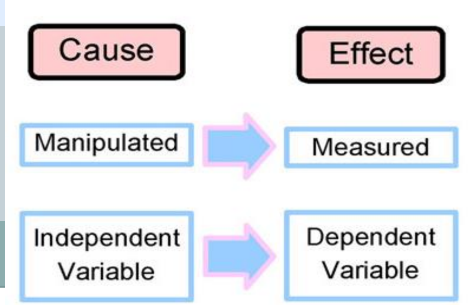
- **Discrete:** variable that can only take on a certain number of values. In other words, they don't have an infinite number of values. E.g. 1, 2, 3, 4, 5.......

Types of Measurements (Variables)

- Dependent variable (Experimental or Response variable)
  - The variable that you measure
  - The **dependent variable** responds to the **independent variable**. It is called **dependent** because it "depends" on the **independent variable**.
  - E.g. outcomes; death, CD4, viral load, blood glucose
- Independent variable (predictor or descriptor variable)
  - Not controlled by experimenter
  - E.g. race, sex, HIV status
- Adjustment variable (cofounder)
  - A variable that can affect both the dependent and independent variable







Goals of Data Analysis

- 1. To describe (summarizes) the population of interest
  - Description of what was observed (measured) in the study/sample population
  - Known as Descriptive Statistics
    - Summarizes continuous variables using
      - Means, standard deviations, percentiles, medians, ranges, mode etc
    - Summarizes categorical variables using
      - Raw or relative frequencies, percentages etc
- 2. To use patterns in the study (sample) to make inferences about a population being represented
  - Uses Inferential Statistics which involves
    - Hypothesis tests and p values
    - Determining associations and correlations
    - Determining relationships, estimating effects, making predictions using regression analysis
    - Confidence intervals

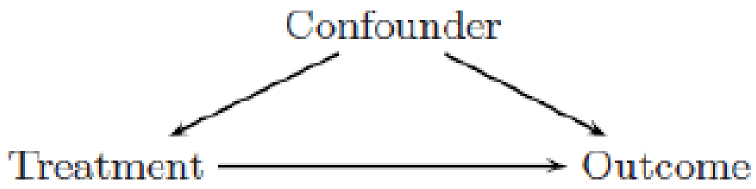
Goals of Data Analysis

- 1. To describe (summarizes) the population of interest
  - Description of what was observed (measured) in the study/sample population
  - Known as Descriptive Statistics
    - Summarizes continuous variables using
      - Means, standard deviations, percentiles, medians, ranges, mode etc
    - Summarizes categorical variables using
      - Raw or relative frequencies, percentages etc

	N	**Drug** $N = 2165$	**Placebo** $N = 570$
Weight (lbs)	2661	191±50 (148 196 233)	188±48 (149 194 229)
Race	2696		
Afr American		41% (868/2134)	38% (215/562)
Caucasian		47% (996/2134)	50% (283/562)
Other		13% (270/2134)	11% (64/562)

Role of Measurement

- Response variable
- Independent variable (predictor or descriptor variable)
- Adjustment variable (confounder)
- Experimental variable



