The Effect of Psychoeducation and Athleticism on the Use of 'Stress' Wearables

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Abstract

Wearables are becoming increasingly popular although many lack sufficient knowledge to interpret the output meaningfully. Although utilised to monitor activity levels, sleep patterns, or even stress, such insufficient knowledge can turn them into stressors, causing adverse effects. Users are mostly unaware of these effects, which is why, for many—especially non-professional athletes—wearables have become integral to their daily routine by measuring performance and recovery. However, as athletes are focused on rigorously measuring their activity, they typically possess sufficient knowledge to do this efficiently which makes them more resilient to the adverse effects. Literature suggests that minimising this discrepancy in knowledge about wearables by offering psychoeducation allows for a more nuanced understanding of the wearable output and, hence, can decrease the adverse effects such as heightened stress. To explore this dynamic, the current study investigated whether psychoeducation predicts lower subjective stress levels. Moreover, since athletes are familiar with wearables and typically possess larger prior knowledge about how their measures are derived than laypeople do, they are better able to make considerate and useful assessments of the information, minimizing adverse effects. For the purpose of this study, athletes were defined as physically active individuals who do not receive rewards for their activity and are differentiated based on their levels of athleticism. This prior knowledge indicates that higher levels of athleticism suggest larger prior knowledge and hence demand less psychoeducation to reduce the adverse effects. To investigate this influence, the current study inspected how a person's level of athleticism influences the relationship between psychoeducation and subjective stress levels. The psychoeducation included explanations about the wearables' measures including HRV, PPG, and stress itself. To analyse these relationships, a sample of 34 people with different levels of athleticism wore a wearable measuring stress for 24 hours and afterwards participated in an online survey regarding their stress experiences. In contrast to suggestions from previous literature, no significant relationship was found between psychoeducation and subjective stress levels. Also, no significant moderator effect was found for athleticism in the relationship between psychoeducation and subjective stress level. This indicates that psychoeducation might not have the desired effect and that wearables were not a stressor for this sample. On the other hand, studies that found significant effects collected data over several months and included samples that clearly differed in levels of athleticism. Future research should therefore employ a more diverse sample and collect data over a longer period of time.

Contents

The Effect of Psychoeducation and Athleticism on the Use of 'Stress' Wearables

In today's fast-paced society, stress has become a constant companion for millions of individuals worldwide. To monitor stress and other bodily functions, many people have begun to implement wearables into their daily lives. Such wearables are especially interesting for athletes as they are often more focused on measuring the body compared to laypeople (Lee et al., 2017). Because athletes of all levels can improve their training and decrease the risks of associated heart diseases caused by overtraining, using such devices to measure stress is valuable (Curfman, 1993). Given that non-professional athletes depend on wearable technology to monitor their training and constitute the majority of athletes using such devices, this study defines athletes as individuals who are physically active in their daily lives but are non-professional and do not engage in their activities for monetary compensation. Further, levels of athleticism are used to differentiate between athletes and non-athletes in terms of this definition.

Although many possess a negative connotation of stress, stress in itself is not problematic. Having manageable amounts of stress, defined as physiological reactions to a stressor, can also have a positive effect on the individual if these are appraised positively (Carroll et al., 2009). Such "positive" stress can increase athletes' and laypeople's performance and resilience as well as help people stay motivated during activity (Aschbacher et al., 2013). However, if these stressors are negatively appraised, "negative" stress can not only become a mental health issue itself but can also act as a precursor of many other major psychiatric conditions such as anxiety or depression (Epel et al., 2018; Ciccarelli & White, 2021). Moreover, such "negative" stress can further increase the already heightened risk of cardiovascular disease among athletes (Epel et al., 2018; Harmon, 2022). Because it has been proven that the initial positive effects of stress can become negative if one experiences prolonged, chronic stress, it is of utmost importance to effectively cope with stressors in a healthy way and to be able to recover from severe stress responses (Ferrari et al., 2020). This is especially important as adverse effects can already be experienced within a couple of minutes and, thus, are not limited to prolonged use (Etkin, 2016). Hence, although stress in itself is not problematic, effective management is key,

To help monitor their stress levels, athletes and lay people make use of stress-tracking wearables. With the aid of such wearables, they hope to decrease the negative effects of stress and benefit from the positive ones (González Ramírez et al., 2023). However, it was found that solely using stress wearables does not have the desired effects. Many laypeople lack the knowledge to meaningfully interpret the output that causes stress instead of regulating it (Rieder et al., 2020). However, Millings et al. (2015) found that simple psychoeducation about stress can already decrease the potential adverse effects of wearables, including reduced stress. This could then lead to a more meaningful interpretation and an overall more beneficial use of the wearable. This might be less applicable to athletes as they often possess the necessary knowledge about wearables before using such devices (Chang et al., 2020). Hence, although athletes and laypeople implement wearables, their use and knowledge differ.

To foster a better understanding of the possible influence of such wearables, the current study focuses on whether simple psychoeducation about stress and the wearables' stress measures can decrease the subjective stress levels of users. Additionally, it inspects whether athleticism predicts lower stress levels, influencing the relationship between psychoeducation and stress.

Stress and Heart Rate Variability

Stress is a complex topic with various definitions which must be clarified to provide specific and effective analysis and psychoeducation. Despite the numerous definitions, it is important to attempt to decide on one common definition to focus on when working with stress wearables. One promising definition that is relevant to the current research comes from Epel et al. (2018) and their differentiation between acute and chronic stress. Acute stress is a response to specific events with a clear beginning and end point such as job interviews or first dates. Chronic stress on the other hand occurs over a longer time, with the potential to last for weeks, months or years (Mariotti, 2015). Hence, the distinction lies in the accumulation and duration of stress over time, with acute stress being short-term and chronic stress persisting over an extended period (Epel et al., 2018). Further, they clarify that stress is a combination of interactions between several factors including psychological and physiological reactivity. People's cognitive appraisals of each of those factors influence their psychological and physiological responses to events that could be stressful. If an individual appraises an event as unpredictable, uncontrollable, or threatening within the context of the aforementioned factors, it becomes a stressor, leading to the experience of stress (Chu et al., 2022). This experienced stress is defined as the stress response. When the stress response is triggered by events with a clear beginning and end, it is categorised as acute stress (Epel et al., 2018). The stress response includes measurable physical reactions (Chu et al., 2022). Since our experiment measures stress using wearables over the course of one day, the focus is on acute stress. This acute stress arises from the stress response detected by the wearable, which may be a potential stressor itself.

Although there are various forms of stress, a wearable can only measure physiological and not psychological stress. Although the definition of acute stress encompasses both physiological and psychological components, it is crucial to differentiate between them for the scope of the current research. As the current study aims to investigate whether psychoeducation decreases heightened stress caused by wearables, it focuses on the wearable's measures, which are derived from physiological stress responses (Sandulescu et al., 2015). Consequently, concentrating solely on physiological stress helps to provide accurate psychoeducation, which is expected to mitigate the adverse effects of wearables arising from a lack of knowledge about the device's measurements. When individuals experience stress the body experiences a variety of physiological stress responses caused by heightened autonomic nervous system activity (Geus & Gevonden, 2024). These physiological responses might not be consciously experienced by the individual but are present, nonetheless. These stress responses are, for example, stronger heart muscle contractions and increased heart rate and blood pressure, caused by heightened autonomic nervous system response, specifically the domination of sympathetic nervous system activity (Chu et al., 2022). On the other hand, when a person is resting, the parasympathetic part of the automatic nervous system becomes more dominant, leading to lower heart rates and blood pressure, indicating recovery (Chu et al., 2022). These physical symptoms can be used to measure the physiological stress response via wearables. Important for such measurements are heart rate (HR) and heart rate variability (HRV). Heart rate (HR) indicates the heart beats per minute and allows for insights into sympathetic nervous system activity (Quer et al., 2020). HRV, on the other hand, measures the interval variability between consecutive heartbeats and quantifies this variability, allowing for insights into the balance between the two branches of the autonomic nervous system. More specifically, HRV is the change in the time between heartbeats that happens during breathing, caused by the modulation of vagal nerve activity by the respiratory cycle. This allows monitoring of the dynamic between the sympathetic and parasympathetic nervous systems (Geus & Gevonden, 2024). Because HRV reflects the balance between the two branches of the autonomic nervous system, it provides a comprehensive view of the body's ability to respond to and recover from stress, making it an effective measurement of bodily stress (Geus & Gevoden, 2024).

Despite common perception, more extreme high HRV parameters are not indicative of better adaptability and regulation but can be associated with mental illness (Heiss et al., 2021). Moreover, Heiss et al. (2021) suggest that an ideal HRV range lies in the middle between high and low HRV parameters, highlighting the importance of balance between the two branches of the autonomic nervous system. Hence, wearables retrieve their measurement from bodily stress responses, limiting the stress feedback to physiological stress.

Stress Tracking Wearables

Stress-tracking wearables allow for personal insights into biometrics such as HR, and HRV as well as into stress and other bodily functions. Through these insights, wearable users can monitor their stress levels, identify high-stress situations and develop strategies to effectively manage them. However, these stress measures are based on bodily functions and not mental states, hence giving only insight into bodily stress reactions and not mental stress (Sandulescu et al., 2015). Stress wearables construct their stress measures based on HR and HRV measures. As aforementioned, both measures are valuable in gaining insights about stress as higher HR and HRV indicate heightened heartbeat and heightened autonomic nervous system activity, respectively, which are physical stress responses.

Wrist-worn wearables provide insights into HR and HRV through Photoplethysmography (PPG). PPG uses light to detect the blood volume in the blood vessels at the wrist (Morelli et al., 2018). Although many commercially available wearables employ such PPG sensors to measure HR and HRV this measure is not as reliable as the sensors used in research laboratories which should be preferred when investigating the measures themselves (Van Lier et al., 2020). Nevertheless, despite the lowered accuracy, athletes and lay people implement these commercial wrist-worn wearables with PPG sensors in their routines as they are more affordable, available, and intuitive, and therefore more convenient (Georgiou et al., 2018). Because such commercially available variables provide stress monitoring and management in people’s daily lives and we are specifically interested in how people perceive this category of technology, the current study focuses on the effects of wrist-worn wearables on the user’s stress levels. Still, although stress wearables offer insight into bodily reactions these should be interpreted deliberately.

Effects of Wearables on Users

Although wearables are an integral part of many athlete’s and laypeople’s daily lives, they can have undesired effects. Aiming to gain insights into their physical activity, many laypeople and athletes implement wearables capable of tracking HR and HRV in their training and daily routines. Such wearables can help manage chronic diseases, increase physical activity, aid in rehabilitation, enhance the quality of life, and measure stress (Dian et al., 2020; Ferguson et al., 2022). Despite the various benefits of wearable use, researchers have found that wearable use can increase stress and that many users do not have enough insights into wearable data to interpret the output meaningfully (Rieder et al., 2020). These adverse effects become particularly important when wanting to monitor and manage stress, as they can increase instead of help manage it. Rieder et al. (2020) found a lack of insight to be a possible source of users experiencing more subjective stress after receiving stress feedback from their wearable. This was caused by over-dependence and discrepancies between users' experience and the data provided by the wearable. Further, Nelson et al. (2020) found, that wearable users experience technology embodiment and face a dilemma when their self-perception does not align with the data provided by the wearable. This discrepancy was found to cause pressure on individuals to reach their goals and fear of not meeting those expectations. Although their study investigated wearables providing physical activity feedback, the findings regarding embodiment suggest that such adverse effects could apply to stress tracking. Additionally, Rieder et al. (2020) found that when users were trying to control their behaviour, the experienced stressors were related to the wearable's technical properties. They suggest that when individuals seek validation from wearable data, discrepancies between data and expectations give rise to stress and other negative emotions (Rieder et al., 2020). Hence, although many studies focus on physical activity feedback rather than stress, these studies suggest that despite wearables' potential to track and manage stress, they can become stressors themselves.

