The Effects of Wim Hof Breathing Techniques and Cold Exposure on Perceived Stress and Subjective Vitality in Students: A Pre-Post and Daily Experience Sampling Study

Ronald H.M. Woortmeijer

Faculty Behavioural, Management and Social Sciences, University of Twente

Master Thesis Health Psychology & Technology, 201600169

Dr. Lean L. Kramer and Prof. Matthijs L. Noordzij

June 30, 2024

UNIVERSITY
OF TWENTE.

Abstract

Emerging adults, particularly students, face significant stress, which can lead to chronically low vitality and associated health risks. The Wim Hof Method (WHM), involving breathing exercises and cold exposure, is proposed as a means to reduce stress and enhance vitality, but its effectiveness requires further investigation. This study aims to assess the impact of the WHM intervention on perceived stress and subjective vitality among students. Additionally, it explores the association between mindset during cold showers and their frequency. Healthy students underwent a 15-day intervention involving daily breathing exercises and cold showers following a WHM workshop. Pre- and post-test questionnaires included the perceived stress scale (PSS), subjective vitality (trait (SVSt) and state (SVSs)), which were tested for significance by the Wilcoxon signed rank test. The Experience Sampling Method (ESM) measured WHM frequency, stress, vitality, and mindset levels. The associations were examined with a multi-linear model. Open-ended questions supplemented data collection and were analysed by deductive coding. 35 participants (91.9%) completed the intervention. Significant reductions in PSS (18.77%) and increases in SVSt (13.22%) and SVSs (23.55%) were observed. ESM data revealed an 87.6% mean compliance rate but was not normally distributed. No significant association was found between WHM frequency and perceived stress or subjective vitality. The impact of daily WHM activities on stress or vitality was inconclusive due to insufficient non-participation data. In conclusion, the WHM shows promise in reducing perceived stress and increasing subjective vitality after 15 days, suggesting its utility for students. Additionally, ESM has potential for gaining deeper insights into the WHM, with improvements like incorporating non-participation periods and using more complex questionnaires recommended for future studies.

Keywords: Wim Hof Method ; Perceived Stress ; Subjective Vitality ; Experience Sample Method ; Breathing Exercise ; Cold Exposure ; Emerging adults ; Students

The Effects of Wim Hof Breathing Techniques and Cold Exposure on Perceived Stress and Subjective Vitality in Students: A Pre-Post and Daily Experience Sampling Study

The transition from adolescence to adulthood consists of a lot of changes and can be a stressful period [7]. The existence of a new life stage at ages 18–29, known as emerging adulthood, has been proposed [3, 4]. This marks the period between the end of adolescence and the entry into stable adulthood [3, 4]. The emerging adulthood phase is an international phenomenon which occurs in developed countries and is responsible for several mental health implications [4]. This phenomenon has also been observed in the Netherlands [38] and is considered a critical period in life [74] and the most unstable period of the lifespan [4]. The changing social roles and increasing stress levels may affect health later in life [7]. Additionally, university students, who predominantly fall within the emerging adolescent age scope [42], show a high rate of stress [14].

Stress is a pervasive issue in modern society and has become a growing global public health problem [79]. Stress can be considered a state of mental or emotional strain or tension resulting from adverse or demanding circumstances [57]. Continuous stress may lead to unproductive rumination that consumes energy and reinforces the experience of stress itself [95]. There is evidence that a great deal of stress can negatively affect both physical and mental health [17, 84, 27]. Stress is also related to one's sense of vitality [73, 92].

Vitality is defined as "one's conscious experience of possessing energy and aliveness" [73]. Ryan et al. state that vitality concerns a specific psychological experience of possessing enthusiasm and spirit [73]. In addition to the psychological influences (e.g., being in love or having a mission) people may experience vitality with physical influences (e.g., states of fatigue) [73]. Repeated exposure to stress may lead to chronically low levels of vitality, termed "vital exhaustion" [34]. There are health risks associated with vital exhaustion, such as incident coronary heart disease and the development of heart failure [34]. Vital exhaustion will get more common as there are trends in modern society that may be accentuating the risk for exhaustive states, such as longer work hours, sustained job stress, increasing commuting time, more time pressure, and other challenges toward maintaining a healthy work-life balance [82].

The escalation of stress and decline in vitality have implications not only at the individual level but also within the broader public sphere. Annual total work loss costs, in the Netherlands per million workers, were estimated at €360 million for any mental disorder [35]. The authors concluded that, as costs stemming from productivity losses were substantial, prevention and treatment of mental conditions in the workforce have the potential to be cost-effective [35].

As a result of rising stress and declining vitality, it comes as no surprise that self-care methods are on the rise. For instance, meditation techniques are believed to reduce stress and physiological arousal [83], leading to favorable effects on the balance of the autonomic nervous system [78]. Moreover, breathing exercises can reduce perceived stress [13, 65]. In addition to a reduction in perceived stress, there is evidence that meditation also increases vitality [29].

While mindfulness practices have incorporated slow, deep breathing to induce relaxation [14], fast deep breathing characteristics have been shown to offer the same benefits [68] Additionally, fast deep breathing enhances respiratory muscle strength and improves quality of life, surpassing the effects observed with slow deep breathing [54]. A possible self-care technique that combines fast deep breathing with cold exposure is called the Wim Hof Method (WHM). The method claims, besides other benefits, to decrease stress and increase one's vitality [102]. However, more research is needed to verify its effectiveness.

Theoretical Framework

Dutch athlete Wim Hof developed the WHM, it comprises of three main components: 1) breathing exercises, 2) various types of cold exposure, and 3) a mindset component [102]. Each component will be discussed in detail below, including physiological changes during breathing exercises and cold exposure, claimed benefits, and scientifically supported effects of the method.

Breathing Exercises

The WHM breathing exercise consists of three or more rounds, each comprising three phases: hyperventilation, breath retention, and recovery breath [15]. These phases are visualised by Kox et al. in Figure 1, which will be elaborated in chronological order.

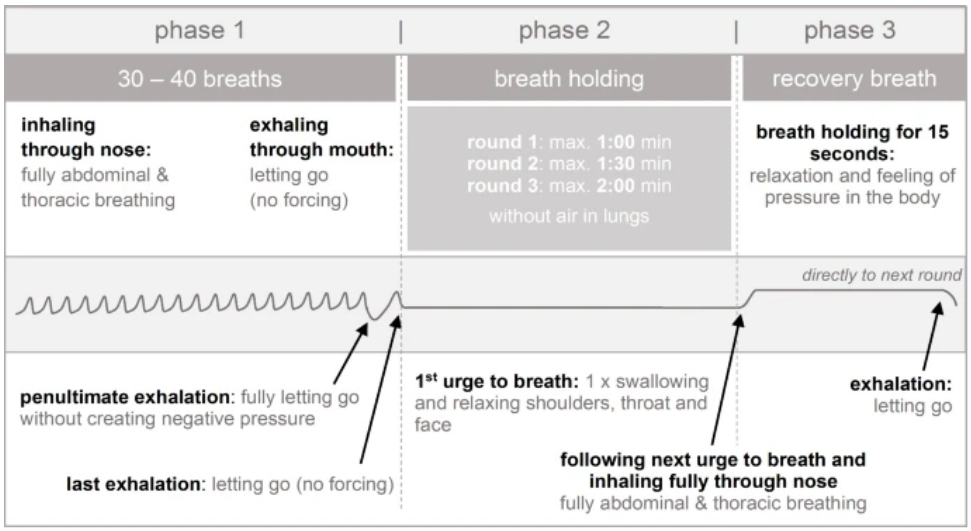


Figure 1: Visualisation of the 3 phases during the breathing exercise by Kox et al.

During the first phase a controlled form of hyperventilation is practised. The individual rapidly increases their respiratory rate to about 20 breaths per minute for several minutes, inhaling deeply through the nose or mouth to fully expand the lungs. This phase induces physiological changes such as increased heart rate and decreased mean arterial pressure, because of the activation of the sympatic nervous system (SNS) [53, 48]. It also lowers blood carbon dioxide (CO2) levels, thereby increasing blood pH [45]. Following hyperventilation rounds, there is a

notable increase in blood oxygen levels (pO2) and pH, with decreased carbon dioxide levels (pCO2) and bicarbonate ions (HCO3-) [48].

The second phase is the breath retention, during which participants hold their breath with empty lungs for a maximum of 2 minutes, depending on the round. This phase exploits the hypocapnia and pre-oxygenation induced by the hyperventilation, allowing for extended breath retention without discomfort [55, 33]. The breath retention helps rebalance pH levels disrupted by hyperventilation [48]. Moreover, the breath retention triggers the body's diving response, promoting vasoconstriction, bradycardia and optimizing blood flow to vital organs with the activation of the SNS [20, 23, 25]. It also stimulates spleen contraction, releasing additional red blood cells into circulation within seconds [87].

The third phase, called the breath hold, concludes each round with a 15-second breath hold at full lung capacity. The physiological changes can be explained by the same mechanics as described in the breath retention phase[20, 25, 87]. Although, the participant may feel more sensations like lightheadedness, because of the full lungs and thus an increase in intrathoracic pressure [10].

Cold Exposure

The cold stimulus in the WHM, achievable through a cold shower or an ice bath, triggers numerous physiological changes in the body. These changes are because the diving response is triggered and the SNS is activated, in response to the cold [71, 56]. Initially, the body responds with vasoconstriction to preserve warm blood for vital organs due to the decrease in body temperature [45]. This response leads to a decrease in heart rate, mediated by baroreceptors, which prevents an increase in blood pressure during cold exposure [77]. These reactions can be observed with a temperature difference as small as 5 degrees Celsius [77].

Mindset

The mindset component is recognized as the third foundational element of the WHM, encompassing willpower, self-control, and commitment [102]. According to the official site, individuals with greater levels of these traits tend to be happier and healthier [102]. This claim is supported by research indicating that self-control positively influences subjective well-being [40], as those with high self-control are more likely to achieve their goals [89]. However, it remains unclear how the WHM specifically aims to enhance self-control. Besides self control, another important aspect of mindset is the visualization of enduring the cold, which aids in coping with cold exposure. This aspect of mindset, in the form of self-efficacy, will be examined in greater detail below.

The effects of self-efficacy in relation to cold or pain endurance have been seen before in research. Individuals with higher self-efficacy, could endure the discomfort associated with cold exposure during a pain tolerance test for a more extended period [101]. Research done by

Kozhevnikov in 2013 [49], illustrates the dual contribution of physical and mental processes in achieving and maintaining increased body temperatures. Specifically, while the physical actions of breathing exercises prompt thermogenesis, it is the neurocognitive process—through meditative visualisation—that sustains these heightened temperatures over time [49]. These findings highlight the critical role that mental state and belief in one's capabilities play in effectively engaging with and benefiting from cold exposure practices, thus supporting the emphasis placed on the mental component within the WHM.

Potential of The WHM

The WHM has garnered attention in the general public for its purported array of benefits [90]. The official site of the WHM claims, for example, the method: improves mood, reduces stress and anxiety, enhances immune function, improves cardiovascular health, and increases energy and vitality [102]. However, these claims should be approached with caution, as scientific support is still limited but growing [90]. For instance, it might be an approach for individuals with sleep disorders [18] and could influence the autonomic nervous system [47, 48, 104].

Furthermore, research suggests a relationship between the WHM and stress reduction [93, 91, 61]. Wim Hof claims that hormetic stressors contribute to this effect [39]. Previous research has shown that hormetic stressors can induce positive mental effects [6, 41, 37]. The theory states that hormetic stressors cause initial disruptions in homeostasis, enhancing one's ability to withstand more severe stress over time [6, 41, 37]. This disruption, and the subsequent restoration of homeostasis after the stressor, are stated as critical to both physical and mental health, promoting the increased resilience against stress [9, 76]. The stressor in this case is the activation of the SNS and the subsequent release of catecholamines—such as dopamine, norepinephrine, and epinephrine— [66], this occurs during the breathing exercise [32, 47, 48, 104] and during the cold exposure [43, 71, 56] of the WHM. An increase in catecholamines can lead to increased alertness, vigilance, focus and could decrease fatigue [43, 8, 97, 11, 19]. Similarly to the WHM, the activation of the SNS and the release of catecholamines are also observed during physical exercise [66], which is recognized as a beneficial adjunct to psychotherapy for depression [63, 50, 98]. Another form of therapy utilising hormetic stressors is hydrotherapy, which has been shown to be effective in managing several stress-related pathologies [6, 51]. Cold showers, considered a form of hydrotherapy [91], act as hormetic stressors because of the change in temperature [6].

Measurement of Stress and Vitality

When studying effects of the WHM on stress or vitality, it's crucial investigate the type of stress or vitality and to use the correct scale. With regards to stress, it is important to differentiate between exposure to stressful events, known as stressors, and the responses to these events [22].

Stressors are specific events that can objectively disrupt psychological functioning. In contrast, stress responses include psychological, behavioural, cognitive, and physiological reactions that occur before, during, or after exposure to a stressor [22]. For this research, measuring stress responses is more relevant, as they often have a greater impact on physical health than the mere exposure to stressors. Additionally, Stress responses provide additional valuable information beyond just the exposure.

Stress responses can be measured through self-reports, behavioural coding, physiological assessments, encompassing emotions, thoughts, behaviours, and physiological changes triggered by stress [22]. To choose appropriate stress measures, it is advised to follow the 7-step process by Crosswell & Lockwood [22]. This process involves determining the type and timescale of stress, identifying the stress responses and life stage affected, selecting relevant stressor characteristics and appropriate measures, and utilising well-validated scales [22]. This scale is primarily focused on capturing psychological stress and does not include physiological health. Although, one the strengths of measures of vitality are the strong associations with both physical and mental components of health [92].

Vitality is considered an integrated index of somatic and psychological functioning. It serves both regenerative and restorative functions, which lend flexibility in the face of stressors [36, 72]. Despite its importance, research on vitality in relation to stress and physiology, is limited [92]. To measure vitality scientifically, there are multiple suited scales [92]. They evaluated these scales for their strengths and weaknesses, considering factors such as suitability for healthy or sick populations, ease of use, reliability, and theoretical integration. This evaluation helps determine the most appropriate scale for specific situations.