Type of Measurement

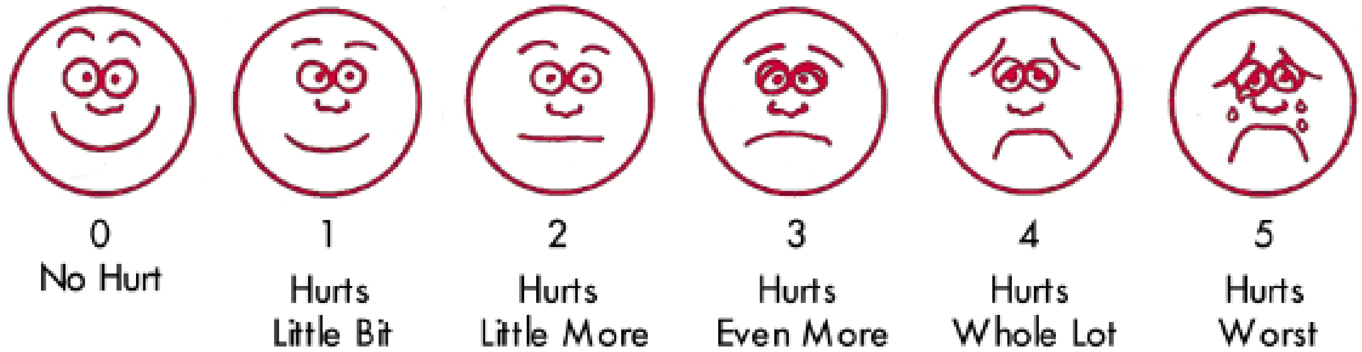
- Nominal scale
- Ordinal scale
- Interval scale

Categorical (or Nominal)

- Two or more possible values that are not necessarily in special order
- Mutually exclusive and exhaustive
- Example:
  - profession
- Sex (male/female) is an example of a dichotomous (or binary) variable.

Ordinal

- A categorical variable whose possible values are in a special order
- Examples:
  - Severity of symptom or disease
  - Satisfaction
  - Agreement

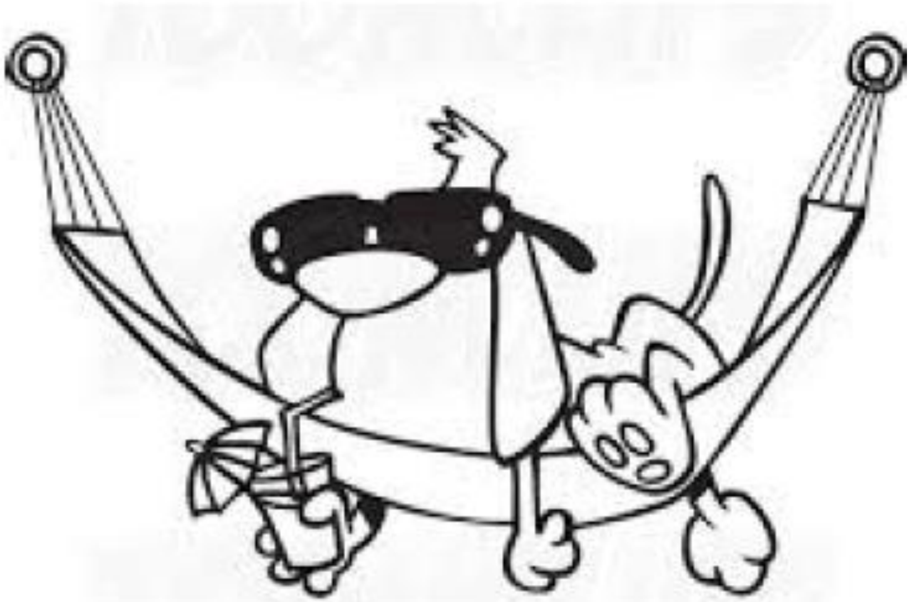


Continuous (or Interval)

- A numeric variable having many possible values representing an underlying spectrum
- Have the most statistical information (assuming the raw values are used in the data analysis) and are usually the easiest to standardize across studies (e.g., household surveys or health facilities)
- Count: a discrete variable that (in theory) has no upper limit, e.g. the number of ER visits in a day, the number of traffic accidents in a month

