The Effects of Swimming Distance and Water Consumption Amount on Blood Glucose Level

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Introduction

This study aims to investigate the impact of swimming distance and water consumption amount on blood glucose levels. The finalized research question guiding this project is: "How does the distance of swimming and the amount of water consumed affect blood glucose level?"

Our general interest and motivation for this research stem from a keen interest in understanding what factors would change blood glucose levels, as it is an important health indicator. Given the rising prevalence of diabetes and other metabolic disorders, exploring how activities like swimming and water consumption can impact blood glucose levels is both timely and relevant.

Therefore, this project aims to reveal significant relationships between swimming distance, water consumption amount, and blood glucose levels, hypothesizing that increased physical activity and hydration lowers blood glucose level.

Design of Experiment

We employed a 2^2 factorial design with one block (with four levels) and two replicates for each treatment combination, resulting in a total of 32 runs. The design allows us to investigate the effects of two factors: swimming distance (high: 1500 meters, low: 200 meters) and water consumption amount (high: 250 mL, low: 60 mL) on the change of blood glucose levels (milligrams per deciliter, or mg/dL). Each factor has two levels, creating four treatment combinations.

To account for potential confounding variables, we included age as a blocking factor, stratified into four groups (≤20, 21-40, 41-60, ≥61). Within each age group, participants were randomly assigned to treatment combinations, ensuring two replicates per treatment combination per age group. This blocking reduces the variability attributed to age, enhancing the reliability of the treatment effects.

We then selected 32 households from Vardo Island through using the runif() function in R, generating random numbers from the population of 595 households. All members of the selected households who consented were randomly grouped into the four age groups, with two participants per treatment combination in each age group.

Sampling in one location helps maintain consistency and reduces variability in data collection, making it easier to control for external factors that might influence the results. Moreover, by using a factorial design, we can explore both main effects and interactions between the factors, providing a comprehensive understanding of how these variables influence the change in blood glucose levels. In addition, the randomization and replication ensure the reliability and generalizability of the findings.

The design of the experiment is shown below (the values are the response variables, the change in blood glucose levels in mg/dL):

	≤20				21 - 40				41 - 60				≥61			
	60 mL		250 mL		60 mL		250 mL		60 mL		250 mL		60 mL		250 mL	
200 m	-5	-1	-1	1	-3	0	4	0	-3	1	-1	1	-2	0	1	-2
1500 m	-1	-1	0	-4	-3	5	-1	-3	-2	-3	1	-1	0	3	0	-3

Results and Interpretation

Analysis of Raw Data

Out of all the 32 runs, the grand mean of the response variable was -0.78. In other words, the blood glucose levels changed by an average of -0.78 mg/dL. Looking at the age groups respectively, the youngest age group (≤20) had the largest decrease in blood glucose level, with an average change of -1.5 mg/dL. This was followed by the third age group (41-60) with an average change of -0.875 mg/dL and then the oldest age group (≥61) with an average change of -0.387 mg/dL. The second age group (21-40) had the smallest change in glucose level of -0.125 mg/dL.

From the raw data, all age groups saw a decrease in blood glucose levels after swimming and drinking water. Moreover, since there seems to be a difference in magnitude of blood glucose level change across the different age groups, blocking by age appears to be appropriate.

