# ABSTRACT

Cox, K.S. A Formula Developed for the Prediction of Residual Volume of Female Subjects While Immersed. M.S. in Physical Education Human Performance, 1989. 48 pp. (R.C. Green)


The closed-circuit oxygen dilution technique was used to measure residual volume (RV) in 100 female Ss, age 10 to 56, while seated on land (RV dry) and while immersed to the neck (RV wet). There was a significant difference ($p<.05$) between RV wet and RV dry. A prediction formula for determining RV was developed by regressing smoking history (SH) and the physical characteristics of age, chest depth (CD), height (HT), weight (WT), and chest diameter (CDI) against RV wet. CDI and SH were not significant ($p<.05$) predictors of RV and, subsequently were not included in the final prediction formula. Through the use of a step-wise multiple regression process, the following prediction formula was developed: 0.0176556(AGE) + 0.0399657(CD) + 0.0149732 (HT) - 0.00747103(WT) - 2.20767. The variation ($R^2$) attributed to the independent variables was .60. This $R^2$ was higher than that reported by Crapo et al. (1982) ($R^2$=.48) and Goldman and Becklake (1959) ($R^2$=.30). The standard error of estimate (S.E.E.) for this prediction formula was 148 ml. This S.E.E. was less than that reported by Crapo et al. (1982), (S.E.E.=381 ml), Goldman and Becklake (1959) (S.E.E.=360 ml), and Grimby and Soderholm (1963) (S.E.E.=326 ml). Using the data obtained from this study, there was a significant difference ($p<.05$) between RV determined from previously published studies (Prev RV) and RV determined from the newly developed formula (New RV). There was also a significant difference ($p<.05$) between Prev RV and RV wet.

# A Formula Developed for the Prediction of Residual Volume of Female Subjects While Immersed

A Thesis Presented

to

The Graduate Faculty

University of Wisconsin - La Crosse

In Partial Fulfillment

of the Requirements for the

Master of Science Degree

by

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May, 1989

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Master of Science in Physical Education Human Performance.

The candidate has completed her oral report.

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Acknowledgements

I would like to acknowledge the following people:

To Dr. Richard Green for his superb guidance and exceptional dedication in helping prepare this thesis. His input was invaluable.

To Dr. John Umbehaun for his clear and thorough explanations of the statistical processing. He was generous with his time, always willing to answer my many questions.

To Dr. Joy Greenlee for her practical statistical explanations. She helped me design and conduct the investigation appropriately.

To Mr. Jeff Tesch for his technical expertise and willingness to put aside his own work when I needed him the most.

To all of those people who participated as subjects during the data collection.

To my classmates who helped me collect the data.

To my parents who taught me the value of a good education and silently encouraged me to accomplish my goals.

To my friends who were always supportive and understanding.

Dedication

For Kim whom I love with all my heart.

I would not have made it through without her.

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# CHAPTER I

# INTRODUCTION

Various lung volumes are measured during body composition analysis. These lung volumes are measured directly or indirectly. Direct methods include the use of a spirometer which measures the volume of air moved during either the inspiratory or expiratory phase of the breathing cycle. Indirect methods include (Wilmore, 1969): 1) pneumatometric method, using some form of plythysmograph, 2) closed-circuit method, where there is dilution used and eventual equilibration of an inert tracer or indicator gas such as nitrogen, helium, or hydrogen, and 3) the open-circuit method, where nitrogen is "washed out" of the lungs during a specified period of oxygen breathing.

A spirometer can not measure the volume of air that constantly remains in the lungs. This volume of air is referred to as residual volume (RV). An indirect method for measuring RV is required.

Hydrostatic weighing determines body density on the basis of Archimedes' Principle which states that an object submerged in water is buoyed up by a counterforce that equals the weight of the water displaced. Air remaining in the lungs during immersion can have an effect when attempting to accurately calculate body density. Residual volume then must be measured accurately and its effect accounted for to ensure the most accurate determination of body density.

Water pressure exerts a greater force on the body than atmospheric pressure. When performing hydrostatic weighing, lung volumes are affected by the pressure exerted on the thoracic cavity. Consideration therefore, must be given to the effect water pressure will have on RV measurement.