Unit of Measurement

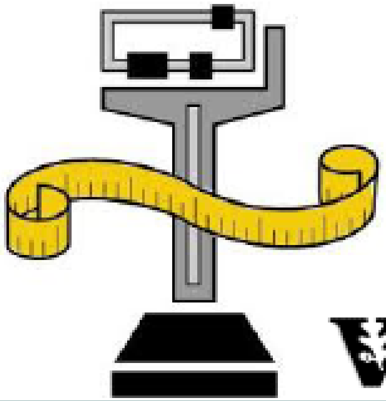
27°F



27°C

Measurement Scales

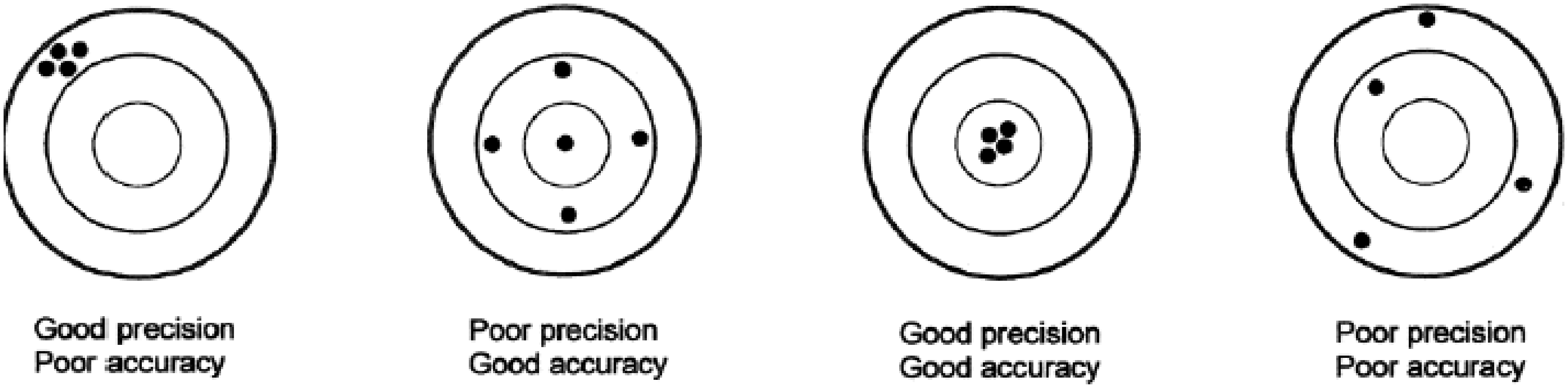
Type of Measurement	**Characteristics of Variable**	**Example**	**Descriptive Statistics**	**Information Content**
Nominal	Unordered categories	Sex; blood type; vital status	Counts, proportions	Lower
Ordinal	Ordered categories with intervals that are not quantifiable	Degree of pain	In addition to the above: medians	Intermediate
Interval	Ranked spectrum with quantifiable intervals	Weight; number of ER visits; pill count	In addition to the above: means, standard deviations	Higher



Reference: Hulley, Stephen B., et al. *Designing clinical research*. LWW, 2013.