Such an effect also exists between lack of knowledge and wearable interaction. Ding et al. (2021) found that a lack of immediate awareness of certain wearable features as well as a lack of pre-required knowledge about how the wearable measures certain data caused confusion and stress for users. In addition to these adverse effects, lacking education about the wearable's features and provided biophysical data hindered users from utilising the wearable's full potential. Moreover, when focusing specifically on stress feedback they found a discrepancy between the user's perception of stress and the wearable's actual stress measurements: Users perceived the provided stress feedback to be of psychological notion although the data provided by the wearable was gathered based on physiological stress responses (Ding et al., 2021). On the opposite, Ding et al. (2021) found that being aware of all functions can also have adverse effects as it can lead to feeling overwhelmed and in turn result in disengagement with the wearable. Although this disengagement helps with feeling overwhelmed, the anticipated positive effects of self-tracking wearables are lost. Focusing on those functions relevant to personal goals helps users engage with the wearable in a more informed and enjoyable manner and prevents them from feeling overwhelmed. Concludingly, a lack of knowledge as well as overwhelming knowledge about the wearable's functions can increase stress caused by wearables.

Moreover, wearables can decrease the enjoyability of a previously enjoyed activity. Although the effectiveness of wearables for increasing activity has been proven, they can have undesired side effects (Ferguson, et al. 2022). Etkin (2016) found that directing the focus during an activity on a wearable's output can make it feel like work. This in turn results in users enjoying the activity less than they did before using a wearable (Etkin, 2016). Hence, employing self-tracking wearables can undermine intrinsic motivation and decrease enjoyment of a previously enjoyable activity, turning it into labour.

Wearable Use and Athletes

For most athletes, wearables are an important measure integrated into their training. Through this extensive use, they possess more knowledge about the wearable's biometric data than laypeople, suggesting the aforementioned adverse effects might be less common. Whether it is a professional or amateur athlete, the majority use a wearable to make their training more effective and monitor their vitals throughout the day. The widespread adoption is exemplified by Ng and Ryba (2018), who found that 65.2% of college athletes aspiring to become professionals use fitness trackers. Fitness trackers using variables like HRV are popular among athletes due to HRV's role in optimising training (Rao et al., 2021). Further, as less professional athletes do not employ a team of experts monitoring their vitals and training, such wearables allow them to gain more detailed insights into their physical activity which would not be possible without wearables (Karahanoglu et al., 2021). Ambitious athletes might experience the adverse effects less prominently due to their detailed training and knowledge of their body's physiology (Chang et al., 2020). Hence, since athletes maintain a more extensive knowledge about wearables than laypeople, they possess a buffer against possible undesired effects.

Moreover, athletes employ wearables to make their training more efficient through monitoring their physical activity, performance and recovery. Further, managing stress levels is especially interesting for athletes as sudden cardiac arrest (SCA) caused by prolonged stress and overtraining is one of the leading causes of death among them (Harmon, 2022; Mittleman et al., 1993). As discussed in previous sections, wearable use not only aids in managing stress but can also become a stressor itself. Having sufficient knowledge about the wearables and their data is mandatory for athletes to effectively monitor stress and performance, and decrease adverse effects. Professional athletes benefit from having a large team of experts around them, making them better able to interpret the wearable output and take advantage of its benefits while being resilient against adverse effects (Luczak et al., 2019). However, professional athletes make up only a small amount of the athletes implementing wearables into their training, making it important to consider the majority who are non-professional athletes and the focus of the study. Despite the lack of an extensive team, non-professional athletes with high enthusiasm for their sport might also benefit over those with low enthusiasm. They have been found to focus on understanding their wearables output to reach the full benefits of incorporating it into their training, suggesting that they are more resilient to the adverse effects of wearables (Karahanoglu et al., 2021). However, even ambitious athletes could potentially experience adverse effects in their daily lives if they do not possess sufficient knowledge. Less enthusiastic athletes, for example, do not have this level of support or enthusiasm for measuring their physical activity extensively and therefore are at risk of experiencing the same adverse effects as laypeople who have not received sufficient psychoeducation. Moreover, as tracking can cause enjoyable activity to feel like work such knowledge is also vital to keeping the training enjoyable, as a lack of enjoyment can decrease an athlete’s performance (Jetzke & Mutz, 2019). Hence, to provide effective potential psychoeducation for athletes, their prior knowledge has to be considered.

Psychoeducation

Psychoeducation helps decrease the adverse effects of wearables caused by a lack of knowledge. Despite the various adverse effects of stress and activity measuring wearables, Millings et al, (2015) suggest that simple psychoeducation can already aid in reducing them. To investigate the suggestions from the previous paragraphs regarding a decrease in adverse effects, the psychoeducation aimed at increasing users’ knowledge about various aspects of wearables and their stress-measuring capabilities. This approach to psychoeducation addresses the lack of knowledge, which was identified as the primary cause of adverse effects (Rieder et al., 2020). A key component of this psychoeducation was an explanation of stress according to the previous definition (Epel et al., 2018; Mariotti, 2015; Chu et al., 2022). This was expected to equip the user with the necessary knowledge to interpret the wearable output meaningfully as they can distinguish between physiological and psychological stress, with the former being the source of the wearable measurements (Sandulescu et al., 2015). This was extended by providing insights into HRV and its relevance to wearable measurements. These insights help users differentiate between physiological and psychological stress, thereby enabling a more detailed understanding of the data provided by wearables (Sandulescu et al., 2015). Finally, as such wrist-worn wearables derive their measurements through PPG-Sensors which are less reliable than laboratory HR and HRV measures, users must be educated about the potential for errors (Van Lier et al., 2020). Hence, to support a reduction of adverse effects, the psychoeducation further includes information about the potential for errors in PPG-Sensor's measurements.

The mentioned studies concerning athletes, however, focus on knowledge and effects of physical activity tracking through wearables and not on stress feedback connected to psychoeducation, which is the focus of the current study. As this is a novel area of research and one of the first to examine the influence of athleticism on wearable knowledge (psychoeducation) in relation to stress, there is a lack of comparable relevant studies. Still, the results of these previous studies and those about non-athletes suggest that this influence of different levels of athleticism on athletes' knowledge might be transferable to stress wearables (Chang et al., 2020; Rieder et al., 2020). Hence, it is of great importance to gain insight into how different levels of athleticism among non-professionals influence the subjective stress levels of users and therefore to understand the amount of knowledge users have about HRV and Stress. To do this effectively, the current study used a form of psychoeducation where the participants were educated about the previously discussed parameters. This is vital in reaching the full benefits of wearable use for athletes of different levels of athleticism and determining the scope of potential future psychoeducation.

Purpose of the Current Study

Having identified that despite its benefits, wearables can have adverse effects such as causing stress instead of helping to manage it the importance of sufficient knowledge becomes evident. Moreover, it was identified that the extent of these adverse effects might be less severe for people with higher levels of athleticism. Therefore, the current study empirically investigates whether psychoeducation decreases the subjective stress levels of stress-wearable users and whether higher levels of athleticism predict decreased subjective stress levels. To investigate this, two research questions were posed: "Does psychoeducation about HRV and Stress decrease the user's subjective stress levels ?" and "Does athleticism moderate the relationship between psychoeducation and stress, with higher levels of athleticism predicting lower subjective stress levels from wearables?".

Method

Participants

Before any data was collected, the study received ethical approval from the ethics committee of the University of Twente (number 240151 approved on 22.02.2024). Afterwards, participants were approached through the social network of the researchers. The two research questions being investigated, made use of the same sample which included both the control and the psychoeducation group. The sample consisted of 34 participants, 10 male and 24 female, with an age range from 18 to 77 (mean age = 37.94, and SD = 17.86). Five of the 34 participants were already using a wearable before data collection. The control and the psychoeducation group consisted of 17 participants with equal distribution of gender in both groups (5 male and 12 female). Distribution over the two groups was done so on a convenience basis. As the participants were recruited from the social network of the researchers, general demographic data on age, gender, nationality, and educational level were previously known. As there are potential other moderators next to athleticism for the relationship between psychoeducation and stress, the strategical allocation of participants over the two groups was vital. Therefore, participants were allocated to the two groups with the aim of achieving equal distribution of age, gender, and educational level across both groups. Inclusion criteria were being fluent in either English or German. No previous wearable use and no demographic exclusion criteria were relevant to investigate the research questions. Participants were included in the dataset when all questions were answered and could be connected to a signed informed consent and debriefing. Data was collected by sending the informed consent and exit survey via phone or email to the participants. The researcher was present while participants filled out the informed consent to ensure understanding, as well as for delivering the wearable, giving instructions or psychoeducation and picking up the wearable. The exit survey, however, was filled out by the participant without a researcher being present to ensure answers that were as unbiased as possible. No payments or other agreements than those described in the procedure were necessary.

Materials and Measures

Materials

All participants filled out an informed consent form before partaking in the study (See Appendix A). The materials of the study entailed a wearable, either Garmin Forerunner 255 or Garmin Vivosmart 4, a psychoeducation or instruction sheet and the Qualtrics website.

These wearables were chosen as they provide stress feedback based on HR as well as HRV and are commercially available. An associated IOS and Android application exists for both wearables, however, as stress scores can be derived directly from the wearables' interface, this application was not employed. Furthermore, a psychoeducation sheet was prepared for the psychoeducation group. The psychoeducation included information about stress, HRV, PPG, and the wearables stress output in addition to the instructions relevant for both groups (for psychoeducation see Appendix B). The exit questionnaire constructed in Qualtrics investigates demographics, subjective stress level and athleticism. All materials were made available in English or German, according to the participant's preferred language of communication.

Measures

To investigate participants' subjective stress levels and athleticism, the following questionnaires were used: Perceived Stress Scale 10 (PSS-10), and physical self-description questionnaire (PSDQ-S). All materials were made available in English and German. For the PSS-10, a German version was previously accessible. The German version of the PSDQ-S, however, could not be accessed. Therefore, it was translated using the Duden and Brockhaus (comprehensive dictionary and encyclopaedia) as well as with the help of native speakers. This was done so to ensure adequate translation of word meaning. In addition to the previous sources, ChatGPT was used to brainstorm alternative variants which were then compared to the previous translation. Ultimately, the native speaker decided upon a translation which is closest to the original word meaning, striving for content equivalence quality (for translation see Appendix C).

Perceived Stress Scale 10

The Perceived Stress Scale 10 (PSS-10) was used to assess participants' subjective stress levels after they had worn the wearable (Cohen et al., 1983). The PSS-10 includes 10 items inquiring about the participant's feelings and thoughts during the last month. Although the PSS-10 measures stress on a time frame of the past month, studies suggest that adapting the time frame to focus on shorter or momentary timeframes is feasible and promises similar results (Harris et al., 2023; Murray et al., 2023). Therefore, to fit the scope of the current experiment, the time frame of "during the last month" was changed to "during the last day". Participants ranked their agreement (e.g." In the last day, how often have you felt nervous and "stressed"?") on a 4-point Likert Scale from zero ("Never") to four ("very often"). The PSS-10 showed acceptable internal consistency ($\alpha > .70$).