## Need for the Study

The main purpose of hydrostatic weighing is to obtain a person's body density while immersed in water. Consideration must be given to RV for the most accurate measurement of this density. Since body weight is obtained while immersed, it was reasoned that RV should be as well in order to increase the validity of the subsequent calculations.

The indirect measurement of RV can be both time consuming and expensive. In order to make RV determination more practical, prediction formulas have been developed that can predict RV accurately. The majority of the prediction formulas available were developed using the measurement of RV determined on land (RV dry). They were also developed specifically using male subjects. There is a need, therefore for measurement of RV immersed (RV wet) and for using female subjects. A prediction formula could then be developed which would be appropriate for the female population, taking into consideration the effect immersion has on the determined RV.

## Purposes

The purposes of this study were to: 1) demonstrate a need for determining RV wet opposed to determining RV dry; 2) perform a test-retest correlation for the closed-circuit, oxygen dilution technique of RV wet determination; 3) develop a formula for the prediction of RV wet using smoking history and the strongest physical characteristics of age, height, weight, chest depth, and chest diameter; and 4) test for adequacy of prediction formula.

## Null Hypotheses

The null hypotheses of this study were:

1. Age, height, weight, chest diameter, chest depth, and smoking history are not significant predictors of RV in females between ages 10-56 years.

2. There is no correlation between trials for the closed-circuit oxygen-dilution technique in determining RV wet.

3. There is no significant difference between the RV wet measurement and the RV measurement determined using the formula developed in this study.

4. There is no significant difference between the prediction of RV using the developed formula from this study and the prediction of RV using the formulas developed from previously published studies.

5. There is no significant difference in RV wet and RV predicted using the previously published formulas.

6. There is no significant difference between RV wet and RV dry.

## Assumptions

The assumptions of this study were:

1. All subjects maximally exhaled during all RV measurements.

2. All subjects were free from cardio-respiratory disease.

3. The water level for all subjects was at the same anatomical landmark, which was midway between the chin and the manubrium.

4. All subjects answered the preliminary questionnaire honestly.

## Limitations

The limitations of this study were:

1. True randomization was not achieved, as all subjects were volunteers.

2. A cross-sectional approach was used rather than a longitudinal approach.

3. Individual differences in maximal exhalation endpoints for each residual volume measurement.

## Delimitations

The delimitations of this study were as follows:

1. Only female subjects with heights between 150 - 180 centimeters were tested.

2. Only female subjects between the ages of 10-56 were tested.

3. Age, height, weight, chest diameter, chest depth, and smoking history were the only independent variables examined.

4. The smoking population represented only 12% of the total test population.

5. Subjects suffering from respiratory dysfunction were screened out before testing and were excluded from the study.

## Definitions of Terms

Selected terms for the purpose of this study are as follows:

Age

Chronological age determined to the nearest year.

Closed-Circuit Oxygen Dilution

Rebreathing a measured volume of gas in a closed system to determine a specific lung volume.

Expiratory Reserve Volume (ERV)

Amount of air forcibly exhaled after tidal volume expiration (McArdle, Katch & Katch, 1986).

Functional Residual Capacity (FRC)

The volume of air remaining in the lungs at the end-normal expiration position (McArdle et al., 1986).

Height

Body length of subject measured to top of head, while standing barefoot.

Hydrostatic Weighing

Technique used to determine body density through total immersion of the subject.

Inspiratory Reserve Volume (IRV)

Additional volume of air that can be inspired above the inspired tidal air volume (McArdle et al., 1986).

Pack Years of Smoking

Number of packs smoked per day multiplied by the number of years smoked.

Residual Volume (RV)

Volume of air remaining in lungs after maximal exhalation (McArdle et al., 1986).

Spirometer

Device which measures exhaled or inhaled air volume per unit of time, by recording breathing patterns on a motor driven drum adjacent to a spirometric cylinder which raises on expiration and lowers on inspiration.

Vital Capacity (VC)

Total volume of air that can be voluntarily moved in one breath, from full inspiration to maximal expiration (McArdle et al., 1986).

## CHAPTER II

## RELATED LITERATURE

This chapter will discuss literature reviewed pertinent to this investigation. Studies that specifically used female subjects were rare, consequently studies using male subjects were included in the review of literature discussion.