Analysis of Variance

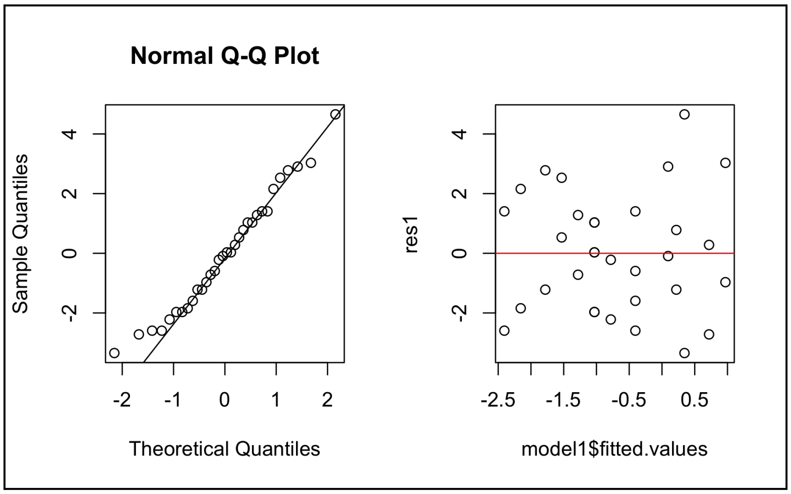
We first constructed the ANOVA table

```
                          Df Sum Sq Mean Sq F value Pr(>F)  
factor(swim)               1   0.28   0.281   0.058 0.8124  
factor(water)              1   1.53   1.531   0.313 0.5808  
factor(block)              3   8.84   2.948   0.603 0.6193  
factor(swim):factor(water) 1  19.53  19.531   3.993 0.0567 .
Residuals                 25 122.28   4.891                 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

None of the main effects (swimming distance and water consumption amount) are individually significant at the 0.05 significance level. However, the interaction between swimming distance and water consumption amount shows marginal significance with a p-value very close to 0.05, suggesting a potential combined effect on blood glucose level change that may need further investigation.

Residuals Analysis

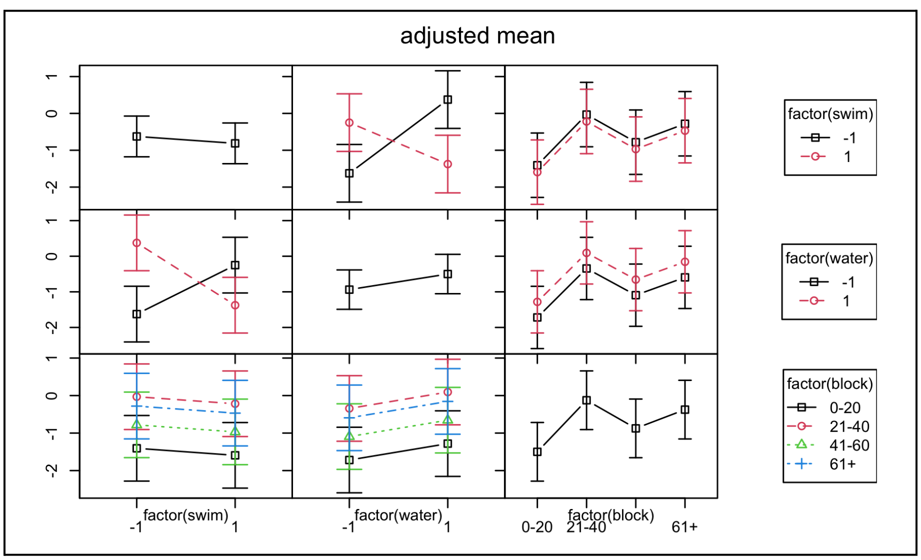
In order to ensure the validity of our model, we conducted residuals analysis



The Normal QQ Plot shows that the points mostly follow a 45-degree diagonal line, with some deviation in the tails, indicating that the residuals are generally normally distributed. In the Residuals vs. Fitted Values Plot, the residuals appear to be randomly scattered without any clear pattern, suggesting that the variance of the residuals is constant. Therefore, the assumptions of normality and constant variance of the model's residuals are satisfied.

Factor Interactions

Looking at the interaction plot



Main effects indicate that a longer swimming distance leads to a greater decrease in blood glucose levels (top left graph), while consuming more water results in a smaller decrease in blood glucose levels (center graph). The interaction effect between swimming distance and water consumption amount is visually evident, as indicated by the intersecting lines of the effects. This aligns with the marginal significance found in the ANOVA summary. Additionally, the values of the response variable across different age groups are visibly different, with older age groups generally experiencing smaller decreases in blood glucose levels.

Power Analysis

In order to conduct power analysis, we calculated the mean change in blood glucose levels for each of the four treatment combinations, disregarding the blocks, since the objective of the power analysis is to find the sample size required to achieve a certain power when determining the effect of the treatment factors. Thus, we will treat the experiment as having 4 treatment groups with no blocking. Below is the ANOVA table for the experiment without the age group blocking.

