THE PHYSIOLOGICAL EFFECTS OF COMPETITION ON EXERCISE PERFORMANCE

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Abstract

Previous research on exercise performance has focused on the psychological effects. Our goal was to quantify the effects of competition on exercise through physiological responses measured in a group of healthy college students. To induce a physiological, competitive reaction, participants in the experimental group cycled alongside another student after an initial solo trial. In the control group, participants rode two solo trials to provide a baseline against which the experimental group could be compared. Mean arterial pressure, tidal volume, and heart rate were measured both before and after the trials to determine exertion level. The results of this study show that there is a strong correlation between riding alongside someone else and an increased exertion level. In these cases, an increase in average heart rate, mean arterial pressure, and tidal volume were observed. Specifically, females showed an increase in average heart rate of 24.2 beats per minute (p-value 0.203) and a decrease in time of 34 seconds (p-value 0.082). Based on this assessment, further investigation regarding female and male interactions in competition could be an especially interesting area of research. Utilizing such research could lead to more effective and intense exercise sessions, higher athletic performance, and as a result, healthier lifestyles.

Introduction

Competition is considered to be a strong motivator for increased performance in many settings, whether it is academics, athletics, or job performance (Cooke 2011). Given this, the goal of this experiment is to further investigate the implications of competition during athletic training, specifically when no explicit competition is defined. The performance of an individual varies due to both personal motivation and the desire to out-
perform another individual. While previous studies have used tangible rewards, this study focuses on the internal motivation determined by the characteristics of an individual’s personality (Cooke 2011, Viru 2010).

We have chosen to focus on gathering physiological data to assess the competitive response of an individual, while still acknowledging the effects of one’s personality. To monitor this, heart rate, mean arterial blood pressure, and respiration will be measured both before and after each trial. The predicted result is that an increase in all three of these variables will occur to a greater extent due to the presence of a competitor as compared to the subject’s solo trial.

Researhcing this particular subject area could provide insight into the most effective exercise strategies in both non-athletic and athletic situations. In non-athletic situations, this may have implications as simple as going to the gym with a friend to increase the effectiveness of a work out. In an athletic setting, cardiovascular training could be modified to include more group or paired exercise to simulate the effect of spectators and competitors in an actual competition.

**Materials and Methods**

Twelve participants were selected from a pool of willing college students ranging from 19-24 years of age, including six women and six men. One male and one female served as negative controls and the remaining ten composed our experimental group. At the beginning of each trial, participants were read a standard script explaining that they would be completing two runs of one mile each on a stationary bike (See Appendix B). It
was explained that the participant would be given time to rest between the trials and that several physiological measurements would be taken at given points in the trial. They also signed a consent form stating they had no preexisting medical conditions and that they would not share the experimental design with other potential participants (see Appendix A).

Physiological measurements were taken before the first trial, after the first trial, and after the second trial (See Appendix C). Baseline and experimental respiration was measured using the spirometer. Each participant was asked to breath into the spirometer until a consistent reading was captured. The spirometer was allowed to run at 160 mm/min while recording. From the spirometer reading, tidal volume of each participant was observed and recorded. Baseline and experimental heart rate were observed with the electrocardiogram (ECG) and measured manually from the carotid artery. Electrodes were placed on the meaty part of the participants’ ventral forearms and lower calves, and a single lead reading was recorded. Lastly, blood pressure was taken manually, by two team members, using a double headed stethoscope and a blood pressure cuff (see Appendix C).

During their trial, participants were instructed to complete one mile on the stationary bike with the instructions “Bike at your own pace, keeping mind you will have to complete two one-mile trials. Ready? On your mark, get set, go.” The participants rode the trial alongside a second unoccupied stationary bike. They were allowed to see the distance they had biked and the RPM at which they were biking but not the time elapsed.

Upon completion of the first run, participants were instructed to move quickly off the bike and into position so all the physiological measurements could be recorded. After the data collection, participants were instructed to return after 15 minutes so that their heart
rate could be measured manually to determine if they had returned to baseline. Baseline was defined as a range of +/- 15 beats per minute of their resting heart rate, as measured before the first trial.

Experimental participants were then instructed to ride the stationary bike for the second trial with no instructions regarding pace stating simply, “Ready? On your mark, get set, go.” Shortly before the participants began, they were joined by the male standardized competitor that rode on the stationary bike alongside their own. This competitor was used in every trial, and he maintained a high, consistent level of exertion during each participant’s second trial. Each participant was accompanied by the standardized competitor for the time it took the participant to complete 0.9 miles. When the standardized competitor appeared, some participants caught on to the competitive aspect of the experiment. One male participant’s data was excluded from the results due to his open admission of purposely trying to defy his perceived expectations of the study. Due to the low number of participants in this study, this greatly skewed the male experimental group’s data.