The development of residual volume determination was examined. Residual volume determined while subjects were immersed (RV wet) was contrasted to RV determined while on land (RV dry). Smoking history and the physical characteristics of age, chest depth, height, weight, and chest diameter were examined for their relationship to RV. Previously published prediction formulas (Prev RV) (Crapo et al., 1980; Goldman & Becklake, 1959; Grimby and Soderholm, 1963) were reviewed for both similarities and differences in methodology.

### Residual Volume Determination

Sir Humphrey Davy investigated the measurement of lung volume of man in the early 1800's. He measured his own lung volume through the use of a hydrogen-dilution method (Boren, Kory & Syner, 1966). According to Boren et al. (1966), Pfluger described a pneumatometric method in 1882. This method used whole body plethysmography in measuring lung volumes which requires that the subject breathe to the outside of an air tight chamber through a mouthpiece. Residual volume was calculated by measuring the change in pressure at the mouthpiece and the volume of expansion of the thorax.

The beginning of the modern type closed-circuit gas dilution method was not seen until the early twentieth century. Lundsgaard and Van Slyke (1918) developed a method in which after maximal exhalation the subject rebreathed oxygen. The oxygen was mixed with the air in the subject's lungs by respiring from 5 to 7 times. The mixture was analyzed and the amount of residual air (RV) was "calculated from the degree to which the air in the chest has diluted the gas in the bag or spirometer" (p. 67).

Van Slyke and Binger (1923) described a hydrogen-dilution method in which the subjects rebreathed for 5 to 7 minutes to allow for complete gas mixing. Christie (1932) introduced the quiet breathing oxygen-dilution technique using hydrogen as an indicator gas. This method was widely used until McMichael (1939) developed a variation of the hydrogen-dilution method. The hydrogen-dilution method was later adapted for helium by Meneely and Kaltreider (1949).

A nitrogen-dilution method was introduced by Darling, Cournand, and Richards (1940) in which nitrogen was "washed out" of the lungs. Rahn, Fenn and Otis (1949) described a nitrogen-dilution method which involved rebreathing 100% oxygen after maximal exhalation. Residual air (RV) was calculated from the percent of nitrogen which was found. Wilmore (1969) proposed a method which was basically a modification of the closed-circuit oxygen-dilution method reported by Lundsgaard and Van Slyke (1918).

RV Wet Compared to RV Dry

Many researchers (Crapo, Morris, Clayton, Nixon, 1982; Donnelly et al, 1988; Timson & Coffman, 1984; Weltman, Janney, Huber, Rians & Katch, 1987) have conducted studies determining RV dry. This value has then been used in the determination of body density through hydrostatic weighing, which is necessary for body percent fat calculations. The question remains whether or not RV dry is an appropriate substitute for RV wet in the determination of eventual body percent fat calculations.

Arborelius, Balldin, Lila, and Lungren (1972) observed pronounced changes in central hemodynamics as a result of immersion. Agostoni, Gurtner, Torri, and Rahn (1966) found that hydrostatic pressure shifted the blood into the thorax and counteracted the force of the inspiratory muscles. This shift could be responsible for decreased RV wet values compared to RV dry values. Craig and Ware (1967) predicted that RV would be decreased when the subject is immersed due to the increase in thoracic blood volume. Dahlback and Lundgren (1972) found that immersion reduced the lung volumes by both compression (Agostoni et al., 1966) and pooling of blood (Arborelius et al., 1972) into the thorax. They theorized that "several hundred milliliters of blood being redistributed into the thorax might engorge the vessels of the lungs and airways, thus presumably directly promoting obstruction and air-trapping" (p.768).

Additional studies have been done on the effect immersion has on volumes. Bondi, Young, Bennett, and Bradley (1976) observed reduced ventilatory efficiency as immersion decreased the range in lung capacities. The authors found that the "inert gas dilution method used to measure RV may have given values lower than the actual volume left in the lungs, since some gas may have been trapped behind closed airways" (p. 740). In agreement with this finding, Robertson, Engle, and Bradley (1978) observed that gas was trapped during immersion and consequently, the dilution method is likely to underestimate RV. They also suggested that since hydrostatic forces tended to decrease RV and vascular congestion tended to increase RV, there should be no significant change in RV while immersed due to the counteracting effect.