```
                          Df Sum Sq Mean Sq F value Pr(>F)  
factor(swim)               1   0.28   0.281   0.060 0.8082  
factor(water)              1   1.53   1.531   0.327 0.5720  
factor(swim):factor(water) 1  19.53  19.531   4.171 0.0507 .
Residuals                 28 131.12   4.683                 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Treatment Combination	Mean	Difference 1	Difference 2	Difference 3	Max Difference (d)
Swim High, Water High	-1.375	1.75	1.125	0.25	1.75
Swim Low, Water High	0.375	1.75	0.625	2	2
Swim High, Water Low	-0.25	1.125	0.625	1.375	1.375
Swim Low, Water Low	-1.625	0.25	2	1.375	2

The table above shows the mean changes in blood glucose levels of each treatment combination. For each treatment combination mean, the absolute value of its difference with another treatment combination mean is calculated, so each treatment combination has a difference with three other treatment combinations. Then, the maximum difference (*d*) of each treatment combination is used to find the effect size *f*

$$f = \sqrt{\frac{\sum_{i=1}^{a} d^2}{a\sigma^2}} = \sqrt{\frac{1.75^2+2^2+1.375^2+2^2}{4\times4.683}} = 0.8315630888$$

where σ^2 is estimated with the MSE of the 2^2 factorial design without blocking.

```
     Balanced one-way analysis of variance power calculation 

              k = 4
              n = 6.202227
              f = 0.8315631
      sig.level = 0.05
          power = 0.9

NOTE: n is number in each group
```

The power analysis shows that in order to detect a maximum difference in mean change in blood glucose levels of 1.75, 2, 1.375, and 2 with a probability of at least 0.90, there should be at least 7 replicates in each treatment group (treatment combination). The current 2^2 factorial design has 8 replicates in each of the 4 treatment combinations, so we have enough replicates in each treatment group to satisfy the results of the power analysis and achieve a power of at least 0.9.

Conclusion:

In conclusion, swimming distance and water consumption amount do not have significant main effects on changes in blood glucose levels at the 0.05 significance level. However, blocking by age revealed that generally higher age groups experienced smaller decreases in blood glucose levels. So, blocking is suitable in this context. Additionally, the interaction between swimming distance and water consumption amount showed marginal significance, with a p-value of 0.0567. This suggests that the effect of one factor is not consistent across the levels of the other factor, indicating that both factors should be considered together when examining their effects on blood glucose levels.

Although there were no significant factors from the result of this experiment, our secondary research supported our initial hypothesis. We found that aerobic exercise generally lowers blood glucose levels by enhancing insulin sensitivity and glucose uptake in muscles. According to the American Diabetes Association, exercise increases muscle cells’ ability to use insulin, thereby lowering blood glucose levels during and after activity, with effects lasting up to 24 hours post-exercise (Diabetes Journals) (American Diabetes Association).

Moreover, hydration also significantly affects blood glucose levels. A study published in BMC Sports Science, Medicine and Rehabilitation found that increased water intake significantly reduced blood glucose levels and improved insulin sensitivity in individuals with type 2 diabetes (BioMed Central).

The combined effects of exercise and hydration are particularly beneficial. Research in the Journal of Clinical Endocrinology & Metabolism demonstrated that hydrated individuals experienced more significant reductions in blood glucose levels post-exercise compared to dehydrated individuals, likely due to improved blood flow, better muscle function, and more efficient glucose uptake (BioMed Central) (American Diabetes Association).

Our study, however, does have several limitations. Firstly, uncontrolled factors such as diet, health status, and lifestyle, which were not controlled for in the study, could introduce confounding variables that may affect the outcomes. Secondly, ensuring that all participants swim with a similar intensity is challenging in practice. Without standardized guidelines or monitoring, participants’ natural variation in swimming styles and efforts cannot be effectively controlled. Thirdly, the short-term focus of the study may not capture the long-term impacts of the treatments, limiting the understanding of these factors' sustained effects. Thus, further research with a more comprehensive design of experiment and long-term follow-up is needed to validate these findings and fully understand the interplay between exercise, hydration, and blood glucose levels.

Works Cited

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