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# What Biological Mechanisms Involved with Physical Activity Determine the Reduction of Stress and Anxiety?

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**ABSTRACT**

In this research paper, we aim to gain a better understanding of the biological functions that occur when an individual takes part in physical activity, especially in regard to their stress and anxiety levels. Previous research has shown that physical activity can increase serotonin levels, decrease amygdala activity, and increase irisin levels. We measured physical activity by minutes of exercise, rated serotonin levels through number of minutes slept, determined amygdala activity from heart rate after viewing scary stimuli, and inferred irisin levels after measuring Body Mass Index (BMI) each day. Our correlational study results showed that the serotonin levels, amygdala activity, and irisin levels were not significantly correlated with physical activity levels.

## 1. Introduction

### *1.1 Research Problem*

Physical exercise is an option for people to reduce their stress and anxiety. Understanding what biological mechanisms are involved in that process can help individuals create better balance between their physical and mental health. With more knowledge, physical activity can be used more efficiently as a tool for lessening anxious feelings. This information will provide individuals new ways to cope with their anxiety and stress disorders while also promoting healthier alternatives to prescribed medications. We would like to find out what causes physical activity to reduce stress and anxiety levels. With the findings, we can teach others the importance of exercise for physical and mental health, as well as how to use exercise as a method of stress and anxiety reduction.

### *1.2 Literature Review*

One factor that has been found that significantly increases serotonin levels in the brain is any form of physical activity. A great deal of research conducted in this field of study is done using either physiological or neuropsychology methods. The reason why physiological psychology is so popular in regards to research about cognitive performance and anxiety levels is due to the fact that experimenters can use lab rats to observe the neural mechanisms under conditions that may be unethical to do with human participants. In a study conducted last year in Beijing, researchers explored the biological benefits that treadmill exercise has on disorders such as Posttraumatic

Stress Disorder (PTSD). The experiment was demonstrated on a time-dependent sensitization model which mimics certain disorders such as PTSD (Zhang et al, 2020). This model was developed to evaluate the possible PTSD-like symptoms after moderate treadmill exercise in a 4-week running program. In the experiment, 47 rats were randomly assigned into four separate groups and were subjected to various elements such as restrainment and electric shocks to their body; causing the rats to develop fear conditioning (Zhang et al, 2020). Certain groups of rats were administered an antidepressant, Sertraline, which affects chemicals in the brain that may be unbalanced due to anxiety or depression. To determine the levels of monoamine neurotransmitters in the rats, the researchers injected high performance liquid chromatography technology that would allow them to observe the neurotransmitters at work (Zhang et al, 2020). The results concluded that the DA levels in the prefrontal cortex that is attributed to anxiety decreased in the rats that were exposed to an intense stressor, such as electric shock, after moderate treadmill exercise (Zhang et al, 2020).  It was reported that the treadmill exercise significantly increased serotonin levels in the hippocampus as well as decreased dopamine levels in the prefrontal cortex (Zhang et al, 2020). These results supported the researchers hypothesis in that treadmill exercise reduces fear conditioning and anxiety-like behaviour due to biological mechanisms such as an increased 5-HT level in the hippocampus and decreased DA levels in the prefrontal cortex (Zhang et al, 2020).