Numerous researchers (Girandola, Wiswell, Mohler, Romero & Barnes, 1977; Dahlback & Lundgren, 1972; Prefaut, Lupi & Anthonisen, 1976) found significant decreases in all lung volumes, except RV, due to hydrostatic pressure. RV seemed to be least affected by hydrostatic pressure and was thought to be the most appropriate lung volume to use when hydrostatically determining body density (Thomas & Etheridge, 1980).

Robertson et al. (1978) however, indicated that RV may be affected by immersion and at the very least, "the effect of immersion on residual volume is less clear" (p. 681). This finding indicates the potential need for testing the effect immersion has on RV to a greater extent.

Ostrove and Vaccaro (1982) conducted one of the few studies which used only female subjects. The results of their study indicated that there was a significant decrease ($p<.01$) of 17.4% in RV when comparing RV wet to RV dry. The effect of the decrease between RV wet and RV dry corresponded to a mean relative error of only 0.35% when calculating body density. The authors, therefore recommended that RV determination be made dry. "This procedure would allow for greater ease in measurement for both the subject and researcher with no loss in physiologic accuracy" (p. 223).

Robertson et al. (1978) conducted a study using nine males for determination of RV dry and RV wet. With the use of the dilution method, a significant decrease ($p<.05$) of 12% was observed between RV wet and RV dry. This finding supports that of Ostrove and Vaccaro (1982).

Girandola et al. (1977) found immersion to have a different effect on RV when determined using male subjects. They reported a significant increase ($p<.01$) in RV wet of 6.7% when compared to RV dry. It was thought that possibly the increase in RV wet was due to the "stiffness" of the lung tissue caused by pulmonary vascular engorgement. Calculations of body density and percent body fat indicated significant differences ($p<.01$) when using RV wet compared to RV dry. From the results of the study it was concluded that, "when obtaining body density values, RV should be measured concurrently while the subject is in the water" (p. 276).

Another study using male subjects was one conducted by Sawka, Weber, and Knowlton (1978). They used the helium dilution method for determination of RV wet and RV dry. They discovered a significant difference ($p<.05$) of 16.2% between RV wet and RV dry. RV wet showed a smaller value than RV dry. The findings of this study indicated that "RVs obtained in air were not a suitable substitute for the measurement of residual lung volume underwater" (p. 92). The results from this study reinforce the importance of measuring RV in conditions identical to hydrostatic weighing.

Esteridge and Thomas (1978), measured RV of women in four positions including seated in air, seated in water, prone in air, and prone in water. They found RV was not significantly affected by water immersion or body position. Although the average RV measurements would support the determination of RV dry in place of RV wet, "for research purposes there is enough individual and treatment variation to necessitate the direct determination of lung volumes during the actual underwater weighing" (p. 61).

It is apparent that previously published studies have not completely agreed on the effect immersion has on RV. As Girandola et al. (1977) appropriately stated, "RV is quite variable as a result of water immersion, with some subjects experiencing a decrease and others an increase" (p. 276).

Whether or not it is critical to determine RV wet or RV dry remains to be seen. Ostrove and Vaccaro (1982) sum it up the best by saying, "total lack of data with regard to the effect of immersion on RV in females warrants investigation" (p. 220).

## Relationship Between Examined Variables and Residual Volume

Provided below is a review of literature pertaining to smoking history and selected physical characteristics and their relationship to RV wet.

### Residual Volume and Smoking

When comparing the regional distribution of young smokers to young non-smokers, York and Jones (1981) found there was no significant difference in overall lung function. However, they did report that

RV was significantly higher ($p<.05$) in the lower lung regions of the smokers. These results suggest that smoking does affect the RV.

In a study using identical twins, one of whom smoked and the other who did not, Webster, Lorimer, Man, Woolf and Zamel (1979) found a difference in the RV of the smoker compared to the non-smoker, but that it was not significant ($p<.05$).

Age and Residual Volume

Many researchers have investigated the effect age has on RV. Researchers investigating this effect (Boren et al., 1966; Brozek, 1960; Crapo et al., 1982; Goldman & Becklake, 1959; Grimby & Soderholm, 1963; Jones, Overton, Hammerlindl & Sproule, 1978) all concluded that RV increased with age. Brozek (1960) explained that the increase could possibly be due to reduced elastic recoil of the lungs and thorax. An increase in RV with age involving both the upper and lower lung regions was observed by Jones et al. (1978).