Physical Self-Description Questionnaire-Short Form

The short form of the Physical Self-Description Questionnaire (PSDQ-S) was used to assess participants' level of athleticism (Marsh et al., 2010). As the entire questionnaire focuses on physical self-description, this study only made use of the sport (4 items) and the activity scale (4 items) from the PSDQ-S. On a 6-point Likert Scale from one ("False") to six ("True"), participants rated how correct an item is about them (e.g. "I have good sports skills"). The PSDQ-S showed good reliability among all scales (α of at least 80). The items on the activity scale showed acceptable reliability (lowest $\alpha$was .75) and the items on the sport scale showed high reliability (lowest $\alpha$was .81).

Procedure

First, participants were approached through the social network of the researchers. They then received a message providing a brief overview of the study. All participants were approached in their preferred language, either English or German, remaining the same for the duration of the experiment. After having agreed to participate, a meeting was scheduled where participants received a detailed explanation of the study and were asked to give informed consent. After informed consent had been given, all participants received instructions on how to wear the wearable and how to monitor their stress levels. For participants in the psychoeducation group, the allocation was determined before the meeting to create diverse groups, the instructions were extended by further explanations about positive and negative stress, as well as how accurately a wearable can measure this (HRV and PPG). This was done to allow the psychoeducation group to make informed interpretations and judgments about the stress output provided by the wearable (Psychoeducation). After having been instructed, participants received the wearable and were instructed to wear it for 24 hours (see Figure 1 for general wearable display; for display at different stress levels see Appendix D). A follow-up meeting was scheduled for the next day. During this meeting, the wearables were returned, and the participants received a link to the exit questionnaire, investigating demographics, subjective stress levels and athleticism. This questionnaire was filled out by the participants without a researcher present to promote honest answers. Additionally, the wearable was reset to default after each participant to allow accurate measurements. Before receiving the wearable and after returning it, participants were asked whether everything had been understood or if any questions remained.

Figure 1

Stress-Wearable interface Garmin Forerunner and Vivosmart

Note. The graphic on the left shows the stress-score screen of the Garmin Forerunner and the graphic on the right the display of the Garmin Vivosmart. Labelling is as follows: “a” = stress score, “b” = time, “c” = date, “d” sunrise, “e” = battery, “d” = stress level category (rest, low, medium, high)

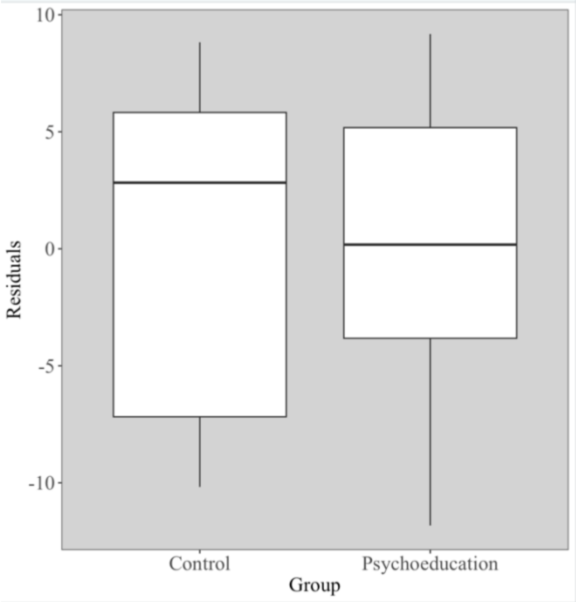
Data Analysis

Before being able to analyse the data, the dataset had to be downloaded from the Qualtrics website and prepared in Excel. To be able to analyse the data effectively, all columns containing instructions, missing variables, and data that was not relevant to the current research question had to be deleted. In addition, for group allocation to the control and psychoeducation group, a dummy had been created assigning 0 to the control and 1 to the psychoeducation group. Of the initial 35 participants, one was excluded because they decided to withdraw consent following the debriefing. After the data had been prepared, it was loaded into R studio to inspect the data and begin the analysis. For the descriptive statistics, observations per category and the corresponding standard deviations for gender and education were calculated, as well as the mean and standard deviation for age.

For the inferential statistics checks of normality, linearity and homoscedasticity were executed to inspect the distribution of the data. This was done by visualising the data using a histogram, scatterplot, and residual plot, respectively (for visualisation of the normality and linearity assumption see Appendix E). The residuals for the residual plot are derived from a linear model with group (control or psychoeducation) as a predictor of subjective stress levels. The outcomes of the residual plot showed that the homoscedasticity assumption was violated, upon which the logistic and square root transformation were employed (for visualisation of homoscedasticity violation see Figure 2).

Figure 2

Boxplot of Residuals by Group



Note. Residuals are based on a linear model with group (control and psychoeducation) as a predictor of stress score.

Both transformations could not resolve the violation, hence, parametric methods were replaced by non-parametric methods. The non-parametric Mann-Whitney U test was employed to check for group differences between the control and the experimental group in terms of subjective stress levels. Two non-parametric tests were used to test whether athleticism acts as a moderator with higher athleticism scores indicating lower levels of subjective stress. First, Spearman's rho was utilised to inspect the relationship between athleticism and subjective stress levels. Upon that, the data was stratified at the threshold of 28, which is the midpoint on the athleticism scale, to create a low and high athleticism group. Afterwards, Mann-Whitney U tests were employed to check for differences in stress scores between the control and the psychoeducation group. This was done for the low and the high athleticism group separately.

Results

Descriptive Statistics

The final dataset consisted of 34 participants of which 24 (70.59%) were female and 10 (29.41%) were male. The mean age of the sample was 37.94 (17.86). Further descriptives and the corresponding percentages for each category are presented in Table 1. The control group consisted of 17 participants, five male and 12 female with an age range from 18 to 77 (mean age = 41.29, SD = 20.97). The psychoeducation group also included 17 participants, five male and 12 female, with an age range from 19 to 55 (mean age = 34.59, SD = 13.94). For the educational level and nationality distribution of the two experimental groups see Table 2.

Table 1

Demographic Characteristics

Characteristics	N	%	M	SD
Gender				
Female	24	70.59		
Male	20	29.41		
Non-Binary	0	0		
Nationality				
Austrian	7	20.59		
German	26	76.47		
Malaysian	1	2.94		
Highest Education				
Secondary Education	13	38.24		
Vocational Training or Trade School	13	38.24		
Bachelor's Degree	2	5.88		
Master's Degree	4	11.76		
Other	2	5.88		
Age			37.94	17.86

Table 2

Percentages of Educational Level and Nationality over Experimental Groups

Group	Educational Level (%)					Nationality (%)		
	Sec.	Vocat.	Bachelor	Master	Other	GE	AU	MA
Control	41.2	29.4	5.9	11.78	11.8	82.3	0	17.6
Psychoeducation	35.3	47.1	5.9	11.7	0	70.5	23.5	5.9

Note. Abbreviations are as follows: Educational level: Sec. = Secondary Education; Vocat. = Vocational training or trade school; Nationality: GE = German, AU = Austria, MA = Malaysian; Gender: F = Female, M = Male.

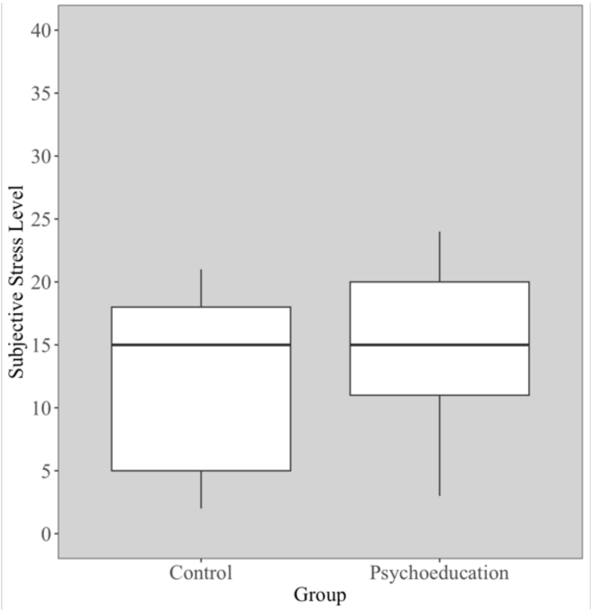
Influence Psychoeducation on Stress

Summary statistics for subjective stress levels showed that the mean stress level for the group variable is 13.5 (6.52) with a range of 2 to 24.0 for both groups combined, the lowest and highest possible scores being 0 and 40, respectively. The mean stress level for the psychoeducation group (Group 1) is 14.82 (6.25) with a range of 3 to 23. For the control group (Group 0), the mean stress level was 12.18 (6.71) with a range of 2 to 21.

To inspect the relationship between the control group and the psychoeducation group on subjective stress levels, a Mann-Whitney U test was employed due to the violated homoscedasticity assumption, which precluded linear regression. The test found no significant differences in stress levels between the groups (Mdn = 15.00 for both; U = 19, p = 0.2543) (see Figure 3 for visual representation). Overall, the findings for the main research question suggest that psychoeducation did not have a significant effect on stress reduction. However, the overall stress scores were very low.

Figure 3

Boxplot of Subjective Stress Level by Group



Note. Subjective stress levels were recorded by using the PSS-10. The similarity in medians between the two groups could derive from distributional differences: the histogram of the psychoeducation group was positively skewed, whereas the histogram of the control shows a multi-modal distribution (see Appendix F for visualisation).

Athleticism

Two separate non-parametric tests were employed to investigate whether athleticism acts as a moderator in the relationship between group and subjective stress level. This was done so because the main relationship between group and stress showed a violation of homoscedasticity leading to a non-parametric test to analyse athleticism as a moderator. The mean athleticism score for both groups combined was 24.09 (9.13), ranging from eight to 43, with the lowest and highest possible scores being eight and 48, respectively. For athleticism scores of the control and experimental group see Table 3. To first get an impression of the overall relationship between athleticism and stress levels, specifically whether higher scores of athleticism predict lower subjective stress levels, the non-parametric Spearman's rho test was employed. This was done for the entire dataset, combining both groups. The Spearman's rho correlation between athleticism scores and subjective stress levels was non-significant ($S = 6191.8$, $p = 0.762$), indicating a negligible negative relationship (see Figure 4 for a visualisation of the relationship).

Table 3

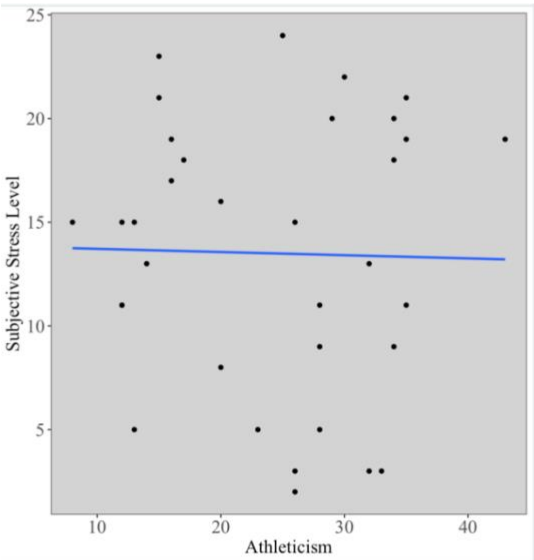
Athleticism Scores by Experimental Group

Group	Mean	SD	Minimum	Maximum
		Control Group		
Action	12.53	5.36		
Sport	12.00	5.48		
Total	24.53	9.50	8	35
		Psychoeducation Group		
Action	11.35	5.90		
Sport	12.29	4.49		
Total	23.65	9.03	12	43
Overall	24.09	9.13	8	43
		Normative Scores		
Action	19.11	4.40		
Sport	15.16	3.15		
Total	34.27			

Note. The lowest possible score for the combination of the action and sport scale of the PDSQ-S is 8 and the highest is 48. Normative Scores are derived from Brown & Bonsaksen (2019).

