Underwater Weighing Familiarization Program for Adults With Prader-Willi Syndrome

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The purpose of the project was to evaluate an underwater weighing (UWW) and residual lung volume (RV) familiarization program developed for adults with Prader-Willi syndrome (PWS). UWW was conducted on 15 adults (10 men, 5 women) with PWS following a UWW familiarization program. Repeated measures ANOVA revealed no difference in percent body fat derived from UWW over the four sessions, $F(3, 27) = 0.80, p = .505$, with an intraclass reliability coefficient of $R = .93$. There was, however, a significant difference in RV, $F(3, 27) = 5.25, p = .006$, with an intraclass reliability coefficient of $R = .65$. The familiarization program is recommended for implementation prior to measuring percent body fat via UWW. However, predicting the RV may be an easier and more consistent alternative to measuring the RV in adults with PWS.

Prader-Willi syndrome (PWS) is a genetic condition caused by a deletion or duplication in the 15q chromosome with an estimated population incidence of 1/10,000 to 1/30,000 live births (Burd, Vesely, Martsolf, & Kerbeshian, 1990). PWS is diagnosed primarily by presence of specific facial features, severe obesity, global developmental delay, and mild mental retardation (Cassidy, Rubin, & Mukaida, 1985). Many other unique physical and behavioral indicators are used as diagnostic criteria, influence body composition, and contribute to an elevated prevalence of obesity. Individuals with PWS typically exhibit many physical indicators, including hypogonadism, with delayed or incomplete gonadal maturation, low lean body mass, low bone density, short stature, and small, narrow hands and feet (Butler, Butler, & Meaney, 1987, 1988; Cassidy, Rubin, & Mukaida, 1985; Meaney &
Behaviors such as hyperphagia, food foraging, and a general obsession with food may also influence body composition and contribute to the high incidence of obesity for individuals with PWS (Bier, Kaplan, & Havel, 1977; Holm et al., 1993).

Because of the high incidence of obesity and the increased health risks associated with obesity, it is important to track the weight and body composition of individuals with PWS as they age. Underwater weighing (UWW), which has not previously been reported for individuals with PWS, has traditionally been considered to be the “Gold Standard” for determining body composition (Wagner & Hayward, 1999). However, no studies investigating the feasibility of measuring body composition via UWW of adults with PWS or mental retardation have been published in *Adapted Physical Activity Quarterly* over the last 7 years. In order to develop appropriate UWW assessment techniques, additional information is needed on the feasibility of measuring body composition via UWW in adults with PWS and mental retardation.

The UWW breathing procedures, which often include the measurement of residual lung volume (RV), can be difficult to perform, especially for individuals with mental retardation. Because of the difficulties and uniqueness of reaching RV while under water during the UWW procedure, there appears to be a learning curve associated with exhaling down to RV (Katch, 1969; Katch, Michael, & Horvath, 1967). Most people gradually become more effective at maximally exhaling under water during the 10 trials with very little improvement after the seventh trial. It is recommended that the mean of the best three attempts of 10 trials be used to calculate total body fat (Katch, 1969; Katch et al., 1967).

Most methods of measuring RV involve a series of breathing steps (Wilmore, Vodak, Par, Girandola, & Billing, 1980). Previous studies have reported the RV of individuals with PWS to be greater than predicted RV; however, this finding may be the result of poor performance of the participants during the RV procedures due to lack of a familiarization program (Hakonarson, Moskovitz, Daigle, Cassidy, & Cloutier, 1992, 1995). Rintala, McCubbin, and Dunn (1995) have recommended a three-step familiarization process, which includes a video presentation, a familiarization session, and a progressive training program, prior to fitness testing of individuals with mental retardation to elicit valid results. A similar three-step familiarization process would likely be beneficial to elicit reliable and valid UWW and RV determinations in adults with PWS and mental retardation.

The purpose of this study was to evaluate the feasibility of a familiarization program developed by the authors for use prior to determining body composition via UWW and RV in adults with PWS.

**Method**

**Participants**

The participants in this study were involved in a larger, U.S. Department of Education, National Institute on Disability and Rehabilitation Research (NIDRR) funded research grant (Grant #H133G40062) investigating behavioral reinforcement of exercise for adults with PWS. The sampling design was cluster purposive. Nineteen participants were recruited from two group homes that specialize in providing residential services for individuals with PWS (see Table 1). Twelve men and 7
Table 1  Age, Height, Weight, and Body Mass Index of Adults with Prader-Willi Syndrome

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<th>Gender</th>
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<th>Weight (kg)</th>
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</table>

Women, $M (SD)$  
36.0 (10.6) 149.3 (5.9) 66.3 (6.7) 29.8 (3.6)

Men, $M (SD)$  
26.7 (5.0) 153.4 (7.3) 68.5 (12.6) 29.1 (4.7)

