What is the True Normal Human Body Temperature?

Background

The mean normal body temperature was held to be 37°C or 98.6°F for more than 120 years since it was first conceptualized and reported by Carl Wunderlich in a famous 1868 book. But, is this value statistically correct?

Exercises

In this exercise, you will analyze a dataset of human body temperatures and employ the concepts of hypothesis testing, confidence intervals, and statistical significance.

Answer the following questions **in this notebook below and submit to your Github account**.

1. Is the distribution of body temperatures normal?
   - Although this is not a requirement for CLT to hold (read CLT carefully), it gives us some peace of mind that the population may also be normally distributed if we assume that this sample is representative of the population.
2. Is the sample size large? Are the observations independent?
   - Remember that this is a condition for the CLT, and hence the statistical tests we are using, to apply.
3. Is the true population mean really 98.6 degrees F?
   - Would you use a one-sample or two-sample test? Why?
   - In this situation, is it appropriate to use the t or z statistic?
   - Now try using the other test. How is the result be different? Why?
4. At what temperature should we consider someone's temperature to be "abnormal"?
   - Start by computing the margin of error and confidence interval.
5. Is there a significant difference between males and females in normal temperature?
   - What test did you use and why?
   - Write a story with your conclusion in the context of the original problem.

You can include written notes in notebook cells using Markdown: - In the control panel at the top, choose Cell > Cell Type > Markdown - Markdown syntax: http://nestacms.com/docs/creating-content/markdown-cheat-sheet #### Resources + Information and data sources: http://www.amstat.org/publications/jse/datasets/normtemp.txt, http://www.amstat.org/publications/jse/jse_data_archive.htm + Markdown syntax: http://nestacms.com/docs/creating-content/markdown-cheat-sheet ****

In [1]:

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

df = pd.read_csv('C:/human_body_temperature.csv')
```

In [2]:

```
# Your work here.
df.head()
```

Out[2]:

	temperature	gender	heart_rate
0	99.3	F	68.0
1	98.4	F	81.0
2	97.8	M	73.0
3	99.2	F	66.0
4	98.0	F	73.0

In [3]:

```
df.describe()
```

Out[3]:

	temperature	heart_rate
count	130.000000	130.000000
mean	98.249231	73.761538
std	0.733183	7.062077
min	96.300000	57.000000
25%	97.800000	69.000000
50%	98.300000	74.000000
75%	98.700000	79.000000
max	100.800000	89.000000

sample_size = 130

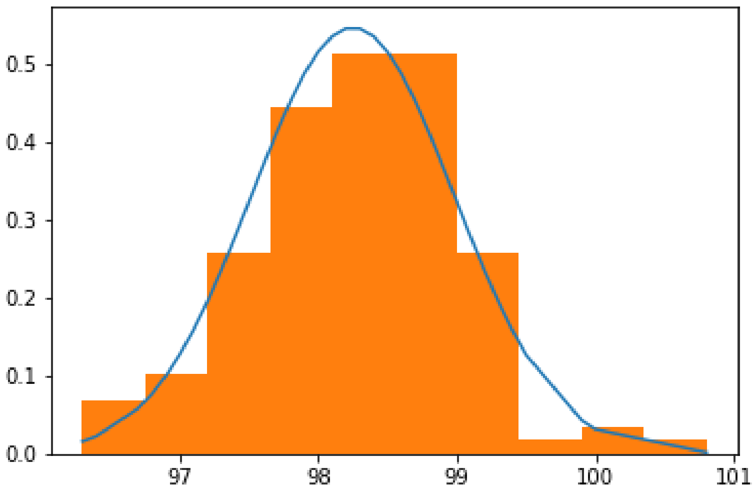
sample_mean = 98.24

sample_std = 0.733

Question:-1. Is the distribution of body temperatures normal?

In [4]:

```
# lets plot the histogram and look at the distribution.
import pylab as pl
import scipy.stats as stats
h = sorted(df.temperature)
fit = stats.norm.pdf(h, np.mean(h), np.std(h))
pl.plot(h,fit,'-')
pl.hist(h,normed=True)
pl.show()
```



Answer 1 : Yes, the distribution looks normal.

Question 2:-> Is the sample size large? Are the observations independent?

Answer : Our sample size = 130 which is greater than 30 making it good for CLT. Also, since the temperature have been collected from different individuals including Males and Females, it's suggestive of fairly independent obervations.

Question 3:-> Is the true population mean really 98.6 degrees F?

Would you use a one-sample or two-sample test? Why? In this situation, is it appropriate to use the t or z statistic? Now try using the other test. How is the result be different? Why?

Answer:-> One-sample test is more appropriate as all the temperatures are grouped in one sample and the values are going to be compared against a fixed value i,e. the population mean of 98.6 F. Also, z- test is applicable since we have a large sample set of n > 30 . Although Std dev for the population is not known yet we could retrieve sample std dev from our sample data set which could be assumed as the best estimate for the population standard deviation. Hence we can use z-test.

Null hypothesis = The accepted fact is that the true population mean is 98.6F, so: H0: μ = 98.6

Alternative hypothesis = true population mean is not equal to 98.6F H1: μ ≠ 98.6

Since alpha value is also not given the assumed p-value would be.05.

If p-value is < assumed p-value of 0.05, null hypothesis can be rejected.

In [5]:

