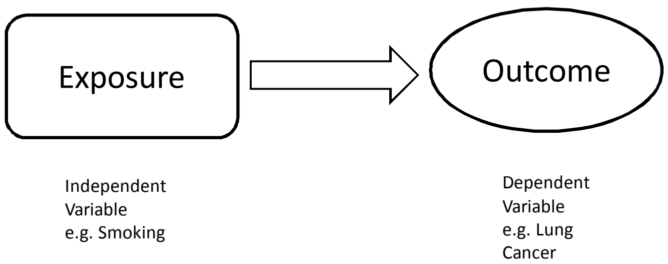
Bi-variable analyses

Dr. Htike Myat Phyu

Learning Outcomes

1. Analyse data using chi-squared, McNemar, t-test, Paired t test, one-way ANOVA, correlation
2. Analyse data using non-parametric data
3. Present the findings

Bi-variable analyses



How to Choose Statistical Test

Bivariate analyses

Variable (IV)	Variable (DV)	Test
		PT (Normal)
Categorical	Categorical	**Chi-square**
Categorical (**2 pop)**	Numerical	Independent sample **t-test**
Categorical (2 pop)	Numerical **(Paired)**	**Paired t**-test
Categorical **(> 2 pop)**	Numerical	One-way **ANOVA**
Numerical (Normal)	Numerical	Pearson **Correlation** Coefficient test

Bivariate analyses

Variable (IV)	Variable (DV)	Test	
		PT (Normal)	NPT (Not Normal)
Categorical	Categorical	**Chi-square**	
Categorical (**2 pop)**	Numerical	Independent sample **t-test**	Mann-Whitney U test
Categorical (2 pop)	Numerical **(Paired)**	**Paired t**-test	Friedman test
Categorical **(> 2 pop)**	Numerical	One-way **ANOVA**	Kruskal-Wallis test
Numerical (Normal)	Numerical	Pearson **Correlation** Coefficient test	Spearman Correlation Coefficient test

Categorical data analysis

Chi-Squared Test

Chi-squared (χ^2)

- Chi-Squared test for independence (Pearson's Chi-squared test) or the Chi-squared test of association
- is used to discover if there is a relationship between two categorical (ordinal or nominal) variables, two or more groups in each variable

Conditions should not use Chi-square

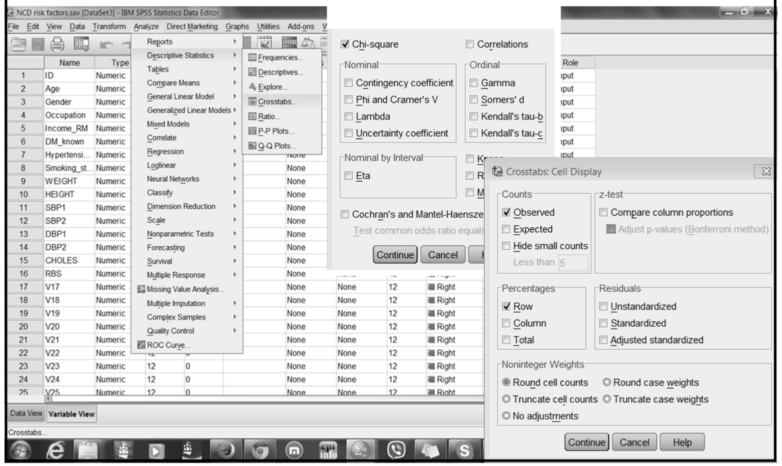
Use Fisher's exact test if

- n < 20
- 20 < n < 40 and small expected value < 5
- > 20% of cells have expected value < 5
- Any cell expected value < 1

Use Yates' correction if

- n < 100
- any cell contains < 10

Chi-square



Chi-Square

Occupation * Gender Crosstabulation

			Gender		Total
			Male	Female	
Occupation	Manager	Count	20	17	37
		% within Occupation	54.1%	45.9%	100.0%
		% within Gender	43.5%	23.0%	30.8%
	Admin staff	Count	2	33	35
		% within Occupation	5.7%	94.3%	100.0%
		% within Gender	4.3%	44.6%	29.2%
	Support staff	Count	24	24	48
		% within Occupation	50.0%	50.0%	100.0%
		% within Gender	52.2%	32.4%	40.0%
Total		Count	46	74	120
		% within Occupation	38.3%	61.7%	100.0%
		% within Gender	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22.386[a]	2	.000
Likelihood Ratio	26.838	2	.000
Linear-by-Linear Association	.002	1	.961
N of Valid Cases	120		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 13.42.

