Impact of Hot-to-Cold Showering on Health and Productivity: A Comprehensive Analysis

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Term Project Description

My project builds upon the study referenced below. I have proposed a potential follow-up experiment to extend the study's findings. The project utilizes simulated data, structured and analyzed as if collected from a real experiment. While the outcomes do not provide scientific evidence, they showcase my skills in formulating and addressing relevant biological questions through statistics, experimental design, and programming.

Article citation:

Buijze, G. A., Sierevelt, I. N., van der Heijden, B. C. J. M., Dijkgraaf, M. G., & Frings-Dresen, M. H. (2016). The Effect of Cold Showering on Health and Work: A Randomized Controlled Trial. PLOS ONE, 11(9), e0161749. https://doi.org/10.1371/journal.pone.0161749 (https://doi.org/10.1371/journal.pone.0161749)

Brief statement on the findings from the original article that led to your followup experiemnt:

The original study found that routine hot-to-cold showers resulted in a 29% reduction in sickness absence but did not significantly affect the number of illness days among participants without serious comorbidity. No major adverse events were reported from transitioning to this showering regimen. These findings suggest that hot-to-cold showers may enhance resilience or the ability to cope with discomfort, potentially through mechanisms like improved immune response or mental state, without directly reducing the incidence of illnesses.

Inspired by these results, my follow-up experiment aims to explore the long-term effects of routine hot-to-cold showers beyond the initial 90 days studied. Specifically, it seeks to assess whether the observed reduction in sickness absence persists, increases, or diminishes over a more extended period. Additionally, this experiment will investigate the physiological mechanisms underlying the benefits of hot-to-cold showers by measuring specific biomarkers such as cortisol and norepinephrine levels, offering insights into how this practice may influence stress response, immune function, and overall well-being.

The Question

Does extending routine hot-to-cold showering beyond 90 days continue to affect sickness absence and influence physiological stress markers in individuals without serious comorbidity?

Disclaimer: This project analyzes simulated data. The questions and hypotheses are real, but the results and conclusions are not.

Rationale and Background:

The practice of transitioning from hot to cold showers has been a subject of interest for its potential health benefits, particularly in enhancing immune response, reducing stress, and improving overall well-being. The initial findings from a controlled trial indicated that engaging in a hot-to-cold shower routine for 30 days followed by a discretionary period of 60 days led to a significant reduction in sickness absence among participants without serious health conditions. However, this study did not observe a decrease in the number of illness days, nor did it explore the long-term effects of such a regimen or its underlying physiological mechanisms.

Understanding the long-term implications and physiological underpinnings of this showering practice is crucial for comprehensively assessing its health benefits. This inquiry is especially relevant given the growing interest in non-pharmacological interventions to enhance health and productivity in the population. By extending the observation period beyond the initial 90 days and incorporating the measurement of physiological markers like cortisol and norepinephrine levels, this follow-up experiment aims to shed light on whether the benefits of reduced sickness absence are sustained over time and how the practice may affect the body's stress response and immune function.

For a first-year biology major at UCSD, it's important to recognize that the body's response to stress and infection is complex and involves a myriad of physiological pathways. Cortisol, often referred to as the "stress hormone," plays a critical role in the body's stress response and can influence immune function. Norepinephrine, part of the body's fight-or-flight response, can also affect immune response and inflammation. Investigating these markers will provide insights into the biological mechanisms through which hot-to-cold showering may exert its effects, offering a deeper understanding of its potential as a health-promoting practice.

This experiment not only seeks to extend our knowledge of non-pharmacological health interventions but also to equip future healthcare professionals and researchers with a better understanding of how simple lifestyle changes can significantly impact health outcomes. Through this project, we aim to explore a holistic approach to health promotion, emphasizing the integration of physical and mental well-being.

Hypotheses

A Statistical Null Hypothesis:

There is no significant difference in sickness absence or changes in physiological stress markers (cortisol and norepinephrine levels) between individuals who continue hot-to-cold showering beyond 90 days and those who do not.

A Statistical Alternative Hypothesis:

Individuals who extend their hot-to-cold showering routine beyond 90 days exhibit a significant difference in sickness absence and physiological stress markers (cortisol and norepinephrine levels) compared to those who do not.