```
sample_mean = df.temperature.mean()
sample_std = df.temperature.std()
sample_size = 130
z_score = (sample_mean - 98.6)/(sample_std/ np.sqrt(sample_size))
```

In [6]:

```
print ("z_score = " +str(z_score)) # ("Sample mean(98.25F) is 5.45 std dev
below the assumed population mean of 98.6F")
```

```
below the assumed population mean of 98.6F')
```

z_score = -5.45482329236

In [7]:

```
p_value=stats.norm.cdf(z_score) * 2 # two sided
p_value #Probability of sample mean being 5.45 std dev below the assumed population mean of 98.6 F
```

Out[7]:

4.9021570141133797e-08

Since calculated p-value comes out to be much below the assumed p-value of 0.05, we can reject the null hypothesis that the true mean of the poulation is 98.6 and accept the alternative hypothesis that the true value of mean population ≠ 98.6F.

z-scores vs t-scores

In [8]:

```
z_score = (sample_mean - 98.6)/(sample_std/ np.sqrt(sample_size))
z_score
```

Out[8]:

-5.4548232923640789

In [9]:

```
#Critical z-value
cv_z=stats.norm.ppf(0.975)
cv_z
```

Out[9]:

1.959963984540054

In [10]:

```
moe_z=sample_std*cv_z/np.sqrt(130)
moe_z
```

Out[10]:

0.1260343410491174

In [11]:

```
t_score = (sample_mean - 98.6)/(sample_std/ np.sqrt(sample_size))
t_score
```

Out[11]:

-5.4548232923640789

In [12]:

```
#Critical t-value
cv_t=stats.t.ppf(1-0.025, 129)
cv_t
```

Out[12]:

```
1.9785244914586051
```

In [13]:

```
#
moe_t=cv_t*sample_std/np.sqrt(130)
moe_t
```

Out[13]:

```
0.12722786362273045
```

In [14]:

```
#Range of confidence iterval for z-test
ub_z=sample_mean+moe_z
lb_z=sample_mean-moe_z
ub_z, lb_z
```

Out[14]:

```
(98.375265110279898, 98.123196428181657)
```

In [15]:

```
#Range of confidence iterval for t-test
ub_t=sample_mean+moe_t
lb_t=sample_mean-moe_t
ub_t, lb_t
```

Out[15]:

```
(98.376458632853513, 98.122002905608042)
```

In [16]:

```
print ("Comparision Analysis")
print ("z_score vs t_score = " + str(z_score) +' ,'+str(t_score))
print ("critical z-value vs critical t-value = " + str(cv_z) + "," + str(cv
_t))
print ("moe_z vs moe_t = " + str(moe_z) + "," + str(moe_t))
```

```
Comparision Analysis
z_score vs t_score = -5.45482329236 ,-5.45482329236
critical z-value vs critical t-value = 1.95996398454,1.97852449146
moe_z vs moe_t = 0.126034341049,0.127227863623
```

Both the z- test and t-test are giving us comparable values for scores, critical values and margin of errors. We also notice almost no difference in the confidence interval which is suggestive of the fact that for this sample size of n = 130, both the tests have competing results.

Question 4:-> At what temperature should we consider someone's temperature to be "abnormal"?

In [17]:

```
#margin of error = 1.96 * sd / np.sqrt(n)
moe = 1.96 * sample_std/ np.sqrt(130)
moe
```

Out[17]:

```
0.12603665700226638
```

In [18]:

```
#Now we will find the confidence interval based of the margin of error we c
alculated above
conf_int= sample_mean + np.array([-1, 1]) * moe
conf_int
```

Out[18]:

```
array([ 98.12319411,  98.37526743])
```

We derrived the range of confidence interval for this question. Normal range is between 98.12F to 98.37F. Anything outside of this range can be considered as abnormal.

Question 5:->Is there a significant difference between males and females in normal temperature?

What test did you use and why? Write a story with your conclusion in the context of the original problem.

In [19]:

