CROSSTAB Example #9

SUDAAN Statements and Results Illustrated

- Kappa measure of agreement
- AGREE statement
- TABLE statement
- MERGHI option
- WSUM option

Input Data Set(s): NHANES3S3.SAS7bdat

Example

Using NHANES III periodontal data, estimate the Kappa measure of intra-dental examiner agreement between ratings of baseline vs. follow-up periodontal assessments of teeth.

Solution

The dataset for this example consists of the approximately 5% of the examined survey sample of **NHANES III** recalled for repeat second dental exams identical to the first. These sample persons were examined twice by the same examining dentist at an interval of 1—6 weeks after the initial exam (Winn, et al 1999). The data from repeat exams on the sub-sample are available as a public use electronic dataset. Intra-examiner reliability is assessed using the Kappa measure of agreement on the repeat visits (baseline and follow-up) for each sample member. In this example, the periodontal outcome of interest is *Probing Pocket Depth Score, upper central incisor, mesial surface* (measured in millimeters).

Recall that *NHANES III* is a cross-sectional sample survey of the civilian, non-institutionalized population aged 2 months or older, fielded during 1988-1994. The sample weight variable is WTPFQX6, and the stratification and PSU variables are SDPSTRA6 and SDPPSU6, respectively.

The SAS-Callable SUDAAN code for this example is displayed in ***Exhibit 1***. The square table to be used for estimation of Kappa is defined by the last two variables on the AGREE and TABLES statement—gender (*hssex*) by baseline (*depumpc1s*) by follow-up (*derumpc1s*) . The AGREE statement requests SUDAAN to estimate kappa for each level of gender (*hssex*) and overall. The TABLES statement is not needed to estimate Kappa but is added here in order to display the sample size and estimated population size in each cell for descriptive purposes.

When requesting the Kappa measure of agreement, the RxC variables that define rows and columns in the table <u>must</u> be specified on the SUBGROUP and LEVELS statements. Stratification variables can appear on either the SUBGROUP or CLASS statements, and in this example the stratification variable is included on the CLASS statement.

The PRINT statement instructs SUDAAN to print sample size (NSUM) and estimated population size (WSUM) in each cell of the stratified table, and then to print point estimates and 95% confidence limits of Kappa and a test for H_0: Kappa=0 for each of the stratification levels specified on the AGREE statement.

This example was run in SAS-Callable SUDAAN, and the SAS program and *.LST files are provided.

Exhibit 1. SAS-Callable SUDAAN Code

```
* This program calculates the KAPPA statistic using the NHANES III periodontal data;

LIBNAME dent "\\rtints29\sudaan\data\nhanes3\dental";

PROC FORMAT;
       value gen_ 1="Male"
                  2="Female";
      value mm 1="0 mm"
                2="1 mm"
               3="2 mm"
               4="3+ mm";

PROC CROSSTAB DATA=dent.dental2 NOTSORTED MERGEHI;
   NEST sdpstra6 sdppsu6;
   WEIGHT wtpfqx6;

   SUBGROUP depumpc1s derumpc1s;
   LEVEL    4         4;

   CLASS HSSEX;
   TABLES hssex*depumpc1s*derumpc1s;
   AGREE  hssex*depumpc1s*derumpc1s;

   SETENV ROWWIDTH=10 COLWIDTH=6 COLSPCE=1 TOPMGN=0 lblwidth=8;
   PRINT NSUM="SamSize" / nsumfmt=f10.0;

   SETENV ROWWIDTH=10 COLWIDTH=6 COLSPCE=1 TOPMGN=0 lblwidth=8;
   PRINT WSUM="PopSize" / wsumfmt=f10.0;

   SETENV COLWIDTH=10 COLSPCE=1 TOPMGN=0 LABWIDTH=12;
   PRINT / KAPPA=default KTEST=default lowkfmt=f9.4 upkfmt=f9.4 ;

   RFORMAT hssex gen_.;
   rformat depumpc1s mm.;
   rformat derumpc1s mm.;

   RLABEL depumpc1s="Baseline: Probing Pocket Depth Score, upper central incisor,
                     mesial (mm)";
   RLABEL derumpc1s="Follow up: Probing Pocket Depth Score, upper central incisor,
                     mesial (mm)";

   RTITLE "Intra-Examiner Agreement Baseline vs. Follow-up Periodontal Assessments
          of Teeth";
   RFOOTNOTE "Data Source: NHANES III, 1988-1994";
```