Besides the investment into the search for a correct scale, it is important to investigate the correct study method. The studies measuring the effects on stress or vitality of the prior WHM studies used a randomised controlled trial [90, 91], which can be underpowered when used with a small sample size [75]. This suggests that an additional approach could help clarify whether the WHM affects stress and vitality. The use of Experience Sampling Method (ESM) provides a continuous data collection, which could allow for a more comprehensive understanding of the effects of WHM on stress and vitality [28, 62]. ESM offers the potential to capture real-time fluctuations in psychological parameters, providing valuable insights into the dynamic nature of stress and vitality in response to WHM practices [28, 62].

Research Questions

The mixed results regarding how the WHM affects stress and vitality [90], combined with the absence of studies focusing on emerging adults [3, 4], and the absence of continuous ESM data, highlight a significant gap in the current research. This study investigates the impact of the breathing exercises and cold exposure of the WHM on stress and vitality with emerging adults over a two-week intervention period. Additionally, the association of mindset on cold showers will be assessed. The following hypotheses were formulated:

Stress

H1Sa There is a significant negative between-subject association between the mean stress score and the number of days the breathing exercise was performed.

H1Sb There is a significant negative between-subject association between the mean stress score and the number of days the cold shower was performed.

H2Sa Individuals report a significantly lower stress score on days they did a breathing exercise than on days they did not do a breathing exercise.

H2Sb Individuals report a significantly lower stress score on days they did a cold shower than on days they did not do a cold shower.

H2Sc Individuals report a significantly even lower stress score on days they did the combination of the method than on days they did only one aspect of the method.

H3S There is a significant decrease in perceived stress in the post-test measurement compared to the pre-test measurement.

Vitality

H1Va There is a significant positive between-subject association between the mean vitality score and the number of days the breathing exercise was performed.

H1Vb There is a significant positive between-subject association between the mean vitality score and the number of days the cold shower was performed.

H2Va Individuals report a significantly higher vitality score on days they did a breathing exercise than on days they did not do a breathing exercise.

H2Vb Individuals report a significantly higher vitality score on days they did a cold shower than on days they did not do a cold shower.

H2Vc Individuals report a significantly even higher vitality score on days they did the combination of the method than on days they did only one aspect of the method.

H3V There is a significant increase in subjective vitality in the post-test measurement compared to the pre-test measurement.

Mindset

H1M There is a significant positive within-person association between the average level of mindset in maintaining the cold exposure and the total number of daily cold exposures.

Theoretical Model

Combining the literature with the research questions leads to the development of the theoretical model. This model, which is depicted in Figure 2, illustrates the central components of the WHM, namely the three pillars: breathing exercises, cold exposure, and Mindset. This model predicts that by utilising the breathing exercise and cold shower, the perceived stress should decrease and vitality should increase [102]. Furthermore, the model predicts that combining these methods will produce a more substantial effect than using each one individually, as has been shown in research before [91]. Additionally, research has explored the impact of mindset on the endurance of cold exposure [49], prompting the model to propose that an increase in mindset of maintaining the cold exposure, is positively associated to the total amount of daily cold exposures. The numbers related to the hypothesis are added to the model in Figure 2 for a more concise overview.

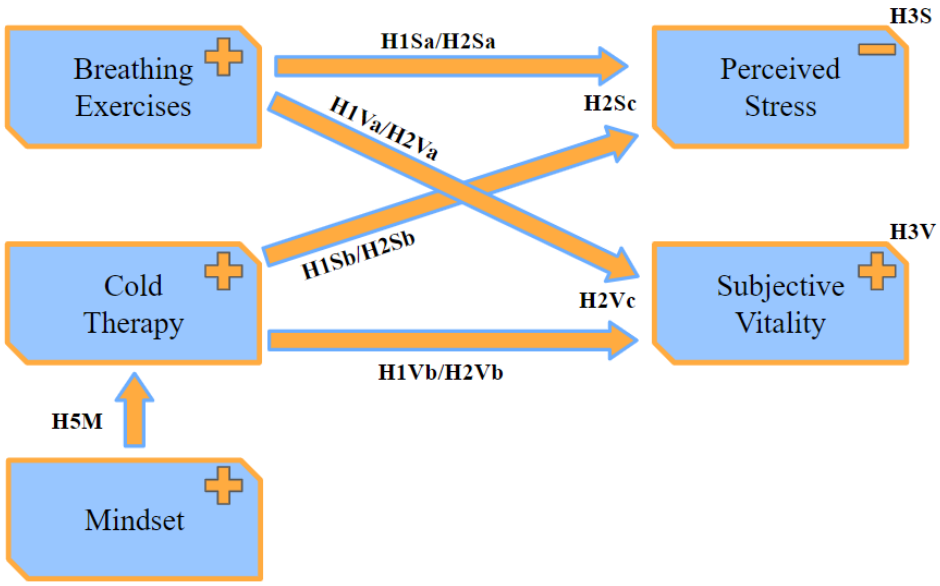


Figure 2: The theoretical model.

Methodology

The methods used to test these hypotheses, and therefore test the theoretical model, are outlined as follows. First, the study design is discussed, followed by details on the participants, procedure, intervention, materials, data analysis, and finally, the ethical considerations.

Study Design

A pretest-posttest design was utilised to evaluate the effectiveness of the WHM on perceived stress and vitality over a 15-day intervention period, as done in previous studies [90, 91]. The pretest was administered at 16:00 on the day of the workshop before the intervention began, and

the posttest was administered at 16:00 on the 15th day, after the intervention ended. Both tests included the Perceived Stress Scale (PSS) and Subjective Vitality Trait (SVSt) and State (SVSs) scales. The pretest also included two open-ended questions about the reasons for participation and expectations of the intervention, while the post-test asked if these expectations were met.

ESM was used to record the frequency of daily breathing exercises and cold exposure, as well as daily perceived stress and vitality levels. All ESM questionnaires were sent out at 16:00 and could be submitted until 18:00. Participants attended a workshop the day before the intervention, where they received instructions on the m-Path app and a lecture on the three components of the WHM by a certified WHM instructor. Two starting dates, separated by one day, were offered for the workshop, and participants chose their preferred date during recruitment, which took place 1 to 3 weeks prior to the first workshop.

Participants

Students from secondary vocational education, higher professional education, and university education in the Twente region were recruited using reverse snowball sampling. Information about the study, including details on the WHM, research goals, inclusion/exclusion criteria, health risks, time commitment, and starting dates, was shared on various social media platforms (WhatsApp group chats, LinkedIn, and Instagram) three weeks before the intervention. Additionally, the SONA system at the University of Twente was used to recruit students required to complete test subject hours [96].

Interested students filled out a Google form at least one week prior to the first workshop, providing their email address and selecting one of the two available workshop dates. They confirmed they met the inclusion criteria (18-29 years old, student or scholar, able to read and understand English, no prior experience with fast deep breathing exercises or cold exposure, and able to attend the workshop at the University of Twente on May 7th or 8th) and did not meet any exclusion criteria (various physical and mental health conditions contraindicated for the WHM, as listed by [91, 102]. Sample size and power analysis, performed using G*Power version 3.1.9.7 [30], indicated that 73 participants were needed, with an effect size of $f = 0.4$ and a significance level of $\alpha = 0.05$ [90].

Procedure

Three weeks before the first workshop, participants received a Google form to confirm their availability and choose a workshop date. One week before the workshop, they received an email with detailed study information (Appendix A). Participants available on both dates were randomly assigned to one of the two groups, so that the groups became equal. A reminder email with workshop details was sent the day before the workshop.

The workshop, held during the lunch break at the University of Twente, lasted from 12:30 to 13:30. Participants signed an informed consent form and a health declaration form (Appen-

dices A & B) and downloaded the m-Path app for research participation. Instructions on using the app and answering the questionnaires were provided. The remaining time was dedicated to teaching the components of the WHM by a certified instructor. The focus was on correct breathing techniques, tips for taking cold showers, and mindset strategies. Specifically, participants practiced a short version of the breathing exercise, consisting of 10 breaths, to get familiar with the rhythm and phases. Additionally, they learned mindset techniques for enduring cold exposure by placing their hands in an ice bath while practicing slow breathing and remaining calm. They were advised to perform the WHM components (breathing exercises followed by cold exposure) in the morning, at least three hours postprandial.

After the workshop, participants were asked to immediately complete the demographics questionnaire. In addition, they received an informational handout (Appendix C) with exercise timing details, questionnaire schedules, and a QR code linking to a WHM video. The pre-intervention questionnaire was sent via the m-Path app at 16:00 on the workshop day, followed by a summary of the workshop and exercise tips through the mail. Throughout the 15-day intervention, participants received daily ESM questionnaire, which could be submitted from 16:00 till 18:00. On the day after the intervention, they received an email thanking them for their participation and reminding them to complete the post-test questionnaire, which was also available at 16:00.

Intervention

Participants followed a specific sequence of deep, cyclic breaths guided by a Wim Hof video on YouTube. They sat or lay in a comfortable position and performed 30 conscious breaths, inhaling deeply into their abdomen and chest and exhaling without effort. Each breath had a frequency of approximately 0.32 Hz, and the hyperventilation phase lasted about 1 minute 30 seconds per round. At the end of this phase, participants fully exhaled to residual volume and held their breath until they felt a stimulus to breathe or reached a safety time limit (60 seconds for the first round, 90 seconds for the second, and 120 seconds for the third). Afterward, they took a deep inhalation (recovery breath) and held it for 15 seconds. This procedure was repeated three times. Participants were instructed to perform the breathing exercises on an empty stomach at the start of the day before cold exposure.

The cold exposure involved taking cold showers. Participants were instructed to end their shower with cold water for 30 seconds, using a timer app or counting the seconds. They started by showering their feet and legs (front and back) for 10 seconds, then their torso for 10 seconds, and finally their back for 10 seconds. The water temperature was adjusted to the coldest possible setting, ranging between 10 and 15 degrees Celsius in Overijssel [99] which can be considered cold [52].

Materials

Data was collected using m-Path, a free, GDPR-compliant platform. Participants completed the demographics, pre-intervention, post-intervention, and ESM questionnaires on their mobile phones via the m-Path app. Demographic data included gender, age, height, body mass, study level, and weekly medium-intensity activity in minutes.

Besides that, the pre- and post-intervention questionnaires were utilised, which included the PSS, SVSt, and SVSs. The pre-test also asked participants why they joined the study and their expectations, while the post-test asked if the intervention met their expectations. Open-ended responses were coded using ATLAS.ti [80]. The PSS-10 consisted of 10 items rated on a 5-point scale (0 = “never” to 4 = “very often”) [21]. Responses to positively stated items (4, 5, 7, 8) were reversed before summing the total score, with higher scores indicating greater perceived stress. Both the SVSt and SVSs used a 7-point rating scale (1 = ”not at all true” to 7 = ”very true”). Higher scores indicated better psychological well-being, while lower scores were associated with negative mental health outcomes [73, 12].

Moreover, the daily ESM questions asked participants whether they completed the breathing exercises and cold showers (yes/no), rated their stress, vitality and mindset on a 7-point Likert scale. An optional open-ended question allowed participants to provide additional comments.

Data Analysis

Data analysis was conducted using RStudio (version 4.4.0) [69]. For pre- and post-test data, Cronbach’s alpha assessed internal consistency for the PSS, SVSt, and SVSs. Item correlations below 0.5 were noted. The Shapiro-Wilk test ($p<0.05$), skewness (<2) and kurtosis (<7) checked normality [60, 81]. In addition, Levene’s test examined equality of variances and the The variation inflation factors (VIF) checked the multicollinearity. Differences in perceived stress and vitality were analyzed using the Wilcoxon signed-rank test. Open-ended responses were analyzed through deductive content analysis by a single coder.

For ESM data, the Shapiro-Wilk test checked normality. Yes/no questions determined compliance with the breathing exercises and cold showers. Responses of ’yes’ were coded as 1, and ’no’ responses as 0. Additionally, doing both the breathing exercises and cold exposure was coded as 1 and a value of 0 if not. Multilevel modeling was employed to assess the association of the WHM with perceived stress and vitality, as well as the association of mindset with cold showers. Missing data were handled using maximum likelihood estimation in R. If missing data exceeded 40%, adjustments were made [85, 58]. ESM open-ended questions were examined in case of abnormalities in the participant’s data.

Ethical Considerations

This study adhered to the Declaration of Helsinki [103] and University of Twente ethical guidelines, with approval from the Ethics Committee of the Faculty of Behavioural, Management, and Social Sciences (240502). Participation was voluntary, with a small WHM workshop as an incentive. A certified WHM instructor ensured safety and correct technique. Recruitment targeted acquaintances, including friends of the researcher. Clear communication emphasized that participation should be based on personal interest in the Wim Hof Method, not personal support for the researcher.

Participants were informed about risks and safety measures, advised not to perform breathing exercises during activities requiring attention. Participants signed an informed consent form and filled out a health declaration form at the workshop's start. They were informed of their right to withdraw at any time without consequence. Upon completion, participants were debriefed on the findings and received a copy of the full thesis.

Participants could withdraw at any time without consequences. Data confidentiality was maintained by having anonymous data with unique identifiers in m-Path. Raw data were stored securely and preserved for three years before being destroyed. Health declaration and consent forms were destroyed one month after the study to ensure anonymity and confidentiality.

Results

Utilising these methods, results were produced which will be discussed in the following order. First, the demographics of the study population will be presented, followed by the pre-post test data. Then, the ESM data will be examined, with separate discussions on the subcomponents of perceived stress, subjective vitality, and mindset. Finally, the qualitative data from the three open-ended questions in the pre- and post-tests will be analysed.

Demographics

The recruitment rate is absent in this study, as it is unknown how many individuals were reached by the different social media platforms. Initially, 40 participants signed up to the study, but three were absent at the workshop, leaving 37 participants to be enrolled for the intervention. Out of these participants, 35 were included in the ESM pre- and post-test data analysis, as two participants stopped filling in the ESM questionnaires as well as failing to fill in the pre- or post-test questionnaires. It is assumed that they resigned without a given reason. The flow diagram can be seen in Figure 3 [5].