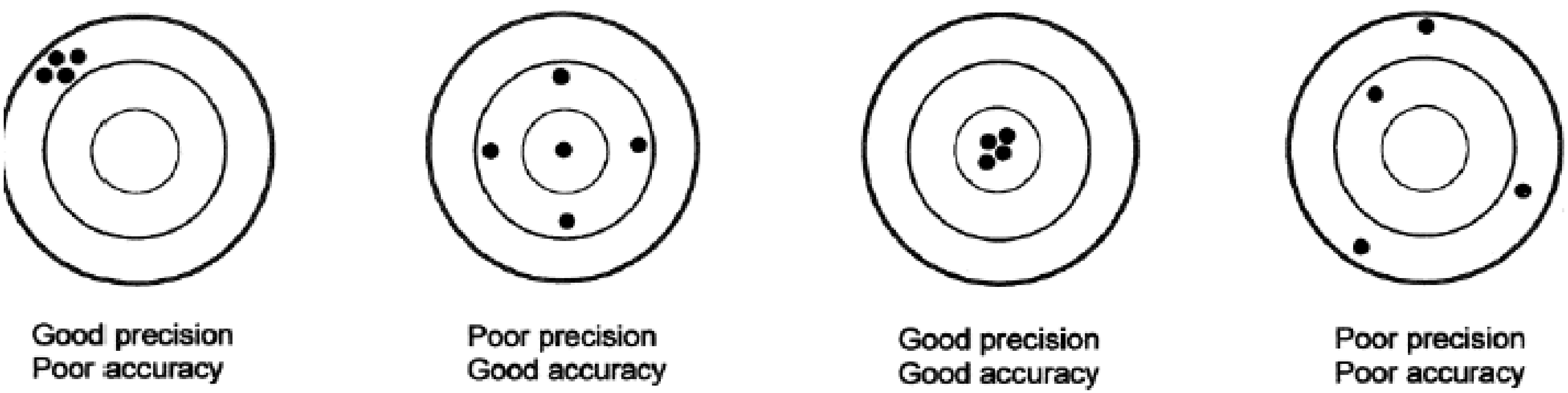
Precision

- Definition: the degree to which a variable has nearly the same value when measured several times.
- Example: Child's weight is not always the same if they are moving.

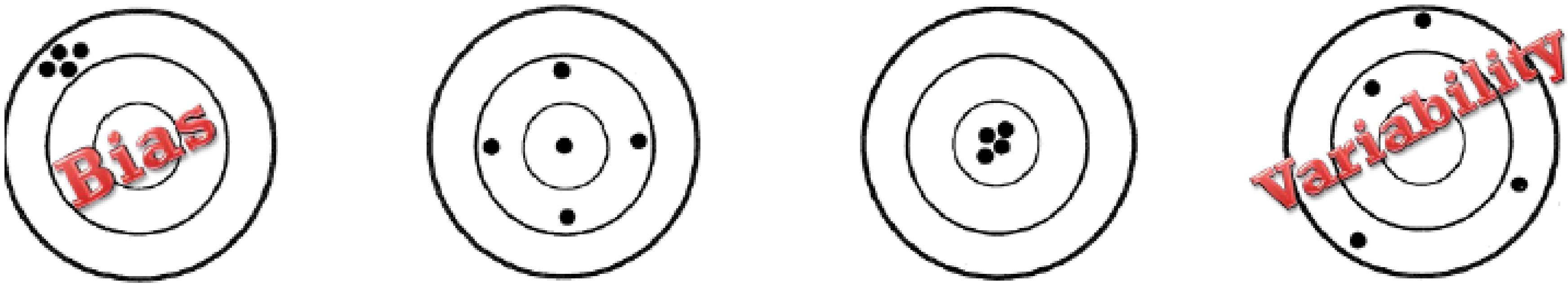


Accuracy

- Definition: the degree to which a variable actually represents what it is supposed to measure.
- Example: If the scale is not at zero with no weight, then readings will not be correct.