Consistent exercise can contribute to anxiety reduction from reactivity in the amygdala. Chen et al. (2019) have looked at how regular exercise alters activity in the amygdala when a person perceives a happy or fearful face in an implicit or explicit expression after physical activity. Chen et al. (2019) used implicitly and explicitly expressed emotions to test levels of perceptions based on how well a person can identify the emotion of happy or fearful. Implicit expression would be someone not outwardly expressing an emotion on their face, where explicitly would be an expression outwardly showing on their face so a person could easily identify the emotion. In the implicit condition Chen et al. (2019) used a medical face mask to cover the noise and mouth of the face being shown to the participant. The experiment used forty human volunteers (Chen et al., 2019). Subjects completed a survey on habitual physical activity and a survey on anxiety traits at the start of the experiment (Chen et al., 2019). There was a running and a walking condition which consisted of a 3-minute warm up, 12 minutes walking or running, and a 10-minute cool down (Chen et al., 2019). After the running or walking session was done the subject filled out a survey on the state of their anxiety (Chen et al., 2019). Next the subject had a 20-minute fMRI scanning session (Chen et al., 2019). The stimuli used for the fMRI scanning were black and white photos with male and female faces in the expression of either happy, fearful, or neutral with the faces coloured red, yellow, or blue (Chen et al., 2019). The fearful and happy emotions were explicitly expressed and implicitly expressed (Chen et al., 2019). Fearful and happy faces that were explicitly expressed where faces that had non-masked faces and the emotions that were implicitly expressed had face masks on the persons with happiness or fearfulness (Chen et al., 2019). Subjects were shown a randomly selected face for 200-ms and then allowed 1200-ms to identify the colour of the face shown (Chen et al., 2019). After the fMRI scanning subjects were shown the faces again and were told about the three emotional states of the faces that were either explicitly expressed or implicitly expressed (Chen et al., 2019). Then the subjects had to go through the same process as the fMRI but identifying the emotional state of the face presented (Chen et al., 2019). Chen et al. (2019) analysed the amygdala and looked at the relationships between habitual physical activity, anxiety lowering effect from acute exercise and physical fitness. During the explicitly expressed fear condition, the walking had more activity in the amygdala compared to the running and during the explicitly expressed happiness condition running had less activity in the amygdala (Chen et al., 2019). In the running, there was a stronger reactivity in the amygdala in regard to the implicit happiness condition compared to the fear and the walking had stronger amygdala reactivity to implicit fear (Chen et al., 2019). There was a positive correlation with consistent exercise resulting in anxiety reduction and reactivity in the amygdala (Chen et al., 2019). There is less activity in the amygdala after a short amount of exercise which contributes to feelings of anxiety reduction after physical activity.

Anxiety could be reduced by the amount of irisin in the body after consistent exercise. There is a correlation between anxiety reduction, voluntary exercise and increased levels of irisin in the brain as well as in white adipose tissue (Uysal et al., 2018). Uysal et al. (2018) conducted an experiment with two groups of mines, one control group and one exercise group. For 6 weeks, the exercise group had access to a running wheel and the control group did not (Uysal et al., 2018). After the 6 weeks the two groups were put through an "open field test", where each mouse was put in a 1 X 1 m area for 5 minutes and measured locomotor activity and anxiety (Uysal et al., 2018). Uysal et al. (2018) then used a "elevated plus maze test" to observe anxiety in the mice. The maze consists of a middle platform with 4 arms connected to the middle, two open and two closed arms (Uysal et al., 2018). The mice were observed for 5 minutes, measuring the time on both the open or closed arms (Uysal et al., 2018). The last component of the experiment was analyzing blood and tissue samples from the mice in the controlled and exercise group as well as weighting the irisin levels (Uysal et al., 2018). The results of the "open field test" showed that the exercise group had increased movement and speed and stayed to the centre of the field compared to the control group (Uysal et al., 2018). In the "elevated plus maze test" the mice that were a part of the exercise group spent more time in the open arms than the mice in the control group (Uysal et al., 2018). Uysal et al. (2018) discovered that in the mice of the exercise group had higher levels of irisin in the brain, brown adipose tissue, white adipose tissue, kidney, and the pancreas. There was a positive correlation between irisin levels in the brain and irisin levels of white adipose tissue and with activity in the "open field test" and the "elevated plus maze test" (Uysal et al., 2018). Another correlation was found in irisin levels of brown and white adipose tissue as well as irisin levels in kidneys were correlated with adipose tissue (Uysal et al., 2018). These results can help us understand that voluntary physical activity can lead to higher levels of irisin (Uysal et al., 2018).

### *1.3 Hypotheses*

Based on the above literature review, we predicted the following hypotheses:

- Hypothesis #1: If the amount of physical activity increases, then the serotonin will increase.

- Hypothesis #2: If the amount of physical activity increases, then the amygdala activity will decrease.
- Hypothesis #3: If the amount of physical activity increases, then the irisin levels in the body will increase.

## 2. Methods

### *2.1 Participants*

The two authors of this paper were also the participants in its studies. The participants were both female, aged 22 and 27. Both participants were undergraduate students at Camosun College enrolled in Psychology 215- Biological Psychology. The participants shared a common interest in physical activity and regularly engaged in some form of exercise.