- ✓ Chi-square(2) = 22.386, P = 0.000
- ✓ This tells us that there is statistically significant association between Gender and Occupation
- ✓ When ≥ 20% of cells have EC < 5, use Fisher's Exact Test

E.g. Factor associated with depression among Respondents

Factor		Depression (n=19) (%)	No depression (n=281) (%)	p value
Age	60-69 years 70 and above	12 (5.6) 7 (8.3)	204 (94.4) 77 (91.7)	p > 0.05
Gender	Male Female	4 (2.8) 15 (9.6)	140 (97.2) 141 (90.4)	*p = 0.015
Ethnicity	Malay Chinese Indian	15 (5.3) 0 (0.0) 4 (33.3)	269 (94.7) 4 (100.0) 8 (66.7)	*p = 0.028
Marital status	Married Not married (Widow/divorced single)	9 (4.4) 10 (10.3)	194 (95.6) 87 (89.7)	p > 0.05
Living arrangements	Alone With family (spouse & /children)	1 (25.0) 18 (6.1)	3 (75.0) 278 (93.9)	p > 0.05
Working status	Not working Working (retired/unemployed)	19 (7.0) 0 (0.0)	253 (93.0) 28 (100.0)	p > 0.05
Education level	No education Formal education (primary/ secondary/tertiary)	5 (9.4) 14 (5.7)	48 (90.6) 233 (94.3)	p > 0.05
Chronic illness	Present Absent	14 (9.5) 5 (3.3)	134 (90.5) 147 (96.7)	* p = 0.028

Mc Nemar's Test

McNemar's Test for Paired Samples

- Common subjects being observed under 2 conditions (2 treatments, before/after, 2 diagnostic tests)
- Two possible outcomes (Presence/Absence of Characteristic) on each measurement

McNemar's Test for Paired Samples

Condition	Present	Absent
Present	n_{11}	n_{12}
Absent	n_{21}	n_{22}

Example: Reporting of Silicone Breast Implant Leakage in Revision Surgery

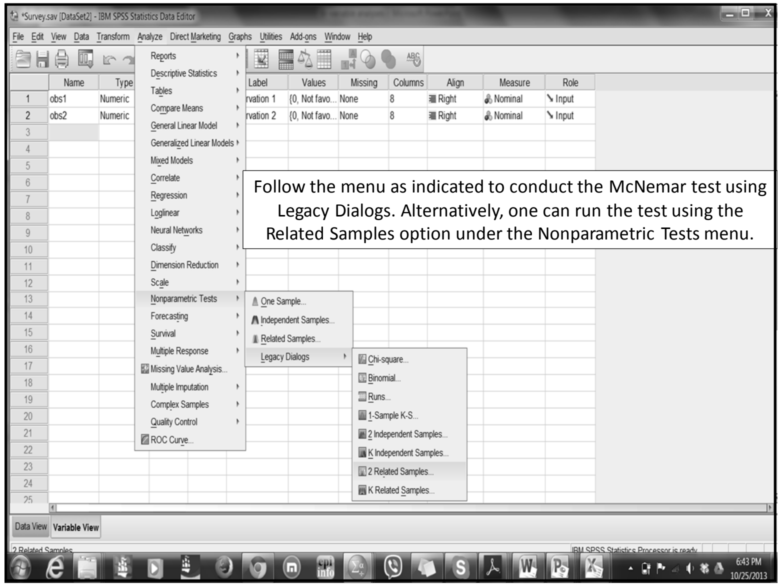
- Subjects - 165 women having revision surgery involving silicone gel breast implants
- Conditions (Each being observed on all women)
  - Self Report of Presence/Absence of Rupture/Leak
  - Surgical Record of Presence/Absence of Rupture/Leak

