ACTIVITY 2

Measuring Well-Being

LABORATORY

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ACTIVITY SUMMARY

Students investigate the impact of exercise on short-term well-being by measuring changes in heart rate, alertness, and mood. They analyze their class data and explore the challenges of studying well-being by identifying other factors that might explain their results, such as music. Finally, students compare their results to existing research on exercise and discuss ways to design studies that limit alternative explanations.

ACTIVITY TYPE
LABORATORY

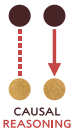
NUMBER OF
40–50 MINUTE
CLASS PERIODS
1–2

KEY CONCEPTS & PROCESS SKILLS

1. Some effects are difficult to identify due to insufficient evidence, multiple causes, delayed effects, or confounding factors.
2. Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations.
3. Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:
Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. (*Science and Engineering Practice: Analyzing and Interpreting Data*)

CONCEPTUAL TOOLS



VOCABULARY DEVELOPMENT

alternative explanation
another possible explanation for a result, such as an unnoticed variable or random chance

TEACHER BACKGROUND INFORMATION

Alternative Explanations

Philosophers of science argue that for any set of evidence, there is usually more than one possible explanation for it. In other words, having evidence for one specific theory or idea isn't enough to prove it's correct—an alternative explanation could be responsible. However, when the alternative explanations are highly unlikely, overly complex, or both, we can feel more confident in the accuracy of our original explanation.

Considering alternative explanations is a crucial step in evaluating the strength of evidence. If there is an alternative explanation for a result, then the evidence is weaker. Alternative explanations can apply in different ways when evaluating cause-and-effect relationships. One type of alternative explanation questions the cause of an effect. For example, if a study finds that students who sleep more tend to have higher well-being, an alternative explanation could be that another factor, such as lower stress, causes both better sleep and higher well-being. This challenges whether sleep itself is the true cause. Another type of alternative explanation questions whether the study's results are accurate. Even if sleep genuinely improves well-being, the findings of a study might be misleading due to random chance. For example, if the study includes only a small number of participants, the results might not represent what would happen in a larger group. In this case, the issue isn't whether sleep affects well-being, but whether the study's evidence is strong enough to confidently support that claim.

A common mistake in evaluating evidence is ignoring possible alternative explanations, even when they seem obvious later on. For this reason, we ask students to practice thinking about both types of alternative explanations throughout the unit—questioning the cause of an effect and questioning the accuracy of a study's results.

Exercise and Well-Being

There are numerous studies showing that exercise boosts many aspects of well-being, including both physical and mental health. Exercise triggers the release of endorphins, which help reduce anxiety and depression. A large study of 1.2 million American adults, published in the journal *Lancet Psychiatry*, found that people who exercised had 40% better mental health than those who didn't exercise, even after accounting for factors such as body mass index (BMI), physical health, age, and race. Team sports had the strongest connection to better mental health, likely because it combines physical activity with social interaction.

Both short-term and regular exercise can be beneficial. Short-term bouts of exercise can lead to immediate improvements in mood and cognitive function. For instance, studies have shown that a single session of physical activity can enhance attention, working memory, and problem-solving skills for up to two hours post-exercise. Regular physical activity offers more substantial long-term advantages, including sustained improvements in mental health, reduced risk of chronic diseases, and better overall well-being.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 2.1 "Class Results: Change in Heart Rate, Alertness, and Mood" (OPTIONAL)
- VISUAL AID 2.2 "Sample Class Results" (OPTIONAL)
- VISUAL AID 2.3 "Studies on Exercise and Well-Being"
- COMPUTER TO PLAY A 3-MINUTE VIDEO OR A CLASSROOM AUDIO DEVICE

FOR EACH PAIR OF STUDENTS

- TIMER THAT DISPLAYS SECONDS
- CALCULATOR
- STUDENT SHEET 2.1 "Measuring Physical and Mental Responses to Exercise"

Each pair of students should receive one copy of the student sheet to complete together.

Consult with a physical education teacher about what types of exercises might be most appropriate for your student population (see Teaching Step 2). Inform students in advance that they will be exercising in class. Encourage them to wear appropriate attire, including appropriate shoes, and be prepared to perspire.

Choose a 3–minute song or video with music that will be likely to affect students' moods and act as a possible confound during the experiment. This could be a popular, high energy, or funny dance song that is played for the duration. If a video with a countdown is used, a timer is not required for each pair of students.