### *2.2 Materials and Procedure*

We conducted a correlational study to test all three of our hypotheses by examining the levels of the variables in a normal day. Each participant kept a notebook with them during the study's two week period, which was how they recorded their self-observations. The three variables that were being measured were: (1) physical activity (2) serotonin level, (3) amygdala level and (4) irisin level.

To measure the amount of physical activity each participant recorded the number of minutes of exercise. The minutes were logged in the participants notebook on the days of physical activity. Physical activity was defined as medium to high intensity which included biking, yoga, and weight lifting.

To measure the level of serotonin released, each participant recorded in their notebook how many minutes of sleep they got. The amount of sleep was when the participant fell asleep till when they woke up in the morning. These observations were recorded first thing in the morning after waking up on days where they had no physical activity as well as on days of physical activeness.

To measure the levels of response in the amygdala, each participant measured their heart rate changes in response to a scary stimulus. The scary stimuli consisted of 30-second videos found on Youtube that were different daily. The participants recorded in their notebook their heart rate before they were shown the video and directly after they were shown it. These observations were recorded on days where there was no physical activity as well as on days where they were physically active. In order to measure heart rate before and after being shown the scary stimulus, the participants placed two fingers against their wrist and counted the beats for 15 seconds. They then multiplied the numbers of beats by 4 to find out their heart rate per minute.

To measure the level of irisin, the Body Mass Index (BMI) was used. Each participant weighed themselves on a scale each day for two weeks. The participants logged their weight in their notebook and then did the BMI calculation. Weight in kilograms divided by height in meters squared equals BMI. The formula is BMI = kg/m2.

To assess the strength and statistical significance of associations between variables predicted by our three hypotheses, we performed Pearson product moment correlations of their predictor variables (serotonin level, amygdala response and irisin level) with their outcomes variable (anxiety levels). For testing Hypothesis #1, we correlated the high level of serotonin released in the participant with their amount of physical activity. For Hypothesis #2, we correlated the decrease in amygdala activation with the participants amount of physical activity. For testing Hypothesis #3, we correlated the high level of irisin released in the participants body with their amount of physical activity. We performed all of the above correlations separately for each participant as well as using data pooled across all of the participants. For the correlations using pooled data, in addition to using the raw data, we also performed correlations after we had first transformed the data from each participant into *z*-scores in order to standardize differences in averages and variability seen between the participants in their data and thus make them more comparable. A correlation coefficient was considered statistically significant if the probability of its random occurrence ($p$) was <.05 (i.e., less than 5% of the time expected by chance alone).

## 3. Results

As shown in Table 1, all three variables were not significantly correlated with reduced anxiety levels. For the outcome variable for serotonin, tested through minutes of sleep, the results from the pooled standardized data were not significant ($r$ = .03, $p$ = .86; see Figure 1B). The pool raw data for serotonin was also not significant ($r$ = .22, $p$ = .259; see Figure 1A). Irisin levels and minutes of exercise were not significant in the results from the pooled standardized data ($r$ = .33, $p$ = .085; see Figure 3B); furthermore, the pooled raw data shows it was significant ($r$ = .54, $p$ = .00248; see Figure 3A). Lastly, the results from the amygdala and heart rate per minute were not significant from the pooled standardized data ($r$ = .09, $p$ = .66; see Figure 2B); however, the pooled raw data shows it was significant ($r$ = .42, $p$ = .02; see Figure 2A).

## 4. Discussion

### *4.1 Summary of Results*

Based on previous research, we hypothesized that three different variables would decrease anxiety levels after physical activity: the serotonin level (Hypothesis #1), the irisin level (Hypothesis #2), and the amygdala activity (Hypothesis #3). Data pooled across participants in our correlation study did not support any of our hypotheses in the relationship between amount of exercise with serotonin levels, irisin levels, and amygdala activity (Hypotheses #1, 2, & 3).