The study population consisted of 25 males (71.4%) and ten females (28.6%), with an average age of 22.7 ± 2.6 years. Among the participants, 32 (86.5%) were university education students, while 5 (13,5%) were students in professional education. The population had a mean BMI of 23.4 ± 2.8 and 77.1% of the participants maintained a healthy BMI falling within the

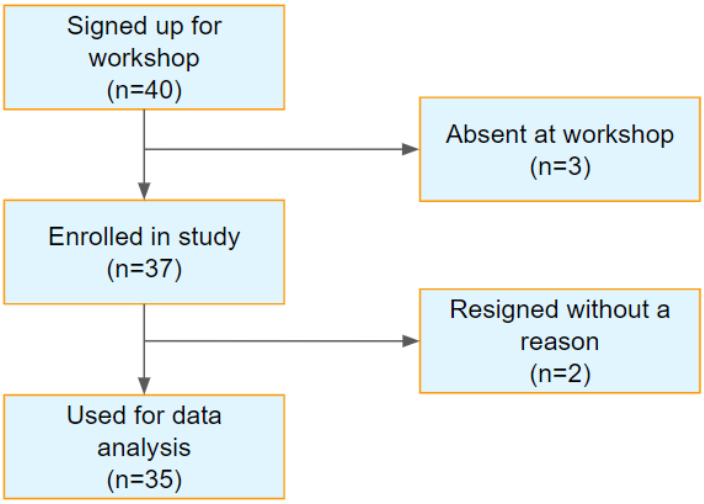


Figure 3: Flow diagram for the study population.

range of 18.5 to 25, while 22.9% were overweight. In terms of exercise habits, 62.9% exercised more than 150 minutes weekly, followed by those exercising between 100 and 150 minutes (28.6%), and between 50 and 100 minutes (8.6%). The nationalities of the population consisted of 26 Dutch participants (74.3%), followed by three Italian (8.6%), and single entries for Israeli, German, French, Polish, Swedish, and Belgian backgrounds (2.9%).

Pre- Post-Test Data

In this section, the pre- post-test data regarding the PSS, SVSt and SVSs scales are assessed. First the quality and reliability of the data will be examined, before moving on the significance of the difference. To asses the quality and reliability, the important values are added in Table 1 and contain the mean scores, standard deviation (SD), Median, interquartile range, results of the Shapiro-Wilk test, Cronbach's alpha and the lowest item correlation score. The data of the pre-test PSS, SVSt, and SVSs are normally distributed according to the rejection of the null hypothesis of the Shapiro-Wilk test, as seen in Table 1. In the post-test dataset the PSS scale was normally distributed, but not the post-test SVSt and SVSs. The distribution is visualised using box plots in Figure 4. The values of the Cronbach's alpha in all the scales were all above 0.78, as shown in Table 1. The pre-test PSS-10 showed values of item correlation below 0.5 for question 4 (0.32) and question 9 (0.43). The values of item correlation for the pre-test SVSt and SVSs were well above 0.5. The post-test item correlations were below 0.5 for questions 1 (0.48), 6 (0.45), 7 (0.44), and 9(0.12) of the PSS scale. In the SVSt scale question 2 had a value below 0.5 (0.38) and the SVSs scale had all the values above 0.5. Levene's test was 0.78, suggesting that there is no significant difference between the variances of the two data sets.

Table 1: Values of measurements for the PSS, SVSt, and SVSs in the pre- and post test.

Test	Measurement	PSS	SVSt	SVSs
Pre-test	Mean & SD	17.69 ± 4.93	26.7 ± 5.88	24.20 ± 4.79
	Median & IQR	19.00 ± 6.00	28.0 ± 9.50	23.00 ± 10.00
	Shapiro-Wilk test p-value	0.51	0.62	0.44
	Cronbach's alpha	0.78	0.85	0.91
	Lowest item correlation	0.32	0.58	0.61
Post-test	Mean & SD	14.37 ± 5.10	30.23 ± 4.79	29.09 ± 5.59
	Median & IQR	13.00 ± 6.00	31.00 ± 7.50	30.00 ± 6.00
	Shapiro-Wilk test p-value	0.13	0.04	0.04
	Cronbach's alpha	0.83	0.83	0.89
	Lowest item correlation	0.12	0.38	0.60

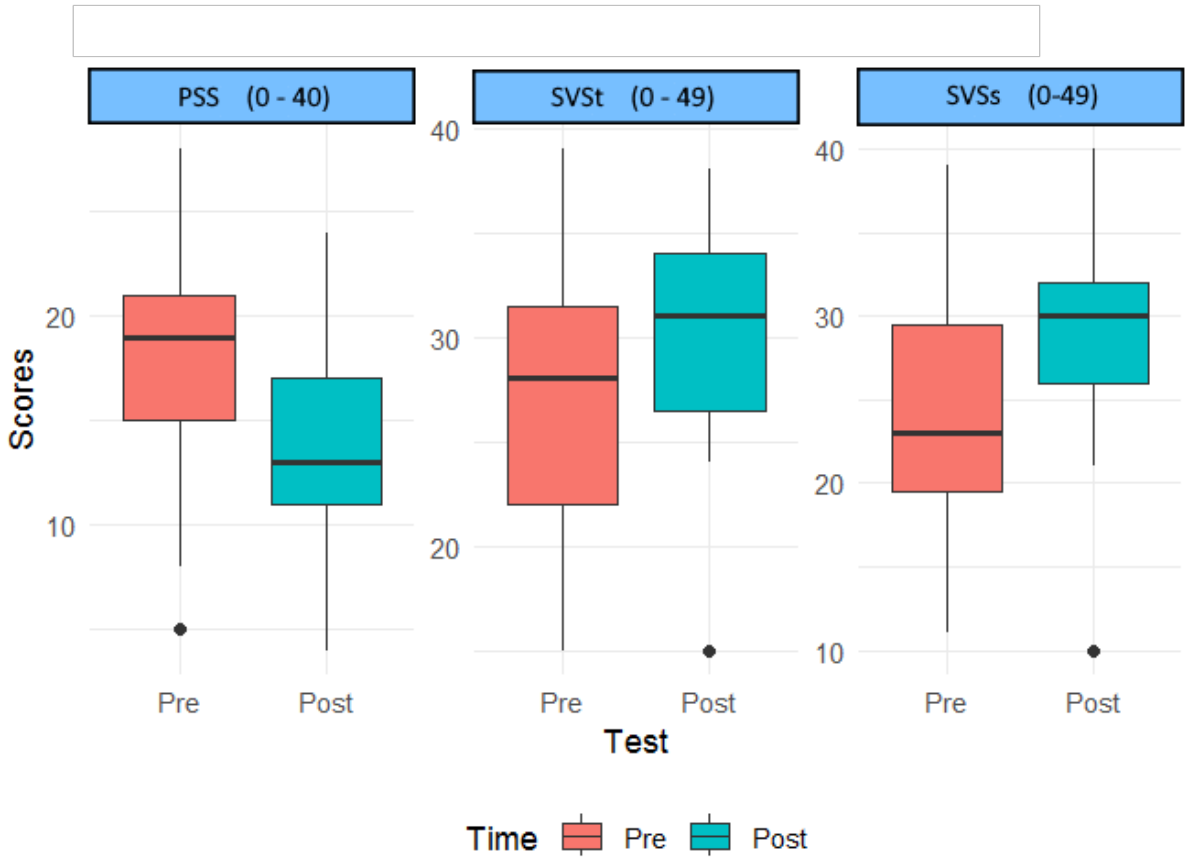


Figure 4: Boxplots of the PSS, SVSt, and SVSs scales pre-and post-test.

The p-values of the Wilcoxon signed-rank tests show there is a significant pre- post-test difference for all the scales, as seen in Table 2. However, there are zero's and ties within the pre- and post-test dataset, the Wilcoxon signed-rank test drops these values and gives therefore an approximation of the p-value [70]. To ensure the correctness of the p-value, a paired sign test was added which also showed a significant difference.

Table 2: Results of the Wilcoxon tests and Paired sign test for the PSS, SVSt, and SVSs.

Scale	Wilcoxon test p-value	Paired sign test p-value	Confidence interval
PSS	6.40×10^{-4}	1.75×10^{-2}	(-Inf, -3.00)
SVSt	1.20×10^{-5}	1.62×10^{-4}	(3.00, Inf)
SVSs	2.53×10^{-5}	2.54×10^{-4}	(3.12, Inf)

These results ultimately indicate a significant decrease in perceived stress in the post-intervention measurement compared to the pre-test measurement and a significant increase in subjective vitality in the post-intervention measurement compared to the pre-test measurement. When measuring the reduction of the mean as shown in Table 1, a reduction in PSS score by 18.77%, and an increase in SVSt and SVSs by 13.22% and 23.55% was calculated respectively.

ESM data

Having evaluated the pre-post test data to assess changes before and after the intervention, our attention now shifts to the continuous ESM data. In this section, the values of adherence, compliance, means and SD's of the ESM data are presented. Next, the distribution and multicollinearity of the data are examined. Before moving on to the results on perceived stress, subjective vitality, and mindset, which will be separately discussed. Finally concluding with a summary of these findings.

The retention rate of the population enrolled in the ESM study was 91.9% (35/37), and the mean compliance rate was 87.6% (458/525). The mean daily frequency of breathing exercises was 0.86 ± 0.27, cold exposures was 0.92 ± 0.27, and the completion of both was 0.83 ± 0.37. The daily frequency of the method's aspects is graphed in Figure 5A, showing a slight decrease in adherence as the intervention progresses. Additionally, there is a noticeable dip on the 9th and 12th days; the dip on the 12th day may be due to the Pentecost weekend.

During the intervention, the mean stress level in the ESM data was 2.06 ± 1.33, the mean vitality was 3.48 ± 1.24, and the mindset for maintaining cold exposure had a mean of 4.50 ± 1.41, indicating relatively high vitality and mindset (Figure 5B). The compliance rate for filling in the questionnaire also gradually declined over time, as seen in Figure 5C.

The answers of the perceived stress, vitality and mindset in the ESM questionnaires were not normally distributed, as indicated by the Shapiro-Wilk test in Table 3. The asymmetry and the tailedness were examined by the skewness and kurtosis tests respectively, these values were within the acceptable range and also shared in Table 3. The VIF values were added in table 4 and show a medium correlation for the cold showers and a large correlation for the breathing exercises and the combined use of the method, for both stress and vitality.

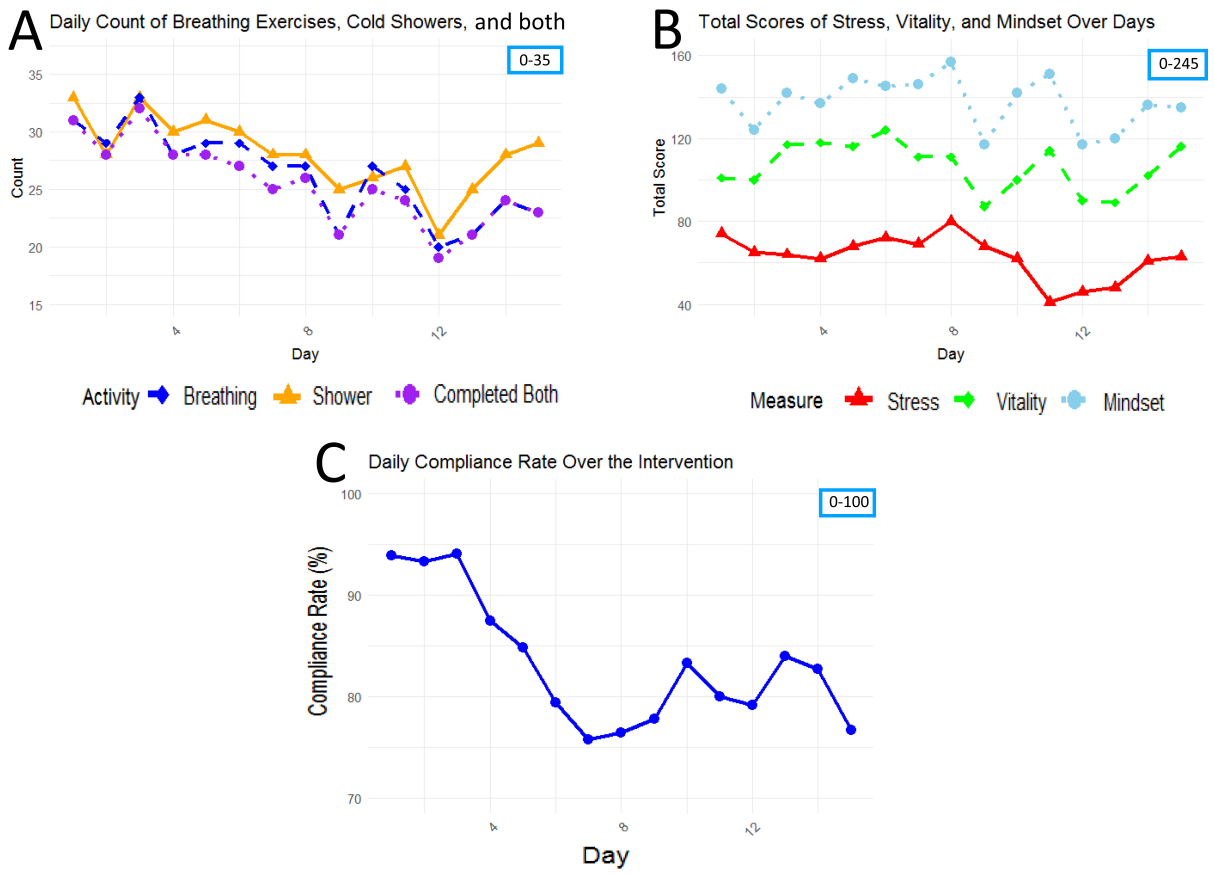


Figure 5: Daily count of breathing exercises, cold showers and the completion of both (A). Total scores of Stress, vitality and mindset over the days of the intervention (B). Daily compliance rate of the ESM during the intervention (C). The y-axis is adjusted for visibility; min and max values are in the blue square at the top right.

Table 3: Values of the Shapiro-Wilk, Skewness and Kurtosis tests.

Question	**Shapiro-Wilk p-value**	**Skewness**	**Kurtosis**
Stress	9.50×10^{-14}	0.44	2.95
Vitality	4.50×10^{-13}	-0.29	2.88
Mindset	2.20×10^{-16}	-0.88	3.44

Table 4: The Variation inflation factors of the variables on Stress and Vitality.

	ESM_Breathing	**ESM_Shower**	**Completed_both**
Stress	5.99	2.18	8.56
Vitality	6.10	2.19	8.69

Perceived Stress

This section first examines the hypothesis relating the impact of the number of days performing the exercise on stress levels. Next, the associations and outliers are explored regarding the breathing exercise and cold shower on perceived stress for each day. A linear regression model was used to test the significance of the association between stress levels and the number of days the methods were performed, as shown in Table 5. The days performing breathing exercises showed a association of 0.08, while the days performing cold showers showed a association of -0.04. However, neither the breathing exercise (p=0.25) nor the cold shower (p=0.66) had a significant effect according to this model.