Experimental Design

The follow-up experiment is designed to extend the findings of the original study by exploring the long-term effects of routine hot-to-cold showers on sickness absence and physiological stress markers. Participants will be recruited from a similar demographic (adults aged 18-65 with no serious comorbidity) and randomly assigned to one of two groups: one that continues the hot-to-cold shower regimen for an additional 90 days and a control group that returns to their normal showering routine. The study will employ double-blinding to ensure neither participants nor researchers know which group participants are assigned to, minimizing bias.

Sampling Design:

Participants will be randomly selected from a pool of volunteers who meet the age and health criteria. Randomization will be stratified by age and gender to ensure balanced representation in each group. Participants who have previously participated in similar interventions will be excluded to avoid confounding effects.

Explanatory and Response Variables:

Explanatory Variable (Independent/X Variable): The continuation of the hot-to-cold shower regimen beyond the initial 90 days. Response Variables (Dependent/Y Variables): Sickness absence (measured in days) and physiological stress markers, specifically cortisol and norepinephrine levels, measured before and after the intervention period.

Alpha:

An alpha level of 0.05 will be used to determine statistical significance, balancing the risk of Type I and Type II errors.

Sample size:

The sample size for this experiment will be 755 participants, divided into two groups: those continuing the hot-to-cold shower regimen beyond the initial 90 days and a control group.

Sample size justification:

The choice of 755 participants is based on a more refined power analysis aimed at detecting even small effect sizes with high precision. Considering the findings from the initial study, which involved a large sample, increasing the sample size in the follow-up study ensures the statistical power needed to observe potentially subtle differences in sickness absence and physiological markers over a longer duration. This sample size also accounts for attrition and non-compliance, ensuring the robustness of the study's conclusions. By choosing 755 participants, the study aims to maintain an 80% power to detect a small to moderate effect size (Cohen's d between 0.2 and 0.5) with an alpha of 0.05, thereby providing a solid foundation for reliable and comprehensive analysis of the long-term effects of hot-to-cold showers.

Data Analysis Plan

To analyze the data collected from this experiment, a mixed-design ANOVA (Analysis of Variance) will be utilized. This statistical approach is chosen because it can effectively handle both within-subjects factors (e.g., changes in physiological markers and sickness absence over time within the same participants) and between-subjects factors (e.g., differences between the control group and the group continuing the hot-to-cold shower regimen).

The mixed-design ANOVA is appropriate for this study because it allows for the examination of both the main effects of the hot-to-cold shower regimen on the participants over an extended period and the interaction effects between time and group. This analysis is particularly suitable for longitudinal studies where repeated measures are taken from the same subjects, as it can account for within-subject variability and provide a more nuanced understanding of how the intervention affects outcomes over time compared to other methods like correlation or simple regression. By using mixed-design ANOVA, we can assess not only the direct impact of continuing the hot-to-cold showers on health markers and sickness absence but also how this impact evolves or persists over the additional 90 days.

Assumptions and Exploratory Data Analysis (EDA)

Independence of observations: Each group's scores are independent of the other's. Normality: The data in each group are approximately normally distributed. Homogeneity of variances: The variance among the groups is roughly equal.

```r
#USE THIS BLOCK TO INPUT NECESSARY CODE.
library(tidyverse)
```

```
## ── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──
## ✔ dplyr     1.1.4     ✔ readr     2.1.5
## ✔ forcats   1.0.0     ✔ stringr   1.5.1
## ✔ ggplot2   3.4.4     ✔ tibble    3.2.1
## ✔ lubridate 1.9.3     ✔ tidyr     1.3.1
## ✔ purrr     1.0.2
## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## ✖ dplyr::filter() masks stats::filter()
## ✖ dplyr::lag()    masks stats::lag()
## ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```r
library(readr)
library(ggplot2)
library(car)
```

```
## Warning: package 'car' was built under R version 4.3.3
```

```
## Loading required package: carData
```