### *4.2 Relation of Results to Past Research*

Our correlation study between two variables, physical activity and serotonin levels, did not produce statistically significant results. Our prediction was based on previous research involving lab rats by Zhang et al. (2020). These researchers had found that treadmill exercise produced biological benefits for disorders such as Posttraumatic Stress Disorder (PTSD). Zhang et al. (2020) reported that the physical activity significantly increased serotonin levels in the hippocampus, as well as decreased dopamine levels in the prefrontal cortex; therefore, their research demonstrated that exercise can reduce anxiety-like behaviour. For our study, we measured serotonin levels by recording how many minutes of sleep per night the participants got, as well as recorded their amount of physical activity during the day. Contrary to our hypothesis, our participants did not consistently experience an increase in serotonin on days in which they engaged in physical activity. This could be due to environmental factors that could have affected their sleep, as well as lifestyle variability. In Zhang et al. (2020) study, their lab rats were in a controlled environment to reduce any potential conflicting variables. This controlled environment could have produced more accurate results compared to our research model. Another difference between our research and the previous research conducted is that Zhang et al. (2020) injected high performance liquid chromatography technology into their lab rats as a way to observe their neurotransmitters. In our study, we did not administer any chemicals or liquid chromatography technology into our participants. Future studies in this area should examine if getting the recommended amount of sleep per night increases humans serotonin levels.

Our correlation study between physical activity and amygdala activity failed to represent a relationship. This prediction was made after previous research. Chen et al. (2019) had found that after a participant did physical activity and then was exposed to scary stimuli, their amygdala would decrease in activity. In contrast, our participants did not consistently experience a decrease in amygdala activity to scary stimuli on days with more minutes of exercise. This could be due to the way in which the amygdala activity was measured as well as the timing of the measuring after physical activity. The way Chen et al. (2019) measured amygdala activity in their participants was using a fMRI scanning. This could produce more accurate results compared to our method of using heart beats per minute. Another aspect that differed between Chen et al. (2019) and our study was the timing in between physical activity and the measuring of amygdala activity after scary stimuli. In Chen et al. (2019) lab they gave the participants a ten minute cool down and then participants filled out a survey, then continued onto the fMRI scan. In our study there was varying amounts of time in between the physical activity and the measure of amygdala activity using heart rate per minute. Future studies should examine whether amygdala activity is able to predict that physical activity reduces anxiety.

In our correlation study we could not confirm a relationship between irisin levels and physical activity. Uysal et al. (2018) had discovered that through voluntary exercise there could be higher levels of irisin found within the body. Our participants did not always find an increase in irisin levels after days with more minutes of exercise. Uysal et al. (2018) had done this study on mice compared to us who performed the correlation study on ourselves. This aspect could be a large component as to why we failed to find a correlation. Uysal et al. (2018) were able to dissect the mice after the experiment to weight the amount of irisin. We did not have access to this method so we had to use Body Mass Index (BMI) to measure irisin levels in us. The results that we got were most likely less accurate to the different methods of measuring irisin. Future studies should examine whether irisin levels are able to be predicted in humans instead of mice after physical activity.