Total, $M (SD)$  
30.1 (8.6) 151.9 (6.9) 67.7 (10.7) 29.4 (4.3)

BMI = Body Mass Index (kg body weight/height in m$^2$), ID = identification number, W = women, M = men, $^a$participant refused to do testing, $^b$participant had open sores on legs and could not participate in UWW procedures, $^c$participant had tubes in ears and could not do UWW procedures, $^d$participant refused to put head underwater.

women with PWS with mild to moderate mental retardation agreed to participate in the project, received written approval from their legal guardians, and met the criteria of ability to perform and willingness to perform. Two participants could not do the procedures due to medical conditions, one participant refused to do all physiological procedures, and one participant refused to put his head underwater. The participants received monetary compensation ($3-$5), as specified by the grant, for their efforts in completing the tasks for the familiarization program, the UWW procedure, and the RV procedure.

The participants were asked to not eat 3 hr prior to reporting for testing and to not exercise prior to testing. All participants were driven to the testing site by the group home staff or research staff to ensure that the participants would not eat prior to testing. The participants completed the UWW familiarization program.
prior to reporting for UWW testing. The first author administered all of the UWW and RV determinations for all participants.

Familiarization Program

The participants went through an extensive familiarization program developed by the authors before completing the UWW and RV procedures. As recommended by Rintala et al. (1995), the familiarization program was initiated approximately 1 week prior to each testing session and involved an orientation of the facilities through a videotape and a step-by-step training in UWW and RV procedures. Viewing the videotape was the first step of the familiarization program. The videotape showed the outside and inside of the building with all of the equipment to be used. The tape also showed a demonstration of the UWW and RV procedures. Two adolescents males demonstrated the procedures as the researcher directed them through the steps of the procedures. Adolescents were chosen as demonstrators to help give the participants a sense of ease about the testing.

The next step of the familiarization program was designed to acquaint the participants with the mouthpiece and nose-clip used during the residual volume procedures. The individuals were taught to place the mouthpiece properly into their mouths. After the mouthpiece was in place, the nose-clip was fitted. This allowed the participants to feel the proper fit of the mouthpiece and to experience breathing solely through the mouth.

The third step involved a progressive learning of the breathing techniques used during the measurement of the RV and during the UWW procedure. The individuals went through a series of one-on-one sessions to learn how to maximally exhale down to RV. Before each of the individual familiarization sessions, the participant was instructed and encouraged to take deep breaths. The sessions started with participants blowing a whistle, moved to a party favor, then a straw, and finally to exhaling with the face in a small tub of water. In each session the participant was instructed to "Get all of your air out of your lungs . . . keep blowing, keep blowing . . . .". The familiarization procedures were demonstrated for each step prior to the participant performing the act. The participants were also coached during each step of the procedure. The participants were given the option of wearing a nose-clip during the familiarization sessions.

Whistle. Participants were instructed to blow into the whistle until all of the air was out of their lungs. Participants were encouraged to keep blowing even after the whistle stopped making a sound.

Party Favor. Participants were instructed to blow into the party favor until all of the air was out of their lungs. Participants were encouraged to keep blowing even after the party favor rolled back up.

Straw. A straw was placed in a cup with a little water. Participants were instructed to blow into the straw until all of the air was out of their lungs and they could make no longer make bubbles. At this time, participants were taught to extend their finger and wait until they heard a tapping noise made by the trainer about 2 s later. At that time, participants could take a breath. The 2-s delay simulated the delay during the UWW process needed to make the measurement.

Face in Water. A 12” × 18” × 6” pan was half-filled with water. Participants were instructed to lower their face into the water and blow until all of the air was out of their lungs. At that time, the participants extended their finger and
waited until they heard a tapping noise made by the trainer. Participants then lifted their head out of the water and took a breath. Participants were instructed that they could come up for air at any time prior to the signal if they felt they needed air.

Residual Volume Determination

Because there is only a minimal difference between determining RV in air as opposed to submerged (Brozek, Henschel, & Keys, 1949), the RV was measured out of water by the oxygen-dilution method described by Wilmore et al. (1980). The test position was seated in a chair with the body bent over, similar to the position of maximal exhalation in the water tank. The RV procedure involved completing five steps while breathing through a three-way breathing valve and wearing a nose-clip. The steps included (a) maximal exhaling to RV and hold the air out of the lungs, (b) signaling to the researcher, (c) inhaling and taking seven more deep breaths, (d) maximally exhaling to RV again and holding the air out of the lungs, and (e) signaling to the researcher when RV had been reached. The participants were instructed on all procedures before starting the test, were verbally instructed through each step of the RV process, and were encouraged to blow all the air out of their lungs at the first and fourth step. The gases were analyzed with a calibrated Beckman LB-2 carbon dioxide analyzer and a Beckman OM-11 oxygen analyzer. The anesthesia bag volumes were calibrated prior to use. The RV was measured twice, and the values were averaged. If the first two trials were not within 0.15 liters of each other, a third trial was conducted and the two closest trials were averaged. The predicted RV was determined for each participant (Russel, 1987; Weidman, Tesch, Castek, Wilson, & Buckenmeyer, 1987).