While the Student Book includes instructions for measuring pulses at the wrist or neck, you might prefer to have students use heart monitors/sensors, such as those available from science or sports-gear suppliers. Alternatively, students can download and use free heart rate monitoring apps on their phones or watches.

Safety Note

Do not allow students to participate in this activity if they have any condition that prevents them from exercising.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 **Have students read the Introduction and discuss how well-being can be measured.**

- Ask, If you decided to exercise for a little while, what kinds of changes—mental or physical—would you expect to notice? Students may share various answers such as feeling tired, sweaty, satisfied, happier, less stressed, more pained, more focused. Let students know that in this activity, they will be thinking about both physical and mental aspects of well-being.
- When students finish reading the Introduction, have them consider how well-being can be measured. Ask, Do you think it's easier to measure physical changes, such as heart rate and breathing, or mental changes, such as mood and feelings? Encourage students to briefly share their thoughts, highlighting that both physical and mental measurements have their own challenges and benefits. Sample responses include thinking that physical measures of well-being are better because they can't be faked or misreported. Some students may feel that mental changes are better to measure because emotions and feelings are a more important aspect of well-being. Explain to students that understanding both types of changes are important, as physical and mental measurements together provide a more complete picture of how well-being strategies, such as exercise, affect a person.

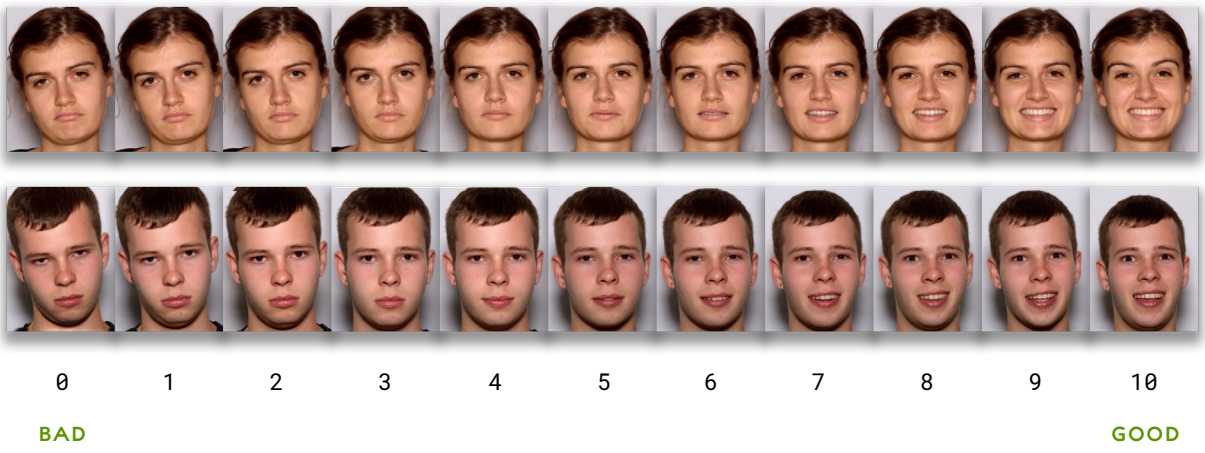
PROCEDURE SUPPORT (20 MIN)

2 **Prepare students for the laboratory.**

- The scenario presented in Step 1 can be shared with the class in multiple ways. Read the scenario aloud to the class or have individual students read it aloud while others follow along with the text (either as a whole class or in small groups).
- Reading the scenario aloud can better support comprehension for many students, including neurodiverse students and emerging multilingual learners who often have more highly developed listening and oral skills than reading comprehension skills. Alternatively, students can read the scenario independently.

- Decide how you would like to pair students for this activity. The procedure is set up so that one student in each pair will perform the exercise and rate their mood (the test partner), while the other student acts as a timer and records the data (the recorder). If you prefer, you can adjust the roles or group sizes to ensure all students can participate in the exercise. Be aware of any student who might have a physical reason why they cannot perform the exercise and assign them to be the recorder. Since this is an inquiry-based lab, you may want to use heterogeneous groups to help support the needs of all learners and encourage all students to participate. Create specific groupings that might encourage greater participation and best support your student population.