## References

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**Table 1**

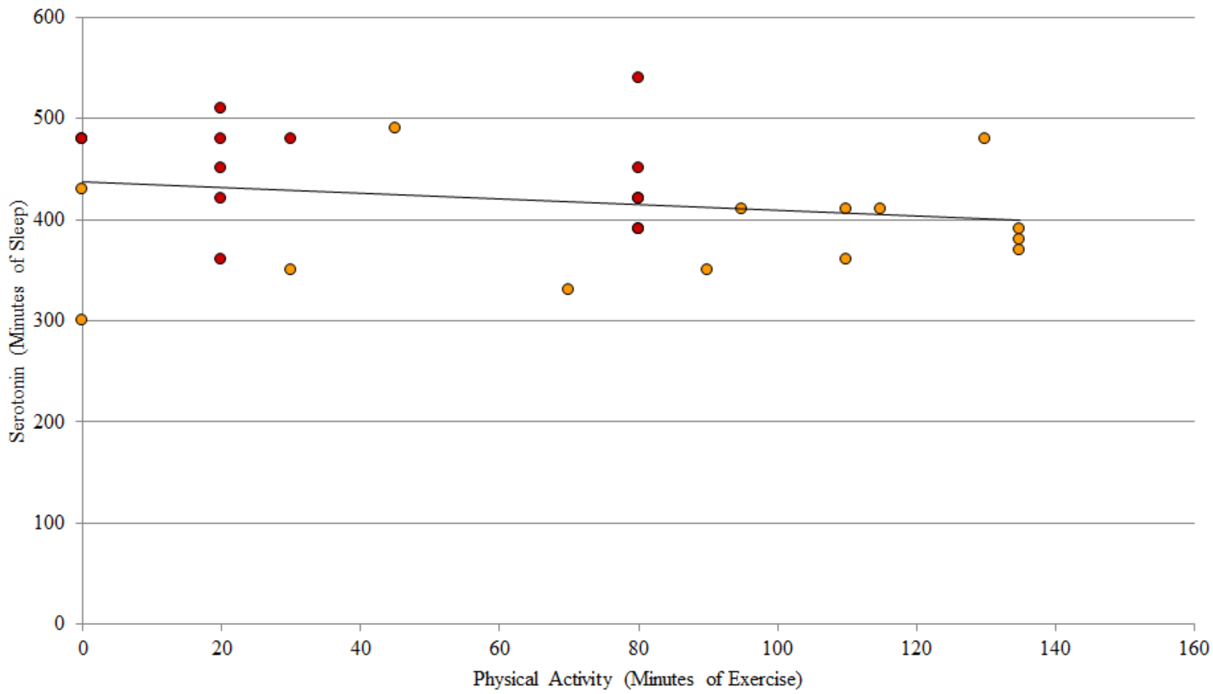
*Correlation coefficient (r) values, with number of daily trials (n) per correlation in brackets.*

| Variables correlated | Participant #1 | Participant #2 | Pooled raw data | Pooled standardized data |
|---|---|---|---|---|
| Serotonin Level & Physical Activity | -.25(14) | .18(14) | -.22(28) | -.03(28) |
| Amygdala Activity & Physical Activity | -.17(14) | 0.00(14) | .42(28)* | -.09(28) |
| Irisin Level & Physical Activity | -.14(14) | -.52(14) | -.54(28)* | -.33(28) |

