A scalable system for large spherical treadmills

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Methods

The spherical treadmill

The spherical treadmills used here are high-density polystyrene spheres (HDP) commercially available in a wide range of sizes (www.smoothfoam.com). While they are similar in material to those used in previously published reports of spherical treadmill systems, we employ larger diameter HDP spheres (16" diameter for mice; 24" diameter for young-adult rats). To reduce the weight to a desirable range, the half-spheres can be shipped to a company that further hollows them down (www.wecutfoam.com). We currently feel the optimal treadmill weight for mice (20-25 g) using the 16" system is ~65 g, ~30-32 g per half before gluing (treadmill:animal weight ratio = ~2.5-3:1). For developing young-adult rats (ex, 70-120 g), we currently feel the optimal treadmill weight using the 24" system is ~225-250 grams, ~110-120 grams per half before gluing (treadmill:animal weight ratio = ~2.5-3:1).

To create the spherical treadmill, two equally weighted half-spheres are placed together inside the gluing ring overnight (Appendix A, fig A15). For effective gluing, first generously coat the rim of a half-sphere with a Styrofoam glue product. Next, place the half-sphere in the gluing ring. Now place the second half-sphere in the gluing ring to form the sphere. It is helpful to place a flat surface on top of the sphere at exactly the height of the diameter of the sphere. This will ensure downward pressure and good contact between the half-sphere rims during the glue-drying process. After several hours (overnight), carefully remove the sphere from the gluing ring. If necessary, continue to fill any gaps and ridges with additional layers of Styrofoam glue to create a smooth, continuous seam.

Treadmill support structure and floatation system

The treadmill support structure and floatation system consists of a user-positioned array of air-cushioned ping-pong ball bearings connected to a lightweight acrylic frame via form-fitting aluminum clamps (Appendix A, see Fig A1 for an overview of the assembly). A small, but continuous volume of air ported to each cannon (pressure range: 5-20 psi via flexible tubing: 1/16" I.D.) is sufficient to lift the ping-pong balls (Gold 3-star; Joola, Inc.) and support the treadmill and animal. The primary components of the support system include:

1) **Acrylic treadmill frame (Fig A2, A7-A9)**. The treadmill frame is designed to be lightweight (~2 kg) and strong (expected to hold up to 75 kg when suspended from one half of the rim, ~20 kg tested successfully) while leaving the treadmill surface highly accessible. In the models shown throughout the documentation, the top rims are accented with ¼" through holes evenly spaced at 15 deg, which provides many points for connecting useful tools around the system.

2) **Air cannons (Fig A3, A10-A11).** Each air cannon (1.577"/40.06 mm I.D.) is carefully matched with a ping-pong ball (~40.00 cm) to optimize ease of lift and bearing rotation. The acrylic tube should be ~50-100 um wider than the ping-pong ball. The lip of the acrylic tube should be rounded and the entire inner surface smoothed by

sanding with soft acrylic sandpaper. This will reduce turbulence and friction, improving the function of the air-cushioned ball bearing. It may help to group the air cannons into sets of three that all respond similarly to a given psi value. That is, a set of 3 would rise and fall with similar rates to ~10-15 psi.

3) **Air cannon clamps and treadmill frame clamping system (Fig A4, A12-A14)**. Note that the inner surfaces of the treadmill frame clamps (shown in red) are curved to match the radius of the arms on the treadmill frame. In these examples, the red clamps match with the 18" I.D. diameter treadmill frame for the 16" treadmill. The blue clamps match the 26" I.D. diameter treadmill frame for the 24" diameter treadmill.

4) **Air regulation (Fig A5)**. In these examples, the air cannons are grouped into sets of three and each group is regulated by a single air source. Groups of three are then placed at equal radial distances along the frame arms (Top right, 120 deg separation with a 60 deg offset between groups).

   With minimal air-flow (~200 Nl/min total air-flow with 10 air cannons), this sparse, point-based floatation system provides evenly distributed pressure and a highly accommodating surface for smooth rolling of the treadmill under various configurations and behavioral conditions. Configurations shown: 10 air-cannons, example psi values: one centered at bottom (14 psi), three at 20 deg (18 psi), three at 45 deg (14 psi), and three at 85 deg (5 psi).

5) **Treadmill mounting (Fig A6)**. The treadmill can be mounted and secured in many ways. For example, as shown in the top and middle panels, we have hung the 24" treadmill system from the underside of a custom-designed air table (Newport). An aluminum adaptor plate connects the acrylic treadmill frame to the air table via nine structural rods (extra-hard stainless steel tubing, ¼" I.D., e.g., McMaster-Carr). This allows us to place the subjects as close to the surface of the air table and recording equipment as possible, which reduces potentially harmful vibrations. A second example is shown highlighting a 16" treadmill system. Here, the treadmill and treadmill frame are simply placed on three pillars (14" height, 1.5" diameter stainless steel, e.g., Thorlabs).

Acknowledgements

We would like to thank the Howard Hughes Medical Institute and Janelia Research Campus for their support. We would like to thank Jason Osborne and Steve Bassin for their mechanical engineering, design, and machining work throughout the development of the project. We would like to thank Art Lee for his assistance with the air regulation. We would like to thank Dr. Carmen Robinett for helpful discussions regarding the floatation mechanism. We would like to thank Dr. Nicholas J. Sofroniew for assistance with the documentation.