Precision and accuracy



Good precision
Poor accuracy

Poor precision
Good accuracy

Good precision
Good accuracy

Poor precision
Poor accuracy

Data Collection and Data Entry

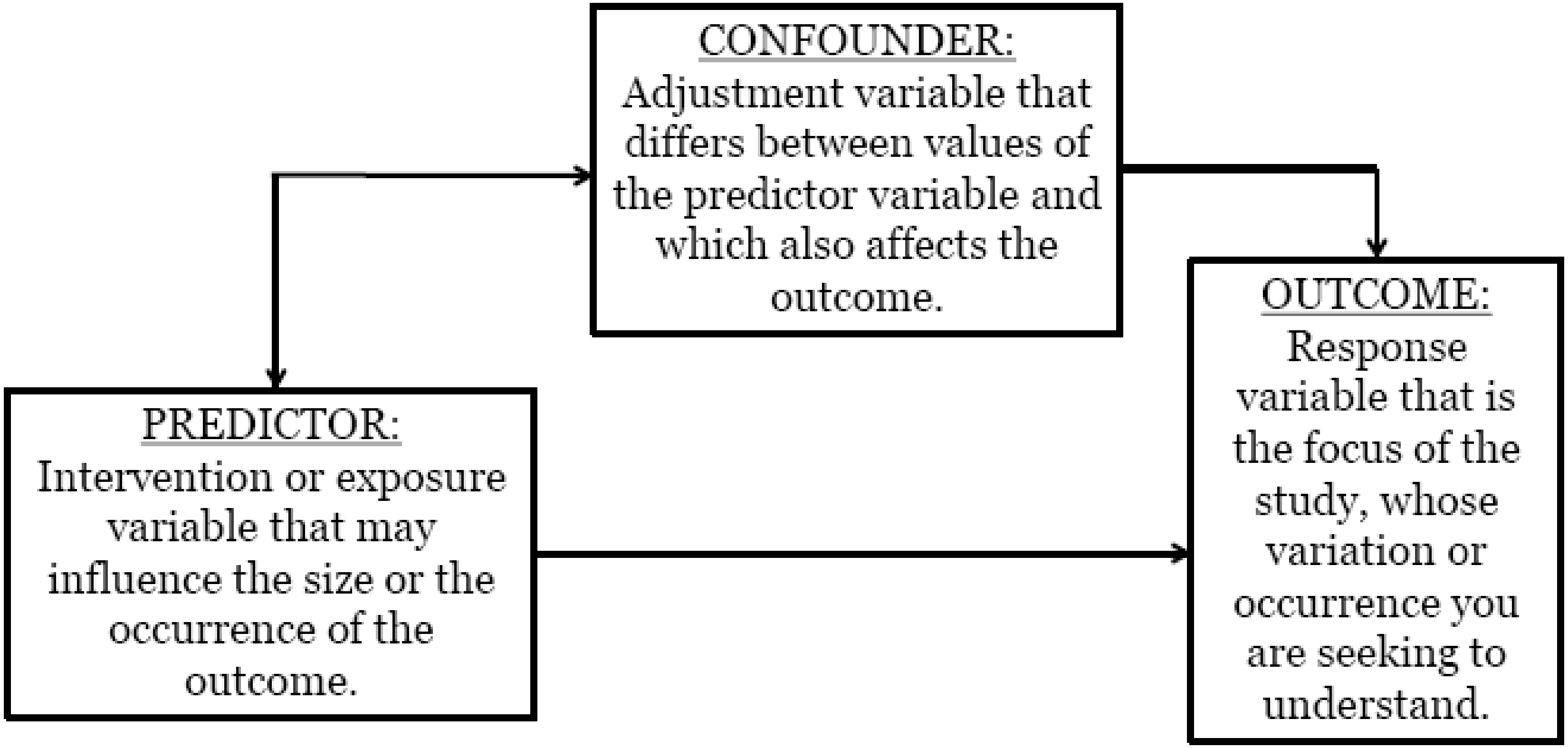
References:

- Designing Clinical Research (3rd edition) by Hulley, et al.
- “The Little Handbook of Statistical Practices” - Gerard Dallal. http://www.tufts.edu/~gdallal/LHSP.HTM
- “Spreadsheets from Heaven/Hell” from Daniel W Byrne, MS.

Step 1: Create your data dictionary

- **Before** *any data is collected*, write a detailed list of the information to be collected and the concepts to be measured in the study.
- Directly relate this list to the research question.
- Make sure the list includes all the information needed to
  - 1) describe the *sample* of "subjects" you will study
  - 2) perform the planned statistical analysis.
- If using a questionnaire, make sure all the necessary information is collected in the questionnaire.
- Define the role of each variable: response, independent, adjustment, or experimental.

Role of collected variable



Predictor-confounder and confounder-outcome associations are needed to correctly estimate the predictor-outcome association.

