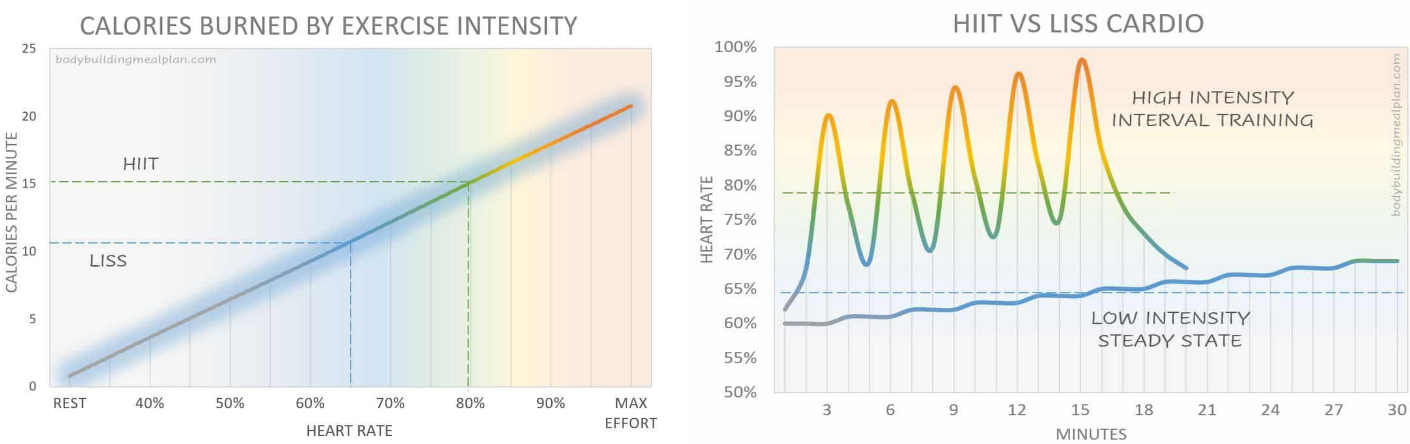
Efficacy of High Intensity Interval Training: Bona Fide or Fad?

Irina Koleva and Mary Ardoin

Background

High-intensity interval training (HIIT) is a training protocol alternating short periods of intense or explosive anaerobic exercise with brief recovery periods until the point of exhaustion, which thereby relies on "the anaerobic energy releasing system almost maximally. HIIT workouts have grown in popularity over the past few years because of how efficient they claim to be; they are successful in elevating the heart rate and burning calories over a short period of time (Gibala 2007).



https://www.bodybuildingmealplan.com/hiit-vs-liss/

Figure 1: HIIT has been shown to increase heart rate more effectively (left) and burn more calories (right).

One of the biggest benefits of aerobic exercise are the cardiovascular adaptations. Recent works have shown that performing HIIT exercises in comparison to long, slow distance training, improved stroke volume (volume of blood pumped out by the heart), as well as increased the left ventricle heart mass and cardiac contractility (Zuhl and Kravitz 4). Similarly, HIIT has been found to increase the amount of calories burned. Since HIIT workouts become so intense in such a little amount of time, this causes the body to call upon its immediate source of energy (carbohydrates) and has been shown to burn through these calories more than other exercises (Bunda 3). This increase in cardiovascular activity is what makes HIIT seemingly so effective. Our goal is to investigate if HIIT is truly more effective than moderate intensity training such as jogging. A comparison between HIIT and moderate intensity continuous training will be done as a reality check to see what the difference between the two training forms is.

Hypothesis

High-intensity interval training (sprints) will be more effective in increasing heart rate and burning calories than moderate-intensity continuous training (jogging).

Protocol

Our data collection consisted of 11 participants, ranging between the ages of 18 and 22. Participants were to wear their Fitbits and make sure they were synced to their phone. Data collection was divided into three sections (see Figure 2). The first was gathering baseline measurements, in which specified attributes (respiratory rate, likert scale of exhaustion, time start, time end, height and weight) were measured after a minute of rest (see Figure 3). These measurements were recorded in the “resting” row of the provided Excel spreadsheet. The second section was sprinting, which represented a HIIT exercise. The third section was jogging, which represented a low/moderate intensity exercise.

