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Capstone Project

February 11, 2026

Inquiry question: How can heart-rate monitoring equipment enhance both athletics and program accessibility for underserved student communities (specifically, my nonprofit rowing team, Philadelphia City Rowing)?

Annotated Bibliography

Achten, Juul, and Asker E Jeukendrup. "Heart Rate Monitoring." Sports Medicine, vol. 33, no. 7, 2003, pp. 517–538, https://doi.org/10.2165/00007256-200333070-00004.

This source examines the scientific foundations of heart rate monitoring in athletics by exploring both its applications and limitations. The authors investigate the relationship between heart rate (HR) and oxygen uptake (VO2 max), demonstrating how heart rate serves as a practical indicator of training intensity across many forms of exercise. Particularly relevant to rowing, the article highlights heart rate variability (HRV) as a sign of recovery and training adaptation, emphasizing that HR data best shows broader health metrics, rather than a single number. The review also addresses important limitations, noting that factors such as dehydration, temperature, and individual differences can affect measurement accuracy. This shows me the need for careful interpretation of HR data rather than blind reliance. For this capstone project, the source provides scientific benefits for implementing heart rate monitors within a rowing program and offers evidence-based help for how to both select equipment and use heart rate data to optimize training and minimize overtraining.

Pasadyn, Selena R., et al. "Accuracy of Commercially Available Heart Rate Monitors in Athletes: A Prospective Study." Cardiovascular Diagnosis and Therapy, vol. 9, no. 4, 1 Aug. 2019, pp. 379–385, www.ncbi.nlm.nih.gov/pmc/articles/PMC6732081/, https://doi.org/10.21037/cdt.2019.06.05.

This Cleveland Clinic study analyzes the accuracy of four commercially available heart rate monitors by comparing them to medical-grade ECG measurements across five treadmill speeds (four to nine mph) in fifty healthy, athletic adults. What makes this study especially relevant is its focus on high-intensity exercise, which closely mirrors competitive rowing, where athletes will frequently train at an elevated heart rate. The findings show that the Polar H7 chest strap was the most accurate (0.98), followed by the Apple Watch III (0.96). While other wrist-worn heart-rate monitors showed lower correlations, they remained within acceptable accuracy ranges. Importantly, the study reveals that accuracy declined for all wrist-worn devices as exercise intensity increased,

with none maintaining acceptable precision at the highest speeds. For this capstone project, the research provides clear advice for equipment selection, suggesting that chest straps may be preferable for high-intensity rowing sessions where precision matters most.

Understanding your target heart rate | Johns Hopkins Medicine. Accessed February 12, 2026. https://www.hopkinsmedicine.org/health/wellness-and-prevention/understanding-your-target-heart-rate.

This source from Johns Hopkins Medicine, by cardiologists Seth Martic and Michael Blaha, breaks down the cardiovascular science of finding your target heart rate. The physicians explain that the target heart rate (which is typically 50%-85% of your maximum heart rate) represents the optimal training zone where exercise is intense enough to build cardiovascular fitness without risking overtraining. The source's particular value lies in its emphasis on how heart rate monitoring both helps athletes train effectively while also protecting them from overexertion that could lead to injury. The article offers practical guidance beyond numbers, encouraging exercisers to start programs gradually and pay attention to how their bodies feel, even acknowledging that monitoring devices sometimes malfunction. For this capstone project, having medical experts validate the health and safety benefits of heart rate monitoring strengthens the entire rationale for my project. This source validates my argument of why I'm making heart-rate monitors by arguing that they both increase performance and decrease the likelihood of preventable injuries.

M Plews DJ; Laursen PB, Kilding AE; Buchheit. "Heart-Rate Variability and Training-Intensity Distribution in Elite Rowers." International journal of sports physiology and performance. Accessed February 12, 2026. https://pubmed.ncbi.nlm.nih.gov/24700160/.

This study followed nine elite rowers (including four Olympic medalists) through the 26-week training period before the 2012 Olympics, examining how heart rate variability (HRV) responds to different training intensities. Researchers tracked daily HRV and training distribution across three intensities (below the first lactate threshold, between the two thresholds, and above the second threshold). The findings provide compelling evidence to support a polarized training method, demonstrating that high-intensity sessions lower HRV and suppress parasympathetic activity. For my capstone project, the study's focus on elite rowers offers directly applicable insights. I could apply this by suggesting to my coaches to collect HR data to catch overtraining before it strikes, and track when athletes need more rest. This would prevent both burnout and injury.

"Polar Electro." Wikipedia, January 6, 2026. https://en.wikipedia.org/wiki/Polar_Electro.