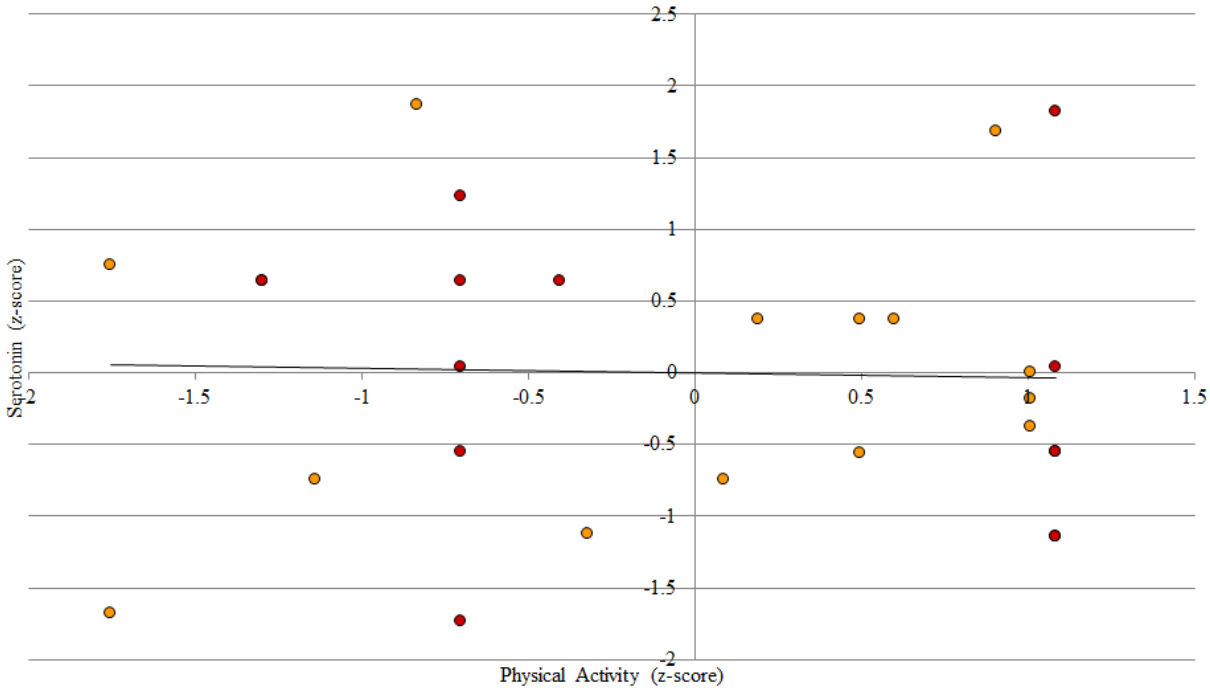
**Figure 1**

*Scatterplot of Physical Activity and Serotonin Level using pooled (A) raw and (B) standardized data across participants.*

A



B.

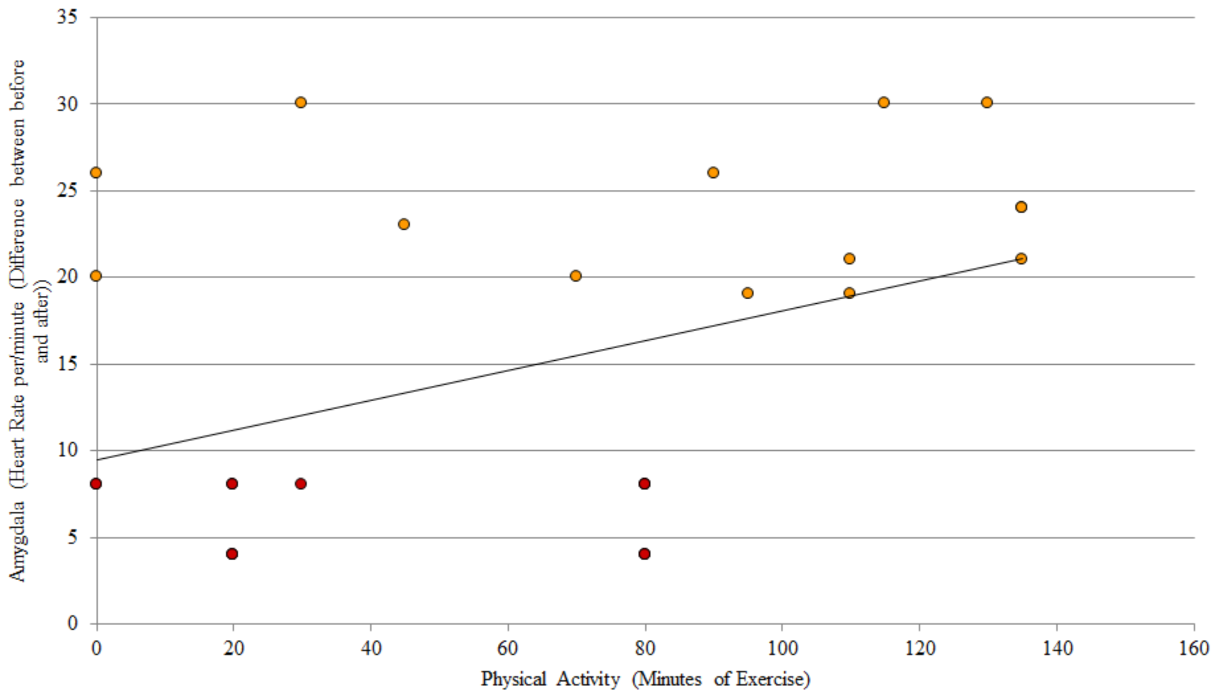



Marker color indicates which participant data is from: red = participant #1, orange = participant #2. Some data might not be visible in the figure due to overlapping markers.