- Opportunity for advanced learning. If you want students to explore another way researchers measure well-being, consider adding an objective behavioral measurement, using a scale for facial expression. The recorder would use the scale to rate and record the test partner's mood before and after exercise, alongside the other measurements on the student sheet used in this activity. To do this, the recorder asks the test partner to look at them for 5 seconds and then selects the mood that best matches the partner's natural facial expression. Comparing self-ratings and observer ratings can lead to discussions about how mood perception differs between oneself and others. You can find a facial expression scale online by searching for standardized emotion rating charts similar to the one shown here.



- Select an aerobic exercise that test partners will perform for 3 minutes. You may want to reach consensus as a class to decide on the exercise. Some options are jogging in place, a step exercise, jumping jacks, or squats. You can have students do the exercise in the classroom, outside, or in the gym—as long as there's a way to play a song or music video while they exercise.

TEACHER'S NOTE: Inform students that all test partners must wait for your signal to start the exercise (Procedure Step 7) so they are all exercising at the same time. Let students know that test partners will only exercise once. Afterward, the recorder will take 3 readings for heart rate, one after the other, and calculate the average. Taking the average of 3 30-second intervals leads to a more accurate reading but has the disadvantage of a heart rate returning to baseline during the post-exercise measurement. If students recognize this, add it to the list of things that could be changed about the experiment in order to be more confident in the results (in Teaching Step 6).

3 Review how to measure heart rate.

- In Procedure Step 4, hand out one copy of Student Sheet 2.1, "Measuring Physical and Mental Responses to Exercise," to each pair of students. Review how to measure heart rate, as described in Procedure Steps 4 and 5. Explain that test partners should sit in a relaxed manner and breathe as normally as possible. Show them how to find their pulse. Observe them as they practice taking their pulse and assist as necessary until you are reasonably confident that all test partners know how to proceed. Check that most of them are getting resting heart rate data within a reasonable range (normally 60–100 beats per minute). If anyone is having trouble or getting extremely high or low results, assist as needed. However, problems with measuring heart rate by students can also be discussed as another challenge for the experiment later in the activity.

- To help students better understand their heart rate measurements, you may want to review the content on the circulatory system found in the Science Review at the end of the Student Book activity. To provide further context, you may also want to review the respiratory system or other body systems to discuss how and why exercise leads to changes such as faster breathing, sweating, or muscle fatigue.

4 Students perform the exercise experiment.

- Review Procedure Steps 5 and 6 to make sure all students understand the "before exercise" part of the experiment and how the recorder in each pair will fill in the data for Trials 1–3 in the Before Exercise table on the student sheet.

- In Procedure Step 7, after students have collected their baseline data, have them prepare for exercising. Have students wait for your cue to begin. After 3 minutes, end the music and have test partners stop exercising.

  TEACHER'S NOTE: Have students carry out the exercise test at the same time while the music plays. Later in the activity when students are introduced to alternative explanations (Teaching Step 5), they should realize that the music (and/or other factors) may have affected their results. Therefore, wait until after students have completed all the trials and analyzed the data as a class to discuss factors besides exercise or any potential issues with the experiment.

- Support students in determining their average (mean) heart rates before and after exercise. In general, students should find that exercise increases heart rate and alertness. It may also improve mood. A sample student response for Student Sheet 2.1 can be found at the end of this activity. You should expect exercise to increase test partners' heart rates by as much as 40–50 beats per minute.

5 Guide students as they analyze the class results.

- After Procedure Step 9, ask students to briefly share any differences they noticed between the before exercise data and the after exercise data. To set up a later discussion about variability, ask students to share their individual results, making sure to hear from at least one student whose results are the opposite of another's. Encourage comparisons to highlight differences in outcomes.

- In Procedure Step 10, compile all the test partners' values for the three variables (heart rate, alertness, and mood) for both before and after exercise. You may want to create a spreadsheet and have students share their data. Students may share data with their names, or each student can be assigned a number instead. Average the variables and display the results for the class. Alternatively, as a class, fill out optional Visual Aid 2.1, "Class Results: Change in Heart Rate, Alertness, and Mood." Then, create and display the data in the bar graphs. You can refer to optional Visual Aid 2.2, "Sample Class Results," to see a completed sample table and graphs from Visual Aid 2.1.

