The Effect of Alcohol on Hydration, by Weight

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Introduction

The consumption of alcohol results in an increase in the amount of urine produced by the individual. This increases arises because alcohol inhibits the body's mechanism for regulating urine production. Normally, an individual's pituitary gland will increase the production of anti-diueretic hormone (ADH) when (s)he is dehydrated in order to slow the creation of urine, but alcohol reduces ADH production, causing one's body to create more urine than it normally would. Consuming one serving of alcohol results in approximately 120mL of excess urine. Using back of the envelope forumlas, we can approximate the effects of alcohol consumption on the level of hydration of individuals with varying weights.

Background

A man or woman who weighs "X"kg will urinate approximately "X"mL of urine per hour under average conditions but can urinate several times that amount depending on factors like heat and level of activity. Let's consider a 60kg man (132lbs) under normal conditions who therefore urinates 60mL per hour, or 1440mL per day. This man should consume at least 1440mL (equal to 6 cups) of water per day in order to retain a safe amount of water. This offers a baseline understanding of the logic we will apply here, and hopefully some insight into where recommendations for water consumption come from. Because an increase in activity is typical during alcohol consumption, let's add an additional 20mL of water loss per hour while drinking, due to perspiration and increased breathing rate. Now let's throw alcohol into the mix.

Th consumption of beer with an alcohol content $\leq 4\%$ does not usually result in significant dehydration. This is because although one can of beer (about 355mL of liquid) consumed over one hour will generate 120mL of urine above normal, the drinker intakes about 340mL of water from the beer. In one hour, the same man would intake a net 140mL of water.

$$-60mL - 120mL - 20mL + 340mL = 140mL$$

If he is already hydrated, he will most likely urinate in excess of normal, but this will not contribute to his dehydration. However, other drinks such as wine and liquors with a much smaller water content than beer will cause the drinker to dehydrate quickly. The same amount of excess urine will be created (120mL per drink from alcohol), but the water intake will be significantly less than with beer.

A final consideration here is the impact of the dehydration on health. Average water mass is about 60% of body weight. So the individual described above has about 36kg of water in his body, or 36000mL. If he were to lose 1500mL of water, his level of hydration would reduce to 58.6% (34kg $\div$ 58kg = .586). As little as 2% loss in hydration is enough for the brain's function to diminish, the mind to lose alertness, and for the body to fatigue. 6-10% dehydration is considered cause for immediate concern, and anything beyond that is severe and requires hospitalization and an IV. If the man above wants to rehydrate back to normal, he will have to consume approximately 3000-4500mL (12-19 cups) of water because only $\frac{1}{3}$ to $\frac{1}{2}$ of water consumed will be retained. The rest well be released as urine. For this analysis we will assume that 40% of water consumed to rehydrate is retained.

Method & Computation

We will consider here the consumption of shots of alcohol, whose water content are so minimal that we will consider the drinker to not intake any water with each drink. We can then generate a matrix representing the total water loss for individuals of varying weights who consume varying numbers of drinks over a period of three hours.

```
weights <- seq(50, 90, 5)  # Weights from 50-90kg in 5kg increments
drinks <- c(1:12)  # 1-12 drinks possible
hrs <- 3  # Consumed over 3 hrs
water_loss <- function (weight) {
  natural_water_loss <- weight * hrs
  loss_due_to_activity <- 20 * hrs
  loss_due_to_alcohol <- drinks * 120
  total_loss <- natural_water_loss + loss_due_to_activity + loss_due_to_alcohol
  return(total_loss)
}
loss_matrix <- data.frame(sapply(weights, water_loss))
names(loss_matrix) <- weights
```

```
##      50   55   60   65   70   75   80   85   90
## 1   330  345  360  375  390  405  420  435  450
## 2   450  465  480  495  510  525  540  555  570
## 3   570  585  600  615  630  645  660  675  690
## 4   690  705  720  735  750  765  780  795  810
## 5   810  825  840  855  870  885  900  915  930
## 6   930  945  960  975  990 1005 1020 1035 1050
## 7  1050 1065 1080 1095 1110 1125 1140 1155 1170
## 8  1170 1185 1200 1215 1230 1245 1260 1275 1290
## 9  1290 1305 1320 1335 1350 1365 1380 1395 1410
## 10 1410 1425 1440 1455 1470 1485 1500 1515 1530
## 11 1530 1545 1560 1575 1590 1605 1620 1635 1650
## 12 1650 1665 1680 1695 1710 1725 1740 1755 1770
```