Control group participants still completed the second trial but without the standardized competitor riding alongside them. The data from these trials were included as a negative control. Upon completion of the second run, the participant was again instructed to move quickly off the bike and into position so all the physiological measurements could be recorded. At the completion of the trial, participants were allowed to ask any questions they had about the experimental design.
Results

To assess the participants’ level of exertion, physiological measurements of heart rate, mean arterial blood pressure and tidal volume were recorded (See Appendix D). The average change in physiological measurements, calculated by the difference in average measurements between post trial two and post trial one, are presented in Table 1. Data is organized in groups based on gender and experimental group. Each of the three physiological measures shows an increase in the average value with the second (competitive) trial compared to the first trial for the experimental group, whereas the controls show less variation between the two trials. Table 1 illustrates that none of the physiological measures show statistical significance, with a p-value ≤ 0.05, but that the females’ p-value is lower, and thus more significant, than the males’ in each physiological measure.

<table>
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<tr>
<th>Average Change in Physiological Measures (Post 2-Post 1)</th>
<th>MAP (mm Hg)</th>
<th>p-value</th>
<th>HR (beats/min)</th>
<th>p-value</th>
<th>Tidal Volume (mL)</th>
<th>p-value</th>
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<td>24.2</td>
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<td>300</td>
<td>0.39453812</td>
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<td></td>
<td>0.66788116</td>
</tr>
<tr>
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<td>0.756076377</td>
<td>1.5</td>
<td>0.916655386</td>
<td>252.75</td>
<td>0.66788116</td>
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<td>Control Male</td>
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<td>-2</td>
<td>-1</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*Experimental Males excludes single experimental outlier.
Figures 1, 2 and 3 show the average change in each of the three physiological measures, calculated by the difference of post trial two minus post trial one. An average increase is seen for each of the three physiological measures in the experimental group, whereas the controls do not show the same trend for each measurement, some even showing a slight decrease in measurements from post trial one to post trial two. Females show a greater average increase in heart rate between trial one and trial two compared to males (24.2 beats per minute and 1.5 beats per minute, respectively), whereas males show a greater average increase in mean arterial pressure between the two trials (3.75 mm Hg and 1.8 mm Hg, respectively). Females also show a greater average increase in average tidal volume compared to males (300 mL and 252.75 mL, respectively), although this difference is not as pronounced.

**Figure 1**
Average change in heart rate between trial one and trial two for experimental and control groups. Difference calculated as the average heart rate of trial two minus the average heart rate of trial one.

*Experimental Males excludes single experimental outlier.*
**Figure 2**
Average change in mean arterial pressure between trial one and trial two for experimental and control groups. Difference calculated as the average mean arterial pressure of trial two minus the average mean arterial pressure of trial one.

*Experimental Males excludes single experimental outlier.

**Figure 3**
Average change in tidal volume between trial one and trial two for experimental and control groups. Difference calculated as the average tidal volume of trial two minus the average tidal volume of trial one.

*Experimental Males excludes single experimental outlier.
Difference in time to complete each trial for both males and females decreased in experimental subjects. Females show an average decrease in time to complete trial two of 34 seconds with a p-value of 0.0819, whereas males show an average decrease of four seconds with a p-value of 0.6647. In comparison, the female control has no change in time to completion between trial one and trial two and the male control decreases by 13 seconds with trial two. This demonstrates an increase in exertion with competition in the second trial.

**Figure 2**
Difference in time to complete trial one versus trial two for each female participant, calculated as trial one time minus trial two time. Average increase of 34 seconds for females and p-value of 0.0819 calculated for change in time to complete trial. The control female saw no change in time between the two trials.
**Figure 5**
Difference in time to complete trial one versus trial two for each male participant*, calculated as trial one time minus trial two time. Average increase of four seconds and p-value of 0.6647 calculated for change in time to complete trial.

*Experimental Males excludes single experimental outlier.

**Discussion**

The average increase in physiological measures seen with the experimental group between trial one and trial two inferred an increased level of exertion in a competitive setting. This increased exertion was evident in both sexes. This finding is consistent with previous research regarding increases in heart rate, blood pressure, and other physiological measures in competitive versus non-competitive settings (Cooke 2011, Harrison 2001).

Results from this study showed that females had a much greater average increase in heart rate as compared to males (24.2 beats per minute compared to 1.5 beats per minute, respectively). While previous research has illuminated very little in competitive trends between females and males in settings comparable to this study, many studies have investigated personality and used other psychological assessments of the individual as it...
relates to competitiveness (Gill 1988). In contrast, this experiment focused solely on physiological measures in assessing exertion with competition. Previous research has also used asocial settings to analyze competitiveness, whereas this experiment included a live standardized competitor, complicating the results with emotional interaction, communication, and variability between sexes.

The differences seen between sexes for each physiological measure may be indicative of other factors affecting competition, specifically emotions such as anxiety, attraction, or joy (Cooke 2011). Female participants may have reacted differently to the male standardized competitor than males. They may have been more conscientious, had a desire to impress, or have been attracted to the male competitor, thus increasing heart rate in the competitive setting (Cooke 2011). A future experiment that deserves attention would be running more trials with a standardized competitor of the opposite sex. These intrasexual and intersexual competitions may invoke different responses than running all participants against a male competitor. These experiments could use four experimental groups: male standardized competitor with male and female participants and a female standardized competitor with both male and female participants. The control groups would remain the same with participants riding two solo trials. Unfortunately, the comparisons found in this study were based on a small pool of experimental participants and only two controls, limiting the ability to generalize results. A larger experimental and control group may have provided greater significance and applicability of the results.