Height and Residual Volume

Goldman and Becklake (1959) found that RV correlated significantly ($p<.01$) ($r=.29$) with height. In agreement with these findings, Boren et al. (1966) also found a significant ($p<.01$) ($r=.23$) relationship between RV and height. It was demonstrated that predicted values of lung volumes could be extended to include persons at the extremes of stature (Aitken, Schoene, Franklin & Pierson, 1985).

Weight and Residual Volume

Weight was reported as having a significant ($p<.01$) correlation ($r=.17$) with RV in the study of Boren et al. (1966). None of the previously published studies developing a prediction formula for women used weight as a variable in the prediction of RV.

Chest Measurements and Residual Volume

No studies were found that used either chest depth or chest diameter measurements in the determination or the prediction of RV. However, Kory, Callahan, Boren, and Syner (1961) found that chest expansion (particularly circumferential expansion) related positively with most of the pulmonary function measurements in their study. Chest circumference and anteroposterior diameter (fourth costochondral junction) were measured during maximal inspiration and maximal expiration. Chest depth and chest diameter were examined in this study because the author thought some previously unexplained relationship existed between these variables and the prediction of RV.

## Residual Volume Prediction Formulas

Prediction formulas have been published in the past by various authors. This section will discuss those formulas developed using female subjects.

Crapo et al. (1982) developed a prediction formula using nonsmoking female subjects. The physical characteristics used as predictor variables were age (years) and height (cm) ($R^2$ =.48). Measurement of RV was done using a single breath helium-dilution technique. The standard error of estimate (S.E.E.) reported was 381 milliliters.

Goldman and Becklake (1959) developed a prediction formula for RV for women using the physical characteristics of age (years) and height (cm) as the predictor variables ($R^2$=.30). They derived RV by subtracting expiratory reserve volume (ERV) from functional residual capacity (FRC). ERV was directly measured using spirometry and FRC was measured using the closed-circuit hydrogen-dilution technique (McMichael, 1939). The S.E.E. reported was 360 milliliters.

Grimby and Soderholm (1963) developed a prediction formula for women using age (years) and height (cm) as the predicting physical characteristics to estimate RV ($R^2$ not reported). Actual RV values were determined by subtracting ERV (spirometry) from FRC (helium-dilution method). The S.E.E. resulting was 326 milliliters (this was reported as the "residual standard deviation" = 320 ml).

## Summary

A number of methods have been developed for the indirect analysis of RV. Some methods are a modification of an earlier method and others use newly developed techniques for determining RV. Common methods available for measuring RV indirectly include plethysmography, tracer gas dilution (closed-circuit), and nitrogen washout (open circuit) (Wilmore, 1969). The closed-circuit oxygen-dilution method seems to be the most commonly used.

The physical characteristics examined for this study which were found to significantly correlate with RV were those of age, (Boren et al., 1966; Brozek, 1960; Crapo et al., 1982; Goldman & Becklake, 1959; Grimby & Soderholm, 1963; Jones et al., 1978) height, (Aitken et al., 1985; Boren et al., 1966; Crapo et al., 1982; Goldman & Becklake, 1959; Grimby & Soderholm, 1963) and weight, (Boren et al., 1966). Smoking history was also found to significantly correlate with RV (Boren et al., 1966; Webster et al., 1979; York & Jones, 1981). Chest depth and chest diameter were reported as having a positive relationship with most of the pulmonary function measurements, but not a specifically significant correlation (Kory et al., 1961).

It is apparent that there exists the need for determining RV wet. According to Robertson et al. (1978):

> Water immersion caused two influences on lung functions to occur: 1) a gradient of hydrostatic pressure counteracts the force of the inspiratory muscles and deforms the chest wall inward when the muscles are relaxed, and 2) blood shifts into the thorax due to compressive effect of the water on the blood vessels of the extremities. (p. 681)

These noted influences can have an effect on RV. Since hydrostatic weighing determines body density while the subject is immersed, so too should RV be determined while the subject is immersed (Etheridge & Thomas, 1978; Girandola et al., 1977; Sawka et al., 1978).

Those studies which used female subjects determined RV dry. Studies using female subjects for prediction of RV wet have not been found in the literature. The need exists for further research in this area. In conclusion, it is apparent that a prediction formula, to estimate RV wet for females, is needed.