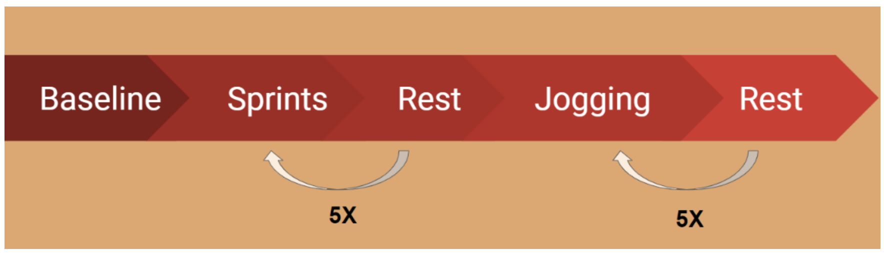


Figure 2: visualization of protocol

The first phase was “Baseline”, where participants were told to rest for 1 minute, and then record their data. The next step were the HIIT exercise sprints. This step consisted of 5 sets of one-minute long intervals split into 20 seconds on and 10 seconds of recovery (40 total seconds of exercise). The participants were instructed for their effort level on the sprints to be 10/10. Once completed, participants rested until they felt they had recovered and then repeated the cycle. The next step was low intensity jogging. Similar to sprinting, participants completed 5 sets of one-minute long intervals jogging at a comfortable pace for a minute straight. After their minute of jogging, participants rested until they felt they ahd recovered and then repeated the cycle.

For both the sprints and the jogging, participants began their exercise on the minute, recording what time they started at (**Time Start**). It was necessary to have participants start on the minute so that analysis of the data later on would be clean and have a clear 1 minute block of data. They completed their minute of exercise, and immediately recorded the aforementioned attributes (**Time End, Resp Rate, Likert Scale**). They then rested until they felt recovered (heart rate and respiratory rate go back to baseline), and completed the next set.

Exercise	Time Start	Time End	Resp Rate	Likert Scale	Height(in)	Weight(lb)
Resting	1023	1024	12	0	163	124
Sprint	1027	1028	36	3	163	124
Sprint	1029	1030	36	3	163	124
Jog	1049	1050	20	2	163	124

Figure 3: Example of spreadsheet used to record attributes.

Participants were asked to record the above values on a spreadsheet provided to them. They're hight and weight were to be consisted the entire time, and both time columns, 'Resp Rate', and 'Likert Scale' were recorded after each minute of exercise

All participants wore fitbits during data collection, and were asked to extract their fitbit data via Fitbit REST API for the workout using code provided. This data consisted of their **Heart Rate**, **Calories**, and **Steps** measured by Fitbit during their workout. That fitbit data was then added with the manually recorded data to one singular dataframe and saved as a .csv file for analysis.

Analysis and Discussion

<u>No significant difference between exercise groups for heart rate and calories burned:</u>
Exploratory data analysis was conducted on the compiled fitbit data. Graphs of each of the features were created (**Heart Rat**e, **Calories**, **Resp Rate**, **Steps**, **Likert Scale**), splitting the data based on exercise type (Figure 4). These visualizations showed a surprising finding: the heart rate and calories burned didn't differ between the sprint (high intensity) group and the jogging (moderate intensity) group. Independent t-tests were conducted to analyze both features (calories and heart rate), and both t-tests failed to find a significant difference between the jogging and sprinting groups at an alpha level of 0.05.

An even more fascinating finding was that respiration rate and steps actually did have a significant difference between jogging and sprinting groups at an alpha level of 0.05. How was it that respiration rate was significantly different between high intensity and moderate intensity cardio, although heart rate stayed similar?

We hypothesize that these findings, which are inconsistent with existing literature, are a result of a lack of control for participants' athletic ability. The protocol asked participants to jog "at a comfortable pace" and sprint "at a 10/10 effort level", which are subjective instructions. This is likely the reason why heart rate and steps had such a wide distribution for the sprints. An amendment to the protocol would instruct participants to use a specific speed on the treadmill for the running and jogging, to maintain consistency. This study's sample size and sampling population also likely led to the unexpected results for heart rate and calories. Our analysis was done on data compiled from eleven students, most of whom are young college athletes. They are all likely in good cardiovascular health, which explains why their heart rate would remain fairly level for both high intensity and moderate intensity exercise. It's interesting that respiration rate and heart rate don't change proportionally, however, since the influence of respiration rate on heart rate variability is well accepted in literature (Schipke 1999).

<u>Most Accurate ML Model Is Logistic Regression:</u>
Several classification models were created to try to predict exercise type by using collected features, including a decision tree, K-Nearest Neighbors, and Logistic Regression. For the

creation of the models, the "resting" data was dropped from the exercise column of the dataframe. This meant that our classification problem was one of binary classification.

