The Healthy Heart Race: a short-duration, hands-on activity in cardiovascular physiology for museums and science festivals

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Pressley TA, Limson M, Byse M, Matyas ML. The Healthy Heart Race: a short-duration, hands-on activity in cardiovascular physiology for museums and science festivals. Adv Physiol Educ 35: 275–279, 2011; doi:10.1152/advan.00026.2011.—The “Healthy Heart Race” activity provides a hands-on demonstration of cardiovascular function suitable for lay audiences. It was field tested during the United States of America Science and Engineering Festival held in Washington, DC, in October 2010. The basic equipment for the activity consisted of lengths of plastic tubing, a hand pump, collection containers, clamps, and simulated blood prepared by tinting water with red food coloring. Student participants were first asked to experience the effort required to pump through an unaltered tube. A presenter then applied a strong clamp that pinched each tube downstream from the pump, and students were asked to pump against the increased resistance. The students’ observations were then used as the basis for discussions of atherosclerosis and coronary heart disease with the presenters. Distribution of informative postcards during the 2 days of the festival indicated that at least 2,500 students completed the Healthy Heart Race activity. Our experiences to date suggest that the Healthy Heart Race activity can be accomplished effectively in the high-volume, high-distraction environment of a science fair or museum.

TEACHING IN A CLASSROOM or lecture hall provides a captive audience or, at least, an expectation that the instructor has the students’ attention for the 50 min or so needed for a lesson. The mobile crowds of a museum or science festival pose a very different challenge. With many competing exhibits, any learning activity must be sufficiently engaging to attract and hold a participant’s attention for a brief period. Hands-on, straightforward activities are the order of the day, and focused content objectives that can be achieved in the face of numerous distractions are essential (2, 3). Nevertheless, informal science activities cannot only generate excitement about and interest in science but can also effectively teach science concepts, engage participants in scientific reasoning, and help participants understand how science is related to their everyday lives (2, 3).

The United States of America (USA) Science and Engineering Festival held in Washington, DC, in October 2010, offered an opportunity for the American Physiological Society (APS) to highlight principles of physiology to thousands of K–12 students and their families. The festival engaged families in a wide variety of science and engineering activities offered by over 500 organizations. In developing activities for the festival, members of the APS Education Committee and APS Education Office were fully aware of the challenge posed by such events. Like many educators in this situation, we found that our existing activities required too much explanation, discussion, and time to be effective with a mobile audience. It therefore became apparent that more focused activities were needed. Moreover, we recognized that a single activity could not convey the diversity represented by modern physiology. For the purposes of the festival, we chose to concentrate on two areas that were likely to capture the imagination of the lay public. The first activity was an exploration of evolutionary strategies in thermoregulation that took advantage of easily recognized animals that live in extreme environments (e.g., whales, polar bears, and high-altitude birds). The second activity, which we describe here, was a demonstration of blood flow, vascular resistance, and mechanical load on the heart that emphasized the function of the heart in health and disease. It seemed likely that the medical relevance of the subject and a high-energy, compelling hands-on activity would prove to be attractive to students and their families.

As a starting point for the cardiovascular activity, named the “Healthy Heart Race,” we drew from long experience with a popular inquiry-based activity in hemodynamics conducted in workshops for high school students and teachers at the Experimental Biology meetings, the “Elvis experiments” (4). The familiarity of students with garden hoses, straws, and household plumbing makes these experiments a nonintimidating activity for exploring the determinants of flow in a biological context (i.e., diameter, length, and viscosity). Its unusual name is derived from a hypothetical inquiry into Elvis Presley’s death that is used as the justification for the experiments. It was clear, however, that only a small fraction of the concepts explored in the Elvis experiments could be covered at the festival booth. Accordingly, the Healthy Heart Race was designed to engage students in an activity that would attract their attention, require ~5 min to complete, convey a concise physiological concept, have relevance to human health, and suggest further activities that could be completed at home. The field test at the USA Science and Engineering Festival suggests that this activity can be easily adapted for use at local science festivals and museums as well as the classroom.