Note the option MERGEHI on the PROC statement. The outcomes in the raw data range from 0—12mm, with the vast majority between 0—3mm. The MERGEHI option includes all values above 3mm in the same category as 3mm. Therefore, the last category of probing pocket depth score is 3mm or greater. Kappa can only be computed for square tables.

The probing pocket depth outcome that is used in analysis effectively has 4 levels, defined as follows (values that are coded "could not be assessed" are set to missing):

    1=0 mm

    2=1 mm

    3=2 mm

    4=3+ mm

Exhibit 2.   First Page of SUDAAN Output (SAS *.LST File)

```
                         S U D A A N
          Software for the Statistical Analysis of Correlated Data
       Copyright      Research Triangle Institute      May 2011
                        Release 11.0.0


DESIGN SUMMARY: Variances will be computed using the Taylor Linearization Method, Assuming a
With Replacement (WR) Design
    Sample Weight: WTPFQX6
    Stratification Variables(s): SDPSTRA6
    Primary Sampling Unit: SDPPSU6


Number of observations read   :   2596   Weighted count : 24789861
Denominator degrees of freedom :     49
```

There are 2,596 records (sample persons) on the file, representing 24,789,861 people in the population.

Exhibit 3.   CLASS Variable Frequencies

```
Frequencies and Values for CLASS Variables
by: Sex.

---------------------------------
Sex              Frequency    Value
---------------------------------
Ordered
  Position:
  1                1204     Male
Ordered
  Position:
  2                1392     Female
---------------------------------
```

Males and females are roughly evenly divided in the dataset.

Exhibit 4.   Baseline*Follow-up Crosstabulation (Sex=Total)

```
Variance Estimation Method: Taylor Series (WR)

Intra-Examiner Agreement Baseline vs. Follow-up Periodontal Assessments of Teeth

by: Sex, Baseline: Probing Pocket Depth Score, upper central incisor, mesial (mm), Follow up:
Probing Pocket Depth Score, upper central incisor, mesial (mm).

for: Sex = Total.
----------------------------------------------------------------------------
|           |         | Follow up: Probing Pocket Depth Score, upper central |
| Baseline: |         | incisor, mesial (mm)                               |
| Probing   |         |----------------------------------------------------|
| Pocket    |         | Total   | 0 mm   | 1 mm   | 2 mm   | 3+ mm  |
| Depth     |         |         |        |        |        |        |
| Score,    |         |         |        |        |        |        |
| upper     |         |         |        |        |        |        |
| central   |         |         |        |        |        |        |
| incisor,  |         |         |        |        |        |        |
| mesial    |         |         |        |        |        |        |
| (mm)      |         |         |        |        |        |        |
----------------------------------------------------------------------------
|           |         |         |        |        |        |        |
| Total     | SamSize |     969 |     32 |    514 |    310 |    113 |
----------------------------------------------------------------------------
|           |         |         |        |        |        |        |
| 0  mm     | SamSize |      21 |     13 |      7 |      1 |      0 |
----------------------------------------------------------------------------
|           |         |         |        |        |        |        |
| 1  mm     | SamSize |     528 |     17 |    415 |     88 |      8 |
----------------------------------------------------------------------------
|           |         |         |        |        |        |        |
| 2  mm     | SamSize |     301 |      2 |     85 |    185 |     29 |
----------------------------------------------------------------------------
|           |         |         |        |        |        |        |
| 3+ mm     | SamSize |     119 |      0 |      7 |     36 |     76 |
----------------------------------------------------------------------------
Data Source: NHANES III, 1988-1994
```

A total of 969 observations have both a baseline and follow-up dental exam that could be assessed (the balance of the observations on the file were persons that had at least one time point in which the outcome could not be assessed). Observations in cells along the diagonal represent instances of agreement between baseline and follow-up exam—there was 71% agreement between baseline and follow-up using unweighted data.