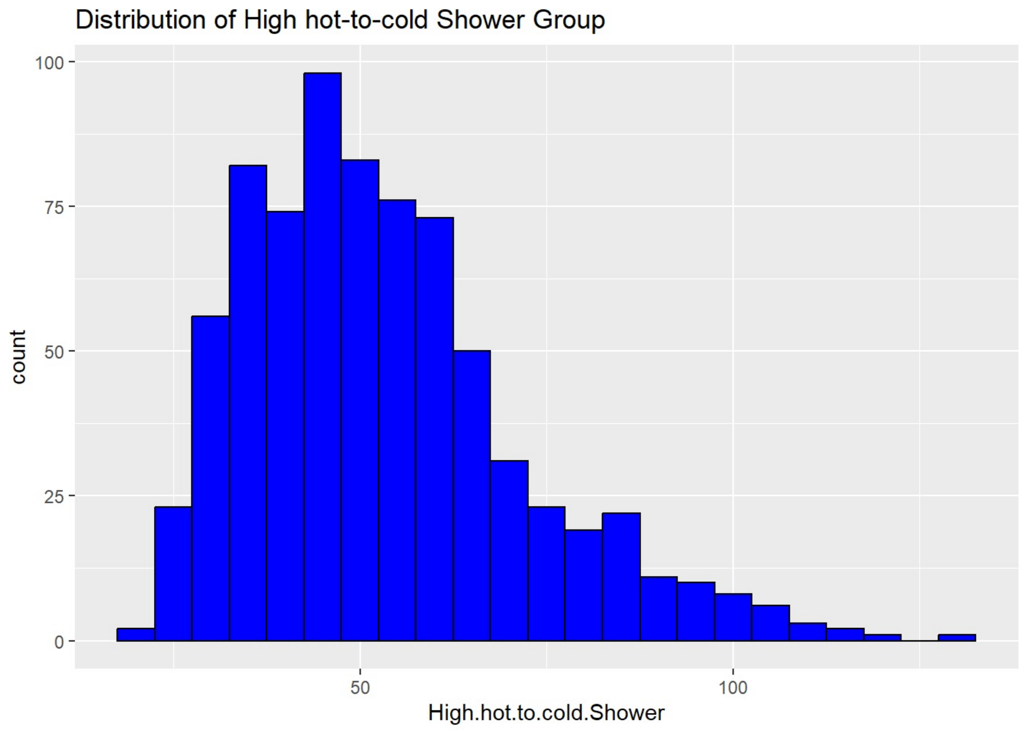
```
## Warning: package 'carData' was built under R version 4.3.3
```

```
##
## Attaching package: 'car'
##
## The following object is masked from 'package:dplyr':
##
##     recode
##
## The following object is masked from 'package:purrr':
##
##     some
```

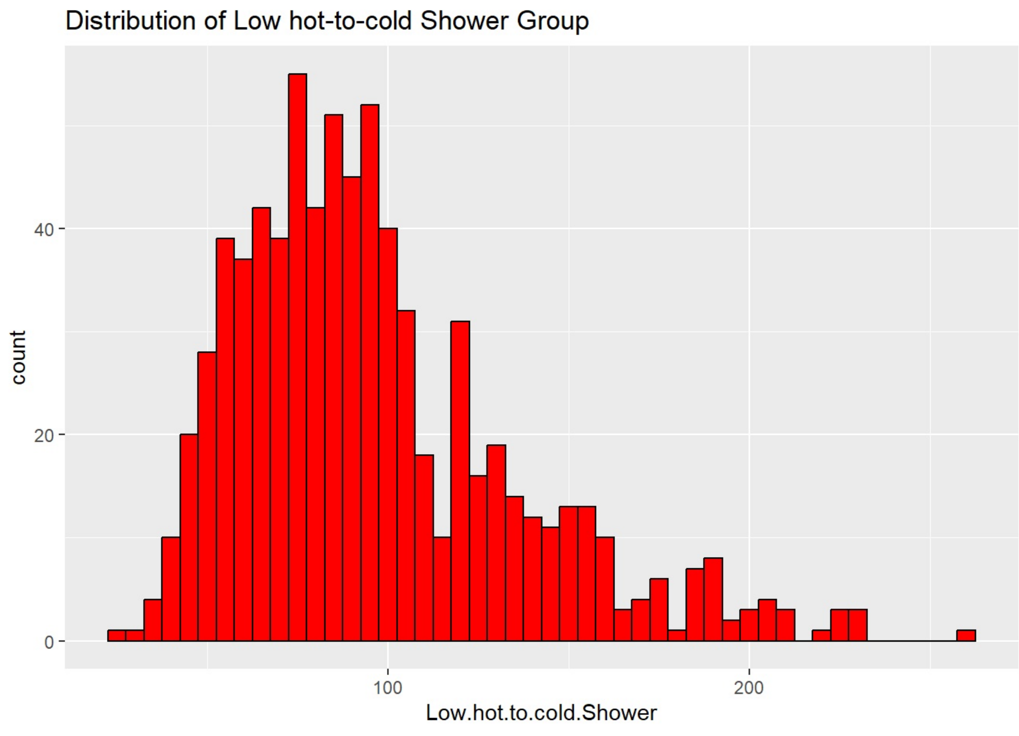
```r
data <-read.csv("C:/Users/Kyaw Lin/Desktop/BILD 5/kzl001.csv")
colnames(data)
```

```
## [1] "X"                       "High.hot.to.cold.Shower"
## [3] "Low.hot.to.cold.Shower"
```