Setup for the Activity

In designing the activity’s setup, we wanted a configuration that would require minimal space, be sturdy and easy to use, and could be constructed predominantly from readily available household materials (Table 1). Using everyday materials helps to promote user recognition of the equipment. The basic equipment for the activity consisted of lengths of plastic
tubing, a hand pump, collection containers, clamps, and simulated blood prepared by tinting water with red food coloring. Central to the activity’s success was the identification of suitable hand pumps. The model that we chose was a squeeze-bulb pump intended for use in marine diesel engines, and it offered several advantages. It contained built-in check valves that restricted flow to one direction (Fig. 1A). Its rubber construction was resistant to damage and simple enough that its operation was readily visualized by the user. Finally, it was relatively inexpensive, costing less than $10.

A 3-ft length of 5/16-in. inner diameter plastic tubing was attached to the input end of the pump, and the end of the tubing was inserted into a fluid reservoir consisting of a plastic carboy and red-tinted water (Fig. 1, A and B). The pump was primed before each use, if needed. A flat carboy with a water-tight lid was chosen to minimize the opportunities for spillage, and multiple tube-pump combinations could draw from the same reservoir. A funnel was inserted into the lid to allow for easy refilling of the reservoir. The reservoir was positioned on a platform higher than the receiving container to prevent backflow of fluids. An additional 2-ft length of similar-sized plastic tubing was attached to the output end of each pump, and the end of the tubing was inserted into a receiving container (Fig. 1, A and B). This receiving container was equipped with a lid containing a hole for the tubing, and the tubing was secured with malleable clay (Fig. 1A). The receiving container was made of translucent plastic, and graduations were drawn with a black marker to indicate volumes of 500 ml, 1 liter, and 2 liters. A spring-loaded clamp was attached to the output tubing at appropriate times to simulate a partially occluded artery. To secure and stabilize the entire setup, simple laboratory equipment stands and tubing clamps were used (Fig. 1B). A poster depicting a mammalian heart, an atherosclerotic blood vessel, and children running was developed and printed as a large visual aid for the activity (Fig. 2). This provided an eye-catching means of attracting students to the activity, and it served as a useful reference during discussions.

**Conduct of the Activity**

Student participants were first asked to experience the effort required to pump through an unaltered tube. When presented with multiple students, we would establish a competition, with each student racing to see who could pump to the 1-liter graduation fastest. This encouraged each student to make a maximal effort. While discussing their impressions of the amount of work needed for pumping against the unaltered tube, slower students continued to pump until all fluid levels in the receiving containers were brought to the 1-liter graduation. A presenter then applied a strong clamp that pinched each tube downstream from the pump, and students were asked to race to the second 2-liter graduation. The instructor emphasized that pinching the tube mimicked a partially occluded artery. When discussing the new observations, students were encouraged to compare the effort required to work against the partially

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**Table 1. One experimental setup with two systems side by side**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heavy ring stand base</td>
</tr>
<tr>
<td>1</td>
<td>Large rod for the ring stand</td>
</tr>
<tr>
<td>2</td>
<td>2.5-Gallon/9.5-liter plastic tub containers as a reservoir (lids with drilled holes for the tubing and funnel)</td>
</tr>
<tr>
<td>1</td>
<td>Funnel (for returning fluid back into the reservoir)</td>
</tr>
<tr>
<td>2</td>
<td>1-Gallon/3.785-liter plastic pitchers with handles (marked at 500 ml, 1 liter, and 2 liters)</td>
</tr>
<tr>
<td>2</td>
<td>Clamps for holding the tubing</td>
</tr>
<tr>
<td>2</td>
<td>Clamps for stabilizing the pitchers by their handles</td>
</tr>
<tr>
<td>2</td>
<td>Spring clamps for the tubing to restrict flow</td>
</tr>
<tr>
<td>2</td>
<td>Unidirectional primer bulbs, 5/16-in. hose barb (Moeller Manufacturing Primer Bulb 5/16-in. Hose Barbs, MOE-03469010)</td>
</tr>
<tr>
<td>10 ft.</td>
<td>5/16-in.-diameter tubing, cut 24-in. in length for the pump-pitcher connection and 36-in. in length for the reservoir-pump connection</td>
</tr>
<tr>
<td>~6 liters</td>
<td>Water (recycled from the reservoir to the pitcher)</td>
</tr>
<tr>
<td></td>
<td>Red food coloring (sufficient amount in drops to color the water deep red)</td>
</tr>
<tr>
<td></td>
<td>Modeling clay (sufficient amount to secure the tubing to the lip of the pitcher opening)</td>
</tr>
</tbody>
</table>

