

SAS code:

```
%let path=C:\...\Confounding;
libname PS "&path";
%inc "&path/NLMeans.sas";
%inc "&path/NLEst.sas";

/* ----- Starts here -----*/

data rhc2;
    set ps.rhc;
    treatment=swang1;
    if dth30="No" then dth_grp=0; else dth_grp=1;
    label age="Age" edu="Education" ninsclas="Insurance Class";
run;

%let _class_ = sex race income ninsclas cat1 dnr1 ca resp card neuro gastr
               renal meta hema seps trauma ortho;
%let _covariate_ = age sex race edu income ninsclas cat1 das2d3pc
dnr1 ca surv2md1 apsl scom1 wtkilo1 templ meanbp1 resp1
hrt1 pafil paco21 ph1 wblc1 hema1 sod1 pot1 creat bili1 alb1
resp card neuro gastr renal meta hema seps trauma ortho
cardiohx chfhx dementhx psychhx chrpulhx renalhx liverhx gibledhx
malighx immunhx transhx amihx;

*** Crude Estimand ***;
*** Traditional regression without any covariates ***;
proc logistic data=rhc2;
    class treatment(ref="No RHC") &_class_ / param=glm;
    model dth30(ref="No") = treatment;
    lsmeans treatment / ilink e;
    store LogFit;
    ods output coef=CoeffsCrude;
run;

* Risk Difference using SAS nlmeans macro;
%nlmeans(instore=LogFit, coef=Coeffs, link=logit, title=Risk Diff Crude)

*** CATE Estimand ***;
*** Traditional regression with all covariates ***;
proc logistic data=rhc2;
    class treatment(ref="No RHC") &_class_ / param=glm;
    model dth30(ref="No") = treatment &_covariate_ / expb;
    lsmeans treatment / ilink e;
    store LogFit;
    ods output coef=CoeffsCATE;
run;

%nlmeans(instore=LogFit, coef=CoeffsCATE, link=logit, title=Risk Diff CATE)

*** ATM Estimand ***;
*** PS Matching ***;
proc psmatch data=rhc2 region=cs;
    class treatment &_class_;
    psmodel treatment(Treated='RHC') = &_covariate_;
    match method=greedy(k=1) exact=cat1 stat=lps caliper=0.2;
```

```

        assess allcov / weight=none ;
        output out(obs=match)=Outgs lps=_Lps matchid=_MatchID ;
        ods output StdDiff=StdDiffData;
run;

proc sort data=outgs out=outgs1; by _ps_; run;

data StdDiffDat;
    set StdDiffData;
    where Obs="Matched";
    AbsStdDiff=abs(StdDiff);
    keep Variable AbsStdDiff;
run;

proc logistic data=outgs1;
    class treatment(ref="No RHC") &_class_ / param=glm;
    model dth30(ref="No") = treatment age sex race edu ;* &_covariate_;
    lsmeans treatment / ilink e;
    store MatchFit;
    ods output coef=CoeffsMatch;
run;

%nlmeans(instore=MatchFit, coef=CoeffsMatch, link=logit, title=Risk Diff
Matching)

*** ATT Estimand ***;
*** PS Weighting, ATT ***;
proc psmatch data=rhc2;
    class treatment &_class_;
    psmodel treatment(Treated='RHC') = &_covariate_;
    output out=ATTWgt lps=_Lps;
run;

proc logistic data=ATTWgt;
    class treatment(ref="No RHC") &_class_ / param=glm;
    weight _ATTWGT_;
    model dth30 (ref="No") = treatment &_covariate_;
    lsmeans treatment / ilink e;
    store ATTWgtFit;
    ods output coef=Coeffs;
run;

%nlmeans(instore=ATTWgtFit, coef=Coeffs, link=logit, title=Risk Diff ATT
Weighting)

*** ATE with PS Weighting ****;

proc psmatch data=rhc2;
    class treatment &_class_;
    psmodel treatment(Treated='RHC')= &_covariate_;
    output out=ATEout lps=_Lps atewgt=_ATEWGT_;
run;

proc logistic data=ATEout;
    class treatment(ref="No RHC") &_covariate_ / param=glm;

```

```

weight _ATEWGT_;
model dth30 (ref="No")=treatment;
lsmeans treatment / ilink e;
store ATEWgtFit;
ods output coef=Coefffs;
run;

%nlmeans(instore=ATEWgtFit, coef=Coefffs, link=logit, title=Risk Diff)

*** Add weight as a covariate with others ***;
proc logistic data=ATTWgt;
  class treatment(ref="No RHC") &_class_ / param=glm;
  model dth30 (ref="No")= treatment _ATTWGT_ * &_covariate_;
  lsmeans treatment / ilink e;
  store ATTWgtCovar;
  ods output coef=Coefffs;
run;

%nlmeans(instore=ATTWgtCovar, coef=Coefffs, link=logit, title=Risk Diff )

*** PS Stratification ****;
proc psmatch data=rhc2;
  class treatment &_class_ ;
  psmodel treatment(Treated='RHC')= &_covariate_;
  strata nstrata=5;
  assess lps var=(sex age edu) / weight=attwgt plots=(boxplot barchart);
  output out(obs=all)=OutStr lps=_Lps;
run;

proc sort data=OutStr; by _STRATA_;run;
proc logistic data=OutStr;
  class treatment(ref="No RHC") / param=glm;
  by _STRATA_;
  model dth30 (ref="No")= treatment;
run;

proc logistic data=OutStr(where=( _STRATA_=1));
  class treatment(ref="No RHC") / param=glm;
  by _STRATA_;
  model dth30 (ref="No")= treatment;
  lsmeans treatment / ilink e;
  store ATTWgtFit;
  ods output coef=Coefffs;
run;

%nlmeans(instore=ATTWgtFit, coef=Coefffs, link=logit, title=Risk Diff
Stratification)

**** Doubly robust estimator in SAS;
proc causaltrt data=rhc2 method=AIPW covdiffps;
  class &_class_ dth30;
  psmodel treatment(ref='No RHC')= &_covariate_ * /plots=(PSDist);
  model dth30(ref="No") = &_covariate_ / dist=bin link=logit;
  output out=out ps=ps ipw=ipw;
  ods output CausalEffects=ce;