Convert the detailed list to a data dictionary

- A document that includes a description of the study variables and data management procedures.
- For each variable, it includes the
  - variable name,
  - role of the variable (in the statistical analysis),
  - variable label,
  - unit of measurement (if applicable),
  - type of variable,
  - permissible values or range of values
  - definitions of redefined and derived variables
  - additional edits to be performed (eg, logic/consistency checks).
- Should be created *before* any data are collected.
  - Expect revisions and review with your statistician.

Data dictionary in detail

Variable name: used to identify the variable in the data file(s).

- Should be short but understandable/self-explanatory.

Variable label: "Pretty" label to fully describe the variable.

- Example: "Age at baseline".

Type of variable:

- **Continuous:** has any number of possible values (eg, weight).
- **Categorical:** has only certain possible values (eg, race).
  - **Binary** (dichotomous)
  - **Ordinal** (ordered categories)

Data dictionary in detail, *cont'd*

Permissible values: (for categorical variables)

- Can be coded as numeric or text values.
- Example: For gender (a binary variable)
  - Numeric coding: 0 (Female) and 1 (Males).
  - Text coding: "F" (Female) and "M" (Male).

Permissible range of values: (for continuous or discrete numeric variables)

- Purpose: to guide data editing - values outside the defined range must be checked for accuracy.

Redefined/derived variables: should be (re-) calculated by your statistician (eg, BMI).

Additional considerations

- Continuous variables: Do not collapse into categories.
  - If collected categorized, original continuous values cannot be recovered and you cannot recode with new categories.
- Be consistent with
  - Text coding of categorical variables; note that many statistical programs are case-sensitive (“M” ≠ “m”).
  - Date formats (eg, mm/dd/yyyy *vs*. dd/mm/yyyy).
  - Representation of missing values (eg, blank or NA).
- Break up *non-mutually exclusive* values.
  - Example: Maternal complications of bleeding, high blood pressure, and fever can occur in any combination.
  - Code as three separate Yes/No columns of bleeding, high blood pressure, and fever (instead of a single text field).

Example data dictionary

Name	Role	Label	Units	Type	Values
GROUP	Predictor	Treatment		Binary	1 = Placebo; 2 = Treatment
AGE	Predictor	Age	Years	Continuous	18 - 75
SEX	Predictor	Gender		Binary	1 = Female; 2 = Male
HT	Predictor	Height	in.	Continuous	48 - 96
WT	Predictor	Weight	lbs.	Continuous	75 - 350
HCT	Predictor	Heart rate	beats/min.	Continuous	30 - 50
BPSYS	Predictor	Systolic BP	mmHg	Continuous	100 - 160
BPDIAS	Predictor	Diastolic BP	mmHg	Continuous	80 - 150
STAGE	Predictor	WHO stage		Discrete numeric	1 - 4
RACE	Predictor	Race		Categorical	1 = White; 2 = Black; 3 = Other
DATE1	Additional	Date of last visit			mm/dd/yyyy
COMPLIC	Outcome	Complications?		Binary	0 = No; 1 = Yes

Step 2: Create your data file(s)

- Most common and easily accessible approach to creating your data file(s) is to use a spreadsheet program, like Microsoft Excel.
  - Easy to enter the data values directly into the appropriate cells (rows and columns) using a keyboard.
- Other possible data entry programs: STATA, SPSS, Microsoft Access, EpiInfo, and **REDCap**.
- CAUTION! Not good enough that data is merely entered into a spreadsheet.
  - Data often are entered without thinking about statistical analysis.
  - Many spreadsheets require considerable cleaning before they are suitable for analysis.
  - There are ways to enter data so that they are nearly unusable - the Spreadsheet from Hell…