Figure 4

Scatterplot of Athleticism as a Predictor of Stress

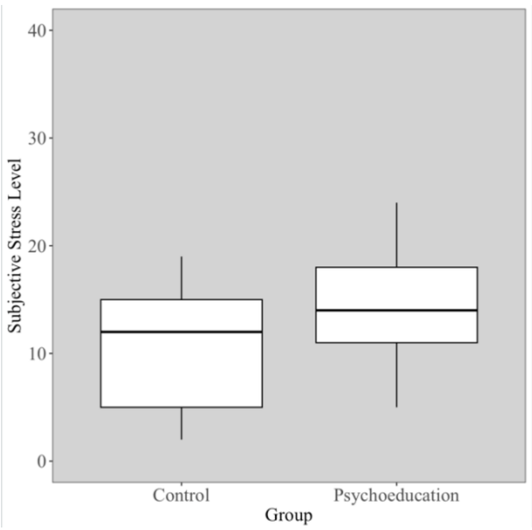


Note. Subjective stress levels were measured with the PSS-10 (possible scores between 0-40) and Athleticism by summing up the PSDQ-S' Sport and Action Scale (possible scores between 8-48).

To determine whether athleticism acts as a moderator in the relationship between psychoeducation and stress, the data was stratified at a threshold of 28 to create two groups: one low (Mdn = 16.5) and one high (Mdn = 34) athleticism group. This stratification allowed for a comparison of stress levels between the control and psychoeducation groups across low and high levels of athleticism. To investigate this comparison, the Mann-Whitney U test was employed once for the low and once for the high-athleticism group. The Mann-Whitney U test for the low athleticism group (n = 22) revealed no significant difference in stress scores between the control group and the psychoeducation group, U = 40.5, p = 0.21 (for visualisation see Figure 5). Similar results were found for the high athleticism group (n = 12), for which the Mann-Whitney U test also revealed no significant differences in stress scores between the two experimental groups, U = 14.5, p = 0.68 (for visualisation see Figure 6). This is in line with the results from the previous Spearman's rho test (S = 6191.8, p = 0.762) which also suggests differences between stress scores for different levels of athleticism, but these are, again, not significant. Overall, both analyses for the second research question combined suggest that athleticism does not act as a moderator in the main relationship between group and stress score and hence does not influence stress scores.

Figure 5

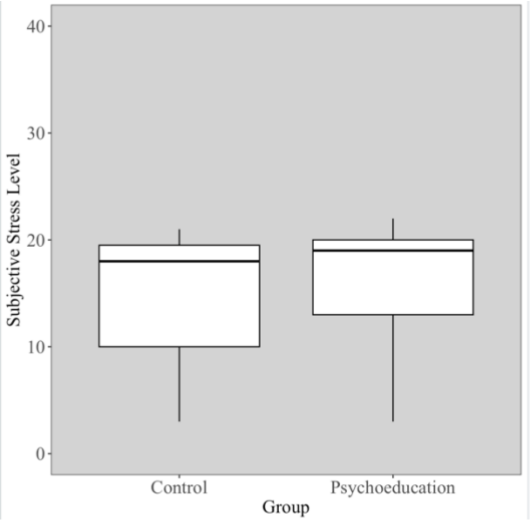
Boxplots of Subjective Stress Level by Group for Low Athleticism



Note. Group low athleticism contains 22 participants who had an athleticism score lower than 28 derived from the PSDQ-S.

Figure 6

Boxplot of Subjective Stress Level by Group for High Athleticism



Note. Group high athleticism contains 12 participants who had an athleticism score of 28 or higher derived from the PSDQ-S.

Discussion

This study investigated whether psychoeducation about HRV and stress reduces subjective stress levels of stress wearable users and whether athleticism influences this relationship. An experimental research design was implemented to monitor stress scores for participants who have received psychoeducation as well as for the control group. The subjective stress levels were measured using the PSS-10 (Cohen et al., 1983). To measure the level of athleticism, the PSDQ-S was implemented as it proved to be of high psychometric quality (Marsh et al., 2010). The findings suggest that psychoeducation did not significantly impact subjective stress levels and that athleticism does not significantly influence this relationship.

Having found no significant effect of psychoeducation on stress does not align with the findings of different studies that showed how wearables can be a cause of higher stress levels, suggesting that psychoeducation could alleviate this effect. Rieder et al. (2020) as well as Ding et al. (2020) who employed qualitative measures of stress examination over a duration of several weeks to months, found that wearable use can cause stress due to a lack of insight into its measures which can cause confusion and stress for the user. In conclusion, these studies suggest that increasing this knowledge through psychoeducation should decrease stress levels. Further, Nelson et al. (2020) found, through the use of interviews, that wearable use can create technology embodiment, causing participants to feel stressed and pressured as a response to discrepancies between their goals and the provided data. This in turn suggests that receiving education about the wearable's measurements might decrease the impact of these discrepancies as users can better differentiate the wearable output.

Although these studies suggest that psychoeducation could alter these findings and decrease adverse effects, the current study did not find support for these ideas. However, the current study utilised the quantitative PSS-10 over a daily timeframe rather than monthly and hence did not employ qualitative methods to examine stress levels. Further, the overall stress levels of the current sample were low compared to those of qualitative studies. From the possible highest score of 40, the control group reported a score of 12.18 and the psychoeducation group 14.82 (possible range is 0 to 40). Although Harris et al. (2023) and Murray et al. (2023) suggest that the PSS-10 can be successfully adapted to shorter time frames, this might not be applicable to the current sample. Hence, the adapted PSS-10 might not be as effective as expected in measuring stress over a daily timeframe, resulting in low stress scores. However, next to qualitative and longer data collection periods, Rieder et al. (2020), as well as Ding et al. (2020), employed a sample of people who already used wearables in their private lives, suggesting that the adverse effects of wearing the device may require longer periods of use to manifest, such as heightened stress levels. This is supported by Nelson et al. (2020), although they did not require prior daily wearable use, they still employed extensive qualitative data collection. Furthermore, given that all studies featured a diverse sample encompassing various ages, educational backgrounds, employment sectors, and genders, the sole distinguishing factor appears to be prior wearable use. Therefore, variations in stress levels across the studies do not appear attributable to demographic differences but rather to prior wearable usage (Rieder et al., 2020; Nelson et al., 2020; Ding et al., 2020). Hence, the sample of the current study is not inherently more likely to have lower stress levels compared to those in previous studies based on its demographics. In conclusion, the low stress scores in the current sample may stem from limited differentiation in stress assessment methods, duration of data collection and inclusion criteria (previous use of wearables).

On the other hand, the non-significant but slightly higher stress levels in the psychoeducation group can be an indicator of positive stress as participants might have felt more secure reporting healthy levels of stress after having received psychoeducation. Hence, this suggests that given a much larger sample, the psychoeducation group could, against prediction, potentially show higher levels of stress than the control group. Alternatively, the low stress scores could be a result of underreporting of the actual levels of perceived stress due to social desirability and instrument choice. While the PSS-10 is recognised for its reliability and validity as a stress measurement tool, the aforementioned studies employed interviews to examine stress in greater detail. This methodological difference could account for the variation in overall stress scores observed in comparison to previous studies, as interviews permit a more nuanced assessment of participants' stress experiences. Moreover, qualitative stress measures rely on experts to code the level of stress whereas the PSS-10 relies on self-description which further affects the overall stress scores. In addition, the low stress scores could be attributed to the small sample size (n = 34) compared to previous studies employing the PSS-10 (Bastianon et al., 2020). This suggests that the sample size might have been insufficient to show significant effects for quantitative methods such as the PSS-10 and the PSDQ-S. relies on self-description which further affects the overall stress scores.

Furthermore, the duration of the current experiment was 24 hours, whereas the experimental conditions in the previously mentioned studies on stress extended over several months or involved participants who were already accustomed to using wearables. This suggests that these studies were able to capture larger fluctuations in participants' stress levels. In contrast, the current study, with its 24-hour duration, only recorded stress levels at a single point in time. The overall low stress scores observed might indicate that the measurements coincided with a period of low stress for the participant. Still, Etkins (2016) who inspected enjoyment was able to record significant effects with experiments much shorter than 24 hours, which implies that the methodological set-up of the current study is justified and feasible. Although Etkin's (2016) study focused on decreased enjoyment as a result of wearable use, it demonstrates that shorter experiments investigating the effects of wearables should not be prematurely dismissed as yielding insignificant results based solely on the duration of data collection.

Moreover, the analysis of athleticism provided new insights into the interplay between psychoeducation and stress. Having found no significant effect of athleticism influencing the relationship between psychoeducation and stress challenges the idea that higher levels of athleticism suggest larger prior knowledge and hence less necessity for psychoeducation. Chang et al. (2020) and Luczak et al. (2029) found that athletes possess larger prior knowledge about wearables due to their teams as well as their focus on monitoring performance. Although they focused on professional athletes, the findings suggest that higher levels of athleticism imply larger prior knowledge. In turn, this suggests that people of lower athleticism do not have such a team, leaving them less educated about wearables. Hence, this suggests that people with higher levels of athleticism might be less subjective to the negative effects of wearables as they have already received sufficient psychoeducation and possess sufficient knowledge. Again, this was not supported by the findings of the current study.

Additionally, Karahanoglu et al. (2021) found that non-professional athletes use wearables to gain insight into their performance and improve their training. This study suggests that non-professional athletes with high enthusiasm for their sport possess sufficient wearable knowledge to effectively interpret the output, indicating that they are less subjective to adverse effects. This, in turn, suggests that higher levels of athleticism can reasonably be assumed to predict larger knowledge and hence demand less psychoeducation. Again, this idea cannot be supported as the current study did not find significant effects for athleticism as a moderator. However, overall athleticism scores as well as those in the high athleticism group (Mdn = 34 out of 48) were low, indicating that the current convenience sample lacks the necessary distinction between athletes of higher levels of athleticism. Further, the previous studies employed interviews and observations as measurements of athleticism which allow for a more nuanced and accurate assessment of their level of athleticism. The current study, however, employed a questionnaire that relies on self-description. This might have led participants to underreport their abilities resulting in more modest answers to avoid being perceived as arrogant. Additionally, because of the novelty of the focus on stress for athletes, the previous studies only provide an idea of possible effects and lack substantial evidence to compare the current findings with. Given that participants were more secure reporting healthy stress levels, athleticism might be less effective in decreasing stress scores than anticipated due to an overall lack of high-stress perceptions. Furthermore, as the overall athleticism scores were low, the sample lacked participants who fit the criteria of high athleticism, to analyse this relationship effectively.

Implications

When looking at the overall stress levels, it was surprising to see that the stress levels for the experimental as well as for the control group were both low and did not differ significantly. This suggests that the participants in this sample might experience less stress in general, are less subjective to it or employ strategies that make them more resilient towards stress. However, when comparing the design of the current study with the design of previous studies it becomes clear that the studies that found significant results employed an experimental set-up of a much longer duration. Further, as the current study adapted the PSS-10 to focus on a single day instead of the past month, the actual stress levels might have been underreported. This suggests that the experimental set-up of the current study might have been too short and, perhaps, unreliable, to find significant changes in participants' stress levels. Hence, this indicates that investigative studies focusing on psychoeducation interventions aimed at reducing stress may require a sample with overall higher stress scores or prolonged engagement with the wearable to be effective. Despite this, the current findings suggest that psychoeducation might not be enough to reduce stress levels. This could indicate that the reason for higher stress levels might be influenced by more than just a lack of knowledge and feeling overwhelmed.