A measurement that was taken, although not fully utilized in analyzing the results of this study, was the time elapsed to complete each trial. While this measurement is not purely physiological, it implies an increased performance level in the participants, with trial
run times decreasing as much as 50 seconds with an average of a 34 second decrease in females and a 4 second decrease in males. In conjunction with the other physiological variables, this measurement further supports the hypothesis that competition enhances performance level.

An additional complication of this study was that a three-minute mile appeared to be at the upper limits of exertion. People who rode at under three minutes the first time had a hard time going any faster than that during the second trial. This effect could be reduced by extending the length of the trials to deter participants from operating with a sprint mentality. A further benefit of this increase in distance would be ensuring a more complete transition from a resting state to a performance level.

With this change, fatigue will be an increased issue. To remedy this, the participants could be given longer breaks between trials or asked to perform an analogous trial on a separate day. If the second trial were performed on a different day, taking all of the participant’s vitals again – instead of just the heart rate – would be necessary to account for any day-to-day variation.

An ideal, albeit implausible, alteration to the experimental procedure that would improve the solo trial would be to remove all the spectators, including group data takers, from the room. This would provide a situation where the person’s motivation in exercising is entirely internal. As the experiment was set up, there were at least four spectators in the room at any given time during the first, solo trial. This change would require machinery that was unavailable. Also, covering up the display completely could help to discourage the participant’s urge to out-compete their initial trial, providing a more natural pace.
During the second trial, when the standardized competitor appeared, many participants developed an inkling of the experimental design. Some participants conformed to what they perceived as expected results while others consciously and openly admitted to tampering with their trial time. One male participant’s data was excluded from the results due to his open admission of purposely trying to defy his perceived expectations of the study. Due to the low number of participants in this study, this greatly skewed the male experimental group’s data. This type of influence could be reduced by having random participants with no former relationships to any group members. To account for this, with limited availability of participants, it was made sure that experimental participants had no former relationship with the standardized competitor.

For future experimental designs, swapping the two trials so that the competitive run is first could help to reduce the bias created by people figuring out the goal of the research. This way, the participant may be less likely to understand the objective until the second trial and the results will not be affected as greatly. Also, instead of direct competition, a virtual competitor could be used to remove the bias of gender, physical ability, and verbal interaction. By applying these approaches, the underlying question of the experiment may be veiled to a greater extent.


Appendix

A) Consent Form

**Liability Waiver/Consent Form**

I agree to voluntarily take part in this experimental study performed by Group 12 of Lab Section 602 of Physiology 435. I understand that the activity required by this experiment will stress the cardio-respiratory system and I affirm that I am of reasonable physical condition and will be able to withstand the testing.

It is not the responsibility of Group 12 or the Physiology department if something should happen during or after the process including, but not limited to, accidental injury or death. Any pre-existing conditions that could affect my ability to take part in this exercise should be disclosed prior to the experiment. I understand that I am able to decline my participation in this activity at any time due to any circumstance.

**Confidentiality Agreement**

I agree to not disclose any of the information that I was told in the process of the experiment, including, but not limited to, procedure and experimental purpose.

In return, Group 12 agrees any information disclosure will be totally anonymous, and your personal results will not be shared with others.

*I have read both of these waivers and agree to the terms set forth.*

Signature:________________________________________________________

Date:____________________

Print Name:_____________________________________________________

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B) Script

**First trial:** Thank you for coming in and participating in our experiment today. We will be starting by measuring your blood pressure with the arm cuff and rate of breathing and tidal volume using the spirometer, as well as performing an ECG. You will then be riding the stationary bike for one mile. After you have completed one mile, we will be retaking the measurements at which point you will be given half an hour to rest before returning to repeat the experiment.

*After measurements have been taken* – Remember, this is your first of two one-mile trials. Please, go at your own pace keeping in mind that you will be repeating another trial in 15 minutes.

On your mark, get set, go.

**Second trial:** Before your ride this time we will just be taking your blood pressure. After your last one-mile ride, we will need you to come back and sit on the chair as we will be measuring ALL stats again: blood pressure, breathing, and ECG.
C) Data Collection

Figure 6
Images of electrocardiogram (ECG) read out for participant 1 for pre-trial 1 (a), post-trial 1 (b) and post-trial 2 (c). ECG was used to calculate heart rate.

Figure 7
Images of spirometer read out for participant 8 for post-trial 2 (a), post-trial 1 (b) and pre-trial 1 (c). The spirometer was used to tidal volume.
Figure 8
Photo of experimental set up illustrating ECG station (a), blood pressure station (b) with cuff (*), and spirometer (c).

Figure 9
Photo of experimental set up for trial 2, illustrating an experimental female with standardized male competitor.
D) Data

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<th>PARTICIPANT</th>
<th>SEX</th>
<th>AGE</th>
<th>MAP</th>
<th>HEART RATE (MANUAL)</th>
<th>HEART RATE (ECG)</th>
<th>TIDAL VOLUME</th>
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<td>Post 1</td>
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<td>97</td>
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