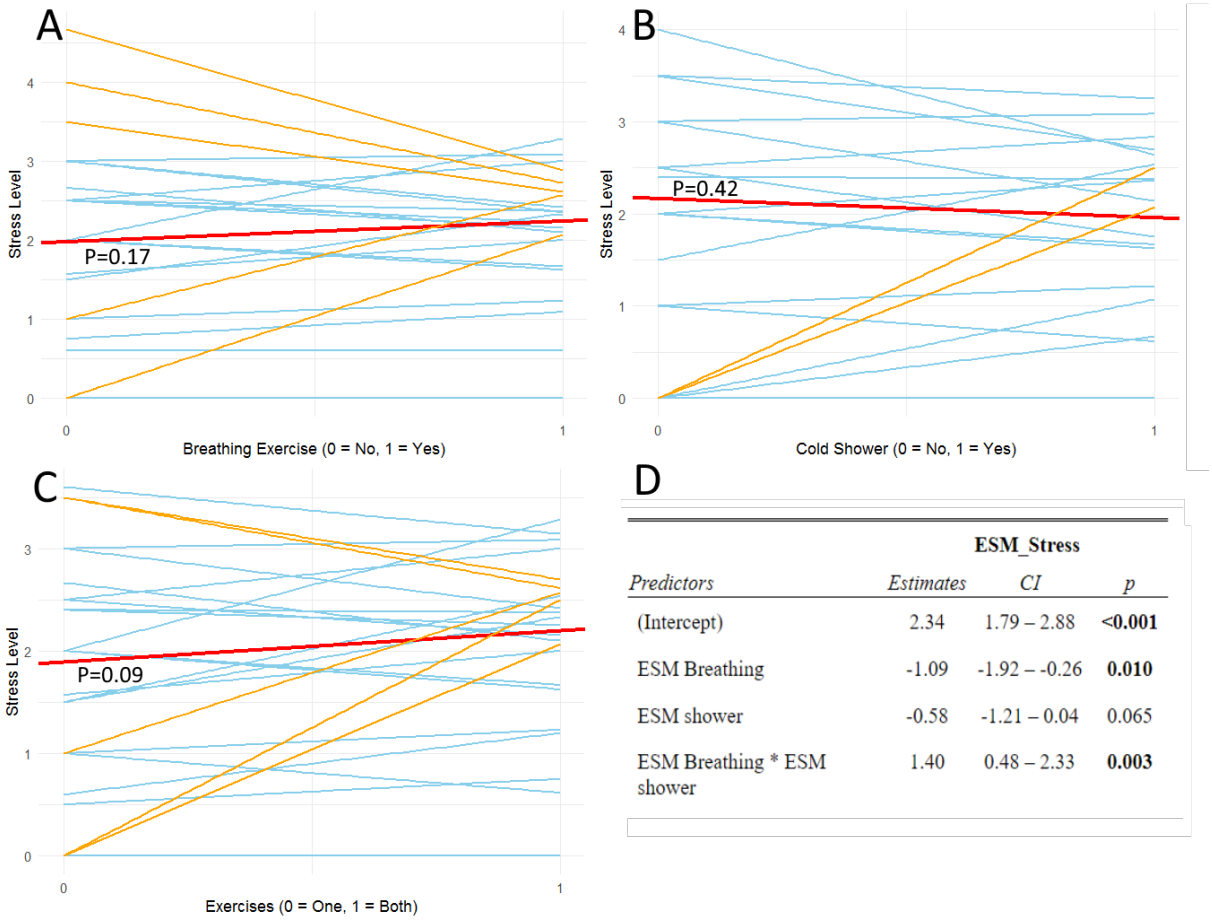
Table 5: Linear model of the days performing breathing exercises and cold showers on perceived stress.

Predictors	**Estimates**	**CI**	**p-value**
(Intercept)	1.52	0.30 – 2.74	0.016
Days Done Breathing	0.08	-0.06 – 0.23	0.254
Days Done Shower	-0.04	-0.20 – 0.13	0.656

When examining within-subject relationships, first spaghetti plots were utilised to examine the individual regression lines and to identify outliers. Twelve participants were excluded for having no non-participation data in breathing exercises, leaving 23 participants with 303 observations for the within-subject analysis of breathing exercises. This analysis showed a positive but non-significant association of 0.26 (p=0.17) (Figure 6A). For cold showers, sixteen participants were excluded, leaving 19 participants with 243 observations. This analysis showed a non-significant negative association of -0.21 (p=0.42) (Figure 6B). The combined effect of both methods included 23 participants with 328 observations, showing a non-significant positive association of 0.30 (p=0.09) (Figure 6C).

In the same spaghetti plots of Figure 6A, B and C, the abnormal values are visualised using the orange lines. These are values with more than two SD's from the mean. The ESM data of participants 2, 14, and 24, who showed abnormal stress increases, are detailed in Appendix D. Due to the open-ended questions in the questionnaire, these outliers can be examined in more detail. Participant 14 mentioned that a holiday and a headache led to skipping the method on a low-stress day, and an exam caused increased stress despite performing the method. Participant 24 associated increased stress with occupational days early in the intervention, but mentions no comment and a low stress on the day of non-participation. Participants 2 and 24 provided no explanation for low stress on non-exercise days. None of the three mentioned any influence of the WHM on their perceived stress.

Using the linear model on all 35 participants, Figure 6D shows the estimated associations and significance of the effects of the breathing exercise, cold exposure, and their combination on perceived stress. Breathing exercises had a significant negative association of -1.09 with stress, cold showers had a non-significant negative effect of -0.58, and the combined methods showed a significant positive association of 1.40, in addition to the negative association of -1.09 from breathing exercises alone.



D

	ESM_Stress		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	2.34	1.79 – 2.88	**<0.001**
ESM Breathing	-1.09	-1.92 – -0.26	**0.010**
ESM shower	-0.58	-1.21 – 0.04	0.065
ESM Breathing * ESM shower	1.40	0.48 – 2.33	**0.003**

Figure 6: A spaghetti plot of the association of breathing exercise (A), cold shower (B) and the combination of the method compared to the individual practise (C) on the perceived stress of that day. The orange lines are showing the abnormal values bigger than 2*SD from the mean. The linear model showing these associations without the excluded participants is located in the below right corner (D).

Subjective Vitality

This section investigates the hypothesis regarding the effect of the number of days performing the exercise on subjective vitality. Besides that, the association and outliers related to the breathing exercise and cold shower on subjective vitality for each day will be examined. A linear regression model linking subjective vitality to the number of days the methods were performed is shown in Table 6. Neither the breathing exercise (p=0.99) nor the cold shower (p=0.93) had a significant effect.

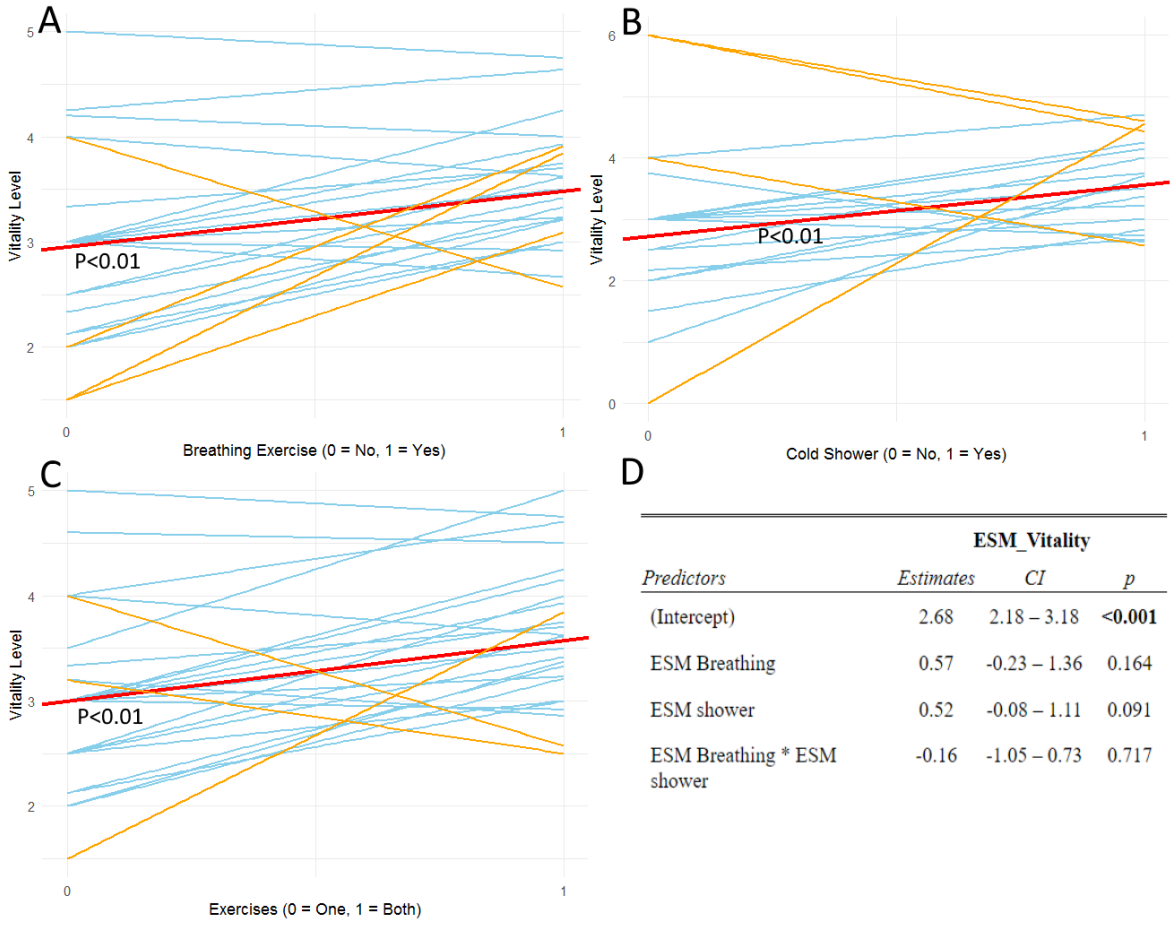
Table 6: Linear model of the days done the breathing exercises and the days done the cold shower on the subjective vitality.

Predictors	**Estimates**	**CI**	**p-value**
(Intercept)	3.59	2.57 – 4.60	< 0.001
Days Done Breathing	-0.00	-0.12 – 0.12	0.992
Days Done Shower	-0.01	-0.14 – 0.13	0.933

For the within-subject analysis with spaghetti plots, the same participants and observations as the perceived stress analysis were utilised due to similar exclusions. The breathing exercise showed a significant association of 0.53 with subjective vitality ($p<0.01$). The cold shower also showed a significant association of 0.84 with subjective vitality ($p<0.01$). The combined effect of both methods showed a significant positive association of 0.58 ($p<0.01$).

In the spaghetti plots (Figure 7A, B and C), the orange lines represent abnormal values more than two SD's from the mean. Participants 4, 12, 14, and 16 showed abnormal decreases in vitality. and their ESM data are detailed in Appendix D. Unlike the abnormal stress values, participants 4, 12, and 16 skipped the method more than once. Participant 14, who also had abnormal stress values, noted being on holiday on a low-vitality day and experiencing increased stress due to an exam. Participant 16 mentioned having a long day with no time for the exercise, coinciding with low vitality. Participants 4 and 12 did not provide any comments. None mentioned the WHM's influence on their subjective vitality.

Using the linear model on all 35 participants, Figure 7D shows the estimated associations and significance for the effects of the breathing exercise, cold exposure, and their combination on subjective vitality. The breathing exercise had a non-significant positive association of 0.57, cold showers had a non-significant positive association of 0.52, and the combined methods showed a non-significant negative association of -0.16, in addition to the 0.57 association from the breathing exercises alone.



	ESM_Vitality		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	2.68	2.18 – 3.18	**<0.001**
ESM Breathing	0.57	-0.23 – 1.36	0.164
ESM shower	0.52	-0.08 – 1.11	0.091
ESM Breathing * ESM shower	-0.16	-1.05 – 0.73	0.717

Figure 7: A spaghetti plot of the association of breathing exercise (A), cold shower (B) and the combination of the method compared to the individual practise (C) on the subjective vitality of that day. Together with the linear model showing these associations (D).

Mindset

Figure 8 illustrates the average mindset level plotted against the total number of daily cold showers. The regression line indicates a positive association, though the data points are widely distributed. According to the linear model in Table 7, an increase in mindset by one unit is associated with an increase of 0.71 in the number of daily showers. However, this association is not significant (p=0.19).

Table 7: Linear model of the average mindset on amount of total cold showers

Predictors	**Estimates**	**CI**	**p**
(Intercept)	8.86	3.93 – 13.79	0.001
Avg Mindset	0.71	-0.36 – 1.78	0.187

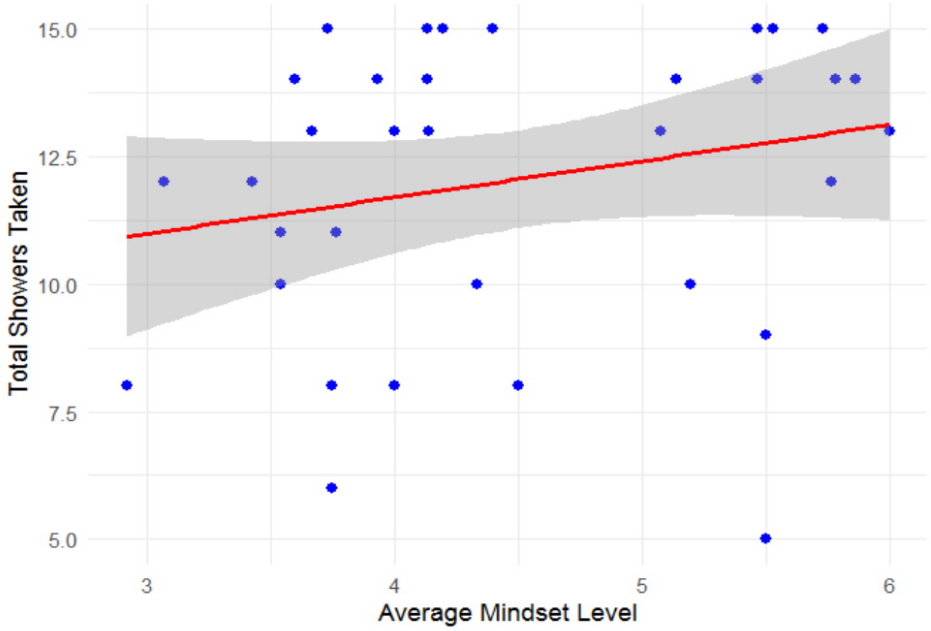


Figure 8: The average mindset on the total amount of showers taken with a mean regression line and the standard error.