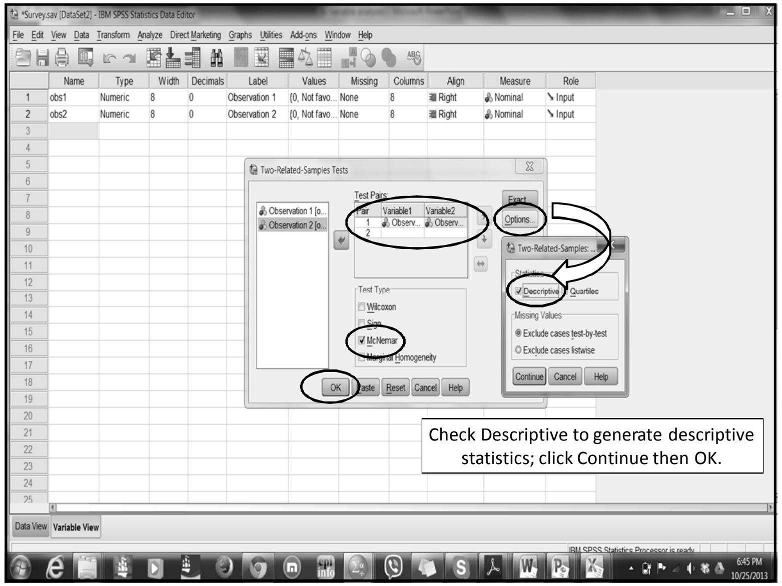
SELF * SURGICAL Crosstabulation

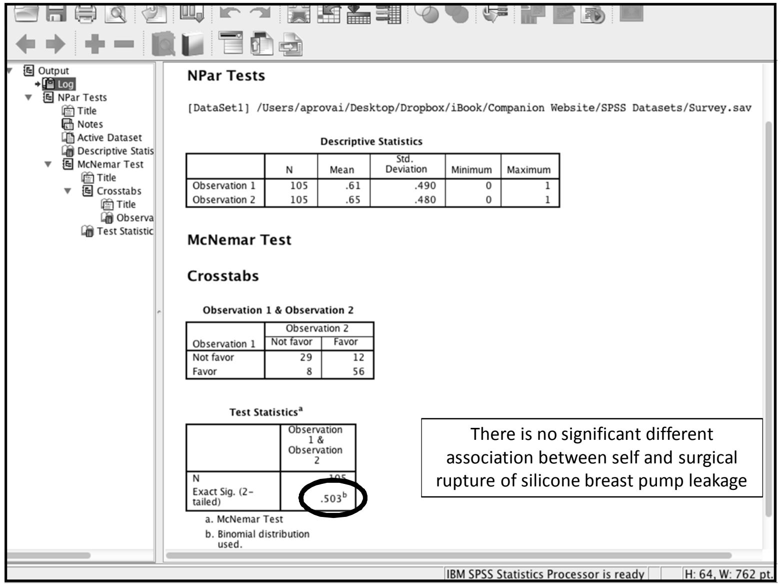
Count

		SURGICAL		
		Rupture	No Rupture	Total
SELF	Rupture	69	28	97
	No Rupture	5	63	68
Total		74	91	165

Source: Brown and Pennello (2002)







NUMERICAL DATA ANALYSIS

Independent Sample t-test

Independent Sample (Student) t-test

- Compares the *means* between two unrelated independent groups for *continuous* (either interval or ratio) dependent variable

Assumptions

- The sample is a random sample, normally distributed either $n \geq 30$ or $n < 30$ if population is normally distributed
- Similar variances between the two groups (homogeneity of variances)

Test of Normality

- Anderson-darling Test
- Corrected Kolmogorov-Smirnov Test (Lilliefors Test)
- Crame`r-von-mises Criterion
- D'agostino's K-squared Test
- Jarque-bera Test
- Pearson's Chi-square Test
- Shapiro-francia
- Shapiro-wik Test

➢ Use Normality test with caution

➢ Small samples almost always pass a normality test.