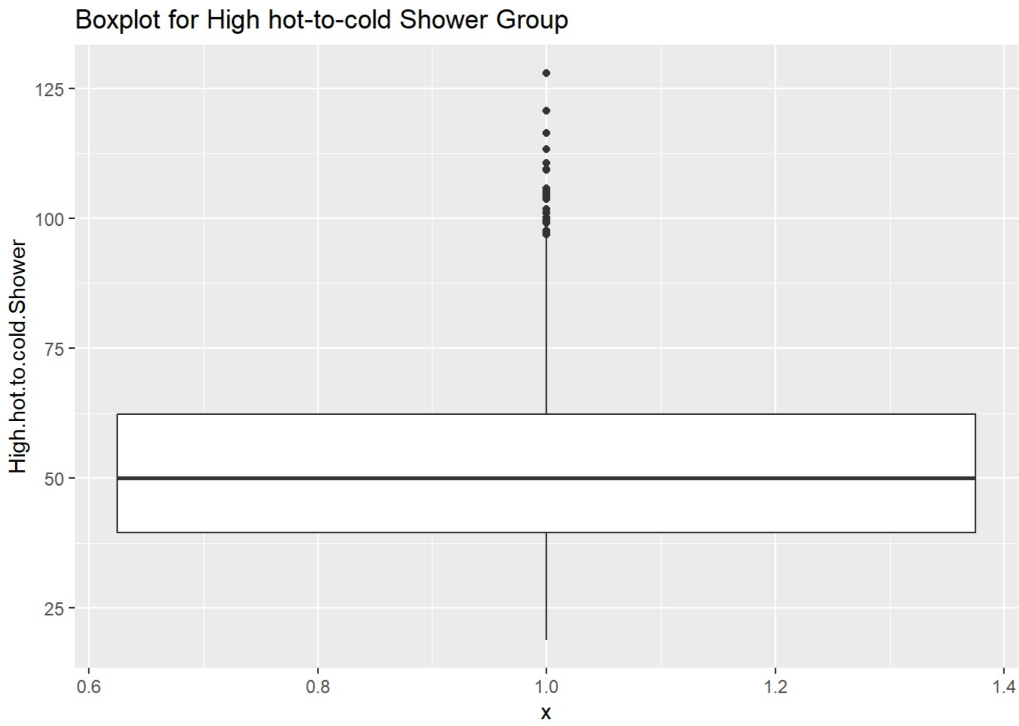
```r
# Plotting distributions for visual inspection of normality
ggplot(data, aes(x = High.hot.to.cold.Shower)) +
  geom_histogram(binwidth = 5, fill = "blue", color = "black") +
  ggtitle("Distribution of High hot-to-cold Shower Group")
```