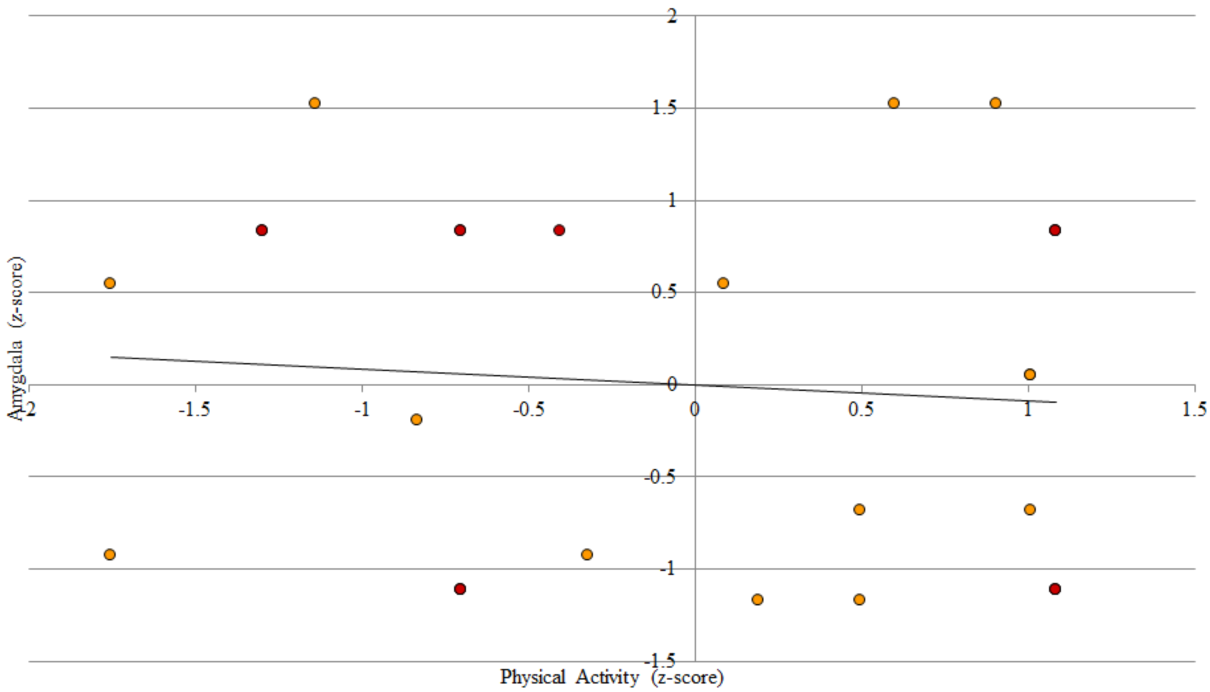
**Figure 2**

*Scatterplot of Physical Activity and Amygdala Activity using pooled (A) raw and (B) standardized data across participants.*

A.



B.