When considering the findings for athleticism as a moderator, it is important to keep in mind that the overall athleticism scores, especially those for the high athleticism group, were still quite low and that comparable previous studies did not offer insights into stress and merely focused on physical activity feedback, hence, making it difficult to meaningfully compare the current findings (Karahanoglu et al., 2021). However, when considering samples of previous studies focusing on physical activity it becomes evident that the differentiation between levels of athleticism was much higher, including larger differences between high and low levels of athleticism (Chang et al., 2020). This difference, however, might be a result of more detailed measures as those studies employed observation rather than self-descriptions to measure athleticism. Further, as the PDSQ-S, despite its reliability and validity, is a less common measure, comparison to previous studies is limited. Still, this indicates that a more diverse sample of athletes, especially those of high athleticism, is required to effectively investigate and conclude whether athleticism moderates the relationship between psychoeducation and stress. Nevertheless, the current findings suggest that, given the non-significant effect of athleticism as a moderator, such a psychoeducation intervention could potentially be broadly applicable to all levels of athleticism without the need for adjustment.

Limitations

While this study provides valuable insights, it is essential to address the limitations that shape its findings. First, the small sample size limits the power of the study to detect significant effects and affects the generalisability of the findings. Additionally, it was found that the overall stress and athleticism levels were low, indicating a lack of diversity in the sample. Next, the study design needs to be considered. As there are no examinations of stress levels prior to receiving the wearable, this study lacks insights into changes in stress from pre- to post-experiment that could provide further insights into the actual effects of the experiment. Lastly, no insights into previous knowledge about wearable use and data have been collected, which could be a potential moderator in the relationship between psychoeducation and stress.

Future Research

Building on the insights gained and recognising the existing limitations, this study suggests several avenues for future research. First, as overall stress scores were low and differentiation between levels of athleticism was difficult, including larger and more diverse samples with people of high levels of athleticism to enhance the generalisability and robustness of the findings could provide significant results. Next, as the current study did not provide insights into changes in stress levels prior to the experiment, insights into pre- and post-measures are missing. Extending the study design by implementing pre- and post-measures of stress could result in more detailed insights into the effects of psychoeducation on stress levels. Moreover, to gain insights into whether the current form of psychoeducation is appropriate, alternative psychoeducation approaches should be tested to investigate whether their content influences the effectiveness and, hence, whether one approach should be considered more favourably. Finally, future studies should explore other potential moderating factors, such as psychological resilience or baseline stress levels, to gain a more comprehensive understanding of factors that influence the effectiveness of psychoeducation in reducing stress scores.

Conclusion

Wearables are becoming increasingly important in the daily lives of laypeople and athletes. Wearable integration allows them to monitor their stress levels and aid in developing resilience strategies to manage high-stress situations effectively. As wearable use is found to be a source of stress caused by factors such as lack of information, psychoeducation poses a feasible intervention to reduce these negative effects. The current research provides insight into the relationship between psychoeducation and subjective stress levels, as well as athleticism as a moderator. In contrast to suggestions of previous findings, the current study did not find a significant reduction in subjective stress levels in participants who had received psychoeducation. Moreover, although it was hypothesised that stress wearables can be a source of stress for many individuals resulting in increased stress levels, this was not true for the majority of the current sample. Furthermore, athleticism was not found to be a significant moderator in this relationship. However, the duration of the current experiment was short with a small sample, and the overall stress and athleticism scores were relatively low compared to those previous studies suggesting significant effects. Hence, the results of this study suggest that a larger, more diverse sample and more extensive research design should be employed when further investigating the relationship between psychoeducation, athleticism, and stress.

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Appendix A

Informed Consent (English and German Version)

English Version
Researchers: Daria Mirferdows (s2768259), Elisa M. Wüpping (s2755041)

Introduction:
You are invited to participate in a research bachelor thesis study exploring how stress wearables influence subjective stress levels. Before you decide whether to participate, you must understand the purpose, procedures and potential risks.

Study Purpose:
The purpose of this study is to investigate factors influencing the use of stress wearables connected to dimensions of perceived stress, well-being, and athleticism. An exit survey will pose questions about these three dimensions. The examination of these factors allows for a deeper understanding of possible mediators and correlations. Ultimately, these insights will allow for greater insights into the effects of wearables on the user.

Duration:
The duration of participation is approximated at 24 hours with the addition of an exit survey.

Procedures:
If you agree to participate, you will be asked to wear the Garmin Forerunner 255 wearable or the Garmin Vivosmart 4 for 24 hours and monitor your stress levels throughout the day. At the end of the 24 hours, you will be expected to fill out an end-of-the-study questionnaire about perceived stress, well-being and athleticism. The wearable allows for the following measurements none of which will be analysed during the project:

- *Heart Rate Variability Status (HRV)*
- *Step count*
- *Recovery time*
- *GPS-tracking*
- *Heart Rate (HR)*
- *Sleep monitoring*
- *Energy monitoring*
- *Blood oxygen saturation level*
- *Activity tracking*
- *Stress tracking*
- *Respiration*

Your participation in this experiment is completely voluntary and you have the right to withdraw at any given moment without any consequences and without providing any reasons. No harms are expected by participating in this experiment and participants can contact the researchers in case of unexpected adverse effects or questions (contact information is listed below).

Please tick the appropriate boxes	Yes	No
Taking part in the study		
I have read and understood the study information dated [18/03/2024], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
I understand that taking part in the study involves wearing the Garmin Forerunner 255 or the Vivosmart 4 wearable all day (except when being in the water) and filling out an exit survey.	☐	☐
Use of the information in the study		
I understand that information I provide will be used for a bachelor thesis…	☐	☐
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	☐	☐
Future use and reuse of the information by others		
The data will be anonymised and securely stored on servers from the University of Twente. If future publications utilise this study's data, only groups estimates (e.g., mean, median, standard deviations, max, min, etc) will be reported. By clicking this box, I give permission for the questionnaire data and biomarker data that I provide to be archived in the UT data storage so it can be used for future research and learning. This entails that the thesis will be published on the graduation web of the University of Twente.	☐	☐

Signature

I understand what taking part in this study will involve. I agree to take part in this study. ☐ ☐

Study contact details for further information:

Daria Mirferdows, d.mirferdows@student.utwente.nl

Elisa M. Wüpping, e.wupping@student.utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-hss@utwente.nl

<u>German Version</u>

ForscherInnen: Daria Mirferdows (s2768259), Elisa M. Wüpping (s2755041)

Einleitung:
Sie sind eingeladen an einer Bachelor-Studie teilzunehmen in der untersuch wird, wie Stress-Wearables das subjektive Stressniveau beeinflussen. Bevor Sie sich für eine Teilnahme entscheiden, müssen sie den Zweck, das Verfahren und mögliche Risiken verstehen.

Zweck der Studie:
Das Ziel dieser Studie ist es zu untersuchen ob die Faktoren Stresslevel, Wohlbefinden und Sportlichkeit die Nutzung von Stress-Wearables beeinflussen. Darüber hinaus werden in einem Fragebogen zum Abschluss des Experiments Fragen zu ihrem Wohlbefinden und ihrer Sportlichkeit gestellt. Die Untersuchung dieser Faktoren ermöglicht ein tieferes Verständnis möglicher Mediatoren und Korrelationen. Letztlich werden diese Erkenntnisse einen besseren Einblick in die Auswirkungen von Wearables auf den Nutzer ermöglichen.

Dauer:
Die Dauer der Teilnahme beträgt 24 Stunden, hinzu kommt der Fragebogen zum Abschluss des Experiments.

Verfahren:
Wenn Sie sich bereiterklären an der Studie teilzunehmen, werden sie gebeten entweder das Garmin Forerunner 255 Wearable oder das Garmin Vivosmart 2 wearable für 24 Stunden zu tragen. Weiter werden Sie gebeten durch das Wearable ihr Stressniveau über den Tag hinweg zu überwachen. Am Ende der 24 Stunden werden Sie gebeten, einen Fragebogen auszufüllen der Stress, Wohlbefinden und Sportlichkeit misst. Das Wearable ermöglicht folgende Messungen, von denen keine im Rahmen des Projekts analysiert werden:

- *Herzfrequenzvariabilitätsstatus (HRV)*
- *Schrittzähler*
- *Erholungszeit*
- *GPS-Ortung*
- *Herzfrequenz (HR)*
- *Schlafüberwachung*
- *Energieüberwachung*
- *Sauerstoffsättigung des Blutes*
- *Aktivitätsverfolgug*
- *Stressniveau*
- *Atmung*

Ihre Teilnahme and diesem Experiment ist vollkommen freiwillig und Sie haben das Recht, jederzeit ohne Folgen und ohne Angabe von Gründen auszusteigen. Es werden keine Schäden durch die Teilnahme an diesem Experiment erwartet. Die Teilnehmer können sich bei unerwarteten Effekten oder Fragen and die Forscher wenden (die Kontaktinformationen sind unten aufgeführt)

Bitte kreuzen Sie die entsprechenden Felder an	Ja	Nein
Studienteilnahme		
Ich habe die Studieninformationen vom [18.03.2024] gelesen und verstanden, oder sie wurden mir vorgelesen. Ich hatte die Möglichkeit Fragen zur Studie zu stellen und meine Fragen wurden zu meiner Zufriedenheit beantwortet	□	□
Ich erkläre mich hiermit freiwillig bereit an dieser Studie teilzunehmen und verstehe, dass ich die Beantwortung von Fragen verweigern und die Studie jederzeit ohne Angabe von Gründen abbrechen kann.	□	□
Ich verstehe, dass die Teilnahme an der Studie das Tragen eines Wearables über 24 Stunden (Außer im Wasser) und das Ausfüllen einer Umfrage beinhaltet.	□	□
Verwendung der Informationen in der Studie		
Ich verstehen, dass die von mir gemachten Angaben für eine Bachelorarbeit verwendet werden.	□	□
Ich verstehen, dass über mich gesammelte persönliche Informationen die mich identifizieren können [z.B. mein Name oder Wohnort], nicht über das Studienteam hinaus weitergegeben werden.	□	□
Künftige Nutzung und Wiederverwendung der Informationen durch andere		
Die Daten werden anonymisiert und sicher auf Servern der Universität Twente gespeichert. Wenn zukünftige Veröffentlichungen die Daten dieser Studie verwenden, werden nur Gruppenschätzungen (z.B. Mittelwert, Standardabweichungen, Maximum, Minimum, usw.) angegeben. Durch Anklicken des zustimmenden Kästchens erkläre ich mich damit einverstanden, dass die von mir zur Verfügung gestellten Fragebogendaten und Biomarkerdaten im UT-Datenspeicher archiviert werden, damit sie für zukünftige Forschungen und Lernzwecke verwendet werden können. Dies beinhaltet die Veröffentlichung der Stude im Abschluss-Web der Universität Twente.	□	□

Unterschrift

Ich verstehen, was die Teilnahme and dieser Studie bedeutet. Ich bin damit einverstanden, an dieser Studie teilzunehmen.	□	□

Kontaktdaten für weitere Informationen:

Daria Mirferdows, d.mirferdows@student.utwente.nl

Elisa M. Wüpping, e.wupping@student.utwente.nl

Kontaktinformationen für Fragen zu Ihren rechten als ForschungsteilnehmerIn

Wenn Sie Fragen zu Ihren Rechten als Studienteilnehmer haben oder Informationen erhalten möchten, Fragen stellen oder Bedenken zu dieser Studie mit einer anderen Person als den Forschern besprechen möchten, wenden Sie sich bitte an das Sekretariat der