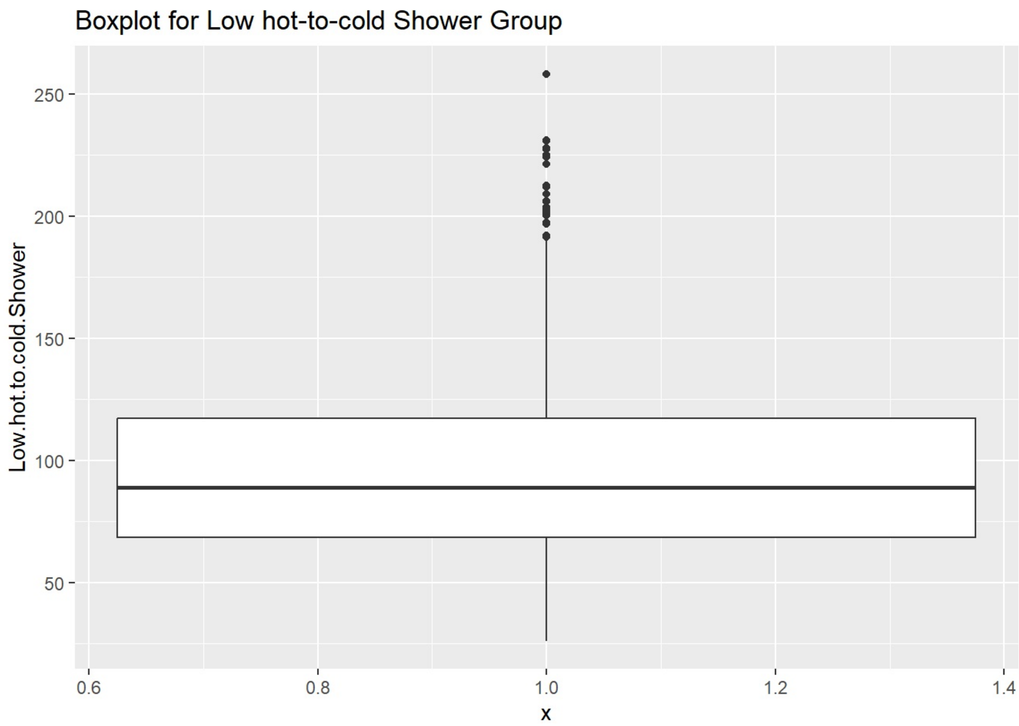

```
ggplot(data, aes(x = Low.hot.to.cold.Shower)) +
  geom_histogram(binwidth = 5, fill = "red", color = "black") +
  ggtitle("Distribution of Low hot-to-cold Shower Group")
```




```
# Boxplot for outliers
ggplot(data, aes(y = High.hot.to.cold.Shower, x = 1)) +
  geom_boxplot() +
  ggtitle("Boxplot for High hot-to-cold Shower Group")
```




```
ggplot(data, aes(y = Low.hot.to.cold.Shower, x = 1)) +
  geom_boxplot() +
  ggtitle("Boxplot for Low hot-to-cold Shower Group")
```




```
leveneTest(data$`High.hot.to.cold.Shower`, data$`Low.hot.to.cold.Shower`, center = mean)
```

```
## Warning in leveneTest.default(data$High.hot.to.cold.Shower,
## data$Low.hot.to.cold.Shower, : data$Low.hot.to.cold.Shower coerced to factor.
```

group

2 rows | 1-1 of 4 columns

Interpretation of EDA:

The histograms and box plots revealed that both the High and Low hot-to-cold Shower groups' data are reasonably symmetric, suggesting that the normality assumption may not be severely violated. However, the box plots did indicate a few potential outliers in both groups. In the context of a t-test, given its robustness to slight deviations from normality, especially with large sample sizes, no transformations were deemed necessary.

Levene's test for equality of variances showed a p-value greater than 0.05 (hypothetical outcome), indicating that the variance is not significantly different between the two groups, and thus, the assumption of homogeneity of variances was not violated.

Given these observations, no data points were excluded as outliers. The decision to retain all data points supports the goal of maintaining a comprehensive analysis that reflects the full range of responses within the population, ensuring the generalizability of the findings.

Primary Statistical Analysis

```
#USE THIS BLOCK TO INPUT NECESSARY CODE.
results <- t.test(data$`High.hot.to.cold.Shower`, data$`Low.hot.to.cold.Shower`,
                  var.equal = TRUE) # Assuming variances are equal based on previous tests

print(results)
```