➢ With large samples, minor deviations from normality may be flagged as statistically significant, even though small deviations from a normal distribution

Test for Normality

Tests of Normality

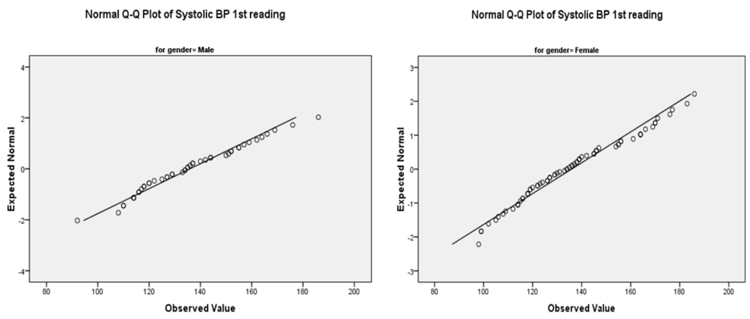
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Gender	Statistic	df	Sig.	Statistic	df	Sig.
Systolic BP 1st reading	Male	.087	46	.200*	.978	46	.533
	Female	.079	74	.200*	.969	74	.062

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

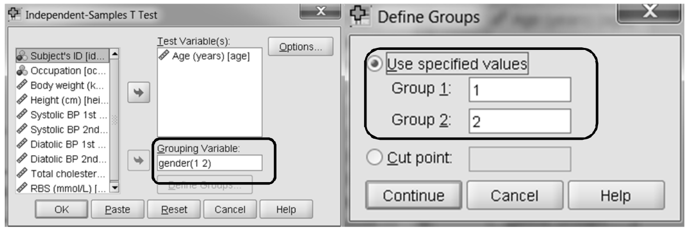
- Kolmogorov-Smirnov Test
- Shapiro-Wilk Test - for small (< 50) and large sample (up to 2000)
- *P value > 0.05 → data is normal*
- P value ≤ 0.05 → data is significantly deviate from a normal distribution

Normal Q-Q Plot



- If the data are normally distributed → data points will be close to the diagonal line
- If the data points stray from the line in an obvious non-linear fashion → data are not normally distributed.

Independent Sample t-test



Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Age (years)	Equal variances assumed	1.383	.242	1.630	118	.106	2.290	1.405	-.493	5.072
	Equal variances not assumed			1.593	88.602	.115	2.290	1.437	-.566	5.146

Test for Equality of Variances

- *Levene's Test for Equality of Variances*
  - If *p > 0.05 – use Equal variances assumed*
  - If p ≤ 0.05 - use Equal variances not assumed

Independent Samples Test

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P value > 0.05 → equal variances assumed

Test for Equality of Variances

- *Levene's Test for Equality of Variances*
  - If *p > 0.05 – use Equal variances assumed*
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Independent Samples Test

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P value > 0.05 → There is no significant different age between gender

Example

	Gender	*N*	Mean	Std. deviation	Std. error mean
Birth weight (kg)	Male	119	3.4414	0.32525	0.02982
	Female	137	3.5316	0.42849	0.03661
Birth length (cm)	Male	119	50.333	0.7833	0.0718
	Female	137	50.277	0.8534	0.0729
Head circumference (cm)	Male	119	34.942	1.3061	0.1197
	Female	137	34.253	1.3834	0.1182

Tests of Normality

		Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Gender	Statistic	*df*	Sig.	Statistic	*df*	Sig.
Birth weight (kg)	Male	0.044	119	0.200*	0.987	119	0.313
	Female	0.063	137	0.200*	0.983	137	0.094
Birth length (cm)	Male	0.206	119	0.000	0.895	119	0.000
	Female	0.232	137	0.000	0.889	137	0.000
Head circumference (cm)	Male	0.094	119	0.012	0.977	119	0.037
	Female	0.136	137	0.000	0.965	137	0.001

Example

		Levene's test for equality of variances		*t*-test for equality of means					95% confidence interval of the difference	
		F	Sig.	*t*	*df*	Sig. (Two-tailed)	Mean difference	Std. error difference	Lower	Upper
Birth weight (kg)	Equal variances assumed	7.377	0.007	−1.875	254	0.062	−0.0902	0.04812	−0.18498	0.00455
	Equal variances not assumed			−1.911	249.659	0.057	−0.0902	0.04721	−0.18320	0.00277
Birth length (cm)	Equal variances assumed	2.266	0.133	0.538	254	0.591	0.055	0.1030	−0.1473	0.2581
	Equal variances not assumed			0.541	253.212	0.589	0.055	0.1023	−0.1461	0.2569
Head circumference (cm)	Equal variances assumed	0.257	0.613	4.082	254	0.000	0.689	0.1689	0.3568	1.0221
	Equal variances not assumed			4.098	252.221	0.000	0.689	0.1682	0.3581	1.0208