Underwater Weighing

The UWW procedure was performed in a sunken concrete tank. Because of the participants’ short stature, a false bottom was put in place. The Underwater Weighing Load-Cell Program designed for our lab (Exertech, Inc., Dresbach, MN) was used to measure the underwater weight. The system, which averages 200 measurements in 2 s during each trial, was composed of a steel frame supporting a steel underwater weighing chair. The system was calibrated prior to each testing session. All participants wore a 3.4 kg diving belt because of their low body density and buoyancy.

Participants were instructed to sit in the chair with their feet on the bottom rung and their hands holding on to the seat or rail of the chair. Participants were then instructed to bend forward so their entire body was submerged and to maximally exhale in a slow and smooth motion. When participants signaled they had exhaled all their air, the weight was measured and the signal was given for the participants to raise their head out of the water. Participants were verbally encouraged to continue exhaling during each of the 10 trials. The three highest readings were averaged (Katch et al., 1967) and used to estimate body density (Brozek, Grande, Anderson, & Keys, 1963) from which percent body fat was calculated according to the equation developed for men and women by Siri (1956). As part of the larger NIDDR research project (with the intent of tracking body composition of the adults with PWS throughout the length of the project), UWW and RV determinations were conducted four times on 10 (6 males, 4 females) participants with PWS over 18 months (see Table 2).
Anthropometry

Height was measured to the nearest tenth of a centimeter with a stadiometer with regular and prosthetic shoes removed. Body mass was measured to the nearest tenth of a kg with a calibrated balance scale. Body mass index (BMI) was calculated by dividing the weight in kg by the height in m² (BMI = kg body weight/height in m²).

Data Analysis

Separate repeated measures ANOVA were used to determine whether the percent body fat values determined by UWW and RV over four measurements were consistent for the adults with PWS. Intraclass reliability coefficients were calculated for the four measurements of percent body fat determined by UWW and RV. A Scheffe’ adjustment was used to test which of the four sessions differed.

To measure the consistency of the individual attempts of the first UWW session, the intraindividual variability (expressed as variance) of the 10 attempts of the first UWW session and the top three attempts of the first UWW session for
each participant were calculated (Katch, 1969; Katch et al., 1967). To test the reliability of the attempts of the RV session, the intraclass reliability coefficient was calculated for the first two attempts of the first RV session.

The SEE, an independent t test, and a Bland and Altman (1986) plot comparing measured and predicted RV were used to test the agreement of the measured and predicted RV in adults with PWS. The probability of a Type I error was set at a < .05 for all statistical tests.

Results

Measurement of UWW and RV Over Four Sessions

Repeated measures ANOVA revealed no difference in percent body fat derived from UWW over the four sessions, $F(3, 27) = 0.80, p = .505$. There was, however, a significant difference between the RV over the four sessions as calculated by a repeated measures ANOVA, $F(3, 27) = 5.25, p = .006$. The means and standard deviations for each of the four UWW and RV sessions are presented in Figures 1 and 2. The intraclass reliability coefficient for the percent body fat derived from UWW was $R = .93$. The intraclass reliability coefficient for the RV was $R = .65$. The fourth session significantly differed from the three other RV sessions with first session, $F = 4.57, p = .046$; with second session, $F = 15.09, p < .001$; and with third session, $F = 7.01, p = .001$. The first RV session differed from the second RV session, $F = 3.05, p = .001$.

Variance of Attempts of the First UWW Session and First RV Session

The intraindividual variance of the 10 attempts of the first UWW session was $M = 0.28$ kg, $SD = 0.48$ kg. The intraindividual variance of the top three attempts of the first UWW session was $M = 0.0025$ kg, $SD = 0.0030$ kg. The number of attempts

![Figure 1 — Bland and Altman (1986) plot of measured and predicted residual lung volume in adults with Prader-Willi syndrome. $N = 15$.](image-url)
needed to produce three acceptable, consistent UWW weight values was $M = 6.4$ attempts, $SD = 2.8$ attempts. The intraclass reliability coefficient of the first two trials of the first RV session was $R = .84$.

**Measured and Predicted Residual Volume**

The Bland and Altman plot between measured and predicted RV indicated that there was good agreement between the measured and predicted values (see Figure 3). There was, however, a slightly larger discrepancy between the measured and

**Figure 2** — Mean measured (UWW) percent body fat with standard deviation bars over four sessions in men and women with Prader-Willi syndrome. $N = 15$.