# CHAPTER III

## METHODS

This chapter discusses the procedures used in obtaining subjects and those physical characteristics of each subject that were tested. Details of the instruments used and a description of each procedure for measuring physical characteristics are also provided.

### Subjects

The subjects used in this study were all females residing in the greater La Crosse, Wisconsin area. All subjects were solicited by posting information sheets in various establishments around the city. As an incentive for greater subject participation each subject also had percent body fat calculated using the hydrostatic weighing technique.

Candidates completed an information questionnaire (see Appendix A) and were randomly assigned a number from 1-127. Slips of paper numbered 1-127 were then cut and placed into a bowl. The numbers were then randomly selected and the number corresponding to the candidate was ranked with the pick of the draw.

From the ranked numbers, the first 100 subjects were selected for this study. In the event that a subject was not able to be contacted or had decided not to participate, the next ranked subject beyond 100 was contacted to keep the sample size at 100.

Subjects used in this study were of varying ages, heights and body weights. The age range was from 10 to 56 years of age ($\underline{M}$=25.5, $SD \pm 8.4$).

## Instruments

The following is a description of each instrument used during the test procedures:

### Anthropometer

A GPM Model 101 Anthropometer was used for height determination in centimeters.

### Chest Depth Caliper

A Sharp & Smith model chest depth caliper was used to determine chest depth measured in centimeters.

### Chest Diameter Caliper

A sliding caliper was used to determine chest diameter measured in centimeters.

### Hydrostatic Weighing Tank

The hydrostatic weighing tank (Hydrotesting Tank, L.H. Wolfla II, Indianapolis, IN) was used to measure RV while the subject was seated on the hydrostatic weighing chair. A Chatillon scale, suspended from the ceiling, was attached to the weighing chair which suspended the subject in the water.

### Questionnaire

A questionnaire was completed by each subject to give information concerning age, height, smoking history, and cardiopulmonary disease history.

### Residual Volume Apparatus

A closed-circuit oxygen-dilution method (Wilmore, 1969) was used to measure residual volume. The percent nitrogen in the system was determined using the model 505D Nitralyzer (Med-Science St. Louis, MO). An Omega chart recorder was connected to the nitrogen analyzer and graphically recorded nitrogen fraction values. A 6-liter spirometer (Collins model p-600 W.E. Braintree, MA) was used in measuring the amount of oxygen which was transferred into a rubber bag for rebreathing. The amount of oxygen used was usually between 3 and 5 liters.

Single-beam Balance Scale

A Health-O-Meter (Continental model #200 DLK) was used to determine the subject's weight in kilograms.

Spirometer

A 9-liter spirometer (Collins Vitalometer) was used in determining vital capacity.

## Procedures

Upon entering the Human Performance Laboratory at the University of Wisconsin - La Crosse, each subject was required to read the Experimental Consent Form (see Appendix B). All procedures were thoroughly explained and all questions were answered. After explanation and a complete reading, all subjects were asked to sign the consent form. They were then reminded of any possible risks and their ability to withdraw from the study at any time.

Subjects were acquainted with the procedures used during testing. It was hoped each subject would become familiar with the equipment to minimize testing error.

For all testing procedures, the subject wore a one-piece bathing suit. The first part of the actual testing involved determining the subject's vital capacity. The subject was instructed to inhale and exhale maximally into the 9-liter vitalometer spirometer. This was done while wearing a noseclip to ensure no loss of air through the nasal passages. Two trials of this procedure were conducted with the higher of the two values used. Vital capacity was measured in order to determine the amount of oxygen used in the rubber rebreathing bag during RV determination. Actual vital capacity was not used as a variable.

Chest depth was measured with a chest depth caliper. The subject stood with the right hand behind the head. One end of the caliper was placed on the tip of the xiphoid process while the other end was placed over the vertebrae of the twelfth rib. The measurement was taken at the end of a normal expiration.

Chest diameter was measured with a sliding caliper. The subject stood with both hands on the crest of the ilium. The caliper was then placed in the axillary region with the ends being placed on the second or third rib. At the end of expiration, the measurement was obtained. All chest measurements were recorded to the nearest 0.1 centimeter. Two trials were conducted with the average of the two being reported.

Residual volume was first determined while the subject was sitting on a chair. This was done to obtain RV dry. This data was then subsequently used to test for significance between RV wet.