```

```

run;

*** ATE is method=IPW or IPWR;
proc causaltrt data=rhc2 method=IPWR covdiffps;
  class &_class_ dth30;
  psmodel treatment(ref='No RHC')= &_covariate_* /plots=(PSDist);
  model dth30(ref="No") = &_covariate_ / dist=bin link=logit;
  output out=out ps=ps ipw=ipw;
  ods output CausalEffects=ceATE;
run;

*** ATT is method=IPWR with ATT;
proc causaltrt data=rhc2 method=IPWR att covdiffps;
  class &_class_ dth30;
  psmodel treatment(ref='No RHC')= &_covariate_* /plots=(PSDist);
  model dth30(ref="No") = &_covariate_ / dist=bin link=logit;
  output out=out ps=ps;
  ods output CausalEffects=ce;
run;

*** AIPW ;
proc causaltrt data=rhc2 method=AIPW covdiffps;
  class &_class_ dth30;
  psmodel treatment(ref='No RHC')= &_covariate_* /plots=(PSDist);
  model dth30(ref="No") = &_covariate_ / dist=bin link=logit;
  output out=out ps=ps;
  ods output CausalEffects=ce;
run;

*** G-computation for ATE;
proc causaltrt data=rhc2 method=regadj covdiffps;
  class &_class_ dth30;
  psmodel treatment(ref='No RHC')=; * &_covariate_;
  model dth30(ref="No") = &_covariate_ / dist=bin link=logit;
run;

*** G-computation for ATT;
proc causaltrt data=rhc2 method=regadj covdiffps att;
  class &_class_ dth30;
  psmodel treatment(ref='No RHC')=; * &_covariate_;
  model dth30(ref="No") = &_covariate_ / dist=bin link=logit;
run;

```

R code:

```

### Use PSweight package using original data with all covariates;
library(PSweight)
names(rhc)
rhc$Treat<-ifelse(rhc$swang1=="RHC",1,0)

# All covariates included in PS model;
ps.form2 = Treat ~ age+ sex+ race+ edu + income + ninsclas + cat1 +
  das2d3pc + dnr1 + ca + surv2md1 + aps1 + scom1 + wtkilo1 + temp1 +
  meanbp1 + resp1 +
  hrt1 + paf1 + paco21 + ph1 + wblc1 + hema1 + sod1 + pot1 + creal +
  bili1 + alb1 + resp + card + neuro+ gastr + renal + meta + hema +

```

```

    seps + trauma + ortho + cardiohx + chfhx + dementhx + psychhx +
    chrpulhx + renalhx + liverhx + gibledhx +
    malighx + immunhx + transhx + amihx

set.seed(0)

# ATE IPTW;
rhc$Y_Bin = ifelse(rhc$dth30=="Yes",1,0)
ate.rhc.ipw = PSweight(ps.formula = ps.form2, yname = "Y_Bin",
    data = rhc, weight = 'IPW', family="binomial")

contrast.rhc <- c(1,-1)
summary(ate.rhc.ipw,type='DIF',constrast=contrast.rhc)$estimates

# ATE IPTW + Augment(Doubly Robust);
out.form2 = Y_Bin ~ age+ sex+ race+ edu + income + ninsclas + cat1 +
das2d3pc + dnrl + ca + surv2mdl + apsl + scomal + wtkilol + templ + meanbp1 +
respl + hrt1 + pafil + paco2l + phl + wblcl + hemal + sodl + potl + creal +
bilil + albl + resp + card + neuro+ gastr + renal + meta + hema + seps +
trauma + ortho + cardiohx + chfhx + dementhx + psychhx + chrpulhx + renalhx +
liverhx + gibledhx + malighx + immunhx + transhx + amihx

ate.rhc.ipw.aug= PSweight(ps.formula = ps.form2, yname = "Y_Bin",
    data = rhc, out.formula= out.form2, weight = 'IPW',
    augmentation=TRUE, family="binomial")
summary(ate.rhc.ipw.aug, type='DIF', constrast=contrast.rhc)$estimates

### Bootstrap, slightly smaller SE;
ate.rhc.ipw.bt= PSweight(ps.formula = ps.form2, yname = "Y_Bin",
    data = rhc, weight = 'IPW', family="binomial",
    bootstrap = TRUE)
summary(ate.rhc.ipw.bt, type = 'DIF', constrast=contrast.rhc)$estimates

### ATT weighting;
ate.rhc.att= PSweight(ps.formula = ps.form2, yname = "Y_Bin",
    data = rhc, weight = 'treated')
summary(ate.rhc.att, type = 'DIF', constrast=contrast.rhc)$estimates

### ATO Overlap weighting;
ate.rhc.ow = PSweight(ps.formula = ps.form2, yname = "Y_Bin",
    data = rhc, weight = 'overlap')
summary(ate.rhc.ow, type = 'DIF', constrast=contrast.rhc)$estimates

### ATO Overlap weighting + Augment(Doubly robust);
ate.rhc.ow.aug= PSweight(ps.formula = ps.form2, yname = "Y_Bin",
    data = rhc, out.formula= out.form2, weight = 'overlap',
    augmentation=TRUE, family="binomial")
summary(ate.rhc.ow.aug, type='DIF', constrast=contrast.rhc)$estimates

```