The model that had the best accuracy, precision and recall was the logistic regression model, which makes sense because logreg is typically used for binary classification problems.

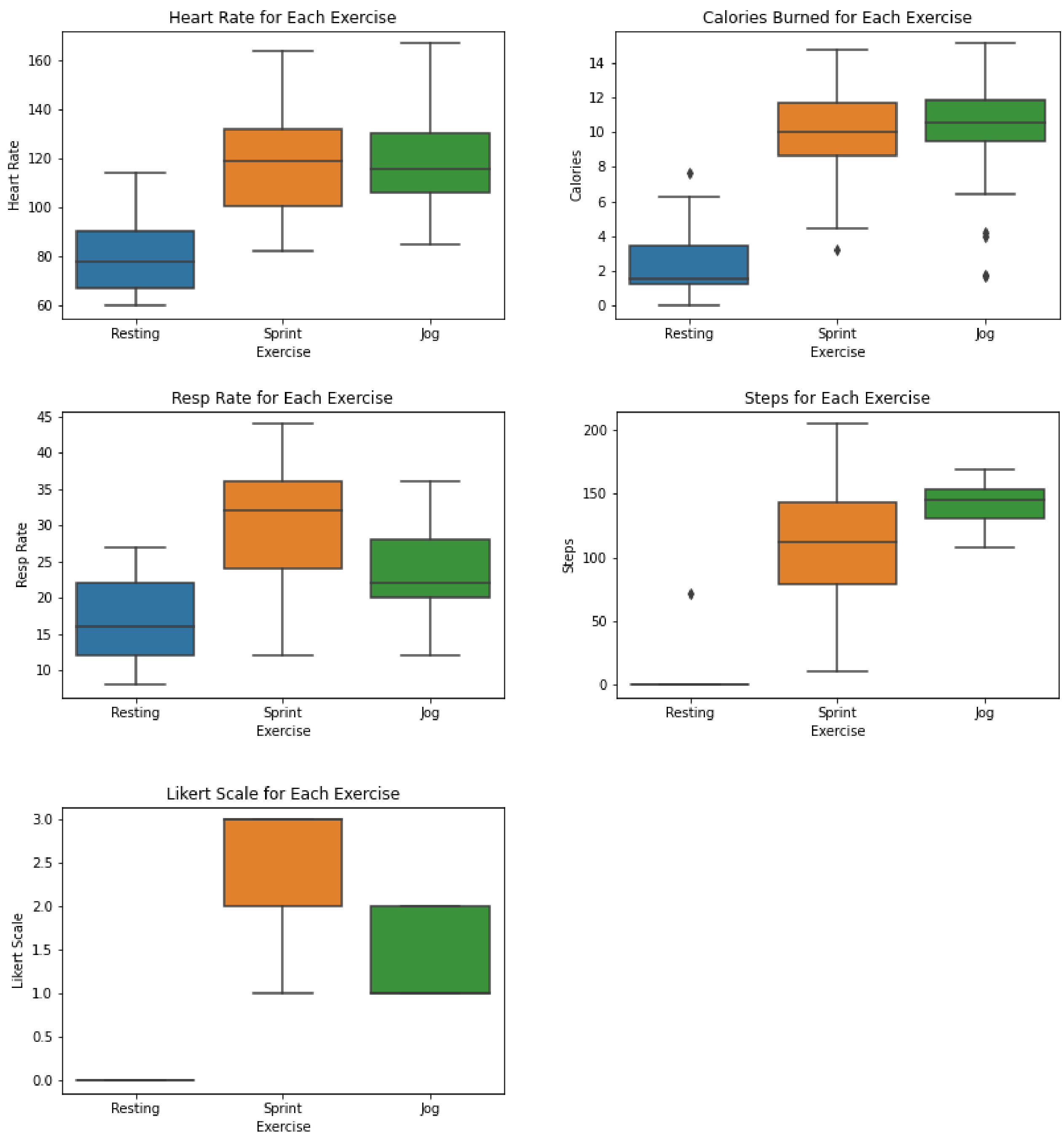


Figure 4: Graphs of heart rate (top left), calories burned (top right), respiration rate (middle left), steps (middle right), and likert scale (bottom left) divided by exercise type.

Logistic Regression: Technical Discussion:

Logistic Regression models the probability of the default class (the first class given as input). Logistic regression is technically a linear method, but the predictions are transformed using the logistic function. This means that we can no longer interpret the predictions as a linear combination of inputs.