Conclusion of The ESM Data

In conclusion, the ESM data suggests that there is no significant negative association between mean stress or vitality scores and the number of days participants performed breathing exercises or took cold showers. Additionally, the average mindset did not significantly affect the number of daily cold showers. Moreover, due to the lack of non-participation data, the data was more perceptible to outliers and external events. Therefore it was difficult to draw definitive conclusions about the association of breathing exercises, cold showers, or their combined use on the stress and vitality levels of that day.

Qualitative Research

In this segment, the qualitative data from the pre- and post-test questionnaires of 35 participants will be discussed. The discussion begins with exploring participants' motivations to participate and their expectations of the results. Following this, an examination of how these expectations were realized will be conducted. Coding schemes are provided with themes and codes listed from most to least frequent. After analysing all the individual questions in the questionnaires, a concluding paragraph summarising the qualitative data will be shared.

Motivation to Participate

The coding scheme for participant's reasons for joining the intervention is detailed in Table 8. The predominant reason, cited 29 times, was interest in the method, driven by curiosity or interest about the study's results or the method itself. Curiosity was specifically noted nineteen times, with Participant 11 commenting, "I am curious to see what consistent breath work and cold exposure can do for me and others". Interest solely in the method was mentioned ten times, exemplified by Participant 6: "I am intrigued by the WHM."

Self-improvement was another key theme, appearing 13 times, with specific mentions of self-improvement alone occurring eight times. For instance, Participant 15 noted it could add "Something for my 'toolbox' for my personal development and self-care." The theme 'self-improvement' was also linked to challenge-seeking, which was mentioned five times. Participants expressed a desire to test their limits, such as Participant 17 who said, "It is also a challenge to see if I can complete these 15 days."

Supporting the researcher was another motivation for joining, noted nine times. For example, Participant 25 aimed to "Help my friend with his master's thesis." Other, less common reasons included trying something new (mentioned twice) and one-time mentions of joining for fun, earning study credits, or finding a compelling reason to engage in the practices. Participant 31 explained, "I have played around with the idea of cold exposure, however, never had the mental strength to continue it. This gives a reason to do it."

Table 8: Coding scheme for the pre-test questionnaire regarding the reason for joining the intervention.

Theme	**Code**	**Frequency**
Interest in method	Curiosity	19
	Interest in method	10
Self-improvement	Self-improvement	8
	Challenge seeking	5
Helping the researcher		9
Other	Trying something new	2
	Sona points	1
	A reason to do it	1
	Fun to join study	1

Expectations of Intervention

The expectations of participants prior to the intervention were organised and displayed in Table 9. The most commonly anticipated outcome was 'Physical Benefits' and was noted 19 times. This included expectations of increased energy, which was mentioned nine times. Increased energy was often linked to feeling more awake, which was referred to in five instances.

For example, Participant 34 said, “To feel more energised and awake every day”. Expectations of improved breathing were noted twice, with Participant 7 aiming to “learn more about how to breathe properly,” and one participant hoped to feel less cold because of the WHM.

‘Psychological Benefits’ emerged as the second most common theme, with a total mention of nine times. Stress reduction through WHM was anticipated five times, exemplified by Participant 19: “I expect that the intervention will help me learn techniques to manage my stress that I can use in everyday life.” Both motivation enhancement and general mental health improvement were mentioned twice, with Participant 28 expressing, “I think this is going to improve my general feeling towards life.”

Eight participants entered the study without specific expectations, like Participant 17 shared, “I don’t have much expectations, just open to see what happens and how it goes,”. Five participants expected initial difficulties with the intervention but believed it would get easier over time, as Participant 25 noted: “I think that at first the intervention will be difficult to follow, but with time it will become easier.” Additionally, three participants did not foresee significant changes but remained open to potential surprises, like Participant 14 who stated, “I don’t expect to notice a lot of difference but I’m ready to be surprised.”

Table 9: Coding scheme for the pre-test questionnaire regarding the expectations of the intervention.

Theme	**Code**	**Frequency**
Physical benefits	More energy	9
	Waking up better	5
	Better breathing	2
	Feeling less cold	1
Psychological benefits	Reducing stress	5
	Improvement in motivation	2
	General Improvement	2
No expectations		8
Struggle		5
No difference		3

Evaluation of Expectations

When asked how the expectations turned out to be correct, many not only answered the question directly, but also mentioned their experiences, preferences, and struggles. The coding scheme can be seen in Table 10 and the most frequently present theme was ‘Beneficial outcomes’ (34). This consisted of predominantly feeling more energised (9) and feeling more awake (7) in the morning. This is also what many expected prior to the intervention. In addition, just like in the pre-test questionnaire, many of these mentions were used together in a

sentence like participant 3 shows: “They made me quite awake during the morning and left me energised because of the cold shock”. Participants also mentioned it helped with feeling less stressed (5), helped with cold exposure (4), made them feel more calm (3) and more alive (2). Single mentions were recorded for a lower heart rate during running, better general breathing, feeling more focused and having more structure during the day.

The second most frequent theme was ‘Preference’ (15), and encompasses whenever participants mentioned they preferred or disliked certain aspects of the method. However, just the preference for the shower (10) and the dislike of the breathing exercises (5) was mentioned. This phenomenon of the preference for the cold shower and the disliking of the breathing exercise was often shown together as participant 13 mentioned: “Having a cold shower in the morning made me feel awake, the breath exercises didn’t do much for me”

The third most frequent theme was ‘Struggle’ (12) This encompasses the struggles with certain events in life, as well as struggles with the method itself. Struggles in life (8) was for example having a struggle with time management, but also factors from outside that might have an impact on one’s stress or vitality level. Like participant 7 who expresses concerns about the effect on the study results: “I’ve had a weird few weeks so i don’t know how this affected my result of this test”. Struggles with the exercises included: having trouble to put it in their schedule, but also their perspective towards the exercises, like participant 32 points out: “i felt like it would be easier, but actually had quite some irritation towards having to take a cold shower and do the breathing exercises”

The fourth theme in the order is the ‘Realisation of the expectations’ (10). It covers the positive and negative realisations compared to their expectations. Negative realisations were mentioned like feeling no effect at all (2), or having no effect on vitality (2), or expected more from the method (2). Like participant 25 mentions: “I personally did not feel much changes from doing the experiment”. On the other hand, there were two positive mentions for the method having more impact (2) and being more pleasant (2) than previously thought. Like shown in the answer of participant 26: “The WHM had more impact than expected i think, because i came into the study very sceptical.”

Table 10: Coding scheme for the post-test questionnaire regarding the correctness of the expectations before the intervention.

Theme	Code	Frequency
Beneficial outcomes	More energized	9
	More awake	7
	Less stress	5
	Helped with cold exposure	4
	Calmness	3
	More alive	2
	Lower heart rate while running	1
	Better breathing	1
	More focus	1
	More structure	1
Preference	Preference for shower	10
	Dislike of breathing	5
Struggles	Struggles in life	8
	Struggle with exercises	4
Realisation of expectations	No change	2
	No effect on vitality	2
	Expected more effect	2
	More impact than thought	2
	More pleasant than thought	2

Conclusion of Qualitative Data

To conclude, interest or curiosity in the WHM itself and the possible results showed to be the most frequent reason for participation, followed by the will to improve themselves and helping the researcher respectively. For the expectations of the population, it was clear that physical benefits showed to be predominantly the most frequent expectation, especially feeling more energised and more awake. This was followed by expected psychological benefits and having no expectations respectively. A smaller amount of the population expected to struggle while doing the WHM or expected no difference at all after the intervention. When participants looked back on their expectations, many indeed experienced more energy and more awakeness, as well as other benefits. Besides that, participants mentioned they prefer the cold shower over breathing exercises.

Discussion

Beginning with a general overview, providing direct answers to the hypothesis, we will then delve into the main findings, discussing the results of the pre- post-test data, the ESM data, and the qualitative data. Finally, the strengths and limitations of this study are addressed.

Overview

The PSS score exhibited a significant decrease in stress, despite the initial low pre-test score [94]. Additionally, both SVSt and SVSs scores showed significant increases. Concerning the ESM data, no significant between-subject association was found between the mean stress or vitality scores and the frequency of method practice. Moreover, definitive conclusions cannot be drawn regarding whether individuals reported significantly lower stress or higher vitality on days they practiced breathing exercises or took cold showers compared to non-practice days. This limitation is attributed to the scarcity of non-participation data, making the data more susceptible to outliers. The same phenomenon applies to combined method use concerning individual stress or vitality scores compared to their individual use. Lastly, there was no significant positive within-person association between mindset in maintaining cold exposure and the total number of daily cold exposures. The scarcity of non-participation in cold showers and lack of variability in mindsets also influenced these findings.

Main Findings

Pre- Post-Test Data

These results align with the claims of the WHM [102, 39] and the reduction observed in perceived stress is consistent with the reduction reported by Kopplin et al. (2022) [91]. With regards to vitality, the increase observed with the WHM surpasses that achieved through other mindfulness or exercise interventions [31, 46]. Both the results of stress as for vitality are contradicting the findings of Ketelhut et al. in 2023 [90].

The decrease in perceived stress is likely due to the increase in hormetic stressors, thus increasing the resilience of the participants against stressful events. [6, 41, 37]. This assumption is based upon the fact that physical activity and hydrotherapy are similar to the WHM in the activation of the SNS [48, 6, 66]. Additionally, both methods utilise the theory of hormetic stressors to explain the positive effects, just like the WHM [39, 6, 66].

The effects on vitality are assumed to be caused by the activation of the SNS and the subsequent release of catecholamines during breathing exercises [32, 47, 48, 104] and cold showers [6, 43]. This activation enhances alertness, vigilance, and focused attention [19], which participants also reported in the qualitative research.

Additionally, in the SVSt and SVSs scores, there was a small difference within the increases; the increase in vitality state was higher than the increase in vitality trait. Participants might have

experienced a greater increase in vitality state due to the immediate physiological effects of the WHM but did not perceive it as a change in their vitality trait. The feeling of increased vitality could have been prolonged even on the day of the final questionnaire, when the WHM was not practiced, because of a higher epinephrine baseline level [48].

In this study, the perceived stress and subjective vitality were chosen as dependent variables to align with WHM's goal of enhancing personal eudaimonic well-being [102, 39]. While these results are promising, further research is needed to connect these findings to objective criteria, such as stress-induced symptoms and diseases, to evaluate WHM's potential impact on public health. For example, as physical activity is a proven adjunct to psychotherapy against depressive symptoms [1, 66], future research could investigate the effects of the WHM on depressive symptoms adjunct to psychotherapy. Additionally, although this and other studies have used a two-week intervention period [47, 48, 90, 91], evidence for the effects of a longer intervention period or follow-up is still lacking.

ESM Data

This study is notable for being the first to utilise ESM to investigate the WHM method. The simplicity of the once-daily questions likely contributed to the high adherence rate, which surpasses that of other ESM studies [86, 59]. The questionnaire took no more than two minutes to complete, adhering to recommended guidelines [28]. However, the ESM data was not normally distributed. Future research should consider including more questions to provide a better understanding of the effects, as this might help mitigate the ceiling effect observed in the current study. More questions could also reduce reactivity by diverting attention from specific items of interest, although this would increase the burden on participants [28]. Additionally, using more frequent questionnaires throughout the day could capture the duration of WHM's effects more effectively. Moreover, a fixed sampling schedule was used for the ESM questions to ensure comprehensive assessment of the target constructs and to facilitate longitudinal statistical analyses [28]. However, this approach may have increased reactivity to the method, as participants knew when they had to complete an assessment and might have adjusted their daily routines accordingly [28]. This could additionally explain the high adherence to the method. Ultimately, all of the above is a trade off between adherence, reactivity, and data quality. Future researchers should decide which course of action is best suited to answer their specific research questions. The high compliance rate and the lower quality of data in study, indicates a approach with more questions is advised.

Although the ESM data supported the pre- post-test questionnaires by giving an accurate calculation of compliance, the study lacked sufficient non-participation ESM data to answer the connected research questions. For example, only 8% of the data covered days when the cold shower was not performed. This limited data makes it challenging to reliably test the difference in stress or vitality between days with and without the method, making the results more susceptible to outliers. For instance, Participant 14 experienced low stress while on holiday and not

performing the exercises but had increased stress due to an exam while doing the exercise. In the same way, the lack of non-participation cold showers had also an effect on the association of mindset on the amount of cold showers. With the lack of non-participation cold showers and a small amount of low mindset values, the association proved to be really small.

To improve these association examinations of the WHM on stress, vitality or cold showers in future studies, it is recommended to gather more data on days when participants do not engage in the WHM. For the association between mindset and cold shower this could be achieved by including a control group. With regards to the association of the WHM on stress and vitality it is recommended to add a non-participation period before the intervention.

Qualitative Data

Qualitative data from the study provided new insights, such as participants expressing a preference for cold showers over breathing exercises. This preference was reflected in the higher frequency of cold showers compared to breathing exercises, possibly because cold showers become easier over time [26] and require less effort. Breathing techniques require a full 15 minutes, whereas cold showers take only 30 seconds. To make the breathing exercises more accessible, it might be beneficial to reduce their duration. Additionally, many participants reported physical and mental improvements in the post-test questionnaire, highlighting the overall positive outcomes as claimed by the WHM [102, 39].

Strengths

New Field of Interest

This is the first study to use ESM on the WHM. The continuous data collection was useful in identifying the compliance rate of participants. Open-ended questions were also used to gain insights into participants' reasons for participation and their expectations. Patterns could be identified through graphs and the data within the ESM questionnaire, providing insights into possible abnormal values.

Adherence

The study population had a high adherence and compliance rate. Typically, ESM data shows a compliance rate of about 60% to 70% [86] [59], but in this study, it was 87.6%. Additionally, the ESM data showed a high daily frequency of the WHM, indicating that the intervention was consistently followed by a significant portion of the study population. The only downside of this was that the it was more challenging to examine the method's effect on the days it was performed, compared to when it was not performed. However it was a great support to the pre-post-test data, showing that a consistent dedication to the method has a positive influence on perceived stress and vitality.

