# Wheeled Robot for Human Performance Analysis on a Running Track

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This research project investigates runners' performance through innovative technology, aiming to foster a human-robot partnership. Our study involves the development of a wheeled, remote-controlled running track robot that will integrate these elements. The robot's capabilities were first modeled using simulations, with an emphasis on efficiency and high torque capabilities. The runner will wear a heart rate sensor during training on a 400m track, which will output biometric data to the running track robot. The robot is designed to analyze this data logged by the heart rate sensor. Future research will aim to develop the robot as a biomarker-driven pacing tool that can leverage the head-to-head psyche that runners experience throughout competition. This will allow the running track robot to act as a pacing robot that can analyze the biometric data in real time and provide personalized pacing support.

Wearable technology has aided athletes' training regimens by providing thorough and accurate biometric data and kinematic data, including heart rate and cadence, respectively. This technology allows for the creation of personalized training plans and real-time feedback, improving overall training effectiveness (1-2). Additionally, understanding the psychology of racing, particularly runners' competitive mindsets, is crucial for determining the role that robotics technology should play in improving their performances. Techniques such as shadowing or drafting play a vital role in aiding runners with maintaining pace and strength through the entire duration of the race (3-4).

To leverage this technology and explore its impact on the psychology of racing, the researchers are developing a wheeled remote-controlled robot that can read and log biometric data and will be able to act as a running track robot alongside runners (Figure 1). The robot will moderate its speed according to the athlete's performance, mimicking a competitor athlete on the track. The researchers first used "Webots," a robot simulation software, to develop their understanding of the robot's functionalities, introducing concepts such as "path following" for the robot (7-8). This was vital for understanding this research project because it helped visualize the robot in a virtual environment before its development in a real-world scenario.

During the robot's construction, the researchers selected brushless DC motors as opposed to brushed DC motors due to their higher efficiency and limited friction. Brushless motors also provide a high torque-to-weight ratio and have better speed control, which is crucial for maintaining speeds that imitate that


**Figure 1. The running track robot designed for this research project.**

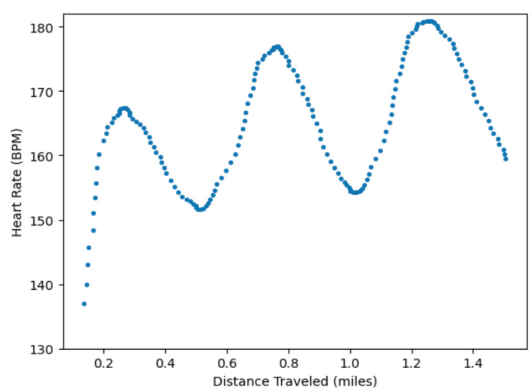


**Figure 2 Graph displaying the relationship between heart rate and distance traveled.** This plot, generated using the Python code, displays data collected with the PolarH10 heart rate sensor, connected to a Garmin Forerunner 245 watch to incorporate GPS function. **The** graph illustrates how the athlete's heart rate fluctuates with the distance covered during the training session. This data reveals how the cardiovascular response fluctuates at distinct stages of the workout, helping to optimize **training** intensity requirements. Future research will aim to integrate GPS directly into the running track robot, eliminating the need for external components such as the Garmin watch.