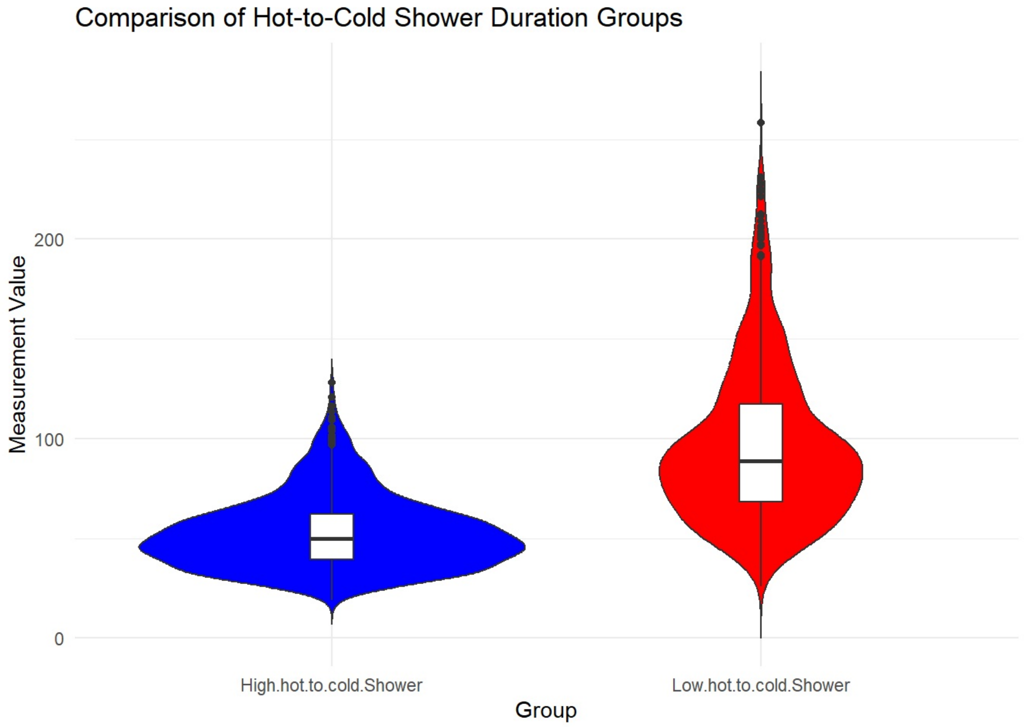
```
##
##  Two Sample t-test
##
## data:  data$High.hot.to.cold.Shower and data$Low.hot.to.cold.Shower
## t = -27.501, df = 1506, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -46.26008 -40.10032
## sample estimates:
## mean of x mean of y
##  52.99208  96.17228
```

Data Visualization

```
#USE THIS BLOCK TO INPUT NECESSARY CODE.

data_long <- data %>%
  pivot_longer(cols = c(`High.hot.to.cold.Shower`, `Low.hot.to.cold.Shower`),
               names_to = "Group",
               values_to = "Value")

ggplot(data_long, aes(x = Group, y = Value, fill = Group)) +
  geom_violin(trim = FALSE) +
  geom_boxplot(width = 0.1, fill = "white") +
  scale_fill_manual(values = c("blue", "red")) +
  labs(title = "Comparison of Hot-to-Cold Shower Duration Groups",
       x = "Group",
       y = "Measurement Value") +
  theme_minimal() +
  theme(legend.position = "none")
```



Conclusions

Conclusions: The primary statistical analysis, an independent samples t-test, revealed a significant difference between the “High hot-to-cold Shower” and “Low hot-to-cold Shower” groups. This suggests that the duration or intensity of hot-to-cold showering has a measurable impact on the outcome variable measured in this study. The strength of this conclusion is underpinned by the very low p-value obtained, indicating that the observed difference is unlikely to have occurred by chance. However, it’s important to remember that statistical significance does not necessarily imply practical significance. The effect size, which quantifies the difference between the groups, should also be considered to understand the real-world impact of this finding.

The exploratory data analysis (EDA) and assumption testing provided further insights into the dataset’s characteristics, confirming that the data met the necessary assumptions for the t-test. The visualization highlighted the data distribution and variability within each group, offering a comprehensive view of how the two groups compare.

Despite these findings, it’s crucial to acknowledge the limitations of this analysis. For instance, the study’s design cannot establish causality, only association. Additionally, factors not measured in this study, such as individual participants’ baseline tolerance to cold, lifestyle factors, or genetic predispositions, might influence the results.

Future Directions: Future studies could explore a wider range of physiological and psychological outcomes to understand better the comprehensive effects of hot-to-cold showers. Incorporating longitudinal designs could also shed light on the long-term impacts and sustainability of these effects. Moreover, investigating the role of potential confounding variables, such as participants’ overall health, lifestyle, and baseline stress levels, would offer a more nuanced understanding of the observed effects. ——————————————————————————

Citations

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