Population

The study population closely resembled the Dutch student population in terms of age, BMI, overweight percentage, amount of sufficient exercise, and proportion of international students [16, 24, 64]. Similarly, the pre-test PSS and SVS scores aligned with literature on this target group [88, 100]. It's noteworthy that the mean PSS score of Dutch students, and consequently the study population, was already relatively low [94]. Despite differences in male-female proportion (53/47) and professional-university education proportion (55/45) compared to the broader Dutch student population [16], we argue that the study findings are applicable to the entire Dutch student population.

Limitations

Quality of Data

The post-test data and ESM data showed no normality in the distribution. In the post-test data the SVSt and SVSs both showed a Shapiro-Wilk p-value below 0.05, suggesting a need for refinement in the measurement tools. This was also true for the stress, vitality, and mindset in the ESM data. Although, skewness and kurtosis values for the ESM data were within the acceptable range, indicating a relatively symmetrical and approximately normal distribution [81]. However, it should also be noted that the ESM data showed, particularly for the breathing exercises and the completion of both aspects, high multicollinearity between the independent variable and other variables [67]. In addition, the lack of non-participation data showed to be a another limitation in this study. Because of the absence, the association was vulnerable to be effected by outliers. Therefore, the results of the ESM linear model should be interpreted with caution.

External Influence

There was a quarterly exam period 1.5 weeks prior to the start of the intervention. Additionally, the PSS questionnaire specifically asked about stress levels over the past two weeks, which may have led the study population to recall the stressful exam period. This timing could have influenced their reported stress levels, potentially skewing the results. However, this effect was not quite visible when the PSS score was compared to the general Dutch student PSS score.

Another external influence might be that some participants struggled with external factors in their lives during the intervention, as mentioned in the qualitative research. Additionally, the participants with abnormal values shown in appendix D, also pointed to external factors influencing stress or vitality. These values were not excluded because this research aims to measure if the intervention can reduce responses to stressors, even during stressful life events.

Finally, the use of questionnaires as a measurement tool introduces self-report bias [2]. Additionally, participants might have been more aware of their stress and vitality levels in the

post-test compared to the pre-test due to the daily ESM questionnaires. This recall bias [44] could be reduced by including a non-intervention period of the same length as the intervention, prior to the pre-test.

Friends in Study Population

As pointed out by the answers in the pre- and post-test of the qualitative data, a part of the research population were friends of the researcher. This could lead to a reduction in validity and replication of the research. For example, the participant could be granting the researcher the results for the hypothesis that the WHM has an effect. Besides that, the high compliance and adherence rate might have been impacted by the fact that friends joined this research. Thus, the next research might have more difficulty with the compliance and adherence rate.

However, precautions have been taken to make sure that the participants were anonymous, thus participants less watched by the researcher. In addition, in the promotional message it was mentioned that the participants should not join for the researcher, but purely for the interest in the method or the results.

Conclusion

In conclusion, the WHM shows promise in reducing the perceived stress and increasing the subjective vitality after 15 days. Therefore suggesting its utility for students dealing with these issues and adding prove to the general potential of the WHM. In addition, ESM shows significant potential for gaining deeper insights into the WHM. This first ESM study on the WHM has identified areas for improvement, including incorporating periods of non-participation and using more complex ESM questionnaires to enhance data quality.

With its benefits demonstrated in healthy participants, future research should explore the WHM's effectiveness as an adjunct to psychotherapy. With growing evidence of the WHM's potential, this simple self-care method could be part of the solution to rising stress and decreasing vitality.

Abbreviations

ESM	Experience Sample Method
PSS	Perceived Stress Scale
SD	Standard Deviation
SNS	Sympatic Nervous System
SVSs	Subjective Vitality State
SVSt	Subjective Vitality Trait
WHM	Wim Hof Method
VIF	Variation Inflation Factors

References

[1] "A Scoping Review of the Relationship between Running and Mental Health". In: *International Journal of Environmental Research and Public Health* 17 (21 Nov. 2020), p. 8059. ISSN: 1660-4601. DOI: 10.3390/ijerph17218059.

[2] Alaa Althubaiti. "Information bias in health research: definition, pitfalls, and adjustment methods". In: *Journal of Multidisciplinary Healthcare* (May 2016), p. 211. ISSN: 1178-2390. DOI: 10.2147/JMDH.S104807.

[3] J. J. Arnett. "Emerging adulthood: A theory of development from the late teens through the twenties". In: *American Psychologist* 55.5 (2000), pp. 469–480. DOI: 10.1037/0003-066X.55.5.469.

[4] J. J. Arnett, R. Žukauskienė, and K. Sugimura. "The new life stage of emerging adulthood at ages 18–29 years: implications for mental health". In: *The Lancet Psychiatry* 1.7 (2014), pp. 569–576. DOI: 10.1016/S2215-0366(14)00080-7.

[5] A. Author. "Title of the Paper". In: *Journal Name* 10.2 (2021), pp. 123–456. DOI: 10.1234/example.doi.

[6] "Balneotherapy, Immune System, and Stress Response: A Hormetic Strategy?" In: *International Journal of Molecular Sciences* 19 (6 June 2018), p. 1687. ISSN: 1422-0067. DOI: 10.3390/ijms19061687.

[7] S. Bell and C. Lee. "Transitions in emerging adulthood and stress among young Australian women". In: *International Journal of Behavioral Medicine* 15.4 (2008), pp. 280–288. DOI: 10.1080/10705500802365482.

[8] Robert M. Berman et al. "Transient Depressive Relapse Induced by Catecholamine Depletion". In: *Archives of General Psychiatry* 56 (5 May 1999), p. 395. ISSN: 0003-990X. DOI: 10.1001/archpsyc.56.5.395.

[9] "Biological mechanisms underlying the role of physical fitness in health and resilience". In: *Interface Focus* 4 (5 Oct. 2014), p. 20140040. ISSN: 2042-8898. DOI: 10.1098/rsfs.2014.0040.

[10] Dusan Blazek et al. "Systematic review of intra-abdominal and intrathoracic pressures initiated by the Valsalva manoeuvre during high-intensity resistance exercises". In: *Biology of Sport* 36 (4 2019), pp. 373–386. ISSN: 0860-021X. DOI: 10.5114/biolsport.2019.88759.

[11] Oswald Bloemen et al. “Challenge and Therapeutic Studies Using Alpha-Methyl-para-Tyrosine (AMPT) in Neuropsychiatric Disorders: A Review”. In: *Central Nervous System Agents in Medicinal Chemistry* 8 (4 Dec. 2008), pp. 249–256. ISSN: 18715249. DOI: 10.2174/187152408786848102.

[12] Thomas J. Bostic, Doris McGartland Rubio, and Morgan Hood. “A Validation of the Subjective Vitality Scale Using Structural Equation Modeling”. In: *Social Indicators Research* 52.3 (2000), pp. 313–324. DOI: 10.1023/A:1007136110218. URL: https://doi.org/10.1023/A:1007136110218.

[13] J. Brenner et al. “Mindfulness with paced breathing reduces blood pressure”. In: *Medical Hypotheses* 142 (2020), p. 109780. DOI: 10.1016/j.mehy.2020.109780.

[14] E. I. de Bruin, R. Meppelink, and S. M. Bögels. “Mindfulness in Higher Education: Awareness and Attention in University Students Increase During and After Participation in a Mindfulness Curriculum Course”. In: *Mindfulness* 6.5 (2015), pp. 1137–1142. DOI: 10.1007/s12671-014-0364-5.

[15] WHM Services Unipessoal LDA - Innerfire BV. “Breathing Exercises”. In: ().

[16] “CBS Nederland in Cijfers$_2022UK$”. In: *CBS* (2022).

[17] S. Ceccato et al. “Social preferences under chronic stress”. In: *PLOS ONE* 13.7 (2018), e0199528. DOI: 10.1371/journal.pone.0199528.

[18] John A. Chavez and Mauro Zappaterra. “Can Wim Hof Method breathing induce conscious metabolic waste clearance of the brain?” In: *Medical Hypotheses* 177 (Aug. 2023), p. 111118. ISSN: 03069877. DOI: 10.1016/j.mehy.2023.111118.

[19] Brianna Chu et al. *Physiology, Stress Reaction*. StatPearls Publishing, Jan. 2024.

[20] Tom Citherlet et al. “Acute Effects of the Wim Hof Breathing Method on Repeated Sprint Ability: A Pilot Study”. In: *Frontiers in Sports and Active Living* 3 (Aug. 2021). ISSN: 2624-9367. DOI: 10.3389/fspor.2021.700757.

[21] S. Cohen, T. Kamarck, and R. Mermelstein. “A Global Measure of Perceived Stress”. In: *Journal of Health and Social Behavior* 24.4 (1983), p. 385. DOI: 10.2307/2136404. URL: https://doi.org/10.2307/2136404.

[22] Alexandra D Crosswell and Kimberly G Lockwood. “Best practices for stress measurement: How to measure psychological stress in health research”. In: *Health Psychology Open* 7 (2 July 2020), p. 205510292093307. ISSN: 2055-1029. DOI: 10.1177/2055102920933072.

[23] Godek D and Freeman A M. *Physiology, Diving Reflex*. StatPearls Publishing, Sept. 2022.

[24] Tom Deliens et al. “Changes in weight and body composition across five years at university: A prospective observational study”. In: *PLOS ONE* 14 (11 Nov. 2019), e0225187. ISSN: 1932-6203. DOI: 10.1371/journal.pone.0225187.

[25] Zeljko Dujic, Toni Breskovic, and Marko Ljubkovic. “Breath hold diving: In vivo model of the brain survival response in man?” In: *Medical Hypotheses* 76 (5 May 2011), pp. 737–740. ISSN: 03069877. DOI: 10.1016/j.mehy.2011.02.012.

[26] Clare M. Eglin and Michael J. Tipton. “Repeated cold showers as a method of habituating humans to the initial responses to cold water immersion”. In: *European Journal of Applied Physiology* 93 (5-6 Mar. 2005), pp. 624–629. ISSN: 1439-6319. DOI: 10.1007/s00421-004-1239-6.

[27] M. Esler et al. “CHRONIC MENTAL STRESS IS A CAUSE OF ESSENTIAL HYPERTENSION: PRESENCE OF BIOLOGICAL MARKERS OF STRESS”. In: *Clinical and Experimental Pharmacology and Physiology* 35.4 (2008), pp. 498–502. DOI: 10.1111/j.1440-1681.2008.04904.x.

[28] “Experience sampling methodology in mental health research: new insights and technical developments”. In: *World Psychiatry* 17 (2 June 2018), pp. 123–132. ISSN: 1723-8617. DOI: 10.1002/wps.20513.

[29] M. de F. Moreira, O. L. Gamboa, and M. A. P. Oliveira. “Mindfulness intervention effect on endometriosis-related pain dimensions and its mediator role on stress and vitality: a path analysis approach”. In: *Archives of Women’s Mental Health* 27.1 (2024), pp. 45–55. DOI: 10.1007/s00737-023-01381-6.

[30] F. Faul et al. “Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses”. In: *Behavior Research Methods* 41.4 (2009), pp. 1149–1160. DOI: 10.3758/BRM.41.4.1149. URL: https://doi.org/10.3758/BRM.41.4.1149.

[31] “Feasibility and Effectiveness of the Web-Based WeActive and WeMindful Interventions on Physical Activity and Psychological Well-Being”. In: *BioMed Research International* 2021 (Oct. 2021), pp. 1–11. ISSN: 2314-6141. DOI: 10.1155/2021/8400241.

[32] G. E. Foster and A. W. Sheel. “The human diving response, its function, and its control”. In: *Scandinavian Journal of Medicine Science in Sports* 15 (1 Feb. 2005), pp. 3–12. ISSN: 0905-7188. DOI: 10.1111/j.1600-0838.2005.00440.x.

[33] C. Frerk et al. “Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults”. In: *British Journal of Anaesthesia* 115 (6 Dec. 2015), pp. 827–848. ISSN: 00070912. DOI: 10.1093/bja/aev371.

[34] D. Frestad and E. Prescott. “Vital Exhaustion and Coronary Heart Disease Risk: A Systematic Review and Meta-Analysis”. In: *Psychosomatic Medicine* 79.3 (2017), pp. 260–272. DOI: 10.1097/PSY.0000000000000423.

[35] R. Graaf et al. “Comparing the effects on work performance of mental and physical disorders”. In: *Social Psychiatry and Psychiatric Epidemiology* 47.11 (2012), pp. 1873–1883. DOI: 10.1007/s00127-012-0496-7.

[36] Katie E. Gunnell et al. “Don’t be so hard on yourself! Changes in self-compassion during the first year of university are associated with changes in well-being”. In: *Personality and Individual Differences* 107 (Mar. 2017), pp. 43–48. ISSN: 01918869. DOI: 10.1016/j.paid.2016.11.032.

[37] “Heat Stress and Hormetin-Induced Hormesis in Human Cells: Effects on Aging, Wound Healing, Angiogenesis, and Differentiation”. In: *Dose-Response* 7 (1 Jan. 2009), dose–response.0. ISSN: 1559-3258. DOI: 10.2203/dose-response.08-014.Rattan.

[38] J. M. Hill et al. “Experiencing emerging adulthood in the Netherlands”. In: *Journal of Youth Studies* 18.8 (2015), pp. 1035–1056. DOI: 10.1080/13676261.2015.1020934.

[39] Wim Hof. *Wim Hof Method Activate Your Full Human Potential*. Ed. by Elissa Epel. Sounds True, Oct. 2020.

[40] Wilhelm Hofmann and Hiroki Kotabe. “A General Model of Preventive and Interventive Self-Control”. In: *Social and Personality Psychology Compass* 6 (10 Oct. 2012), pp. 707–722. ISSN: 1751-9004. DOI: 10.1111/j.1751-9004.2012.00461.x.

[41] “Hormesis can and Does Work in Humans”. In: *Dose-Response* 8 (1 Jan. 2010), dose–response.0. ISSN: 1559-3258. DOI: 10.2203/dose-response.09-041.Rattan.

[42] *Huidige studentenpopulatie en woonsituatie*. Landelijke Monitor Studenten Huisvesting, 2023.

[43] Pirkko Huttunen, Leena Kokko, and Virpi Ylijukuri. “Winter swimming improves general well-being”. In: *International Journal of Circumpolar Health* 63 (2 June 2004), pp. 140–144. ISSN: 2242-3982. DOI: 10.3402/ijch.v63i2.17700.