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Fig. 1. Setup for the Healthy Heart Race activity. A: hand pump used for the activity with the direction of liquid flow labeled. B: complete setup with the components labeled. The dual receiving container equipment setup allowed for up to two participants at a time and provided a stable water reserve.
occluded tubing with that of the control tubing. The students’ observations were then used as the basis for discussions of atherosclerosis and coronary heart disease with the presenters (see discussion points below).

We found that a two-person team was able to engage the students and conduct the activity efficiently. One presenter was staged behind the setups and was primarily responsible for adjusting the equipment and transferring the fluids between racing bouts. During the discussion of the results, for example, this presenter would return the fluid from each receiving container to the original reservoir. With practice, the activity could be completed by multiple students without significant spillage or disruption of the setup. The second presenter was primarily responsible for encouraging the students, asking questions, and using the equipment and poster to expand on concepts. Indeed, the participation of outgoing, charismatic presenters who could lead the discussions was a key to the success of the activity. At the USA Science and Engineering Festival, we were able to take advantage of current and former APS K–12 Outreach Fellows to perform this critical function (1). Outreach Fellows are minority graduate and postdoctoral students who have completed a year of training to work with K–12 teachers and students.

Discussions were guided by a set of key content objectives suitable for K–12 grade levels that we sought to convey in the course of the activity. Four objectives were discussed before and during the activity. They consisted of the following:

- The heart works like a pump to move blood to all parts of the body and back again.
- The heart moves blood through narrow tubes. Your veins are an example of these tubes.
- If the tubes get too narrow or partially blocked, the heart must work harder to move the blood.
- When the heart has to work harder all the time, it is more likely to get sick.
During this discussion, it was often possible to point out the veins visible on the hands and arms of some students. Students found that pumping against the resistance imposed by the clamp was fatiguing, and they would frequently switch hands or even use two hands. This was an opportunity to reinforce the critical and unique ability of the heart to propel blood through the vasculature.

Followup questions were intended to provoke additional conclusions from the students, as follows:

- What causes blood vessels to get clogged or narrowed?
- What effects does exercise have on the heart and blood vessels?

Addressing these questions encouraged students to draw distinctions between the beneficial changes in the cardiovascular system produced by exercise and those elicited by plaque-producing conditions such as poor diet. They also helped students understand hypertension, which was experienced by many of their family members. These questions were also of interest to the students’ parents, offering an opportunity to reinforce the importance of diet and exercise to cardiovascular health.

Participation in the activity included multiple learning modalities. The overall configuration of tubing, fluid, and hand pumps created a strong visual impression that was augmented by the accompanying poster. Pumping the squeeze bulbs provided a vivid tactile experience, and the racing scenario generated a competitive aspect that appealed to the K–12 age group. The explanations and questions helped auditory learners understand the experiment. Finally, the noise and enthusiasm of the festival crowds produced an exciting, albeit noisy, environment in which to learn.
Synergism With Other Activities