PAIRED T-TEST

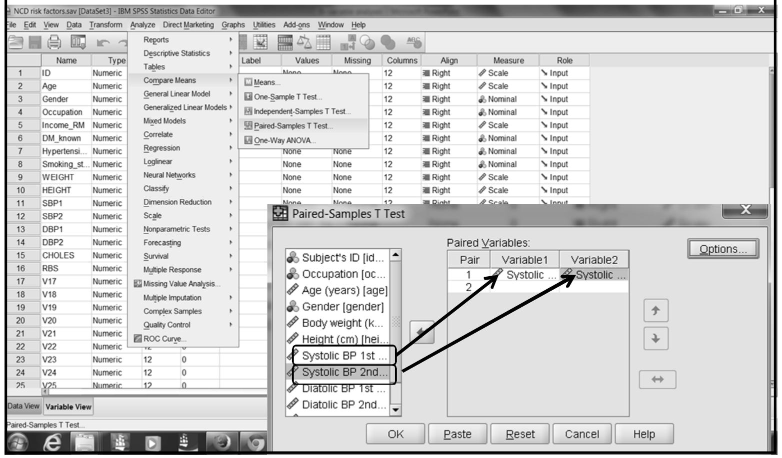
Paired t-test

- Compares the means between two related groups on the same continuous variable.

Assumptions

- Dependent variable is **continuous (interval or ratio)**
- The differences between the two groups on the dependent t-test **approximately normally distributed**
- Independent variable consists of **one group or two "matched-pairs" groups**.

Paired t-test



Paired Sample t-test

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Systolic BP 1st reading	135.89	120	21.307	1.945
	Systolic BP 2nd reading	133.48	120	21.003	1.917

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Systolic BP 1st reading & Systolic BP 2nd reading	120	.948	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Systolic BP 1st reading - Systolic BP 2nd reading	2.417	6.800	.621	1.187	3.646	3.893	119	.000

ONE-WAY ANOVA

One-Way ANOVA

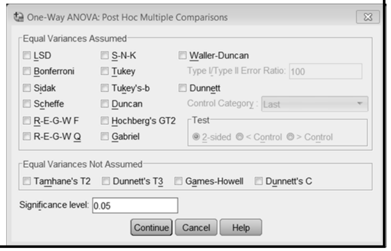
- Used to determine whether there are any significant differences between the means of ≥3 independent groups

Assumptions

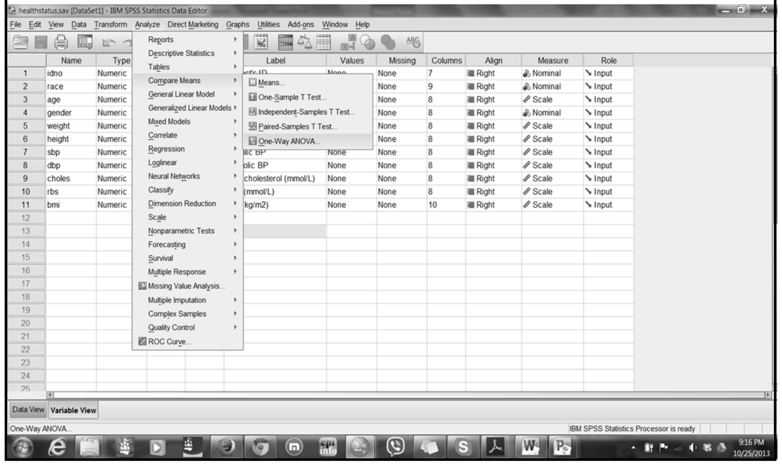
- Independent variable consists of **two or more categorical independent groups**.
- Dependent variable is either **interval or ratio (continuous)**
- Dependent variable is **approximately normally distributed for each category of the independent variable**
- Equality of variances between the independent groups (**homogeneity of variances**).
- Independence of cases