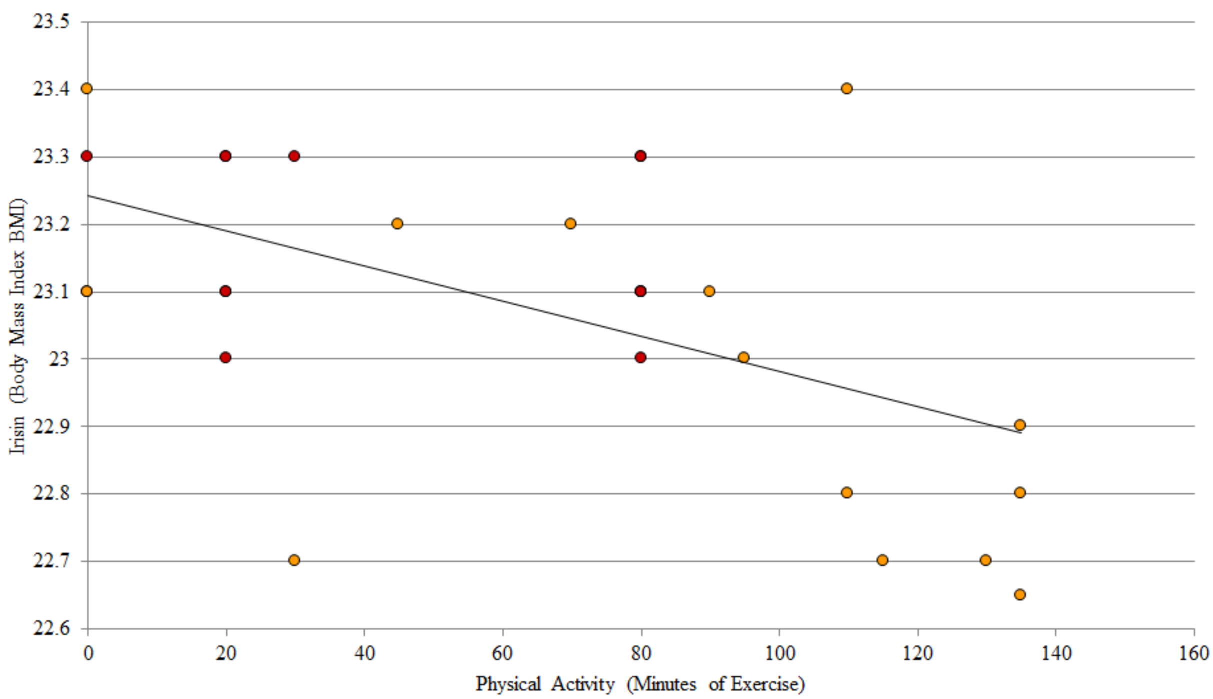



Marker color indicates which participant data is from: red = participant #1, orange = participant #2. Some data might not be visible in the figure due to overlapping markers.

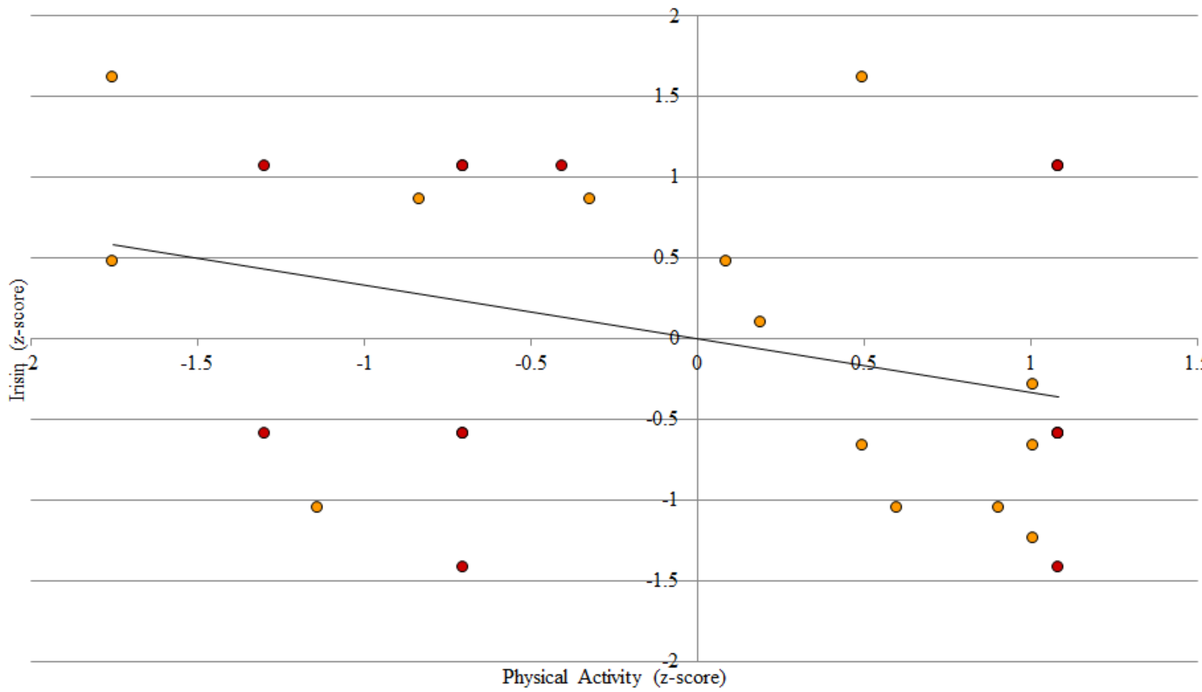
**Figure 3**

*Scatterplot of Physical Activity and Irisin Level using pooled (A) raw and (B) standardized data across participants.*

A.



B.




Marker color indicates which participant data is from: red = participant #1, orange = participant #2. Some data might not be visible in the figure due to overlapping markers.