- Lead a discussion with the class to analyze the results. Encourage students to share their observations and conclusions based on the class data. Ask, How did the averages change from before exercise to after exercise, and what do your results suggest? Answers may vary. The class averages are likely to show an increase for heart rate and alertness but less so for mood. Students may suggest that exercise could or could not be causing an increase in well-being. Ask, How does the data differ from person to person? Students may notice that some individuals showed significant changes, while others remained the same. If there is a lot of variability between individuals, some students may question if enough people were tested. If they raise this concern, acknowledge their reasoning and explain that they will learn more about sample size in an upcoming activity. Students may also discuss whether variation in results from person to person were caused by factors such as measurement inaccuracies, varying levels of motivation, or other individual factors.

- Explain that averages help smooth out individual differences and reveal overall trends in data. Rather than focusing on one person's results, which might be affected by many factors, an average combines everyone's data for a clearer picture of the overall effect of the target factor. This also reduces the impact of extreme values or outliers. For example, if some students' heart rates increased significantly after exercise while others changed only slightly, the average change in heart rate provides a more reliable understanding of the class's response to exercise.

- Before students start Procedure Step 11, prepare them to think about more than individual differences in the data. Explain that they will consider factors that might impact everyone's participation in the experiment and the overall average.

- After Procedure Step 11, have students share their ideas about factors other than exercise that may have influenced their results. Students should recognize that the music or the way they reacted to one another during the exercise could have been large factors that influenced their class results for mood. Encourage students to consider other possible factors affecting heart rate, alertness, and mood. See the following sample student responses for various examples.

Sample Student Responses, Procedure Step 11

The dance music was loud and fun. Plus, everyone was reacting to each other. These things seemed like they made a bigger difference on people's moods than the exercise.

Some people might have felt self-conscious or annoyed that they had to exercise in front of others, so their moods might have been lower afterward because of that.

Being nervous about exercising in front of others could have made some people's heart rates go up a little instead of the exercise.

Most people were not really trying, so they didn't exercise much. This is probably why we didn't see much of a change in heart rate or alertness.

- If students have trouble recognizing factors such as those listed above, guide them by asking questions such as *What kind of music did we play? How could it have affected someone's mood? Could the way we all did the exercise influence someone's mood?*

- Introduce the term *alternative explanation*. Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by adding the term to the word wall and provide an example as needed. For more information on a Word Wall, see Appendix 1: Literacy Strategies. Emphasize that alternative explanations for results can come from either:

  - random chance—if a small number of people are tested or there are extreme data points (outliers), as was discussed after Procedure Step 10. For example, data might show that people's math test scores increase when there are more flowers blooming, but only a few people were surveyed.
  - other possible causes for the effect—a few examples of alternative explanations are the music, how students interacted with one another in the experiment they performed, or concluding that spring causes allergies when the actual cause is the increase in pollen during the spring season.

SYNTHESIS OF IDEAS (20 MIN)

6 Discuss how alternative explanations complicate studying cause and effect.

- Ask students to share their ideas from Procedure Step 13. Ask, Based on the data we collected and the possible alternative explanations, how sure are you that exercise improves mood? Answers may vary but should reflect alternative explanations that address both chance and other possible causes for the experiment results.

Sample Student Responses, Procedure Step 13

I'm not sure at all. We saw a big effect on mood, but this could be because of the music playing, not the exercise.

I think exercise helped, but we only tested a few people. Maybe if we had more data, it would be clearer whether exercise alone makes a difference.

I'm a little unsure. We did not see a big change in average mood, but it could be because some people were less excited to exercise, while others didn't really participate, so it's hard to say if exercise improves mood.

I don't think exercise made a difference at all because there were a lot of things influencing mood, like how people felt about exercising in front of others.

- Based on their responses, ask students to brainstorm and share ways they could have modified the class experiment to increase their confidence in the results. Student responses may include removing the music during exercise, having people exercise individually, and making sure everyone does the same amount of exercise. Some students may also recognize that using more accurate measurement tools, testing a larger number of individuals (sample size), having another group for comparison, or repeating the experiment more times may increase confidence in the results as well.

- Explain that scientists must think about alternative explanations when they design and analyze their research studies. With the class, review Visual Aid 2.3, "Studies on Exercise and Well-Being," to compare the class results to data on exercise and well-being from published studies. You may want to share that while the effects of brief exercise on well-being were tested, research shows that both a single session and regular exercise have positive impacts on well-being. Numerous studies now support the idea that exercise can reduce feelings of stress, enhance mood, increase energy level, and improve sleep.