Exhibit 4.   Baseline*Follow-up Crosstabulation (Sex=Total) cont'd.

```
Variance Estimation Method: Taylor Series (WR)

Intra-Examiner Agreement Baseline vs. Follow-up Periodontal Assessments of Teeth

by: Sex, Baseline: Probing Pocket Depth Score, upper central incisor, mesial (mm), Follow up:
Probing Pocket Depth Score, upper central incisor, mesial (mm).

for: Sex = Total.
```

Baseline: Probing Pocket Depth Score, upper central incisor, mesial (mm)		Follow up: Probing Pocket Depth Score, upper central incisor, mesial (mm)				
		Total	0 mm	1 mm	2 mm	3+ mm
Total	PopSize	9966690	222377	5659305	3276395	808613
0 mm	PopSize	216739	**87469**	106595	22675	0
1 mm	PopSize	6042946	117001	**4805563**	1057887	62496
2 mm	PopSize	2887638	17907	697591	**1906901**	265239
3+ mm	PopSize	819367	0	49556	288933	**480878**

```
Data Source: NHANES III, 1988-1994
```

This table represents the weighted totals in each cell. The 969 observations with complete data for baseline and follow-up represent 9,966,690 people in the population. Observations in cells along the diagonal represent instances of agreement between baseline and follow-up exam—there was 73% agreement between baseline and follow-up exams using weighted data. Kappa is computed from the weighted survey totals in this table.

Exhibit 5.   Baseline*Follow-up Crosstabulation (Sex=Male)

```
Variance Estimation Method: Taylor Series (WR)

Intra-Examiner Agreement Baseline vs. Follow-up Periodontal Assessments of Teeth

by: Sex, Baseline: Probing Pocket Depth Score, upper central incisor, mesial (mm), Follow up:
Probing Pocket Depth Score, upper central incisor, mesial (mm).

for: Sex = Male.
```

Baseline: Probing Pocket Depth Score, upper central incisor, mesial (mm)		Follow up: Probing Pocket Depth Score, upper central incisor, mesial (mm)				
		Total	0 mm	1 mm	2 mm	3+ mm
Total	SamSize	450	6	218	162	64
0 mm	SamSize	4	**2**	1	1	0
1 mm	SamSize	226	4	**178**	39	5
2 mm	SamSize	153	0	37	**101**	15
3+ mm	SamSize	67	0	2	21	**44**

```
Data Source: NHANES III, 1988-1994
```

This table contains the sample size in each cell for Males.