Recognizing that some students would be interested in exploring hemodynamic concepts on their own, we developed an activity that could be completed at home. This was outlined on a postcard-sized handout that was distributed to all students participating in the Healthy Heart Race activity (Fig. 3). The handout featured Phizzy, a cartoon teddy bear that we have introduced to facilitate the recognition of physiology and the APS by students in grades K–5. The postcard encouraged students to expand the exploration of flow and resistance using straws of differing diameters. We obtained coffee stirrers and conventional soda straws from an office supply store and provided one of each with the distributed postcard. The activity included data collection and recording, with a link to a website (www.phunweek.org) at which students could upload their results, compare their results with those of other students, and access additional resources and activities. In this way, students were exposed to higher-order concepts such as quantitative assessment and interpretation of results.

Student Participation Rates at the USA Science and Engineering Festival

The distribution of Phizzy Bear postcards also provided an estimate of the total number of participants. Over the 2 days of the festival, 2,500 postcards were given to students who completed the Healthy Heart Race activity. We achieved these numbers using four pumps, and rarely did we have fewer than three students participating at any one time. The number of distributed postcards is probably an underestimate of the activity’s exposure because some spectators (i.e., individuals who watched rather than participated) declined a postcard. In the month after the festival, we recorded only 20 hits on the online activity, suggesting that some students followed up on the activity at home. The limited number of participants who completed the online activity may be due to the large amounts of take-home materials children received at the festival. We suspect that followup would be more extensive in a more focused environment.

Modifications and Extensions

The setup for the activity can be easily modified to meet local needs. Expenses could be reduced by taking advantage of materials already available in the home or classroom. For example, discarded plastic milk jugs could be used as receiving containers, rather than the more expensive containers with handles that we purchased. Similarly, clamps from sources other than the hardware store could be substituted when restricting the tubing. We had some success in early versions of the setup using metal binder clips suitable for documents. It was tempting to simply kink the tubing to create a restriction, but the analogy with a partially occluded blood vessel was less obvious to the student. Accordingly, we would discourage this particular modification. Although we used laboratory equipment stands and tubing clamps to hold the activity’s configuration, attaching the tubing to a pegboard and adding weights in the bottom of the containers could probably be used to achieve similar stability.

Extensions to the activity could cover additional physiological concepts. Normal arterial blood pressure could be simulated by raising the end of the output tubing. Pumping against a tube of fluid 136 cm high, for example, would be analogous to a mean arterial pressure of 100 mmHg. Any column of fluid significantly higher would therefore represent some degree of hypertension. We experimented with this more sophisticated configuration in early versions of the activity but opted for the simpler setup in the festival environment. Rather than purchasing the marine diesel engine pumps, it should also be possible to construct homemade pumps from squeeze bulbs and check valves. This do-it-yourself approach would offer the opportunity to compare pumps of different capacities, simulating conditions such as the cardiac hypertrophy of a trained athlete or hypertrophic cardiomyopathy. Pumps of different stiffness could be used to demonstrate restrictive cardiomyopathy (also known as “stiffening of the heart”). The addition of inexpensive flowmeters to the output tubing would encourage a more quantitative assessment. Similarly, the output tubing could be modified to illustrate the distinction between resistances in series and parallel. Additionally, to emphasize the difference between cardiac and skeletal muscles, students could try to squeeze the bulb at the same rate as their own resting and exercising heart rate.

The authors recognize that the Healthy Heart Race was not a perfect analogy for the cardiovascular system. Care was necessary during discussions to avoid overextending the model or promoting misconceptions. It is obvious that the activity’s configuration was an open system rather than the closed system found in vertebrates. Filling of the hand pump was driven by the elastic recoil of the squeeze bulb, in contrast to the filling of the heart by the pressure in the great veins. The compliance of the blood vessels was not depicted explicitly. Despite these limitations, however, the Healthy Heart Race proved to be a popular short-duration, hands-on activity for demonstrating cardiovascular concepts, and we hope to use it as the basis for additional activities in grades K–12. The authors welcome suggestions for additional modifications, extensions, or adaptations.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

REFERENCES