A 6-liter spirometer bell was filled with approximately 5 liters of oxygen by a timed valve. The spirometer and rubber bag were filled and emptied at least 2 times to flush out any gases remaining from previous tests. A measured amount of oxygen, usually 3 to 5 liters (depending on subject's vital capacity measurement) was then dispensed into the rubber bag in preparation for rebreathing.

The subject was instructed to take a few normal breaths while connected to the nitrogen analyzer. This was done with a noseclip and disposable mouthpiece in place. The subject was instructed to inhale maximally and without hesitation, exhale maximally. The subject was required to maintain contact of the mouthpiece with the mouth throughout the measuring process. The subject signaled when she felt maximal exhalation had been reached. The tester then immediately switched the valve allowing the subject to rebreath the oxygen contained in the rubber bag.

The subject was encouraged to take deep breaths to ensure adequate mixing of the gases. This was continued until a nitrogen equilibrium between the subject's lungs and the rebreathing bag had been achieved. Absolute equilibrium is never reached, but for the purposes of this study it was assumed to be reached when the readings were indistinguishable on the graphic printout. The values obtained were inserted into Equation 1 (Wilmore, 1969).

$$RV = 1.1 \times \frac{BV\ (EN - IN)}{AN - FN} - DS \qquad (1)$$

<u>Note</u>.

RV = residual volume. BV = amount of oxygen in rebreathing rubber bag. AN= percent of alveolar nitrogen. IN = percent of nitrogen impurity found in oxygen contained in rubber bag before rebreathing. EN = percent of nitrogen in the rebreathing bag at equilibrium. FN = percent of nitrogen found in the expired air at equilibrium. DS = dead space found within the nitrogen analyzer apparatus (.081 liters). 1.1 = correction factor for BTPS.

The subject's height was measured in centimeters, with the back against the wall and with the subject barefoot. The subject's weight was determined in centimeters, while barefoot and wearing a one-piece bathing suit.

The subject was instructed to enter the locker room area and take a shower, with the bathing suit on, in preparation of entering the hydrostatic tank. A pre-measurement of the weighing apparatus with the subject immersed to the chin was determined. This value was used in body density calculations.

Residual volume measurements were made while the subject was immersed, with the water midway between the chin and manubrium, in the hydrostatic tank. The water temperature was kept between 32 and 34 degrees Celcius for all hydrostatic RV measurements. Two trials were conducted with an adequate break allowed between each one to eliminate any excess oxygen remaining in the lungs after rebreathing. All results were recorded on the graph paper and also on subject data sheets the (see Appendix C). An average of the two trials was used and the variable was named "wet".

## Statistical Treatment of Data

All results were processed through the use of a Zenith data systems computer using the step-wise multiple regression formula for IBM compatible ABSTATS software. A test for significant differences was conducted between RV wet and RV dry. This was through the use of a paired t-test. Each independent variable was tested for its effect on RV wet.

The prediction formula was developed by singularly and collectively entering variables into the step-wise regression formula until no significant increase in R squared occurred. Variables not adding to an increase in R squared were not included in the final developed formula.

Residual volume derived from the formulas mentioned in Chapter II was compared to RV determined through the use of the newly developed formula. A paired t-test was used to test for significance. Paired t-tests were used to compare all cited prediction formulas to RV.

## CHAPTER IV

## RESULTS AND DISCUSSION

A comparison was made between RV wet and RV dry. The intent of the comparison was to determine if any significant difference ($p<.05$) existed between the two measurements. Processing of the raw data was done through the use of a step-wise multiple regression formula. A new prediction formula was then developed and its adequacy tested. Residual volume wet was compared to RV obtained through the use of the newly developed formula (New RV). RV wet was also compared to RV derived using the formulas discussed in Chapter II (Prev RV). These formulas were developed using RV dry values to predict RV. The raw data obtained from this investigation was inserted into these formulas to determine RV.

A test for significance was then conducted between New RV and Prev RV. This was done in an attempt to determine the predictability of RV using the different formulas.

### Subjects

The subjects involved in the study were females between the ages of 10-56 years old. They were volunteers from the greater La Crosse, Wisconsin area. A total of 127 subjects volunteered, of which 100 were randomly selected and tested as previously described in Chapter III. Table 1 presents values for RV wet, RV dry, age, height, weight, chest diameter, chest depth, and smoking history.