[44] M.E. Jacob and M. Ganguli. “Epidemiology for the clinical neurologist”. In: 2016, pp. 3–16. DOI: 10.1016/B978-0-12-802973-2.00001-X.

[45] Saladin Kenneth and Miller Leslie. *Saladin: Anatomy Physiology: The Unity of Form and Function, Third Edition Front Matter Preface How We Evaluated Your Needs*. 2003.

[46] Florence-Emilie Kinnafick et al. “Sources of autonomy support, subjective vitality and physical activity behaviour associated with participation in a lunchtime walking intervention for physically inactive adults”. In: *Psychology of Sport and Exercise* 15 (2 Mar. 2014), pp. 190–197. ISSN: 14690292. DOI: 10.1016/j.psychsport.2013.10.009.

[47] Matthijs Kox et al. “The Influence of Concentration/Meditation on Autonomic Nervous System Activity and the Innate Immune Response”. In: *Psychosomatic Medicine* 74 (5 June 2012), pp. 489–494. ISSN: 0033-3174. DOI: 10.1097/PSY.0b013e3182583c6d.

[48] Matthijs Kox et al. “Voluntary activation of the sympathetic nervous system and attenuation of the innate immune response in humans”. In: *Proceedings of the National Academy of Sciences* 111 (20 May 2014), pp. 7379–7384. ISSN: 0027-8424. DOI: 10.1073/pnas.1322174111.

[49] Maria Kozhevnikov et al. “Neurocognitive and Somatic Components of Temperature Increases during g-Tummo Meditation: Legend and Reality”. In: *PLoS ONE* 8 (3 Mar. 2013), e58244. ISSN: 1932-6203. DOI: 10.1371/journal.pone.0058244.

[50] Frank R Kruisdijk et al. “Effect of running therapy on depression (EFFORT-D). Design of a randomised controlled trial in adult patients [ISRCTN 1894]”. In: *BMC Public Health* 12 (1 Dec. 2012), p. 50. ISSN: 1471-2458. DOI: 10.1186/1471-2458-12-50.

[51] Peter Kyriakoulis et al. “The Implications of the Diving Response in Reducing Panic Symptoms”. In: *Frontiers in Psychiatry* 12 (Nov. 2021). ISSN: 1664-0640. DOI: 10.3389/fpsyt.2021.784884.

[52] E. C. P. LaVoy, B. K. McFarlin, and R. J. Simpson. “Immune Responses to Exercising in a Cold Environment”. In: *Wilderness & Environmental Medicine* 22.4 (2011), pp. 343–351. DOI: 10.1016/j.wem.2011.08.005. URL: https://doi.org/10.1016/j.wem.2011.08.005.

[53] H Lderach and W Straub. “Effects of voluntary hyperventilation on glucose, free fatty acids and several glucostatic hormones”. In: *Swiss Medical Weekly* (Jan. 2001). ISSN: 1424-3997. DOI: 10.4414/smw.2001.05735.

[54] J. Leelarungrayub et al. “Preliminary study: comparative effects of lung volume therapy between slow and fast deep-breathing techniques on pulmonary function, respiratory muscle strength, oxidative stress, cytokines, 6-minute walking distance, and quality of life in persons with COPD”. In: *International Journal of Chronic Obstructive Pulmonary Disease* 13 (2018), pp. 3909–3921. DOI: 10.2147/COPD.S181428.

[55] Peter Lindholm and Claes EG Lundgren. “The physiology and pathophysiology of human breath-hold diving”. In: *Journal of Applied Physiology* 106 (1 Jan. 2009), pp. 284–292. ISSN: 8750-7587. DOI: 10.1152/japplphysiol.90991.2008.

[56] Richard V. Lundell et al. “Diving Responses in Experienced Rebreather Divers: Short-Term Heart Rate Variability in Cold Water Diving”. In: *Frontiers in Physiology* 12 (Apr. 2021). ISSN: 1664-042X. DOI: 10.3389/fphys.2021.649319.

[57] B. S. McEwen. “Protective and Damaging Effects of Stress Mediators”. In: *New England Journal of Medicine* 338.3 (1998), pp. 171–179. DOI: 10.1056/NEJM199801153380307.

[58] D. C. McLean, J. Nakamura, and M. Csikszentmihalyi. “Explaining System Missing”. In: *Social Psychological and Personality Science* 8.4 (2017), pp. 434–441. DOI: 10.1177/1948550617708015. URL: https://doi.org/10.1177/1948550617708015.

[59] Derrick C. McLean, Jeanne Nakamura, and Mihaly Csikszentmihalyi. “Explaining System Missing”. In: *Social Psychological and Personality Science* 8 (4 May 2017), pp. 434–441. ISSN: 1948-5506. DOI: 10.1177/1948550617708015.

[60] P. Mishra et al. “Descriptive statistics and normality tests for statistical data”. In: *Annals of Cardiac Anaesthesia* 22.1 (2019), p. 67. DOI: 10.4103/aca.ACA_157_18. URL: https://doi.org/10.4103/aca.ACA_157_18.

[61] Otto Muzik et al. “The impact of a focused behavioral intervention on brain cannabinoid signaling and interoceptive function: Implications for mood and anxiety”. In: *Brain Behavior and Immunity Integrative* 5 (Jan. 2024), p. 100035. ISSN: 29498341. DOI: 10.1016/j.bbii.2023.100035.

[62] Inez Myin-Germeys and Peter Kuppens. *The open handbook of experience sampling methodology a step-by step guide to designing, conducting, and analyzing ESM studies*. ISBN: 9798417682889.

[63] Michael Noetel et al. “Effect of exercise for depression: systematic review and network meta-analysis of randomised controlled trials”. In: *BMJ* (Feb. 2024), e075847. ISSN: 1756-1833. DOI: 10.1136/bmj-2023-075847.

[64] Frank Q. Nuttall. “Body Mass Index”. In: *Nutrition Today* 50 (3 May 2015), pp. 117–128. ISSN: 0029-666X. DOI: 10.1097/NT.0000000000000092.

[65] H. E. Obaya et al. “Effect of aerobic exercise, slow deep breathing and mindfulness meditation on cortisol and glucose levels in women with type 2 diabetes mellitus: a randomized controlled trial”. In: *Frontiers in Physiology* 14 (2023). DOI: 10.3389/fphys.2023.1186546.

[66] David T Ochmann et al. “Association of Innate and Acquired Aerobic Capacity With Resilience in Healthy Adults: Protocol for a Randomized Controlled Trial of an 8-Week Web-Based Physical Exercise Intervention”. In: *JMIR Research Protocols* 10 (11 Nov. 2021), e29712. ISSN: 1929-0748. DOI: 10.2196/29712.

[67] Kumar P.R. *MULTICOLLINEARITY: CAUSES, EFFECTS AND REMEDIES*. 2014. URL: https://www.researchgate.net/publication/255640558.

[68] Valentina Perciavalle et al. “The role of deep breathing on stress”. In: *Neurological Sciences* 38 (3 Mar. 2017), pp. 451–458. ISSN: 1590-1874. DOI: 10.1007/s10072-016-2790-8.

[69] Posit Software. *RStudio Desktop*. Available at https://www.rstudio.com/products/rstudio/. 2024.

[70] John W. Pratt. “Remarks on Zeros and Ties in the Wilcoxon Signed Rank Procedures”. In: *Journal of the American Statistical Association* 54 (287 Sept. 1959), p. 655. ISSN: 01621459. DOI: 10.2307/2282543.

[71] *Prolonged whole body immersion in cold water: hormonal and metabolic changes*. 1990.

[72] Alan Rozanski et al. “The epidemiology, pathophysiology, and management of psychosocial risk factors in cardiac practice”. In: *Journal of the American College of Cardiology* 45 (5 Mar. 2005), pp. 637–651. ISSN: 07351097. DOI: 10.1016/j.jacc.2004.12.005.

[73] R. M. Ryan and C. Frederick. “On Energy, Personality, and Health: Subjective Vitality as a Dynamic Reflection of Well-Being”. In: *Journal of Personality* 65.3 (1997), pp. 529–565. DOI: 10.1111/j.1467-6494.1997.tb00326.x.

[74] S. Saikkonen et al. “Associations of social support and alexithymia with psychological distress in Finnish young adults”. In: *Scandinavian Journal of Psychology* 59.6 (2018), pp. 602–609. DOI: 10.1111/sjop.12478.

[75] Ian J. Saldanha et al. *Inclusion of Nonrandomized Studies of Interventions in Systematic Reviews of Intervention Effectiveness: An Update*. Sept. 2022. DOI: 10.23970/AHRQEPCMETHODSGUIDENRSI.

[76] Robert M. Sapolsky, L. Michael Romero, and Allan U. Munck. “How Do Glucocorticoids Influence Stress Responses? Integrating Permissive, Suppressive, Stimulatory, and Preparative Actions*”. In: *Endocrine Reviews* 21 (1 Feb. 2000), pp. 55–89. ISSN: 0163-769X. DOI: 10.1210/edrv.21.1.0389.

[77] Erika Schagatay and Boris Holm. “Effects of water and ambient air temperatures on human diving bradycardia”. In: *European Journal of Applied Physiology and Occupational Physiology* 73 (1-2 Apr. 1996), pp. 1–6. ISSN: 0301-5548. DOI: 10.1007/BF00262802.

[78] J. K. Schneider, C. Reangsing, and D. G. Willis. “Effects of Transcendental Meditation on Blood Pressure”. In: *Journal of Cardiovascular Nursing* 37.3 (2022), E11–E21. DOI: 10.1097/JCN.0000000000000849.

[79] N. Schneiderman, G. Ironson, and S. D. Siegel. “Stress and Health: Psychological, Behavioral, and Biological Determinants”. In: *Annual Review of Clinical Psychology* 1.1 (2005), pp. 607–628. DOI: 10.1146/annurev.clinpsy.1.102803.144141.

[80] Scientific Software Development GmbH. *ATLAS.ti*. Available at https://atlasti.com/?_gl=1*1c3rbdz*_up*MQ..*_ga*MTIzNTM0MzI1NS4xNzE2NDU4Njkw*_ga_K459D5HY8F*MTcxNjQ1ODY5MC4xLjEuMTcxNjQ1ODc2NC4wLjAuMA... 2024. URL: https://atlasti.com/?_gl=1*1c3rbdz*_up*MQ..*_ga*MTIzNTM0MzI1NS4xNzE2NDU4Njkw*_ga_K459D5HY8F*MTcxNjQ1ODY5MC4xLjEuMTcx..

[81] West SG, Finch JF, and Curran PJ. “Structural equation modeling: Concepts, issues and applications.” In: *Newbery Park* (1995), pp. 56–75.

[82] T. D. Shanafelt et al. “Changes in Burnout and Satisfaction With Work-Life Integration in Physicians and the General US Working Population Between 2011 and 2017”. In: *Mayo Clinic Proceedings* 94.9 (2019), pp. 1681–1694. DOI: 10.1016/j.mayocp.2018.10.023.

[83] M. Sharma and S. E. Rush. “Mindfulness-Based Stress Reduction as a Stress Management Intervention for Healthy Individuals”. In: *Journal of Evidence-Based Complementary & Alternative Medicine* 19.4 (2014), pp. 271–286. DOI: 10.1177/2156587214543143.

[84] V. K. Sharma et al. “Effect of fast and slow pranayama on perceived stress and cardiovascular parameters in young health-care students”. In: *International Journal of Yoga* 6.2 (2013), pp. 104–110. DOI: 10.4103/0973-6131.113400.

[85] P. J. Silvia et al. “Missed Beeps and Missing Data”. In: *Social Science Computer Review* 31.4 (2013), pp. 471–481. DOI: 10.1177/0894439313479902. URL: https://doi.org/10.1177/0894439313479902.

[86] Paul J. Silvia et al. “Missed Beeps and Missing Data”. In: *Social Science Computer Review* 31 (4 Aug. 2013), pp. 471–481. ISSN: 0894-4393. DOI: 10.1177/0894439313479902.

[87] “Spleen and cardiovascular function during short apneas in divers”. In: *Journal of Applied Physiology* 103 (6 Dec. 2007), pp. 1958–1963. ISSN: 8750-7587. DOI: 10.1152/japplphysiol.00182.2007.

[88] S Struijs. *De geestelijke gezondheid van studenten aan hoger onderwijsinstellingen in Nederland*. 2023.

[89] “Taking Stock of Self-Control”. In: *Personality and Social Psychology Review* 16 (1 Feb. 2012), pp. 76–99. ISSN: 1088-8683. DOI: 10.1177/1088868311418749.

[90] "The effectiveness of the Wim Hof method on cardiac autonomic function, blood pressure, arterial compliance, and different psychological parameters". In: *Scientific Reports* 13 (1 Oct. 2023), p. 17517. ISSN: 2045-2322. DOI: 10.1038/s41598-023-44902-0.

[91] "The positive effects of combined breathing techniques and cold exposure on perceived stress: a randomised trial". In: *Current Psychology* 42 (31 Nov. 2023), pp. 27058–27070. ISSN: 1046-1310. DOI: 10.1007/s12144-022-03739-y.

[92] C. S. Tintzman, T. D. Kampf, and N. A. John-Henderson. "Changes in vitality in response to acute stress: an investigation of the role of anxiety and physiological reactivity". In: *Anxiety, Stress, & Coping* 35.2 (2022), pp. 190–203. DOI: 10.1080/10615806.2021.1929935.

[93] Tereza Petraskova Touskova et al. "A novel Wim Hof psychophysiological training program to reduce stress responses during an Antarctic expedition". In: *Journal of International Medical Research* 50 (4 Apr. 2022), p. 030006052210898. ISSN: 0300-0605. DOI: 10.1177/03000605221089883.

[94] Scott Townsend and Oleg N. Medvedev. "Perceived Stress Scale (PSS)". In: Springer International Publishing, 2022, pp. 1–13. DOI: 10.1007/978-3-030-77644-2_91-1.

[95] P. D. Trapnell and J. D. Campbell. "Private self-consciousness and the five-factor model of personality: Distinguishing rumination from reflection". In: *Journal of Personality and Social Psychology* 76.2 (1999), pp. 284–304. DOI: 10.1037/0022-3514.76.2.284.

[96] University of Twente. *Test Subject Arrangement*. University document. 2024.