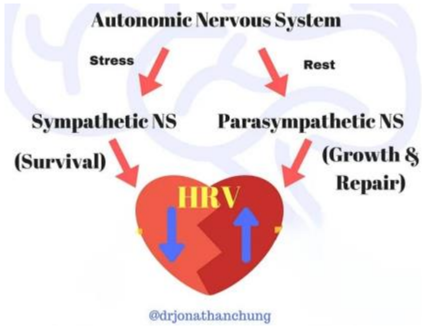
Ethikkommission/des Fachbereichs Humanities & Social Sciences der Fakultät für Behavioural, Management and Social Sciences der Universität Twente unter ethicscommittee-hss@utwente.nl

Appendix B

Psychoeducation (English and German Version)

English Version:

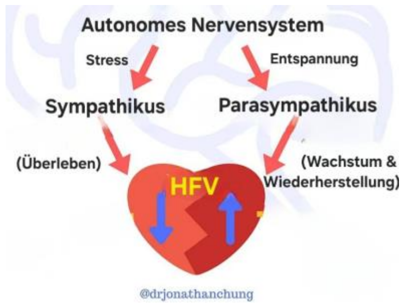
Summary	We are using wrist-worn wearables to get insights into factors that influence the use of wearables measuring stress and connected to this, dimensions of perceived stress, well-being, and athleticism. 
Instructions	We would like you to wear the wearable for a full 24hrs. The wearable is worn about two fingers from the crease of your wrist to get optimal results. You should feel a slight pressure when the wearable is worn. Please check your stress level multiple times throughout the day. At the end of the 24hrs, you will also fill in a short exit survey.
Stress	Although stress often has a negative connotation, in reality, stress can also have benefits: Good Stress: Manageable levels of stress can promote recovery and performance. Bad Stress: Prolonged, chronic stress can cause mental health issues and other adverse effects such as an earlier onset of age-related diseases. There are many forms of stress which are measured differently. We examine stress based on wearables measurements, and therefore focus on physiological stress. This stress is the body's reaction to stressors and is, for example, manifested in heightened heart rate and blood pressure.
Stress feedback	The wearable indicates stress via four different levels: -Resting State: 0-25 -Low Stress: 26-50 -Medium Stress: 51-75 -High Stress: 76-100 ! Be aware that those stress levels can indicate either good or bad stress and the wearable cannot measure that. If the wearable indicates for instance high stress it would be a good time to check with yourself how you feel about this and if you are ready for more challenges or a small break.

HRV	Heart Rate Variability (HRV) relates to the variation in intervals between heartbeats and is a relevant indicator of activities regarding our autonomic nervous system (ANS). The ANS has the function of keeping a balance in our body through the activity of two branches, namely the Sympathetic Nervous System (SNS), which leads to the activation of the body and the Parasympathetic Nervous System (PNS), which is responsible for relaxation.  Lower HRV: domination through the SNS when stress is perceived and low variability between heartbeats Higher HRV: domination through the PNS when body is relaxed and high variability between heartbeats Contrary to the believe that high HRV is good and low HRV bad for the body, new evidence shows that a balance is the optimum.
Stress Measurement through wearables	Wearables measure physiological signals through an optical sensor. This process is called Photoplethysmography (PPG), which works with a light sensor. The light of this sensor gets absorbed by blood vessels and photodiodes detect the changes in the blood volume, indicating the pulse. Algorithms can transform these insights into HRV data based on the intervals of the measured pulse. However, PPG measurements of HRV are often inaccurate. Keep in mind that stress measurement through wearables is not perfect BUT it can also be a helpful tool to self-check and manage your stress.

Note. The picture of the autonomic Nervous System was shortened. Adapted from *Vagal tone and the autonomic nervous system is something I've always been curious about since chiropractic school*, by The Anti-Fragile Chiro [@drjonathanchung], 2018, Instagram. (https://www.instagram.com/p/Bg1fLbKlziB/?igsh=MTQ1Mm5lazQ1OGFpOA==)

German Version:

Übersicht	Wir verwenden am Handgelenk getragene Wearables, um Einblicke in Faktoren zu erhalten, die die Nutzung von Wearables und damit verbunden Dimensionen von wahrgenommenem Stress, Wohlbefinden und Sportlichkeit beeinflussen. 
Anweisungen	Bitte tragen Sie das Wearable volle 24 Stunden lang. Das Wearable wird etwa zwei Fingerbreit von der Handgelenksfalte entfernt getragen, um optimale Ergebnisse zu erzielen. Sie sollten einen leichten Druck spüren, wenn Sie das Wearable tragen. Bitte überprüfen Sie Ihr Stress Level mehrmals am Tag. Nachdem Sie das Wearable für 24h getragen haben werden Sie außerdem eine kurze Umfrage ausfüllen.
Stress	Obwohl Stress oft negativ konnotiert ist, kann er in auch positive Auswirkungen haben: Guter Stress: Ein überschaubares Maß an Stress kann Erholung und Leistung fördern.

	<u>Schlechter Stress:</u> Anhaltender, chronischer Stress kann zu psychischen Problemen und anderen negativen Auswirkungen führen, z. B. zu einem früheren Auftreten von altersbedingten Krankheiten. Es gibt viele Formen von Stress, die unterschiedlich gemessen werden. Da wir Stress (und Herzfrequenzvariabilität (HFV)) auf der Grundlage von Wearables-Messungen untersuchen, konzentrieren wir uns auf physiologischen Stress. Dieser Stress ist die Reaktion des Körpers auf Stressoren und äußert sich zum Beispiel in einer erhöhten Herzfrequenz und einem erhöhten Blutdruck.
Stress-Feedback	Das Wearable zeigt Stress über vier verschiedene Stufen an: -Ruhezustand: 0-25 -Geringer Stress: 26-50 -Mittlerer Stress: 51-75 -Hoher Stress: 76-100 ! <u>Seien Sie sich bewusst</u>, dass diese Stresswerte guten oder schlechten Stress anzeigen können und das Wearable dies nicht messen kann. Wenn das Wearable z. B. hohen Stress anzeigt, wäre es ein guter Zeitpunkt, in sich zu fühlen und herauszufinden, wie Sie sich dabei fühlen und ob Sie bereit sind für weitere Herausforderungen oder eine kleine Pause.
HFV	Die Herzfrequenzvariabilität (HFV) bezieht sich auf die Variation der Intervalle zwischen den Herzschlägen und ist ein wichtiger Indikator für die Aktivitäten unseres autonomen Nervensystems (ANS). Das ANS hat die Aufgabe, das Gleichgewicht in unserem Körper durch die Aktivität zweier Zweige aufrechtzuerhalten, nämlich des Sympathikus, der zur Aktivierung des Körpers führt, und des Parasympathikus, der für die Entspannung zuständig ist.  <u>Niedrigere HRV:</u> Beherrschung durch den Sympathikus, wenn Stress empfunden wird; geringe Variabilität zwischen den Herzschlägen <u>Höhere HRV:</u> Beherrschung durch den Parasympathikus, wenn der Körper entspannt ist; hohe Variabilität zwischen den Herzschlägen Entgegen der Annahme, dass eine hohe HRV gut und eine niedrige HRV schlecht für den Körper ist, zeigen neue Erkenntnisse, dass ein Gleichgewicht das Optimum darstellt.
Stressmessung durch Wearables	Wearables messen physiologische Signale über einen optischen Sensor. Dieser Prozess wird Photoplethysmographie (PPG) genannt, die mit einem Lichtsensor arbeitet. Das Licht dieses Sensors wird von den Blutgefäßen absorbiert, und Fotodioden erkennen die Veränderungen des Blutvolumens, die den Puls anzeigen. Algorithmen können diese Erkenntnisse in HFV-Daten umwandeln, die auf den Intervallen des gemessenen Pulses basieren. PPG-Messungen der HVF sind jedoch oft ungenau. <u>Bedenken Sie, dass die Stressmessung durch Wearables nicht perfekt ist, ABER sie kann ein hilfreiches Instrument zur Selbstkontrolle und zum Stressmanagement sein.</u>

Note. The picture of the autonomic Nervous System was shortened and translated to German. Adapted from *Vagal tone and the autonomic nervous system is something I've always been*

curious about since chiropractic school, by The Anti-Fragile Chiro [@drjonathanchung], 2018, Instagram.
(https://www.instagram.com/p/Bg1fLbKlziB/?igsh=MTQ1Mm5lazQ1OGFpOA==)

Appendix C

Physical Self-Description Questionnaire – German Translation of Sport and Activity Scale

Question:

1. Please indicate for each statement how true it is about you.
    a. Bitte geben Sie für jede Aussage an, wie sehr sie auf Sie zutrifft.

Statements:

Action Scale:

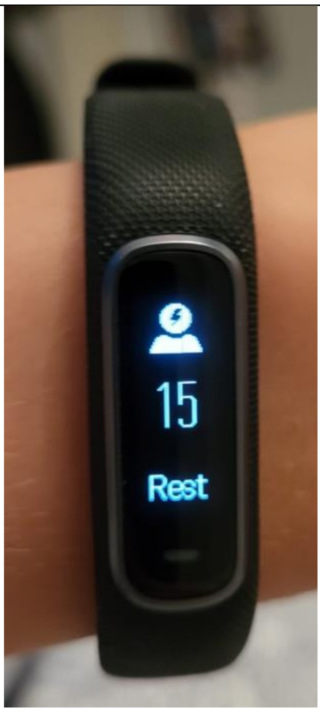
1. I often do exercise or activities that make me breathe hard.
    a. Ich mache oft Übugen oder Aktivitäten die dazu führen dass ich schwerer atme.
2. I do physically active things (e.g. jog, dance, bicycle, aerobics, gym, swim) at least three times a week.
    a. Ich mache mindestens dreimal pro Woche körperlich aktive Dinge (z.B. Joggen, Tanzen, Radfahre, Aerobic, Fitnessstudio, Schwimmen).
3. I do lots of sports, dance, gym, or other physical activities.
    a. Ich treibe viel Sport, tanze, gehe ins Fitnessstudio oder mache andere körperlich aktive Dinge.
4. I do sports, exercise, dance or other physical activities almost every day.
    a. Ich treibe fast jeden Tag sport, trainiere, tanze, oder mache andere körperlich aktive Dinge.

Sport Scale:

1. Other people think I'm good at sports.
    a. Andere Leute denken, dass ich sportlich bin.
2. I am good at most sports.
    a. Ich bin in den meisten Sportarten gut.
3. I have good sports skills.
    a. Ich habe gute sportliche Fähigkeiten.
4. I play sports well.
    a. Ich bin gut im Sport.