- Conclude the activity by revisiting the Guiding Question, *What are the challenges of studying well-being?* Use responses to this question to formatively assess students' understanding of the key concepts and process skills related to causal reasoning, such as difficulties in studying effects and avoiding incorrect conclusions due to alternative explanations.

EXTENSION (10 MIN)

7 Use the Extension as an opportunity for advanced learning.

Show students Dr. Laurie Santos's video, *What Does It Even Mean to Be Happy? The Science of Well-Being for Teens*, to review how scientists view well-being and why they consider surveys reliable for measuring mental well-being. If necessary, review the term *subjective well-being* beforehand (being happy *with* your life and *in* your life). Then, have students conduct their own research to explore why surveys are trusted as tools for assessing mental aspects of well-being.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

① **In the class experiment, do you think it was exercise or some other factor(s) that affected your class results the most? Support your reasoning, using ideas from your class discussion.**

Sample Response 1

I think other factors, like the music or exercising in front of others, could be why we saw an increase in mood in our average class results. For example, the music could have made some people feel happier or more relaxed, which might have improved their mood, even if they weren't exercising. Or, since everyone was having fun at the same time, they were feeling happier. Exercise might be part of the reason, but we can't be sure.

Sample Response 2

Our class results showed a small decrease in average mood after exercise. Instead of exercise, I think it's because a lot of people were feeling self-conscious or annoyed by having to do jumping jacks, which could have negatively affected their mood. There was a lot of variability though, and we did not test that many people, so it could be from chance. Some people felt more alert and happy, while others shared that they might not have gotten enough sleep the night before and that could have affected their mood. So, I think these factors had a bigger effect on our results than the exercise itself.

CONNECTIONS TO EVERYDAY LIFE

② **Imagine you have been having trouble sleeping for several weeks. A friend suggests going for a walk every night after dinner and recording how well you sleep each night to see if it helps.**

a **Do you think having this kind of data would help you decide if the walks were improving your sleep?**

If I did the walks for a long time, like for a few months, the data could be helpful because I could see if I always, or most of the time, slept better.

b **What other data could you record that might offer alternative explanations for a change in well-being?**

It might also help to record if there was anything stressing me out or maybe how much caffeine I had each day, because those are other things that could affect my sleep. The combination of data could help me decide if the walks were helpful or not.

REFERENCES

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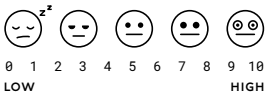
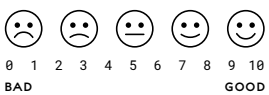
Chekroud, S. R., Gueorguieva, R., Zheutlin, A. B., Paulus, M., Krumholz, H. M., Krystal, J. H., & Chekroud, A. M. (2018). Association between physical exercise and mental health in 1.2 million individuals in the USA between 2011 and 2015: A cross-sectional study. *The Lancet Psychiatry, 5*(9), 739–746. https://doi.org/10.1016/s2215-0366(18)30227-x

Jerath, R., & Beveridge, C. (2020). Respiratory rhythm, autonomic modulation, and the spectrum of emotions: The future of emotion recognition and modulation. *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.01980

Seligson, S. (April 13, 2010). *Exercise: The other antidepressant*. BU today. Boston University. https://www.bu.edu/articles/2010/exercise-the-other-antidepressant/

Data Table for Test Partner

	AVERAGE HEART RATE IN BEATS PER MINUTE see Before Exercise and After Exercise tables for how to calculate	ALERTNESS RATING  	MOOD RATING 
Before Exercise			
After Exercise			
Change in Each Measure After Exercise value minus Before Exercise value			

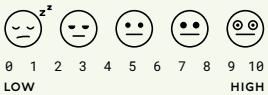
Before Exercise: Average Heart Rate Calculation

	NUMBER OF HEART BEATS IN 30 SECONDS	BEATS PER MINUTE (60 SECONDS) FOR EACH TRIAL	
TRIAL 1		x2 =	
TRIAL 2		x2 =	
TRIAL 3		x2 =	
		Total =	
		Average beats per minute =	

After Exercise: Average Heart Rate Calculation

	NUMBER OF HEART BEATS IN 30 SECONDS	BEATS PER MINUTE (60 SECONDS) FOR EACH TRIAL	
TRIAL 1		x2 =	
TRIAL 2		x2 =	
TRIAL 3		x2 =	
		Total =	
		Average beats per minute =	