Exhibit 5.   Baseline*Follow-up Crosstabulation (Sex=Male) cont'd.

```
Variance Estimation Method: Taylor Series (WR)

Intra-Examiner Agreement Baseline vs. Follow-up Periodontal Assessments of Teeth

by: Sex, Baseline: Probing Pocket Depth Score, upper central incisor, mesial (mm), Follow up:
Probing Pocket Depth Score, upper central incisor, mesial (mm).

for: Sex = Male.
-------------------------------------------------------------------------------
|             |         | | Follow up: Probing Pocket Depth Score, upper central |
| Baseline:   |         | | incisor, mesial (mm)                                 |
| Probing     |         | |------------------------------------------------------|
| Pocket      |         | | Total   | 0 mm    | 1 mm    | 2 mm    | 3+ mm    |
| Depth       |         | |         |         |         |         |          |
| Score,      |         | |         |         |         |         |          |
| upper       |         | |         |         |         |         |          |
| central     |         | |         |         |         |         |          |
| incisor,    |         | |         |         |         |         |          |
| mesial      |         | |         |         |         |         |          |
| (mm)        |         | |         |         |         |         |          |
-------------------------------------------------------------------------------
|             |         | |         |         |         |         |          |
| Total       | PopSize | | 4654498 |   50374 | 2417736 | 1742454 |   443935 |
-------------------------------------------------------------------------------
|             |         | |         |         |         |         |          |
| 0  mm       | PopSize | |   40795 |   15501 |    2619 |   22675 |        0 |
-------------------------------------------------------------------------------
|             |         | |         |         |         |         |          |
| 1  mm       | PopSize | | 2659728 |   34873 | 2051096 |  530940 |    42819 |
-------------------------------------------------------------------------------
|             |         | |         |         |         |         |          |
| 2  mm       | PopSize | | 1495421 |       0 |  341262 | 1020223 |   133936 |
-------------------------------------------------------------------------------
|             |         | |         |         |         |         |          |
| 3+ mm       | PopSize | |  458555 |       0 |   22759 |  168615 |   267180 |
-------------------------------------------------------------------------------
Data Source: NHANES III, 1988-1994
```

This table contains the weighted totals in each cell for Males.

Exhibit 6.   Baseline*Follow-up Crosstabulation (Sex=Female)

```
Variance Estimation Method: Taylor Series (WR)

Intra-Examiner Agreement Baseline vs. Follow-up Periodontal Assessments of Teeth

by: Sex, Baseline: Probing Pocket Depth Score, upper central incisor, mesial (mm), Follow up:
Probing Pocket Depth Score, upper central incisor, mesial (mm).

for: Sex = Female.
--------------------------------------------------------------------------------
|            |          | | Follow up: Probing Pocket Depth Score, upper central |
| Baseline:  |          | | incisor, mesial (mm)                                 |
| Probing    |          | |------------------------------------------------------|
| Pocket     |          | | Total   | 0 mm    | 1 mm    | 2 mm    | 3+ mm    |
| Depth      |          | |         |         |         |         |          |
| Score,     |          | |         |         |         |         |          |
| upper      |          | |         |         |         |         |          |
| central    |          | |         |         |         |         |          |
| incisor,   |          | |         |         |         |         |          |
| mesial     |          | |         |         |         |         |          |
| (mm)       |          | |         |         |         |         |          |
--------------------------------------------------------------------------------
|            |          | |         |         |         |         |          |
| Total      | SamSize  | |     519 |      26 |     296 |     148 |       49 |
--------------------------------------------------------------------------------
|            |          | |         |         |         |         |          |
| 0 mm       | SamSize  | |      17 |      11 |       6 |       0 |        0 |
--------------------------------------------------------------------------------
|            |          | |         |         |         |         |          |
| 1 mm       | SamSize  | |     302 |      13 |     237 |      49 |        3 |
--------------------------------------------------------------------------------
|            |          | |         |         |         |         |          |
| 2 mm       | SamSize  | |     148 |       2 |      48 |      84 |       14 |
--------------------------------------------------------------------------------
|            |          | |         |         |         |         |          |
| 3+ mm      | SamSize  | |      52 |       0 |       5 |      15 |       32 |
--------------------------------------------------------------------------------
Data Source: NHANES III, 1988-1994
```

This table contains the sample size in each cell for Females.