Thus, the equation for the model (after transforming it using a natural logarithm) is

ln(p(X) / 1 – p(X)) = b0 + b1 * X

This equation shows that the input on the left is a log of the probability (or odds) of the default class, while the output on the right is linear. Odds are calculated as the ratio of the probability of an event divided by the probability of not the event; thus we can write the equation as

ln(odds) = b0 + b1 * X

If the exponent is moved back to the right, we get this final equation:

odds = e^(b0+b1*X)

The math behind the model helps us understand that the model is still a linear combination of inputs, but this linear combination relates to the log-odds of the default class.

When building logistic regression models, the coefficients must be estimated using the training data. This is done by using the maximum-likelihood estimation, which is a method of estimating the parameters of an assumed probability distribution given observed data. This estimation seeks values for the coefficients that minimize the error in the probabilities predicted by the model to those in the data.

Several logistic regression models were built to predict exercise type (high intensity or moderate intensity) by using a combination of features. Initially, the plan was to create the model using heart rate and calories burned as the predictor variables. After conducting the exploratory data analysis, we were skeptical that a model using those features would be accurate. As expected, the model was not a great predictor of exercise type. Precision for predicting jogging and sprinting were 67% and 58%, respectively, and overall accuracy and recall were 62%. After trial and error and testing various combinations of predictor variables, we found that the best model uses resp rate, likert scale, steps, and calories. The precision for this model was 91% and 86% for jog and sprint respectively, and 89% accuracy and recall overall. Weight and height didn't seem to have any impact on precision or accuracy, so they weren’t used.

Future research

Our finding of no significant difference between these exercises, in terms of heart rate and calories, provides a basis for future research. As previously mentioned, if this study were to be recreated, athletic variability among participants would be controlled by requiring a certain speed on the treadmill for the sprints and jogs. Additionally, a different feature such as heart rate recovery time would be used as an approximation for heart rate, since heart rate collected in this study seems to be a faulty measurement.

The lack of difference in heart rate+calories may also be due to participant background (athletes) and age (college students). Future studies should collect data from a more representative population, including individuals who range in ages and fitness levels. They should also look into a larger variety of HIIT exercises; this study examined only cardio, but it would be interesting to see how high vs. low intensity impacts heart rate/respiration rate, calories burned and body fat percentage over time for exercises such as weightlifting.

Works Cited

admin_bunda, & admin_bunda. (2019, January 10). Substrate utilization and a deeper look at HIIT workouts. Bunda. Retrieved May 21, 2022, from https://www.trainbunda.com/substrate-utilization-and-a-deeper-look-at-hiit-workouts/#:~:text=The%20reason%20being%20is%20that,lies%20with%20those%20HIIT%20workouts.

Brownlee, J. (2020, August 14). Logistic regression for machine learning. Machine Learning Mastery. Retrieved May 21, 2022, from https://machinelearningmastery.com/logistic-regression-for-machine-learning/#:~:text=Logistic%20regression%20uses%20an%20equation,an%20output%20value%20(y).

Centers for Disease Control and Prevention. (2022, March 17). *How much physical activity do adults need?* Centers for Disease Control and Prevention. Retrieved May 9, 2022, from https://www.cdc.gov/physicalactivity/basics/adults/index.htm#:~:text=Each%20week%20adults%20need%20150,Physical%20Activity%20Guidelines%20for%20Americans%20.&text=We%20know%20150%20minutes%20pf,do%20it%20all%20at%20once.

Gibala, M. J. (2007, August). *High-intensity interval training: A time-efficient strategy ... : Current Sports Medicine Reports*. Curret Sports Medicine Reports. Retrieved May 9, 2022, from https://journals.lww.com/acsm-csmr/fulltext/2007/08000/high_intensity_interval_training__a_time_efficient.4.aspx

HIIT vs Liss: A clear explanation of which is better for Fat Loss & Fitness. Nutritioneering. (2020, December 10). Retrieved May 21, 2022, from https://www.bodybuildingmealplan.com/hiit-vs-liss/

Schipke, J. D., Arnold, G., & Pelzer, M. (1999). Effect of respiration rate on short-term heart rate variability. *Journal of Clinical and Basic Cardiology*, *2*(1), 92-95.

Zuhl, M., & Kravitz, L. (n.d.). HIIT vs Continuous Endurance Training: Battle of the Aerobic Titans. HIIT vs. Continuous Cardiovascular exercise. Retrieved May 21, 2022, from https://www.unm.edu/~lkravitz/Article%20folder/HIITvsCardio.html