Exercise Protocol: Hydrostatic Weighing

Appropriate Applications

This test is used to determine body density and estimate body composition.

Test Description

This procedure utilizes the difference in densities of the fat and non-fat masses to determine overall body density, which can be used to estimate body fat percent. Briefly, the subject is placed in a water tank and weighed after maximally exhaling. Differences in the dry and underwater weights are used to calculate body density. However, an allowance must be made for residual lung volume–the air that remains in the lungs after a maximal exhalation–as this air increases a subject's buoyancy. Residual lung volume can be either measured or estimated. In our laboratory, residual lung volume is usually indirectly measured using an oxygen-dilution technique (Wilmore et al., 1980). A 5-L Douglas re-breathing bag fitted with a two-way breathing valve is flushed and filled with 100% oxygen. While in a seated position and fitted with the mouthpiece on the Douglas bag and a nose clip, the subject takes several normal breaths of ambient air. Afterwards, the subject performs a maximal inhalation followed by a maximal exhalation and briefly holds his/her breath at the end of the exhalation. At this point, the mouthpiece valve is turned so that the subject begins rebreathing from the 100% oxygen. The subject takes 6-8 deep breaths after which the valve is closed and the subject removed from the Douglas bag. At least two, but sometimes three trials are performed with several minutes between trials.

The most accurate estimate of body composition by hydrostatic weighing requires residual lung volume to be measured. There are, however, situations because of expediency or lack of equipment in which residual lung volume is estimated. One way to estimate residual lung volume is from published tables that are based on age and weight. Another method is to estimate residual volume from the measured vital capacity. In this procedure, a seated subject, while fitted with a nose clip and connected to a spirometer, performs a maximal inhalation followed by a maximal exhalation. Vital capacity is the volume of the maximal exhalation from which residual lung volume is estimated based on gender, as a percentage of the vital capacity.

After having measured or estimated residual lung volume, the subject's dry weight is measured and then, wearing a swimming suit or running shorts, the subject climbs into the underwater weighing tank and sits in a seat that hangs from a force load-cell. The procedure involves the subject performing a maximal exhalation and slowly leaning forward in the chair until the top of his/her head is under water. After the underwater weight stabilizes (5-8 seconds), the subject is instructed, though yelling or pounding on the side of the tank, to return to an upright position. During a weighing, the subject is always free to stand up or return to the upright position. Four to eight trials are usually performed.

The non-skid steps up to the top of the tank where the subject enters are equipped with a handrail, and after climbing the steps, the subject climbs down a ladder into the water. Depth of the water is approximately 54 inches, which is maintained between 30 and 34 °C. While seated, the subject faces a clear plexiglas side to minimize feelings of claustrophobia. After each testing session, the water is drained and the tank allowed to dry.

Training/Supervision Needed

All test personnel are required to have current CPR certification and are trained in emergency procedures for the particular lab. A telephone is located within 30 feet of the underwater weighing tank.

Risks

Other than risks of falling while getting into or out of the underwater weighing tank, there are no physical risks associated with this protocol. Subjects not comfortable in water or in putting their head underwater may experience slight anxiety during the underwater weighing.

Risk Management

Subjects are encouraged to be careful while getting into or out of the underwater weighing tank. For individuals who experience anxiety during the underwater weighing, the test administrator will go more slowly with the subject and encourage him/her to stand up in the water should the anxiety become too strong.

The mouthpiece and valves used for the measure of residual volume fall into the semi-critical device category. This device will come into contact with mucus membranes, but will not penetrate body surface. High-level disinfection using liquid glutaraldehyde disinfectants (e.g. Cidex) is acceptable according CDC recommendations. We use EPA-registered sterilants for this purpose in our laboratory.

Potential Benefits

The subject obtains his/her body composition, which is an important component of overall personal fitness.

Consent Content “What Will Happen in this Research?” section

There are two parts to this procedure. First, we will measure your residual volume, which is the amount of air that remains in your lungs after performing a maximal exhalation. Afterwards, we will weigh you underwater. Together, this information will be used to estimate your body fat percentage.

To measure your residual volume, you will perform 2-3 trials of breathing in and out of bag containing 100% oxygen. In a seated position and wearing a nose clip, you'll be connected to a breathing mouthpiece connected to the bag of oxygen. First, you will take several normal breaths from the outside air and then perform a maximal exhalation. At that time, a valve will be turned which will direct your breathing from the bag of oxygen. You'll take 6-8 deep breaths after which you'll be removed from the valve. After a couple of minutes, you will repeat this 1-2 times.

After you change into your bathing suit, you will climb into the underwater weighing tank. Briefly, you will sit quietly on the hanging seat in the tank, and when instructed, perform a maximal exhalation and then slowly lean forward just to the point that your head is completely underwater. You will remain motionless for 5-8 seconds until instructed by the technician to come back to the surface. It is very important that you blow all of the air out of your lungs and remain as motionless as possible while underwater. Should you develop any overpowering anxiety, you can always stand up before being instructed, as the depth of the water is only about 4½ feet. We will do at least four, but as many as eight, underwater weighing in all. Afterwards, you will climb out of the tank, dry off and change back into your street clothes.

Consent Content “What Are the Risks or Discomforts Involved in the Research?” section

There is a small risk of falling while getting into or out of the underwater weighing tank. There is a risk that you might experience anxiety during underwater weighing. If you are feeling anxious the test administrator will proceed with the test slowly and encourage you to stand up in the water if you are feeling very anxious.

The mouthpiece and valves used for the measure of residual volume fall into the semi-critical device category. This device used to measure residual volume will come into contact with mucus membranes, but will not penetrate body surface. The device is sterilized according to recommendations by the Center for Disease Control (CDC) prior to use.