Appendix D

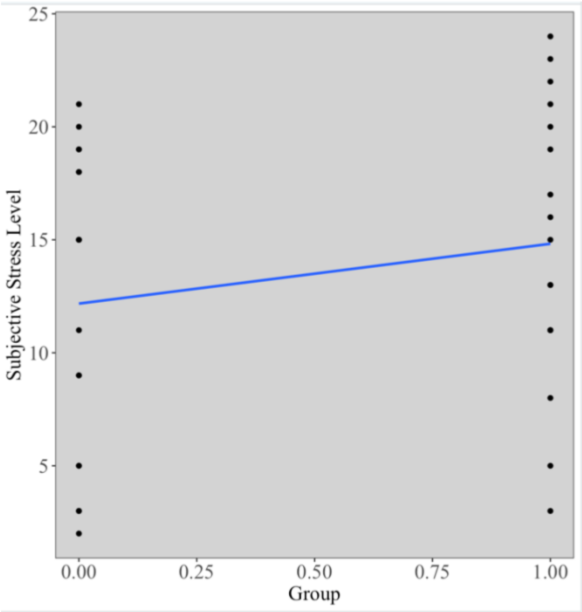
Garmin Forerunner 255 and Vivosmart 4 Interface at Different Stress Levels

Wearable	Rest	Low	Moderate	High
Garmin Forerunner				
Garmin Vivosmart				

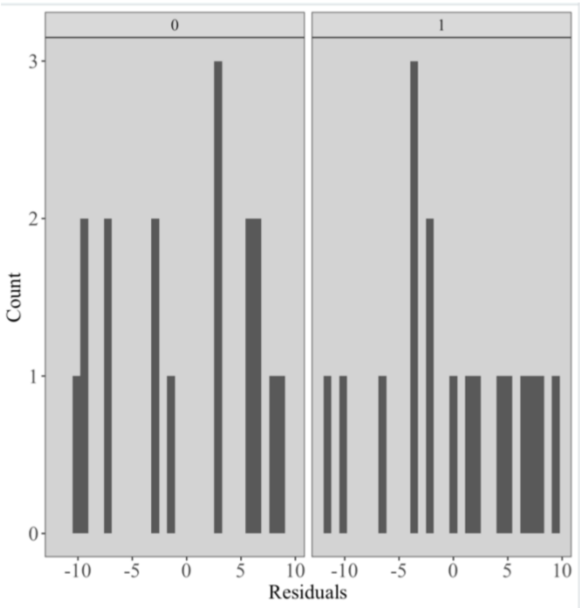
Appendix E

Visualisation of Assumptions

D1 Linearity



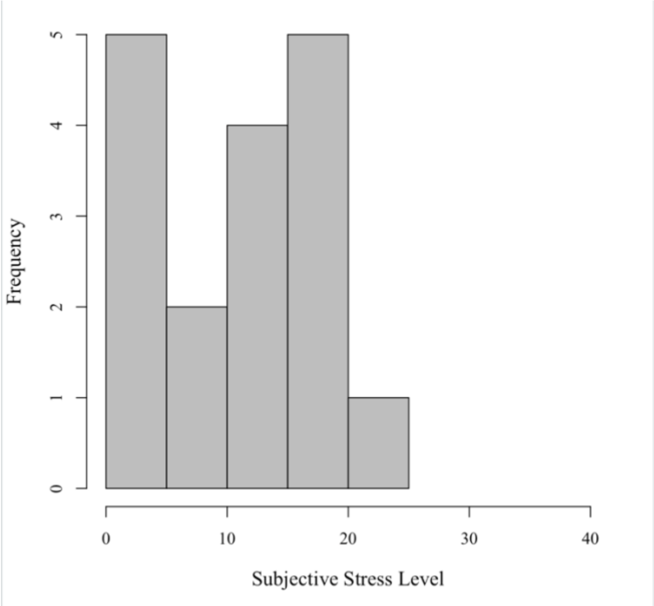
D2 Normality



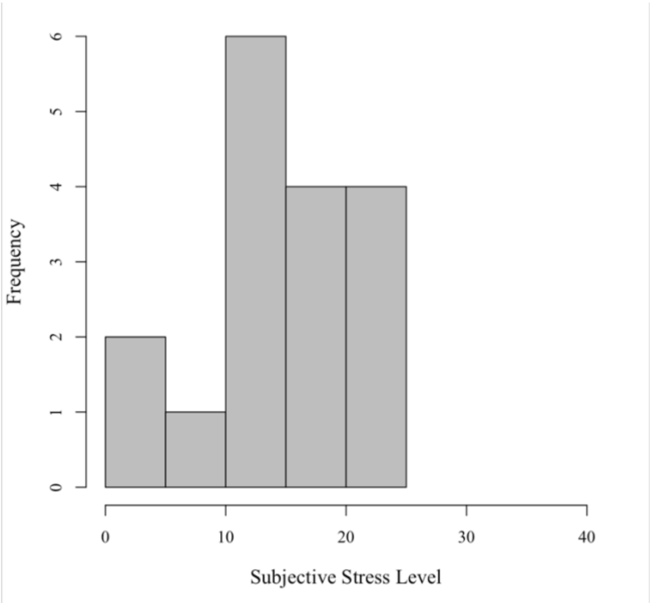
Appendix F

Histograms of Stress Scores for Group

F 1: Histogram Control Group



F2: Histogram Psychoeducation Group



Appendix G

R Code

```
library(gplots)
library(RColorBrewer)
library(tidyverse)
library(cluster)
library(factoextra)
library(dendextend)
library(pheatmap)
library(ade4)
library(ape)
library(vegan)
library (NbClust)
library (hopkins)
library(jtools)
library(ggplot2)
library(modelr)
library(stats)
library(dplyr)

#import data
data <- read.csv("Stress_Dataset.csv", sep =";")

########preparing data for analysis#############
#reversing scores
#Define highest and lowest possible score for stress scale items
max_score_1 <- 4 #highest possible score
min_score_1 <- 0 #lowest possible score

#Reverse score for variables Problems, Way, and Irritations
data$Problems <- max_score_1 + min_score_1 - data$Problems
data$Way <- max_score_1 + min_score_1 - data$Way
data$Irritations <- max_score_1 + min_score_1 - data$Irritations
data$Top <- max_score_1 + min_score_1 - data$Top

#Creating Stress Variable --> Summarised Stress Score
# Specify the names of the stress scale items
stress_items <- c("Happening", "Control", "Nervous", "Problems", "Way",
                  "Coping", "Irritations", "Top", "Angered", "Difficulties")

# Compute the overall stress score for each participant
data$Stress_Score <- rowSums(data[, stress_items], na.rm = TRUE)

#Compute overall Athleticism Score SUbscores (Action, Sports)
# Specify the names of the items in the Action Scale
action_items <- c("Breath", "Physically.Active", "Sports", "Frequency")

# Compute the overall Action score for each participant
```

```
data$Action_Score <- rowSums(data[, action_items], na.rm = TRUE)

# Specify the names of the items in the Sport Scale
sport_items <- c("Talent", "Ability", "Skills", "Playing")

# Compute the overall Sport score for each participant
data$Sport_Score <- rowSums(data[, sport_items], na.rm = TRUE)

#Compute Overall Athleticism_Score
# Compute the overall Athleticism Score for each participant
data$Athleticism_Score <- data$Action_Score + data$Sport_Score

#Creating Dummies:
# Create dummy variable for gender (female = 1, male = 0)
# Replace the original 'gender' variable with the dummy variable
data$Gender <- ifelse(data$Gender == "Female", 1, 0)

# Create dummy variable for 'Wearable' (Yes = 1, No = 0)
data$Wearable <- ifelse(data$Wearable == "Yes", 1, 0)

############Descriptive statistics############
#means
means <- sapply(data, mean, na.rm = TRUE)
print(means)

#descriptive
#Summary of the Numeric Variables (Min, Max, Mean, Median)
summary(data)

#Residuals durch model
modelstress <- data %>%
  lm(Stress_Score ~ Group, data = . )
summary(modelstress)

#Gender
table(data$Gender)
table2 <- table(data$Gender)
prop.table(table2)

#Nationality
table(data$Nationality)
table3 <- table(data$Nationality)
prop.table(table2)

#Nationality group control
nationality_table_control <- table(data$Nationality[data$Group == 0])
nationality_proportions_control <- prop.table(nationality_table_control) * 100
print(nationality_table_control)
print(nationality_proportions_control)
```

```
#Nationality group experimental
nationality_table_experimental <- table(data$Nationality[data$Group == 1])
nationality_proportions_experimental <- prop.table(nationality_table_experimental) * 100
print(nationality_table_experimental)
print(nationality_proportions_experimental)

#Education
table(data$Education)
table2 <- table(data$Education)
prop.table(table2)

#education for group control
education_table_control <- table(data$Education[data$Group == 0])
education_proportions_control <- prop.table(education_table_control) * 100
print(education_table_control)
print(education_proportions_control)

#education group experimental
education_table_experimental <- table(data$Education[data$Group == 1])
education_proportions_experimental <- prop.table(education_table_experimental) * 100
print(education_table_experimental)
print(education_proportions_experimental)

#Stress Score Summary for both groups
# Summary statistics for Group 1 (Experimental Group)
summary_group1 <- summary(data$Stress_Score[data$Group == 1])

# Summary statistics for Group 2 (Control Group)
summary_group2 <- summary(data$Stress_Score[data$Group == 0])

# Print summary statistics for both groups
print("Summary Statistics for Group 1 (Experimental Group):")
print(summary_group1)

print("Summary Statistics for Group 2 (Control Group):")
print(summary_group2)

sd(data$Stress_Score[data$Group == 1])

sd(data$Stress_Score[data$Group == 0])

sd(data$Stress_Score)

#Group 0
mean_age_group0 <- mean(data$Age[data$Group == 0], na.rm = TRUE)
print(mean_age_group0)

summary_age_group0 <- summary(data$Age[data$Group == 0])
print(summary_age_group0)
```

```
sd_age_group0 <- sd(data$Age[data$Group == 0])
print(sd_age_group0)

table(data$Gender[data$Group == 0])
table2 <- table(data$Gender)
prop.table(table2)

#group 1
mean_age_group1 <- mean(data$Age[data$Group == 1], na.rm = TRUE)
print(mean_age_group1)

summary_age_group1 <- summary(data$Age[data$Group == 1])
print(summary_age_group1)

sd_age_group1 <- sd(data$Age[data$Group == 1])
print(sd_age_group1)

table1(data$Gender[data$group == 1])
table2 <- table(data$Gender)
prop.table(table2)

# Summary for Group 0
summary_group0 <- data %>%
  filter(Group == 0) %>%
  summarise(
    mean_stress = mean(Stress_Score),
    median_stress = median(Stress_Score),
    sd_stress = sd(Stress_Score)
  )

# Summary for Group 1
summary_group1 <- data %>%
  filter(Group == 1) %>%
  summarise(
    mean_stress = mean(Stress_Score),
    median_stress = median(Stress_Score),
    sd_stress = sd(Stress_Score)
  )

# Print summaries
print(summary_group0)
print(summary_group1)

############Data Inspection########
my_theme <- theme(
  text = element_text(family = "Times New Roman", size = 16),
  axis.text = element_text(size = 16),
  panel.grid.major = element_blank(),
  panel.grid.minor = element_blank(),
  panel.background = element_rect(fill = "lightgrey")
```

```
)

#Linearity - Scatterplot (dependent + independent Variable)
data %>%
  ggplot(aes(x=Group,y=Stress_Score))+
  geom_point()+
  geom_smooth(method = "lm", se=F) +
  labs(x = "Group", y = "Subjective Stress Level") +
  theme_bw() +
  my_theme

#Normality - Histogram of residuals
data %>%
  add_residuals(modelstress) %>%
  ggplot(aes(x = resid)) +
  geom_histogram() +
  facet_wrap(.~ Group) +
  labs(x = "Residuals", y = "Count") +
  theme_bw() +
  my_theme

#homoscedasticity + Independent Errors - Residual plot
data %>%
  add_residuals(modelstress) %>%
  add_predictions(modelstress) %>%
  ggplot(aes(x = factor(Group), y = resid)) +
  geom_boxplot() +
  labs(x = "Group", y = "Residuals") +
  scale_x_discrete(labels = c("Control", "Psychoeducation")) +
  theme_bw() +
  my_theme

############################################################
# Fit the linear regression model using the entire dataset
model_factor <- lm(Stress_Score ~ Group, data = data)
 #Try reslve homoscedasticity error by transformation
# Log-transform the dependent variable (Stress Score)
data$log_Stress_Score <- log(data$Stress_Score)
# Boxplot of Log-transformed Stress Score by Group
boxplot(log_Stress_Score ~ Group, data = data, xlab = "Group", ylab = "Log-transformed
Stress Score", main = "Boxplot of Log-transformed Stress Score by Group")
#Square root transformation
data$sqrt_transform <- sqrt(data$Stress_Score)
# Boxplot of square root transformed Stress Score by Group
boxplot(sqrt_transform ~ Group, data = data, xlab = "Group", ylab = "Square Root
Transformed Stress Score", main = "Boxplot of Square Root Transformed Stress Score by
Group")
# Rank Transformation
data$rank_transform <- rank(data$Stress_Score)
# Boxplot of Rank Transformed Stress Score
```

```
boxplot(rank_transform ~ Group, data = data, xlab = "Group", ylab = "Rank Transformed Stress Score", main = "Boxplot of Rank Transformed Stress Score by Group")
#########################################################

#########Analysis Group Variable and Stress_Scores
# Perform Mann-Whitney U test (Wilcoxon rank-sum test)
wilcox_test <- wilcox.test(Stress_Score ~ Group, data = data)
print(wilcox_test)

# Perform the Mann-Whitney U test
test_result <- wilcox.test(Stress_Score ~ Group, data = data, exact = FALSE)

# Calculate the U statistic
n1 <- sum(data$Group == 0)  # Number of observations in control group
n2 <- sum(data$Group == 1)  # Number of observations in experimental group
W <- test_result$statistic  # Wilcoxon rank sum statistic
U1 <- W - (n1 * (n1 + 1)) / 2  # U statistic for control group
U2 <- n1 * n2 - U1  # U statistic for experimental group

#extract the u statistics
u <- test_result$statistic

# Print the results
cat("U statistic for control group:", U1, "\n")
cat("U statistic for experimental group:", U2, "\n")
cat("P-value:", test_result$p.value, "\n")