```
male_temp = df[df.gender=='M']
male_temp.head()
```

Out[19]:

	temperature	gender	heart_rate
2	97.8	M	73.0
5	99.2	M	83.0
6	98.0	M	71.0
7	98.8	M	78.0
12	98.2	M	72.0

In [20]:

```
female_temp = df[df.gender=='F']
female_temp.head()
```

Out[20]:

	temperature	gender	heart_rate
0	99.3	F	68.0
1	98.4	F	81.0
3	99.2	F	66.0
4	98.0	F	73.0
8	98.4	F	84.0

In [21]:

```
male_temp.describe()
```

Out[21]:

	temperature	heart_rate
count	65.000000	65.000000
mean	98.104615	73.369231
std	0.698756	5.875184
min	96.300000	58.000000
25%	97.600000	70.000000
50%	98.100000	73.000000
75%	98.600000	78.000000
max	99.500000	86.000000

In [22]:

```
female_temp.describe()
```

Out[22]:

	temperature	heart_rate
count	65.000000	65.000000
mean	98.393846	74.153846
std	0.743488	8.105227
min	96.400000	57.000000
25%	98.000000	68.000000
50%	98.400000	76.000000
75%	98.800000	80.000000
max	100.800000	89.000000

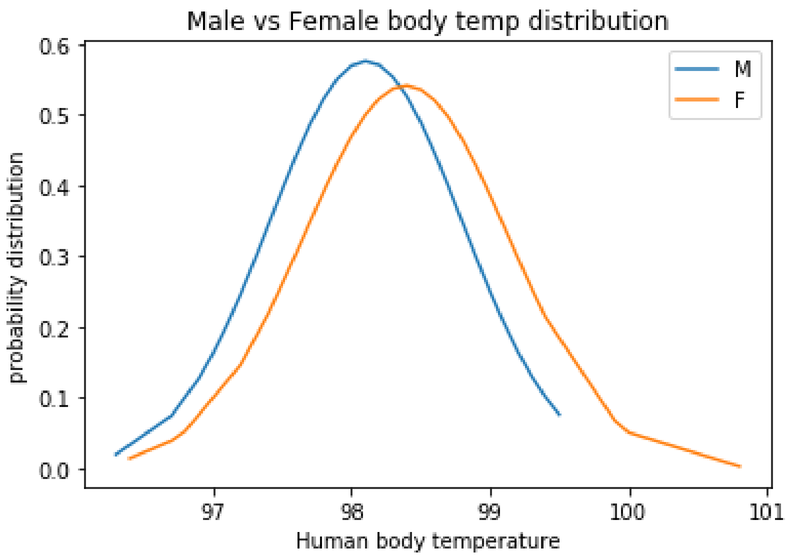
In [23]:

```
import pylab as pl
import scipy.stats as stats
m = sorted(male_temp.temperature)
mfit = stats.norm.pdf(m, np.mean(m), np.std(m))
pl.plot(m,mfit,'-')

f = sorted(female_temp.temperature)
ffit = stats.norm.pdf(f, np.mean(f), np.std(f))
pl.plot(f,ffit,'-')

pl.xlabel("Human body temperature")
pl.ylabel("probability distribution")
pl.title("Male vs Female body temp distribution")
pl.legend(['M', 'F'])
# pl.hist(, normed=True)
```

```
# pl.hist(,normed=True)
pl.show()
```



Comparision of male temperature mean and female temperature mean

In order to compare the means of female and male body temperature we can apply two sample T-test. Here we have two sample sets one for each group of female and males. Lets formulate our hypothesis statement:

Null hypothesis = H0: μF = μM

Alternative hypothesis H1: μF ≠ μM

Our null hypothesis in this case is that there is no statistically significant difference in the mean of male body temperature and female body temperature.

In [24]:

```
#Lets look at the mean differences of these groups:-
male_temp_mean = male_temp.mean()
female_temp_mean = female_temp.mean()
diff_of_mean = female_temp_mean-male_temp_mean
diff_of_mean
```

Out[24]:

```
temperature    0.289231
heart_rate     0.784615
dtype: float64
```

In [25]:

```
# lets find out the t -value and p- values:-
mtemp = np.array(male_temp.temperature)
mtemp
ftemp = np.array(female_temp.temperature)
ftemp
stats.ttest_ind(ftemp, mtemp)
```

Out[25]:

```
Ttest_indResult(statistic=2.2854345381656103, pvalue=0.02393188312239560
9)
```

Our t-statistic value is 2.285. The p-value in this case is 0.023, which is below than the standard thresholds of 0.05, so we have enough evidence to reject the null hypothesis and we can say there is a statistically significant difference between the female and maly body temperatures.