Data Table for Test Partner

	AVERAGE HEART RATE IN BEATS PER MINUTE see Before Exercise and After Exercise tables for how to calculate	ALERTNESS RATING  	MOOD RATING 
Before Exercise	*72.0*	*5*	*4*
After Exercise	*95.3*	*7*	*5*
Change in Each Measure After Exercise value minus Before Exercise value	*23.3*	*2*	*1*

Before Exercise: Average Heart Rate Calculation

	NUMBER OF HEART BEATS IN 30 SECONDS	BEATS PER MINUTE (60 SECONDS) FOR EACH TRIAL	
TRIAL 1	*38*	x2 =	*76*
TRIAL 2	*32*	x2 =	*64*
TRIAL 3	*38*	x2 =	*76*
		Total =	*216*
		Average beats per minute =	*72.0*

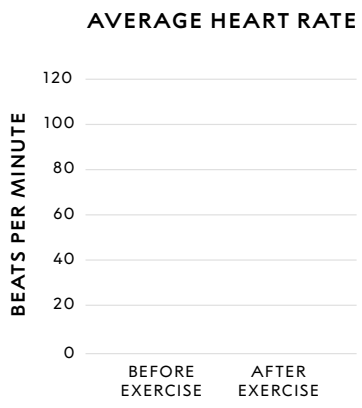
After Exercise: Average Heart Rate Calculation

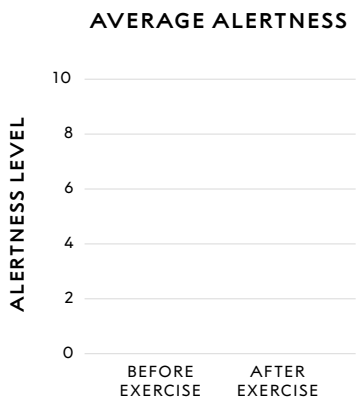
	NUMBER OF HEART BEATS IN 30 SECONDS	BEATS PER MINUTE (60 SECONDS) FOR EACH TRIAL	
TRIAL 1	*52*	x2 =	*104*
TRIAL 2	*46*	x2 =	*92*
TRIAL 3	*45*	x2 =	*90*
		Total =	*286*
		Average beats per minute =	*95.3*

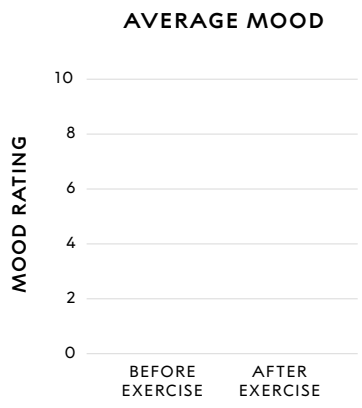
VISUAL AID 2.1

CLASS RESULTS: CHANGE IN HEART RATE, ALERTNESS, AND MOOD

	HEART RATE (BEATS PER MINUTE)		ALERTNESS LEVEL (0–10)		MOOD RATING (0–10)	
Student	BEFORE EXERCISE	AFTER EXERCISE	BEFORE EXERCISE	AFTER EXERCISE	BEFORE EXERCISE	AFTER EXERCISE
Averages						