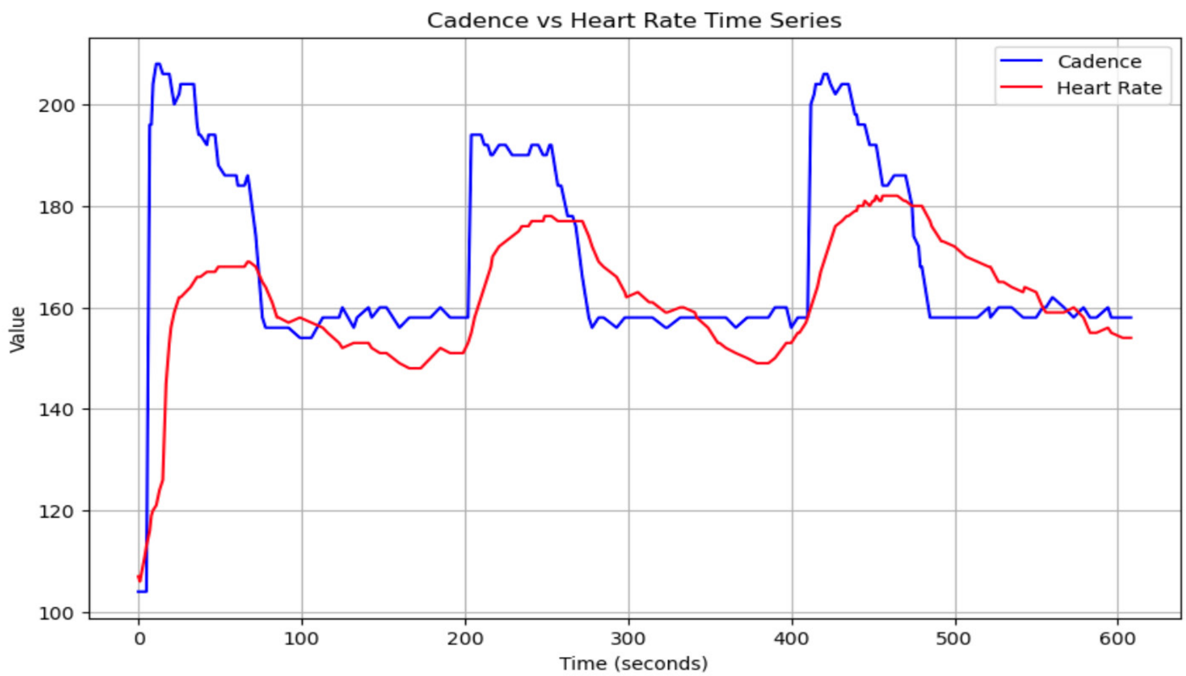


**Figure 3. Time series plot showing cadence versus heart rate.** This graph, generated using Python code, shows how cadence (steps per minute) and heart rate vary over time during the training session. Data was collected with the PolarH10 heart rate sensor and recorded using a Garmin Forerunner 245 watch for GPS function (similarly to Figure 2). The plot reveals the relationship between these two metrics, providing insights into the athlete's pacing and cardiovascular response throughout the workout. Understanding these variations helps in developing precise training strategies.

of a runner authentically (5). The robot will read an athlete's heart rate through a heart rate sensor that will be strapped to the athlete's chest. Among the sensors tested, the PolarH10 was chosen for its superior Bluetooth connectivity and precision in data tracking (6). The PolarH10 sensor will communicate with the robot using Bluetooth low energy (BLE) in real-time to log the athlete's heart rate data.

The PolarH10 sensor will be connected to the robot through a Raspberry Pi Model 5, a single-board computer. This computer will be responsible for logging the runner's biometric data using algorithms in Linux, ensuring the accuracy and reliability of the data. The researchers developed a Python code that parses and analyzes the heart rate activity from the PolarH10 sensor. The code then develops graphs that visually display the athlete's performance during training, and further adjustments can be made, if needed (Figures 2-3).

To strengthen the connection between the data and conclusions, further analysis will examine how variations in heart rate and cadence, as presented in Figures 2 and 3, correlate with improvements in athletic performance. The researchers will later provide additional details regarding experimental procedures, including the robot's future construction, sensor integration, and data logging to ensure the study can be replicated. Also, statistical analysis through analysis of variance and heart rate variability will evaluate the athlete performance more accurately in the coming months. There are existing limitations within our research. These limitations include potential inaccuracies in the Polar H10 data collection and an inability to simulate competitive environments for the running track robot.

This research aims to understand how the running-track robot, through real-time biometric and kinematic data, can influence the psychological aspects of racing, such as the competitive mindset for runners. Future research will focus on transitioning this running-track robot into a pacing robot to mimic the head-to-head psyche athletes endure during competition at their training sessions, as well. Also, the researchers plan to analyze the runners' performance during training and use AI to provide personalized training support, therefore altering the way athletes train for their races. This research will also expand on the robot's effectiveness in various sport disciplines, further developing it as a biomarker-driven pacing tool.

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Amos Colocho ('27) is pursuing a Bachelor of Science in Honors Mechanical Engineering with a minor in Aerospace Engineering. This is his first time conducting research at a collegiate level. Outside the classroom, Amos is the recruiter for Villanova's Chapter of the Society of Hispanic Professional Engineers (SHPE), and he is also a member of Blue Key and Villanova Club Running. He is also a peer advisor for first-year engineering students and students in the honors college. He hopes to participate in more research opportunities in the near future.

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Riquel Owusu ('27) is currently pursuing a Bachelor of Science in Computer Science at Villanova University. This is her first experience conducting research at the collegiate level. Within the Villanova community, Riquel is an active member of several organizations, including the National Society of Black Engineers (NSBE), the Society of Women in STEM (SWIS), and Girls G.A.I.N.S. Through her involvement in these groups, she is dedicated to fostering connections among women and underrepresented minorities in STEM fields. Additionally, Riquel is passionate about promoting the positive impact of women's health on both the campus and surrounding communities.

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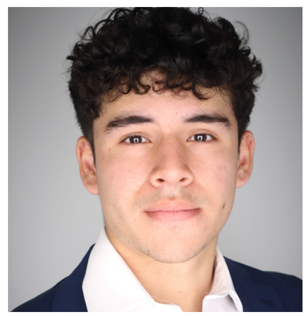

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