Exhibit 6.   Baseline*Follow-up Crosstabulation (Sex=Female) cont'd.

```
Variance Estimation Method: Taylor Series (WR)

Intra-Examiner Agreement Baseline vs. Follow-up Periodontal Assessments of Teeth

by: Sex, Baseline: Probing Pocket Depth Score, upper central incisor, mesial (mm), Follow up:
Probing Pocket Depth Score, upper central incisor, mesial (mm).

for: Sex = Female.
```

Baseline: Probing Pocket Depth Score, upper central incisor, mesial (mm)		Follow up: Probing Pocket Depth Score, upper central incisor, mesial (mm)				
		Total	0 mm	1 mm	2 mm	3+ mm
Total	PopSize	5312191	172004	3241568	1533942	364678
0 mm	PopSize	175944	**71968**	103976	0	0
1 mm	PopSize	3383219	82129	**2754467**	526947	19677
2 mm	PopSize	1392217	17907	356329	**886677**	131303
3+ mm	PopSize	360812	0	26797	120318	**213698**

```
Data Source: NHANES III, 1988-1994
```

This table contains the weighted totals in each cell for Females.

Exhibit 7.   Stratum-Specific Kappa Estimates

```
Variance Estimation Method: Taylor Series (WR)

Intra-Examiner Agreement Baseline vs. Follow-up Periodontal Assessments of Teeth

  Kappa Agreement Statistics
  Variable DEPUMPC1S by Variable DERUMPC1S

by: Sex.
------------------------------------------------------------
Sex                                 Lower 95%  Upper 95%
                 Kappa       SE     Limit      Limit
------------------------------------------------------------
Total           0.4864     0.0336    0.4189     0.5539
Male            0.4772     0.0620    0.3527     0.6017
Female          0.4896     0.0516    0.3860     0.5932
------------------------------------------------------------
Data Source: NHANES III, 1988-1994
```

This table contains the survey-weighted Kappa estimates with 95% confidence limits, within stratification level (gender) and overall. Agreement is close to 0.48 in all cases, indicating moderate agreement between repeat exams. And we can also conclude that reliability between baseline and follow-up exams did not differ across population subgroups defined by gender.

Exhibit 8.   Stratum-Specific Test of H0: Kappa=0

```
Variance Estimation Method: Taylor Series (WR)

Intra-Examiner Agreement Baseline vs. Follow-up Periodontal Assessments of Teeth

  Test Statistics for the Agreement Null Hypothesis H0: Kappa=0
  Variable DEPUMPC1S by Variable DERUMPC1S

by: Sex.
--------------------------------------------------
Sex                 DDF     T-Test     P-Value
--------------------------------------------------
Total                49    14.4707      0.0000
Male                 49     7.7017      0.0000
Female               49     9.4963      0.0000
--------------------------------------------------
Data Source: NHANES III, 1988-1994
```

This table contains the *t*-test for H_0: Kappa=0 for the overall population and for each gender. The confidence limits on the previous page did not contain a value of 0, and hence the *t*-test is significant (*p*=0.0000) in each case.

Note that the same results could have been obtained by specifying HSSEX on a BY statement instead of a stratification variable on the TABLES and AGREE statements:

Exhibit 9.   SAS-Callable SUDAAN Code: BY HSSEX

```
PROC CROSSTAB DATA=dent.dental2 NOTSORTED MERGEHI;
  NEST sdpstra6 sdppsu6;
  WEIGHT wtpfqx6;

  SUBGROUP depumpc1s derumpc1s;
  LEVEL    4         4;

  RBY HSSEX;
  TABLES depumpc1s*derumpc1s;
  AGREE  depumpc1s*derumpc1s;

  SETENV ROWWIDTH=10 COLWIDTH=6 COLSPCE=1 TOPMGN=0 lblwidth=8;
  PRINT NSUM="SamSize" / nsumfmt=f10.0;

  SETENV ROWWIDTH=10 COLWIDTH=6 COLSPCE=1 TOPMGN=0 lblwidth=8;
  PRINT WSUM="PopSize" / wsumfmt=f10.0;

  SETENV COLWIDTH=10 COLSPCE=1 TOPMGN=0 LABWIDTH=12;
  PRINT / KAPPA=default KTEST=default lowkfmt=f9.4 upkfmt=f9.4 ;
  RTITLE "Kappa with BY Statement";
```