**Figure 3** — Mean measured residual lung volume with standard deviation bars over four sessions in men and women with Prader-Willi syndrome. $N = 15$. 
predicted RV at the lower lung volumes. The measured RV ($M = 1.17$, $SD = 0.29$) was not different from the predicted RV ($M = 1.30$, $SD = 0.18$, $p = .176$). The SEE was 0.189.

**Discussion**

At the study onset, our two main concerns with measuring body fat via UWW and RV of adults with PWS were the participants’ ability to follow directions to measure the residual volume and to reach residual lung volume while being submerged. The participants appeared to be comfortable in the underwater weighing tank, so anxiety did not seem to be a negative factor. The participants also seemed to be very comfortable with the surroundings and trusting of the tester and procedures. Though not tested, this comfort level seems to be the result of the individual training sessions along with the training video. If the participants with PWS were not able to perform the procedures properly, the variance of the 10 attempts and three top attempts of the UWW for the adults with PWS would likely have been greater. The mean variance of 0.0025 kg for the three top attempts was similar to the variance (0.0004 kg to 0.0170 kg) reported for men and women without PWS (Katch, 1969; Katch et al., 1967) and would result in approximately a 0.1% difference in total body fat, indicating the top three trials for men and women with PWS were very consistent.

Also similar to previous reports on UWW in men and women without PWS (Katch, 1969; Katch et al., 1967), the UWW weight values of the 10 attempts for the participants with PWS typically increased with each attempt with a leveling off on the sixth to seventh attempt, indicating a consistency in exhalation. The number of attempts needed to get three acceptable (top three attempts) for the men and women with PWS ($M = 6.4$, $SD = 2.8$) was approximately 7 attempts. This finding also agrees with Katch et al. (1967) and Katch’s (1969) explanation of a practice effect of maximal exhalation during the 10 attempts of UWW leading to the variability of UWW weights leveling off after approximately 7 attempts for men and women without PWS.

The RV procedure used in the present study involved five breathing steps, which may have been too difficult for some adults with PWS to perform consistently. The intraclass reliability coefficient for the first two attempts of the first RV session ($R = .84$) indicated a fairly consistent effort within the first RV session. However, the repeated measures ANOVA indicated that there were differences in the RV measured over the four sessions and the intraclass reliability coefficient was fairly low ($R = .65$), indicating that the adults with PWS were not able to consistently perform the RV procedures over the four sessions. The mean difference for RV over the four sessions was 0.41 l, which would result in over a 3% difference when calculating total body fat for the average adult with PWS in the present study. The potential 3% error of the measured RV would be in addition to the overall error of approximately 3–4% typically associated with determining percent body fat by UWW in men without PWS (Bakker & Struikenkamp, 1977).

The Bland and Altman plot indicated no systematic difference between measured and predicted RV; however, a moderate discrepancy ($M = -0.13$, $SD = 0.36$) between measured and predicted RV was evident for a few of the adults with PWS. Using the predicted RV instead of the measured RV would result in approximately a 1% lower total body fat for the average adult with PWS in the present study.
Almost all of the participants required three to four attempts to produce consistent values (within 150 ml) during any one session of the RV sessions. Even though they were coached throughout the procedure, participants had difficulty following directions at times. With the additional time needed for extra attempts during the RV procedures, along with the calibration time needed for the gas analyzers, the RV assessment time was often over 1 hr. Considering the high variability of measuring RV and considering that little information was added by measuring RV versus predicting RV, it appears that predicting the RV may be a much easier, time efficient, and appropriate alternative. Also, when considering the fact that determining RV contributes the greatest amount of error in measuring body composition via UWW (Wagner & Heyward, 1999), eliminating the variable RV procedure may increase the reliability of assessing body composition via UWW in adults with PWS. Reducing the variability of the UWW procedure of adults with PWS will increase the likelihood of detecting real changes in body composition in serial measurements over time (e.g., before and after an exercise or dietary intervention).

Future research is needed on the development of specific anthropometric or bioelectrical impedance analysis prediction equations designed to estimate body composition in men and women with PWS. Using prediction equations to estimate body composition of adults with PWS will provide an easier, less expensive field-based alternative to determining body composition via UWW, which may be used in residential settings to track body composition over time. As population-specific equations result in the most valid results, gender-, race-, and age-specific prediction equations should be developed (Wagner & Heyward, 1999). Additional research is also needed on the appropriateness of methodologies of measuring body composition in other populations with developmental disabilities.

The familiarization program described in the present study is recommended for implementation prior to measuring body composition via UWW in adults with PWS. Predicting the RV may be an easier and more consistent alternative to measuring the RV by the methods of the present study for adults with PWS.

References


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