This source tracks the history of the well-known heart-rate monitor brand, Polar Electro Oy. Seppo Säynäjäkangas founded the company in 1977, when sports technology was new. Five years later, Polar launched the Sport tester PE 2000, the world's first wearable, wireless heart rate monitor, creating the market it now fights to survive in. This source is helpful in how it documents the company's decline despite its innovations. Polar built its reputation on its scientific background, making tools that elite athletes actually used. The

2018 privacy breach, where user data became exposed through the Polar app, was the beginning of the decline. This source shows that in technology markets, being the first guarantees nothing. It also shows that privacy is extremely important, and to casual consumers, having the most accurate machine is not vital to sales compared to innovation. I'll apply this to my capstone by looking beyond the Polar brand heart rate monitors to other known brands and their innovation.

DeBlauw JA; Stein JA; Blackman C; Haas M; Makle S; Echevarria I; Edmonds R; Ives SJ; "Heart Rate Variability of Elite Female Rowers in Preparation for and during the National Selection Regattas: A Pilot Study on the Relation to on Water Performance." Frontiers in sports and active living. Accessed February 12, 2026. https://pubmed.ncbi.nlm.nih.gov/37691642/.

This source examines heart rate variability (HRV) in elite female rowers during high-stakes regattas, analyzing how stress affects HRV and performance. From before training for national selection regattas (NSR) to the race itself, mental energy, physical condition, and motivation significantly increased amongst athletes. Post NSR, the athlete's measures went back to how they were before training. The study proves that HRV monitoring is a useful tool to monitor athletes' readiness both physically and mentally. This source provides another reason why heart rate monitoring is so important and makes me consider making waterproof monitors that could be worn on the water to measure anxiety before races, as well as fitness.

"Wearable Arduino Heart Rate Monitor | Science Project." YouTube. Accessed February 12, 2026. https://www.youtube.com/watch?v=tz_9OInLRIU&t=18s

This instructional video shows a working Arduino heart rate monitor that uses a pulse sensor and LEF array to visualize heartbeats in real-time. The video explains how the pulse sensor works by emitting green light and measuring the reflected light from blood vessels under the skin. As blood pulses with each heartbeat, the amount of reflected light changes in ways detectable by the sensor. The demonstration in the video features a LilyPad Arduino, which is designed to be a sewable microcontroller for wearable electronics. The video shows multiple mounting options, including attachment to a headband with an earlobe sensor or wrist-mounted fingertip monitoring, giving me options in how I might assist my team. This visual demonstration helped me understand the sensors and implementation for my capstone project's design.

Kyriacou A. Panicos, and Allen John. Photoplethysmography: Technology, Signal Analysis and Applications. London, Elsevier Academic Press, 2022.

This academic textbook is the first complete volume about photoplethysmography (PPG) technology, covering theoretical principles, hardware design, and signal processing techniques essential for understanding heart-rate monitoring. The book's detailed examination of current state-of-the-art components and miniaturization technologies directly helps me with my capstone project's sensor selection and circuit design decisions. Chapters on PPG signal analysis, including methods such as using artificial intelligence or machine learning, offer advanced methods for getting the most accurate heart rate data. The book writes on critical design considerations for my capstone, such as LED wavelength selection and signal quality, which can determine both the accuracy and reliability of the heart-rate monitors I donate. Written by leading researchers in biomedical engineering, this book serves as an essential foundation for making design choices through the project development process.

TED. "How Your Emotions Change the Shape of Your Heart | Sandeep Jauhar." YouTube, 5 Oct. 2019, www.youtube.com/watch?v=mwoLhdHRt_0.

In this TED talk, cardiologist and author Dr. Sandeep Jauhar discusses the connection between emotional health and cardiovascular health by explaining how stress, grief, and other emotions can literally alter the heart structure and function. He presents evidence that chronic stress and negative emotions can cause the heart to change shape and therefore increase cardiovascular disease risk. This presentation is relevant to my capstone project because it validates why heart rate variability is valuable beyond athletic performance, as a tool for not just physical health but mental health. This adds another dimension to the value of the heart rate monitors I wish to donate.

Giovino, Bill. "How to Design Low-Power Always-on Wearables: Part 2 – Protect and Recharge Batteries for Long Life." DigiKey, DigiKey's North American Editors, 24 Sept. 2019, www.digikey.com/en/articles/how-to-design-low-power-always-on-wearables-part-2. Accessed 13 Feb. 2026

This article provides guidance on battery management for wearable electronic devices, addressing one of the most critical challenges in creating your own heart-rate monitors. The author explains the advantages of lithium-ion batteries, which are energy-dense and require little maintenance, making them ideal for athletic equipment that my team will (ideally) use repeatedly. For the capstone project, this information is vital for selecting an appropriate battery and implementing proper circuits for charging that will keep the battery usage of the monitors optimal during practice. The technical details and circuit design recommendations will help inform my choice in component selection and layout decisions, ensuring the monitors I donate are reliable and user-friendly.