Spreadsheet from HELL

Comparison of Drug A and Drug B										
Drug A	Age of Patient	Patient Gender	Height (inches)	Weight (pound)	24hrhct	blood pressure	tumor stage	Race	Date enrolled	complications
1	25	Male	61"	>350	38%	120/80	2-3	Hipanic	1/15/99	no
2	65+	female	5'8"	161	32	140/90	II	White	2/05/1999	yes
3	?	Male	120cm		12	>160/110	IV	Black	Jan 98	yes, pneumonia
4	31	m	5'6"	obese	40	140 sys 105 dias	?	African-American	?	
5	42	f	>6 ft	normal	39	missing	=>2	W	Feb 99	
6	45	f	5.7	160	29	80/120	NA	B	last fall	n
7	unknown	?	6	145	35	normal	1	W	2/30/99	n
8	55	m	72	161.45	12/39	120/95	4	African-American	6-15-00	y
9	6 months	f	66	174	38	160/110	3	Asian	14/12/00	y
10	21	f	5'							
Drug B										
1	55	m	61	145	normal	120/80 120/90	IV	Native American	6/20/	3
2	45	f	4"11	166	?	135/95	2b	none	7/14/99	n
3	32	male	5'13"	171	38	140/80	not staged	NA	8/30/99	n
4	44	na	65	?	40	120/80	2	?	09/01/00	n
5	66	fem	71	0	41	140/90	4	w	Sep 14th	y, sepsis
6	71	unknown	172	199	38	>160/110	3	b	unknown	y, died
7	45	m	?	204	32	140 sys 105 dias	1	b	12/25/00	n
8	34	m	NA	145	36	130	3	w	July 97	n
9	13	m	66	161	39	166/115	2a	w	06/06/99	n
10	66	m	68	176	41	1120/80	3	w	01/21/58	n
Average	45		65	155	38					

Data Entry Guidelines

- *Goal:* Create your data file(s) to achieve
  - 1) a smooth transfer between a spreadsheet and a statistical program package
  - 2) optimal statistical analysis.
- *Standard data structure:* A table of numbers and text in which each row corresponds to an individual subject (or unit of analysis) and each column corresponds to a different variable or measurement.
  - One record (row) per subject.
  - Example: For a study that recorded the identification number, age, sex, height, and weight of 10 subjects, the resulting data file would be composed of 10 rows and 5 columns.

Data Entry Guidelines, *cont'd*

Data structure for *repeated measurements* on the same subject (or unit of analysis).

- Example: A study where 5 weekly blood pressure readings are made on each of 20 subjects.
- Two options: a "wide" data file or a "long" data file.
  - "Wide": 20 rows and 6 columns (5 blood pressures and an ID).
    - Still have one record (row) per subject.
  - "Long": 100 rows of 3 columns (ID, week # (1-5), and blood pressure).
    - Have 5 records (rows) per subject.

Data Entry Guidelines, *cont'd*

- *First row* of the spreadsheet should contain only (legal) variable names.
  - Definition of "legal" will vary with the target statistical program.
  - All programs will accept variable names that are no more than 8 characters long, are composed ONLY of letters, numbers, and underscores, and begin with a letter.
  - Good idea to name all variables using lower case, which is easier to type and eliminates mistakes that can occur if software programs are case sensitive (e.g., "Age" vs "age").
  - Each variable name should be unique.
- Actual data values begin on the *second row*.

Data Entry Guidelines, *cont'd*

- Assign each subject (or unit of analysis) a *unique identifier* (ID; eg, 1, 2, 3, etc).
  - Because of HIPAA, the analyst is not allowed to receive data files containing any identifiers.
    - Includes patient name (first, last, or initials), national identification number, medical record (MR) number, street address, and telephone numbers.
    - IDs should not contain any of this information.
  - Create a separate file that matches the identifying information for each subject (unit of analysis) with their unique ID.
    - Place the assigned unique IDs in the first column of your data file(s) to distinguish the subjects on each row.
    - OK to have identifying info in your data files(s) for yourself during data entry; just need to remove it before you send it to your analyst.