One-Way ANOVA Post Hoc Tests

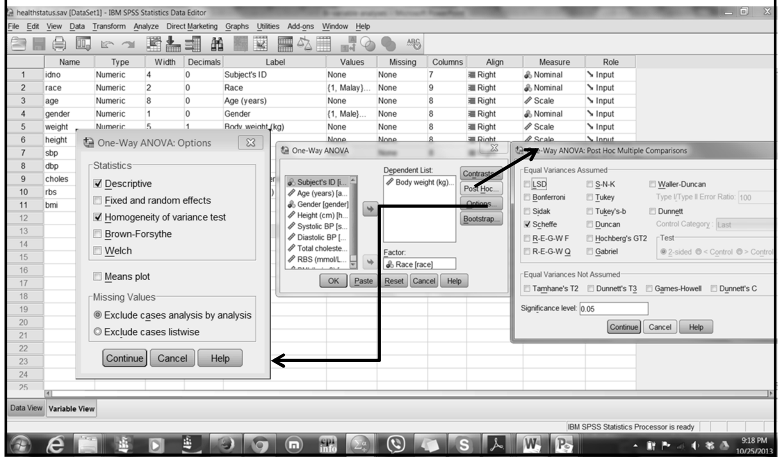
- **Equal Variances Assumed**
  - Scheffé , LSD, Bonferroni, Tukey, Dunnett, etc.
- **Equal Variances Not Assumed**
  - Tamhane's T2, Dunnett's T3, Games-Howell and Dunnett's *C*.



One-Way ANOVA



One-Way ANOVA



One-Way ANOVA

Descriptives

Body weight (kg)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Malay	32	69.250	14.7243	2.6029	63.941	74.559	46.0	110.0
Chinese	33	67.864	11.5314	2.0074	63.775	71.952	45.0	105.5
Indian	35	76.909	14.0549	2.3757	72.081	81.737	48.4	103.4
Total	100	71.473	13.9677	1.3968	68.702	74.244	45.0	110.0

ANOVA

Body weight (kg)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1622.133	2	811.067	4.447	.014
Within Groups	17692.484	97	182.397		
Total	19314.617	99			

- ✓ F test shows that there is significant difference body weight between any two groups of race

One-Way ANOVA

Test of Homogeneity of Variances

Body weight (kg)

Levene Statistic	df1	df2	Sig.
1.592	2	97	.209

- ✓ To decide which Post-hoc test to choose, we have to test for equality of variances i.e. Homogeneity of variances (Levene's test)
- ✓ The significant difference is only for Chinese vs. Indian (P=0.026)

Multiple Comparisons

Dependent Variable: Body weight (kg)
Scheffe

(I) Race	(J) Race	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Malay	Chinese	1.3864	3.3507	.918	-6.944	9.716
	Indian	-7.6586	3.3032	.073	-15.870	.553
Chinese	Malay	-1.3864	3.3507	.918	-9.716	6.944
	Indian	-9.0449*	3.2770	.026	-17.192	-.898
Indian	Malay	7.6586	3.3032	.073	-.553	15.870
	Chinese	9.0449*	3.2770	.026	.898	17.192

*. The mean difference is significant at the 0.05 level.

CORRELATION

Correlation

- Correlation coefficient depicts basic relationship between two numerical variables
- To obtain Pearson's correlation coefficients, Spearman's rho and Kendall's tau-b
- Includes
  - Bivariate
  - Partial Correlations
  - Computes distance statistics that measure similarities or dissimilarities