We then generate similar matrix representations of the final weight of water in the individuals after the water loss due to drinking, and compare that with their new weight after the water loss to calculate their level of dehydration. [We will consider dehydration to be the deviation from the initial standard 60% of body weight is water assumption.] The intermediate steps here are to create matrices representing: 1) the initial amount of water in the individuals and 2) the final amount of water in the individuals, for all drinks and weights.

```
water_weight_initial <- function (weights, drinks) {
  # Need no. of drinks to repeat the data cross the same no. of rows as there are drinks
  watr <- rep.int(rbind(weights * 0.6), length(drinks))
  dim(watr) <- c(length(weights), length(drinks))  # Make the dimensions 9 x 12
  watr <- t(watr)  # Transpose to make dimension 12 x 9 (rows=drinks, cols=weights)
  return(watr)
}
wci <- water_weight_initial(weights, drinks)  # (Intermdiate Step #1)
loss_kg <- loss_matrix / 1000  # wci is in kg, so convert loss_matrix from mL to kg
water_weight_final <- wci - loss_kg  # (Intermediate Step #2) Output below
```

We now have the critical `water_weight_final`, which represents the weight in kg of water present in each individual after the water loss due. Next, we calculate the final weights of the individuals after the water loss, in kg, which is simply their initial weight subtracted by the weight of water loss in kg.

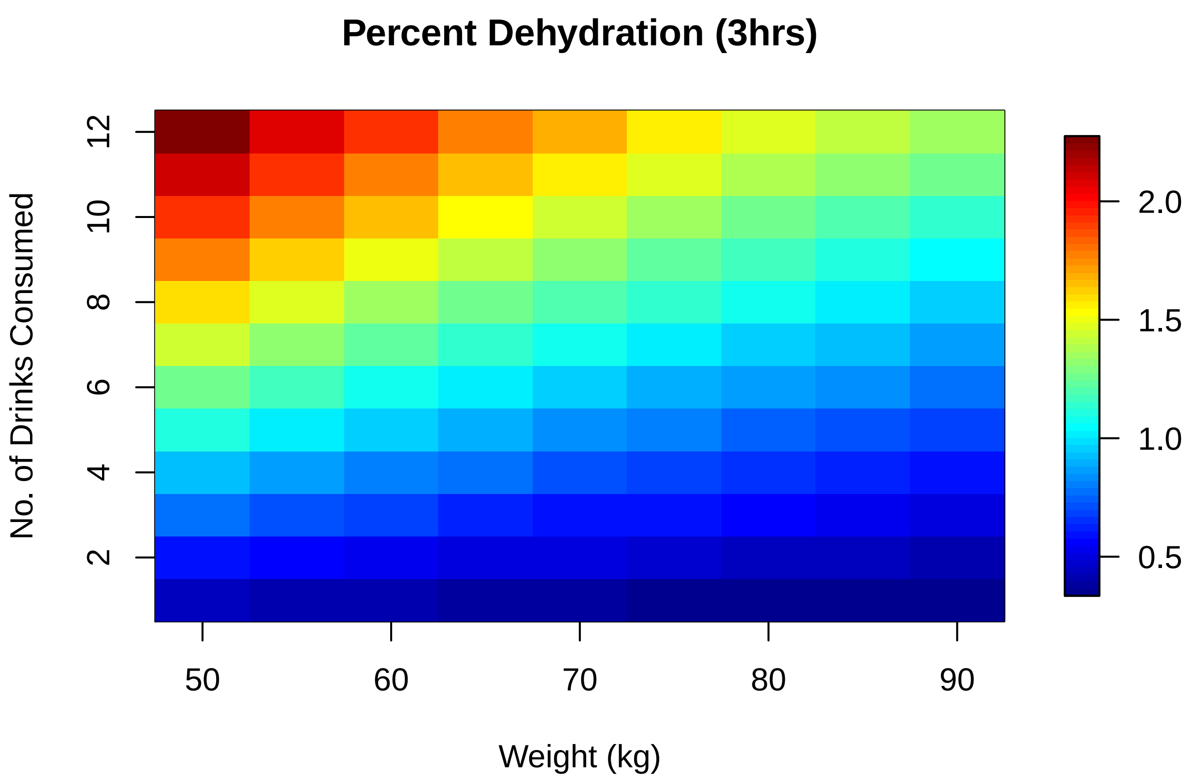
```r
initial_weights <- function (weights, drinks) {
  wpi <- rep.int(rbind(weights), length(drinks))
  dim(wpi) <- c(length(weights), length(drinks))  # Make the dimensions 9 x 12
  wpi <- t(wpi)  # Transpose
  return(wpi)
}
initial_weights_matrix <- initial_weights(weights, drinks)
final_weights_matrix <- initial_weights_matrix - loss_kg # Matrix of final weights
```