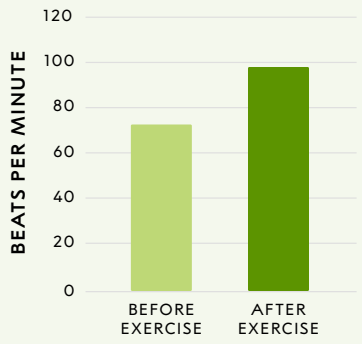




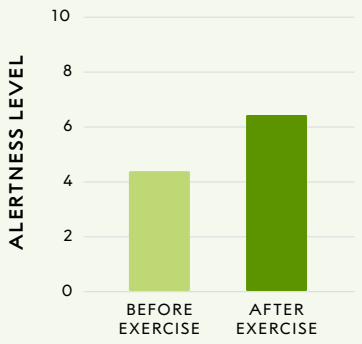
VISUAL AID 2.2 | SAMPLE CLASS RESULTS

	HEART RATE BEATS PER MINUTE		ALERTNESS LEVEL 0–10		MOOD RATING 0–10	
Student	BEFORE EXERCISE	AFTER EXERCISE	BEFORE EXERCISE	AFTER EXERCISE	BEFORE EXERCISE	AFTER EXERCISE
1	*72.0*	*77.3*	*5*	*5*	*5*	*5*
2	*64.0*	*116.7*	*3*	*8*	*3*	*5*
3	*79.3*	*92.7*	*4*	*8*	*6*	*8*
4	*84.0*	*92.7*	*6*	*9*	*6*	*4*
5	*72.0*	*87.3*	*5*	*6*	*5*	*2*
6	*72.0*	*95.3*	*5*	*7*	*4*	*5*
7	*68.7*	*105.3*	*5*	*4*	*5*	*6*
8	*84.0*	*111.3*	*4*	*6*	*6*	*9*
9	*60.7*	*93.3*	*3*	*6*	*5*	*7*
10	*72.0*	*92.0*	*6*	*10*	*5*	*8*
11	*84.7*	*97.3*	*5*	*8*	*6*	*5*
12	*70.0*	*112.7*	*5*	*4*	*5*	*5*
13	*74.7*	*108.0*	*2*	*7*	*6*	*10*
14	*74.7*	*83.3*	*5*	*5*	*2*	*6*
15	*78.0*	*114.0*	*4*	*7*	*5*	*6*
Averages	***74.0***	***98.6***	***4.5***	***6.7***	***4.9***	***6.1***

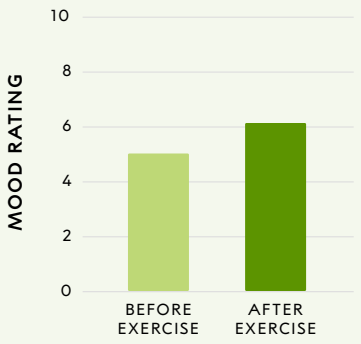
AVERAGE HEART RATE



AVERAGE ALERTNESS

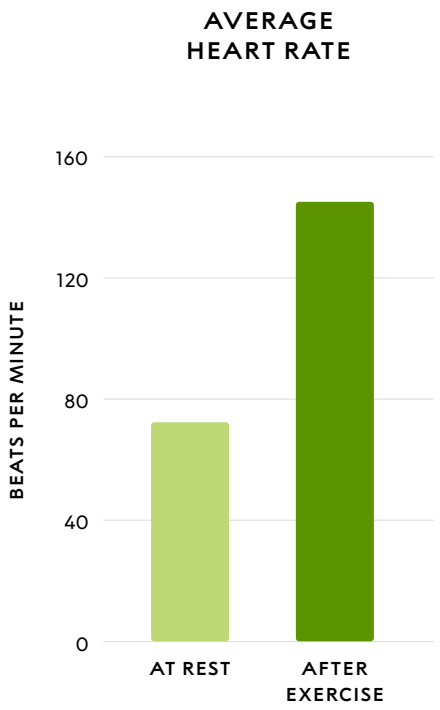


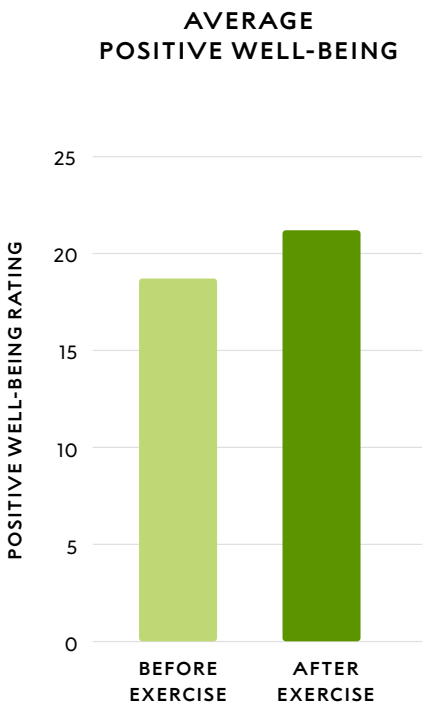
AVERAGE MOOD



Brief Exercise

Healthy young adults were tested for 36 minutes of moderate-intensity exercise at 75% of maximal heart rate.





Regular Physical Activity

In a sample of 1.2 million people, individuals who exercise daily had a 43% reduction in mental health challenges. Researchers asked, “How many days during the past 30 days was your mental health not good?”