Data Entry Guidelines, *cont'd*

- No text should be entered in a column intended for numbers - ie, *don't mix text and numbers* in the same column.
  - This includes notations such as "<20", "20+" and "20%".
  - If text strings are present, the statistical package may consider all of the data to be text strings rather than numbers.
  - In addition, numerical data may be mistakenly identified as text strings when one or more spaces are typed into an otherwise empty cell.
  - Exception to this rule: entering text values that distinguish missing data (eg, NA).

Data Entry Guidelines, *cont'd*

- There should be *no embedded* formulas.
  - The statistical programs may not be able to handle them.
  - Also, the calculated value of a formula is replaced with a blank cell when the spreadsheet is exported as a delimited text file.
- There are two ways to deal with formulas:
  - 1) Rewrite the formulas in the target package so the statistics package can (re-)generate the values.
  - 2) Use Microsoft Excel's "Paste Special" capabilities to store the derived values as actual data values in the spreadsheet.
- Still a good idea to double-check the calculated values in the target statistical package.

Data Entry Guidelines, *cont'd*

- When a study will generate multiple data files:
  - Every record in every data file must contain a subject (or unit of analysis) identifier that is consistent across all files.
  - Data files that are likely to be merged should not use the same variable names (other than the common ID variable).
- For studies that generate repeated measurements on the same subject (or unit of analysis), multiple data files often make data entry and management easier.
  - One data file contains the information that is not repeatedly collected (eg, demographics such as age, race, and gender; 1 record per), the other data file(s) contain(s) the information that is repeatedly collected (eg, blood pressure collected every week for 5 weeks; "long" format of 1 record per).

Data Entry Guidelines, *cont'd*

Missing data must be carefully considered.

- Can use a single value to record missing data across all rows and columns.
  - Example: "NA", ".", or a blank cell.
  - Possible problems with specific choice of value:
    - Example: If missing data are coded as "99" and the statistician is not aware of this, a subject who has a missing value for age may be analyzed as if their age is 99 years.
- Can use several values depending on nature of the data or desire during the analysis.
  - Example: Use ".m" for missing, ".d" for don't know, and ".n" for values that are not applicable.
  - In the analysis, all these values are treated as missing, but the reason the data are missing is retained.

Spreadsheet from *Heaven*

CASE	GROUP	AGE	SEX	HT	WT	HCT	BPSYS	BPDIAS	STAGE	RACE	DATE1	COMPLIC
1	1	25	1	61	350	38	120	80	3	3.0	1/15/1999	0
2	1	65	2	68	161	32	140	90	2	1.0	2/5/1999	1
3	1	25	1	47	150	38	160	110	4	2.0	1/15/1998	1
4	1	31	1	66	161	40	140	105	2	2.0	4/1/1999	0
5	1	42	2	72	177	39	130	70	2	1.0	2/15/1999	0
6	1	45	2	67	160	29	120	80	1	2.0	3/6/1999	0
7	1	44	1	72	145	35	120	80	1	1.0	2/28/1999	0
8	1	55	1	72	161	39	120	95	4	2.0	6/15/2000	1
9	1	0.5	2	66	174	38	160	110	3	4.0	12/14/2000	1
10	1	21	2	60	155	40	190	120	2	2.0	11/14/2000	0
11	2	55	1	61	145	41	120	80	4	5.0	6/20/1999	1
12	2	45	2	59	166	39	135	95	2	1.0	7/14/1999	0
13	2	32	1	73	171	38	140	80	1	1.0	8/30/1999	0
14	2	44	2	65	155	40	120	80	2	2.0	9/1/2000	0
15	2	66	2	71	145	41	140	90	4	1.0	9/14/1999	1
16	2	71	1	68	199	38	160	110	3	2.0	1/14/1999	1
17	2	45	1	69	204	32	140	105	1	2.0	12/25/2000	0
18	2	34	1	66	145	36	130	75	3	1.0	7/15/1997	0
19	2	13	1	66	161	39	166	115	2	1.0	6/6/1999	0
20	2	66	1	68	176	41	120	80	3	1.0	1/21/1998	0