Finally, we calculate the level of hydration after the water loss, which is simply the percentage of body mass that is water, compare that to the initial hydration of 60%, and visualize the data.

```r
# We now have requisite info to calculate level of hydration
hydration_level <- water_weight_final / final_weights_matrix  # (e.g. 0.597, 0.596)

# Use: Fin-Init / Init
fii <- (hydration_level - matrix(rep.int(rep(0.600, length(weights)), length(drinks)),
                                 nrow=length(drinks), byrow=TRUE)) / matrix(
                                   rep.int(rep(0.600, length(weights)
                                   ),
                                 length(drinks)), nrow=length(drinks), byrow=TRUE) * -100
# Load library 'fields', suppress warnings so they don't print here, then turn back on
options(warn=-1); suppressMessages(library('fields')); options(warn=0)
image.plot(weights, drinks, t(fii), xlab='Weight (kg)', ylab='No. of Drinks Consumed',
           main='Percent Dehydration (3hrs)')
```

Results



We can also easily create a table that displays the number of cups of water required to get back to a normal level of hydration.

```
m <- (loss_matrix / 0.4) / 237  # Only 40% of water is retained; 237mL to 1 cup
m <- round(m, 1)
options(warn=-1); suppressMessages(library(knitr)); options(warn=0)
kable(m, row.names=1, caption='Cups of water required to rehydrate, by weight and
      number of drinks consumed over a 3 hr. period')
```

	50	55	60	65	70	75	80	85	90
1	3.5	3.6	3.8	4.0	4.1	4.3	4.4	4.6	4.7
2	4.7	4.9	5.1	5.2	5.4	5.5	5.7	5.9	6.0
3	6.0	6.2	6.3	6.5	6.6	6.8	7.0	7.1	7.3
4	7.3	7.4	7.6	7.8	7.9	8.1	8.2	8.4	8.5
5	8.5	8.7	8.9	9.0	9.2	9.3	9.5	9.7	9.8
6	9.8	10.0	10.1	10.3	10.4	10.6	10.8	10.9	11.1
7	11.1	11.2	11.4	11.6	11.7	11.9	12.0	12.2	12.3
8	12.3	12.5	12.7	12.8	13.0	13.1	13.3	13.4	13.6
9	13.6	13.8	13.9	14.1	14.2	14.4	14.6	14.7	14.9
10	14.9	15.0	15.2	15.3	15.5	15.7	15.8	16.0	16.1
11	16.1	16.3	16.5	16.6	16.8	16.9	17.1	17.2	17.4
12	17.4	17.6	17.7	17.9	18.0	18.2	18.4	18.5	18.7

Table 1: Cups of water required to rehydrate, by weight and number of drinks consumed over a 3 hr. period