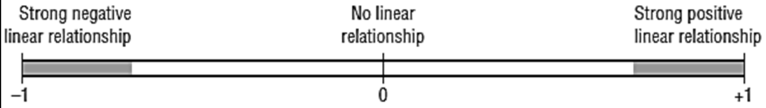
Bivariate Correlation

Pearson product-moment correlation coefficient

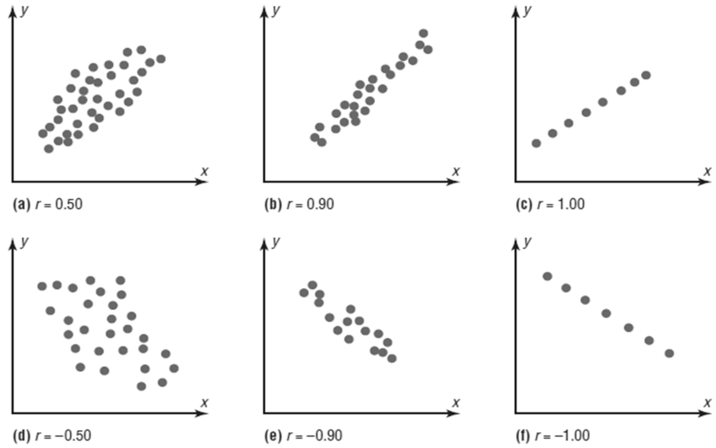
- measure of the *strength and direction* of association that exists between two numerical variables
- Assumption
  - Both variables have normal distributions
  - There is a linear relationship between the two variables.
  - If not normal, consider Spearman correlation

Bivariate Correlation

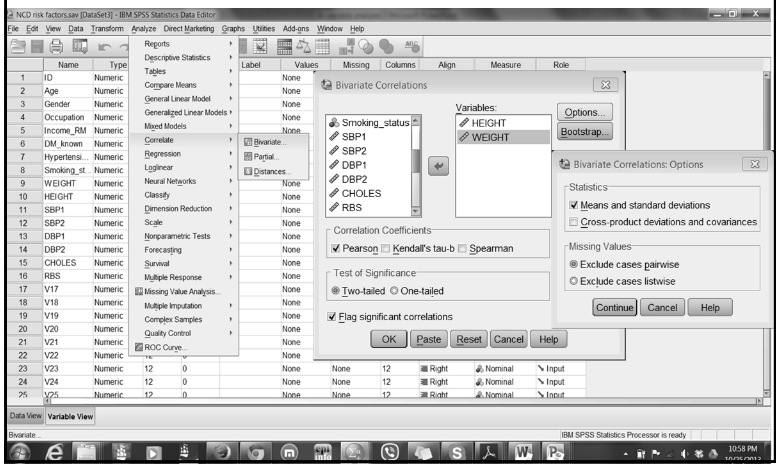
- +1 to – 1



Bivariate Correlation



Bivariate Correlation



Bivariate Correlation

Correlations

		Height (cm)	Body weight (kg)
Height (cm)	Pearson Correlation	1	.078
	Sig. (2-tailed)		.399
	Sum of Squares and Cross-products	5822.035	906.517
	Covariance	48.925	7.618
	N	120	120
Body weight (kg)	Pearson Correlation	.078	1
	Sig. (2-tailed)	.399	
	Sum of Squares and Cross-products	906.517	23375.292
	Covariance	7.618	196.431
	N	120	120

Correlation between 2 variables

correlation not significantly differs

Perfect correlation with itself

Non parametric tests (NPT) (OR) Distribution Free Test

Dr. Htike Myat Phyu

Non-Parametric Test (NPT)

- are not concerned with population parameter
- do not depend on knowledge of distribution of sampled population (non-normal distribution)
- when the assumptions of parametric tests can't be met
- "can be applied in study with small sample size
- fewer and weaker than those associated with parametric tests" (Siegel & Castellan, 1988)

Simple non parametric tests

Discrete data	***Continuous data***
• Chi-squared tests • McNemar χ^2 • Fisher's exact	• sign test, median test, rank sum test • Wilcoxon Signed rank test for location • Mann Whitney U test • Kolmogorov Smirnov test • Kruskal Wallis test • Friedmann test • Spearman Ranks Order Correlation Coefficient • Kendall Rank Order Correlation Coefficient • Non parametric regression analysis

Bivariate analyses

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Categorical	Categorical	**Chi-square**	
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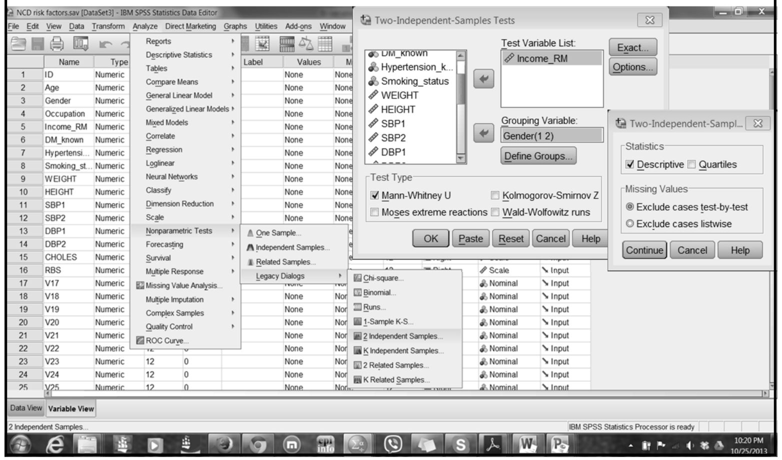
Numerical (Normal)	Numerical	Pearson **Correlation** Coefficient test	Spearman Correlation Coefficient test