cat ("General U statistic:", U, "\n")
cat ("P-value:", test_result$p.value, "\n")


#boxplot for visualisation
data %>%
  ggplot(aes(x = factor(Group), y = Stress_Score)) +
  geom_boxplot() +
  labs(x = "Group", y = "Subjective Stress Level") +
  scale_x_discrete(labels = c("Control", "Psychoeducation")) +
  scale_y_continuous(
    limits = c(0, 40),  # Set y-axis limits from 0 to 40
    breaks = seq(0, 40, by = 5)  # Define breaks at intervals of 5
  ) +
  theme_bw() +
  my_theme

############################################################################
################################

# PART B: ATHLETICISM AS MODERATOR

#########initial linear model which can not be used#####################
#creating interaction term
```

```
data$interaction <- data$Group * data$Athleticism_Score

# Fit the linear regression model with interaction term
model_athleticism <- lm(Stress_Score ~ Group * Athleticism_Score, data = data)
summary(model_athleticism)

modeltest <- lm(Stress_Score ~ Group + Athleticism_Score + Group:Athleticism_Score, data
= data)
####################################################

##########Data Inspection###########
# Scatterplot of stress_score against Group_numeric
data %>%
  ggplot(aes(x=Group,y=Stress_Score))+
  geom_point()+
  geom_smooth(method = "lm", se=F)

# Scatterplot of stress_score against Athleticism_Score
data %>%
  ggplot(aes(x=Athleticism_Score,y=Stress_Score))+
  geom_point()+
  geom_smooth(method = "lm", se=F)

# Scatterplot of stress_score against interaction term
data %>%
  ggplot(aes(x=interaction ,y=Stress_Score))+
  geom_point()+
  geom_smooth(method = "lm", se=F)

#homoscedasticity + Independent Errors - Residual plot
boxplot(residuals(model_athleticism), main = "Boxplot of Residuals", ylab = "Residuals")

plot(model_athleticism, which = 1)

data %>%
  add_residuals(model_athleticism) %>%
  add_predictions(model_athleticism) %>%
  ggplot(aes(x = Athleticism_Score, y = resid)) +
  geom_point()

#Normality - Histogram of residuals
hist(residuals(model_athleticism), breaks = 20, main = "Histogram of Residuals", xlab =
"Residuals")

# Summary for Group 0 (Control Group)
summary_group_0 <- summary(data$Athleticism_Score[data$Group == 0])

# Summary for Group 1 (Experimental Group)
summary_group_1 <- summary(data$Athleticism_Score[data$Group == 1])
```

```
# Print summaries
print("Summary for Group_0 (Control Group):")
print(summary_group_0)

print("Summary for Group_1 (Experimental Group):")
print(summary_group_1)

sd(data$Athleticism_Score[data$Group == 1])

sd(data$Athleticism_Score[data$Group == 0])

sd(data$Athleticism_Score)

#Summary of Action and Sport Scale sepereately for both Group 0
# Summary statistics for Action_Score
action_score_stats_group0 <- summary(data$Action_Score[data$Group == 0])
cat("Summary Statistics for Action_Score in Group 0:\n")
print(action_score_stats_group0)
# Standard deviation for Action_Score in Group 0
action_score_sd_group0 <- sd(data$Action_Score[data$Group == 0])
cat("Standard Deviation for Action_Score in Group 0:", action_score_sd_group0, "\n")


# Summary statistics for Sport_Score
sport_score_stats_group0 <- summary(data$Sport_Score[data$Group == 0])
cat("Summary Statistics for Sport_Score in Group 0:\n")
print(sport_score_stats_group0)
# Standard deviation for Sport_Score in Group 0
sport_score_sd_group0 <- sd(data$Sport_Score[data$Group == 0])
cat("Standard Deviation for Sport_Score in Group 0:", sport_score_sd_group0, "\n")

#Summary of Action and Sport Scale sepereately for both Group 1
# Summary statistics for Action_Score
action_score_stats_group1 <- summary(data$Action_Score[data$Group == 1])
cat("\nSummary Statistics for Action_Score in Group 1:\n")
print(action_score_stats_group1)
# Standard deviation for Action_Score in Group 1
action_score_sd_group1 <- sd(data$Action_Score[data$Group == 1])
cat("Standard Deviation for Action_Score in Group 1:", action_score_sd_group1, "\n")

# Summary statistics for Sport_Score
sport_score_stats_group1 <- summary(data$Sport_Score[data$Group == 1])
cat("\nSummary Statistics for Sport_Score in Group 1:\n")
print(sport_score_stats_group1)
#Standard deviation for Sport_Score in Group 1
sport_score_sd_group1 <- sd(data$Sport_Score[data$Group == 1])
cat("Standard Deviation for Sport_Score in Group 1:", sport_score_sd_group1, "\n")

#########Analysis Athleticism as a Moderator###############
```

```
# Calculate Spearman's rank correlation coefficient for relationship athleticism and stress
score
correlation_total <- cor.test(data$Athleticism_Score, data$Stress_Score, method =
"spearman")

# Print the correlation coefficient for the entire dataset
print(correlation_total)

#Visualisation -->Stress Score by Athleticism Score
data %>%
  ggplot(aes(x = Athleticism_Score, y = Stress_Score)) +
  geom_point() +
  geom_smooth(method = "lm", se = FALSE) +
  labs(x = "Athleticism", y = "Subjective Stress Level") +
  theme_bw() +
  my_theme

#conducting Mann Whitney U test for relationship athleticism and Group
# Load necessary package
library(stats)

# Perform the Mann-Whitney U test
test_athleticism_group <- wilcox.test(Athleticism_Score ~ Group, data = data, exact =
FALSE)

# Extract and print the results
cat("U statistic:", test_athleticism_group$statistic, "\n")
cat("P-value:", test_athleticism_group$p.value, "\n")

# Create a boxplot to visualize the distribution of Athleticism_Score for each Group
ggplot(data, aes(x = factor(Group), y = Athleticism_Score)) +
  geom_boxplot(fill = "white", color = "black") +
  labs(
    title = "Distribution of Athleticism Scores by Group",
    x = "Group",
    y = "Athleticism Score"
  ) +
  scale_x_discrete(labels = c("Control", "Psychoeducation")) +
  theme_bw() +
  my_theme

#median athleticism score for each group
median_athleticism_by_group <- data %>%
  group_by(Group) %>%
  summarize(Median_Athleticism_Score = median(Athleticism_Score, na.rm = TRUE))

# Print the median athleticism scores
print(median_athleticism_by_group)

#conduct Mann-Whitney U test for low and high athleticism group based on stress
```

```
# Define the threshold for splitting athleticism into low and high groups
threshold <- 28

# Create a new variable 'Athleticism_Group' based on the threshold
data <- data %>%
  mutate(Athleticism_Group = ifelse(Athleticism_Score <= threshold, "Low", "High"))

# Split the data into low and high athleticism groups
low_athleticism <- filter(data, Athleticism_Group == "Low")
high_athleticism <- filter(data, Athleticism_Group == "High")

# Perform the Mann-Whitney U test for the low athleticism group
test_low_athleticism <- wilcox.test(Stress_Score ~ Group, data = low_athleticism, exact =
FALSE)
cat("Low Athleticism Group:\n")
cat("U statistic:", test_low_athleticism$statistic, "\n")
cat("P-value:", test_low_athleticism$p.value, "\n\n")

# Create box plot for the low athleticism group
ggplot(low_athleticism, aes(x = factor(Group), y = Stress_Score)) +
  geom_boxplot(fill = "white", color = "black") +
  labs(
    title = "Subjective Stress Levels by Group (Low Athleticism)",
    x = "Group",
    y = "Subjective Stress Level"
  ) +
  scale_x_discrete(labels = c("Control", "Psychoeducation")) +
  scale_y_continuous(limits = c(0, 40)) +
  theme_bw() +
  my_theme

# Perform the Mann-Whitney U test for the high athleticism group
test_high_athleticism <- wilcox.test(Stress_Score ~ Group, data = high_athleticism, exact =
FALSE)
cat("High Athleticism Group:\n")
cat("U statistic:", test_high_athleticism$statistic, "\n")
cat("P-value:", test_high_athleticism$p.value, "\n")

# Create box plot for the high athleticism group
ggplot(high_athleticism, aes(x = factor(Group), y = Stress_Score)) +
  geom_boxplot(fill = "white", color = "black") +
  labs(
    title = "Subjective Stress Levels by Group (High Athleticism)",
    x = "Group",
    y = "Subjective Stress Level"
  ) +
  scale_x_discrete(labels = c("Control", "Psychoeducation")) +
  scale_y_continuous(limits = c(0, 40)) +
  theme_bw() +
  my_theme
```

```
#Number of Participants in the two athleticism groups
count_low <- data %>%
  filter(Athleticism_Group == "Low") %>%
  summarise(count = n())
print(count_low)

count_high <- data %>%
  filter(Athleticism_Group == "High") %>%
  summarise(count = n())
print(count_high)

#Median Athleticism levels for both groups
# Calculate the median athleticism score for each group
median_athleticism_low <- data %>%
  filter(Athleticism_Group == "Low") %>%
  summarise(median_score = median(Athleticism_Score, na.rm = TRUE))

median_athleticism_high <- data %>%
  filter(Athleticism_Group == "High") %>%
  summarise(median_score = median(Athleticism_Score, na.rm = TRUE))

# Display the median athleticism score for each group
print("Median Athletisim Score - Low Athleticism Group:")
print(median_athleticism_low)

print("Median Athletisim Score - High Athleticism Group:")
print(median_athleticism_high)

Group1 <- subset(data, Group == 1)
Group0 <- subset(data, Group == 0)

# Now create histograms for each group
hist(Group1$Stress_Score, main = "Histogram of Stress Scores - Group 1", xlab = "Stress
Score", col = "blue")
hist(Group0$Stress_Score, main = "Histogram of Stress Scores - Group 0", xlab = "Stress
Score", col = "red")
```