[97] N Verhoeff. "A Simple Method to Measure Baseline Occupancy of Neostriatal Dopamine D2 Receptors by Dopamine In Vivo in Healthy Subjects". In: *Neuropsychopharmacology* 25 (2 Aug. 2001), pp. 213–223. ISSN: 0893133X. DOI: 10.1016/S0893-133X(01)00231-7.

[98] Josine E. Verhoeven et al. "Antidepressants or running therapy: Comparing effects on mental and physical health in patients with depression and anxiety disorders". In: *Journal of Affective Disorders* 329 (May 2023), pp. 19–29. ISSN: 01650327. DOI: 10.1016/j.jad.2023.02.064.

[99] Vitens. *Waterkwaliteit*. Online resource. n.d. URL: https://www.vitens.nl/over-vitens/waterkwaliteit.

[100] Marie-Theres Wehming. "Een onderzoek naar de psychometrische eigenschappen van de Subjective Vitality Scale". In: (June 2016).

[101] S Lloyd Williams and Philip J Kinney. *Performance and Nonperformance Strategies for Coping with Acute Pain: The Role of Perceived Self-Efficacy, Expected Outcomes, and Attention 1*. 1991.

[102] *Wim Hof Method benefits*. 2024.

[103] "World Medical Association Declaration of Helsinki". In: *JAMA* 310 (20 Nov. 2013), p. 2191. ISSN: 0098-7484. DOI: 10.1001/jama.2013.281053.

[104] Jelle Zwaag et al. "The Effects of Cold Exposure Training and a Breathing Exercise on the Inflammatory Response in Humans: A Pilot Study". In: *Psychosomatic Medicine* 84 (4 May 2022), pp. 457–467. ISSN: 1534-7796. DOI: 10.1097/PSY.0000000000001065.

Appendix

Informed consent file for participant

Effects of Wim Hof Breathing Techniques and Cold Exposure on Perceived Stress and Vitality Levels

Stress levels are on the rise, and vitality is decreasing, especially among emerging adults or university students. The Wim Hof Method (WHM) might offer a solution to regulate these issues. This study aims to evaluate the effectiveness of the WHM on the stress and vitality levels of students aged between 18 and 29.

Study Procedures

You will be asked to attend a workshop from 12:30 till 13:45 on either May 7th or May 8th, based on your preference. After that, for the 15 days, you're supposed to do a daily 15-minute breathing exercise and end your warm shower with a cold shower everyday. Additionally, you are asked to complete a pretest questionnaire after the workshop, a short 5-question daily questionnaire for 15 days, and a posttest questionnaire after the intervention period on day 16. Questionnaires will be accessible each day from 4:00 PM to 6:00 PM, submitting after the deadline is not possible. Each breathing exercise session will last approximately 15 minutes, completing the pre- post-test questionnaires will take about 10 minutes, and the daily questionnaire will take less than 5 minutes.

Inclusion and exclusion criteria

The inclusion criteria are: between 18 and 29 years old, a student or scholar, able to read and understand English, not having prior experience with fast deep breathing exercises or cold exposure, and being able to physically join the Workshop at the university of Twente on the 7th or 8th of may. The exclusion criteria consist of physical diseases (Asthma, Autoimmune disease, Cold urticaria, Coronary heart disease, Epilepsy, Heart failure, Hypertension, Intake of ACE inhibitors, Intake of beta blockers, Kidney failure, Migraines, Pregnancy, Recent surgery, Raynaud's Syndrome Type II, Stroke, Type 1 diabetes). In addition, you will be excluded when you are diagnosed with a mental illness.

Risks and Discomforts

You may experience dizziness and tingling during the breathing exercises due to controlled hyperventilation inherent in the WHM. Those with physical health issues will be excluded from the research. It is advised to perform the breathing exercises only while sitting or lying down. This is done out of precaution, because there is a small risk of passing out doing more excessive

versions of the exercise. Do not perform the exercise while driving, swimming or any other activity that requires your attention.

Benefits

Although the WHM claims that it has a lot of benefits, scientific evidence still is needed to verify this. This research aims to investigate its effectiveness on vitality and stress levels. Studies have shown that the WHM enhances the immune system.

Confidentiality, withdrawal and compensation

You use a nickname during the research to remain anonymous. Participation is entirely voluntary, and you can withdraw from the study at any time without penalty. Don't join the study just because you feel pressured by the researcher. Make sure you have your own reasons for participating. As a small reward, you are able to join a WHM workshop led by a certified WHM instructor.

Contact Information:

You will receive a confirmation of participation on the 29th of april. For any questions or concerns regarding the study, please contact me at r.h.m.woortmeijer@student.utwente.nl.

Consent Statement:

By signing this form, I confirm that I have read and understood the information provided about the study. I have had the opportunity to ask questions, and all my questions have been answered to my satisfaction. I agree to participate in this research under the conditions described above.

Participant's Signature and Date

Researcher's Signature and Date 7-5-2024

Health Declaration Form

Name: .....

Male / Female

Date of Birth: . . . . / . . . . . / . . . .

Address.....

Postal Code: .....

City: .....

(Mobile) Phone .....

Email: .....

Questions regarding your general health ———————————- Yes No

Are you currently healthy?

Have you had any of the following conditions:

Cardiovascular disease?

High blood pressure?

Epilepsy?

Kidney failure?

Severe asthma?

Recent surgery?

Migraine?

Burnout?

Autoimmune disease? (such as rheumatism, MS, Crohn's, diabetes, asthma) If yes, which?

.....

• Other, including mental disorders

.....

Are you currently using:

• Heart medication

• Other medication, which?

.....

Are you allergic to certain substances? (food/environment etc.)

.....

Are you pregnant or do you want to become pregnant?

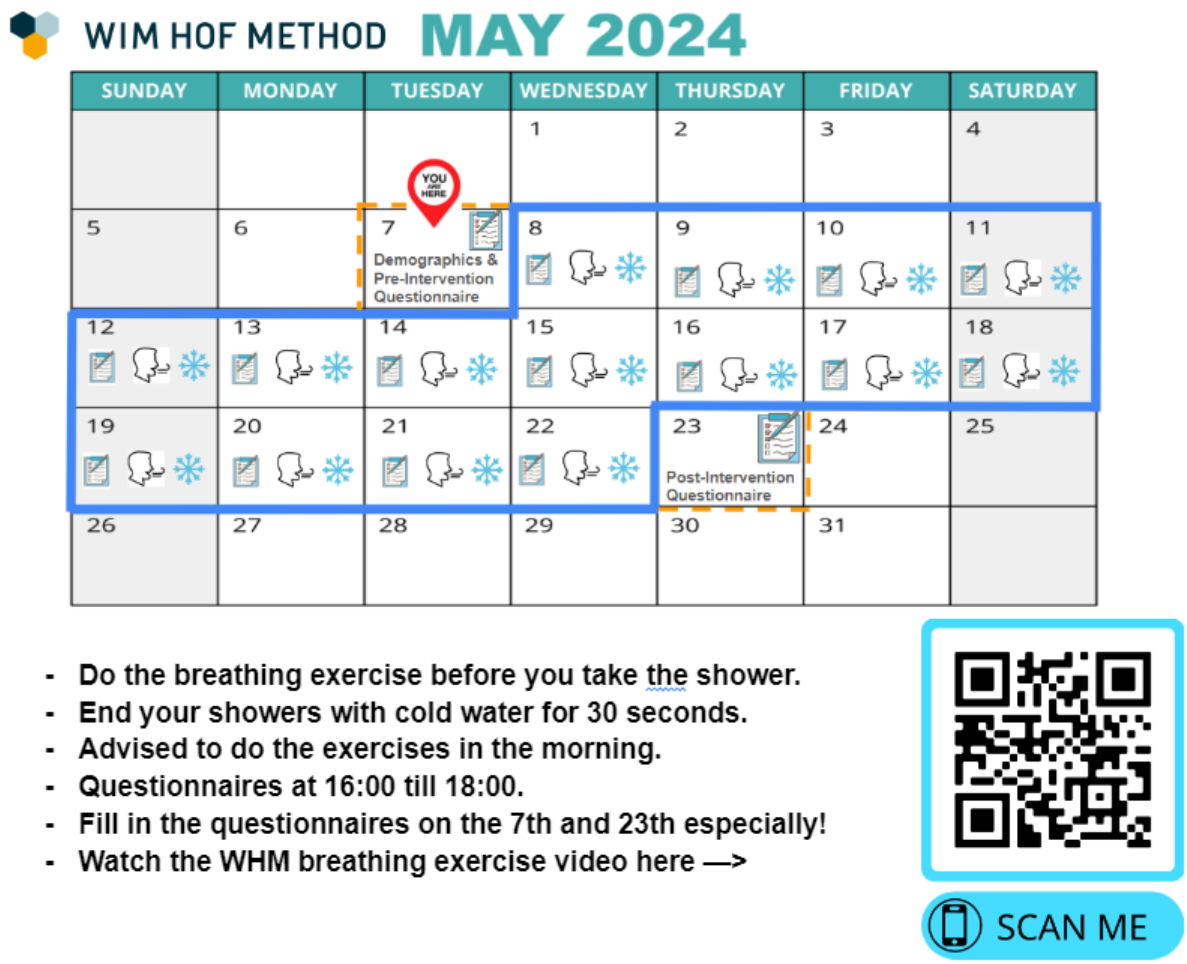
Is there anything else your instructor should know?

.....

I hereby declare that I have filled in this form truthfully

Date: . . . . . ./ . . . . . / ..... Signature of participant:

Informational flyer to take home



Outliers ESM data

width=

P_ID	Date/time	Breathing	Shower	Stress	Vitality	Mindset	Open question
2	5/8/2024	yes	yes	4	3	4	Stressful project meeting
2	5/9/2024	yes	yes	2	4	4	no
2	5/10/2024	yes	yes	3	3	4	no
2	5/11/2024	yes	yes	1	4	2	no
2	5/12/2024	no	yes	1	3	5	no
2	5/13/2024	yes	yes	2	5	5	no
2	5/14/2024	yes	yes	3	5	2	no
2	5/15/2024	yes	yes	1	5	6	no
2	5/16/2024	yes	yes	4	2	1	no
2	5/17/2024	yes	yes	5	3	6	no
2	5/18/2024	yes	yes	1	5	5	no
2	5/19/2024	yes	yes	2	4	3	no
2	5/20/2024	yes	yes	2	4	6	no
2	5/21/2024	yes	yes	3	4	5	no
2	5/22/2024	yes	yes	3	4	4	no
4	5/8/2024	yes	yes	2	3	6	no
4	5/9/2024	yes	yes	3	3	4	no
4	5/10/2024	yes	yes	1	4	6	no
4	5/11/2024	yes	yes	0	6	6	no
4	5/12/2024	no	yes	1	2	6	no
4	5/13/2024	no	yes	0	5	6	no
4	5/14/2024	yes	yes	0	6	6	no
4	5/15/2024	yes	yes	1	1	6	no
4	5/16/2024	yes	yes	0	5	6	no
4	5/17/2024	yes	yes	3	6	6	no
4	5/18/2024	no	yes	1	5	6	no
4	5/19/2024	yes	no	0	6	6	no
4	5/20/2024	yes	yes	1	5	6	no
4	5/21/2024	yes	yes	1	6	6	no
4	5/22/2024	no	yes	1	5	6	no

width=

P_ID	Date/time	Breathing	Shower	Stress	Vitality	Mindset	Open question
12	5/8/2024	yes	yes	2	3	4	No
12	5/9/2024	yes	yes	5	3	4	no
12	5/10/2024	yes	yes	1	4	4	no
12	5/11/2024	yes	yes	1	4	4	no
12	5/12/2024	yes	no	2	4	3	no time for the cold shower unfortunately
12	5/13/2024	yes	yes	2	1	4	no
12	5/14/2024	yes	yes	3	2	4	no
12	5/15/2024	no	yes	3	3	4	no time for the breathing
12	5/17/2024	yes	yes	2	2	3	no
12	5/18/2024	yes	yes	2	1	4	no
12	5/19/2024	no	no	2	2	3	no
12	5/21/2024	no	yes	2	3	4	no
12	5/22/2024	no	yes	3	4	4	no
14	5/8/2024	yes	yes	3	3	4	No just a regular week day
14	5/9/2024	yes	yes	0	0	3	i was insanely hungover puking the entire morning so that explains my vitality
14	5/10/2024	yes	yes	0	3	6	im on holiday
14	5/11/2024	yes	yes	0	3	6	a bit hungover and still on holiday
14	5/12/2024	yes	yes	0	1	6	the cold shower was in the sea and im insanely hungover again
14	5/13/2024	no	no	0	4	3	still on holiday but had a headache so wasn't feeling like doing the exercise
14	5/14/2024	yes	yes	0	3	6	last day on vacation
14	5/15/2024	yes	yes	4	2	6	no
14	5/16/2024	yes	yes	6	3	6	exam tomorrow
14	5/17/2024	yes	yes	3	3	6	had the exam did not go so well

width=

P_ID	Date/time	Breathing	Shower	Stress	Vitality	Mindset	Open question
14	5/18/2024	yes	yes	1	2	6	hungover
14	5/19/2024	yes	yes	3	3	6	no
14	5/20/2024	yes	yes	2	4	6	NK klonkiebal
14	5/21/2024	yes	yes	4	3	6	no
14	5/22/2024	yes	yes	3	3	6	no
16	5/8/2024	yes	yes	0	5	6	Nee
16	5/9/2024	no	no	0	6	5	Lange dag weg, dus geen tijd gehad om de oefeningen te doen
16	5/10/2024	yes	yes	0	4	6	Nee
16	5/11/2024	yes	yes	0	5	5	lekker weer
16	5/13/2024	no	yes	0	4	5	no
16	5/15/2024	yes	yes	0	5	6	no
24	5/9/2024	yes	yes	1	4	4	i was hungover, which was a factor in my mood before and after showering
24	5/11/2024	yes	yes	3	4	3	i am traveling, which is a reason I am a bit more stressful
24	5/12/2024	yes	yes	2	6	3	I had a sports game that I won, which might influence my answers to these questions
24	5/13/2024	yes	yes	4	4	2	I had a long day today. So feel a bit tired
24	5/14/2024	yes	yes	4	4	5	-
24	5/15/2024	yes	yes	2	5	4	-
24	5/16/2024	yes	yes	5	4	5	Busy day today
24	5/18/2024	yes	no	0	4	3	no
24	5/19/2024	yes	yes	0	5	5	-
24	5/22/2024	yes	yes	2	5	3	Today was a good day
24	5/23/2024	yes	yes	2	6	2	-