MANN-WHITNEY U TEST

Mann-Whitney U Test

- Use for two-group independent groups when independent sample 't' test can't be used

Mann-Whitney U Test



Mann-Whitney U Test

Ranks

	Gender	N	Mean Rank	Sum of Ranks
Income_RM	1	46	63.50	2921.00
	2	74	58.64	4339.00
	Total	120		

Test Statistics[a]

	Income_RM
Mann-Whitney U	1564.000
Wilcoxon W	4339.000
Z	-.749
Asymp. Sig. (2-tailed)	.454

a. Grouping Variable: Gender

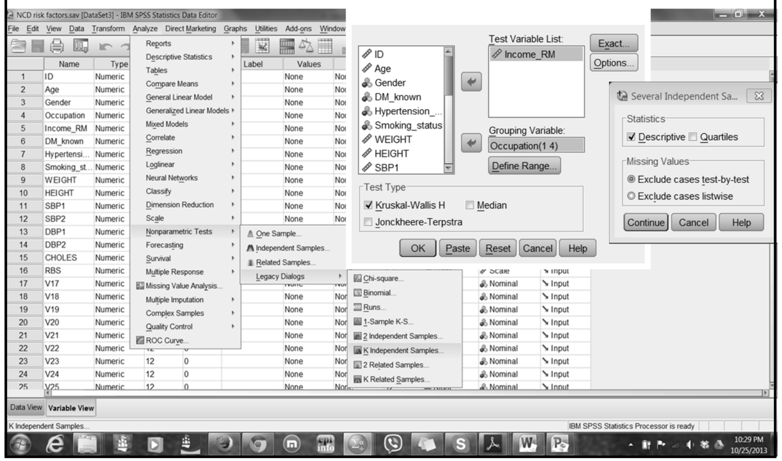
✓ *There is no significant difference between gender and income.*

KRUSKAL-WALLIS H TEST

Kruskal-Wallis H test

- Kruskal-Wallis is one-way analysis of variance (one way ANOVA) by ranks
- Use for *k* independent samples (k is ≥ 3)

Kruskal-Wallis test



Kruskal-Wallis test

Ranks

	Occupation	N	Mean Rank
Income_RM	1	20	85.75
	2	41	64.67
	3	4	60.63
	4	55	48.20
	Total	120	

Test Statistics^{a,b}

	Income_RM
Chi-Square	18.226
df	3
Asymp. Sig.	.000

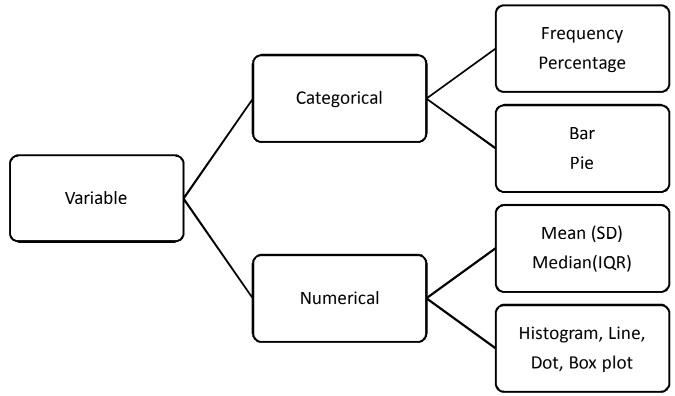
a. Kruskal Wallis Test

b. Grouping Variable: Occupation

✓ There is significant difference between occupation and income.

TAKE HOME MESSAGE

Descriptive Statistics



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THANK U