Table 1

Characteristics of Test Population

| Variable | Mean | S.D. | S.E. of Mean |
|---|---|---|---|
| RV dry (L) | .95 | .25 | .02 |
| RV wet (L) | .92 | .23 | .02 |
| Age (yr) | 25.60 | 8.40 | .84 |
| Height (cm) | 164.01 | 7.56 | .76 |
| Weight (kg) | 62.06 | 11.49 | 1.15 |
| Chest Diameter (cm) | 25.90 | 2.20 | .22 |
| Chest Depth (cm) | 17.20 | 2.00 | .20 |
| Smoking History (pk) | .82 | 3.40 | .34 |

*Note*. Mean smoking value computed for entire test population.
*n* = 100. pk = pack years.

## Comparison of RV Wet to RV Dry

A paired t-test was performed between RV wet and RV dry revealing a significant difference ($p < .05$) between the two measurements. This finding substantiates the need for determining RV wet when using the measurement in subsequent calculations for body composition assessment.

## Development of Prediction Formula

The development of the prediction formula was accomplished by singularly and collectively regressing the physical characteristics on

RV wet. A step-wise multiple regression formula was used for that process. Specifically, age, height, weight, chest diameter, chest depth, and smoking history were each analyzed to determine their effect on the prediction of RV wet. Table 2 depicts the correlation matrix of the variables.

Table 2

Correlation Matrix of Variables

| | Wet RV | Age | Height | Weight | Chest Diameter | Chest Depth | Smoking History |
|---|---|---|---|---|---|---|---|
| Wet RV | | | | | | | |
| Age | .59 | | | | | | |
| Height | .40 | .00 | | | | | |
| Weight | .33 | .37 | .52 | | | | |
| Chest Diameter | .17 | .20 | .44 | .73 | | | |
| Chest Depth | .43 | .26 | .31 | .63 | .20 | | |
| Smoking History | .14 | .23 | -.07 | -.04 | -.06 | .07 | |

Note. All values rounded to nearest 100th.

Age showed the highest correlation to RV wet. Chest depth and height showed the next highest correlation to RV wet, respectively. Weight was the only other variable indicating some correlation to RV wet, ($p<.05$) with smoking history and chest diameter not indicating a correlation. Table 3 illustrates the development of each variable into the regression formula and Table 4 depicts a summary of each step involved. Smoking history and chest diameter were not included in the final formula due to no significant ($p$<.05) improvement in the variance.

Table 3

Statistical Development of Prediction Formula for Residual Volume

| Variable | B | S.E. B | BETA | T |
|---|---|---|---|---|
| Step 1 | | | | |
| Age | .0162455 | .0022 | .591477 | 7.26* |
| Constant | .508202 | | ----- | |
| Step 2 | | | | |
| Age | .0141427 | .0022 | .514916 | 6.49* |
| Chest Depth | .0343844 | .0093 | .293916 | 3.70* |
| Constant | -.0297162 | | ----- | |
| Step 3 | | | | |
| Age | .0150168 | .0020 | .546740 | 7.60* |
| Chest Depth | .0205881 | .0089 | .175986 | 2.32* |
| Height | .0106820 | .0022 | .351355 | 4.81* |
| Constant | -1.5666200 | | ----- | |
| Step 4 | | | | |
| Age | .0176556 | .0020 | .642815 | 8.92* |
| Chest Depth | .0399657 | .0098 | .341624 | 4.10* |
| Height | .0149732 | .0024 | .492500 | 6.31* |
| Weight | -.00747103 | .0020 | -.373541 | -3.78* |
| Constant | -2.2076700 | | ----- | |

*Note*. N=100.

*p<.05

Table 4

Summary of the Development of New Prediction Formula

| Step | R | Adjusted R Square* | R Square | S.E.E. |
|---|---|---|---|---|
| 1 Age | .59 | .35 | .35 | .186 |
| 2 Age + CD | .66 | .43 | .42 | .175 |
| 3 Age + CD + HT | .74 | .54 | .53 | .158 |
| 4 Age + CD + HT + WT | .78 | .60 | .59 | .148 |

Note. *R square modified to recognize number of independent variables.

Age was found to be the single strongest predictor of RV wet, explaining 35% of the variance (R square). The variable chest depth increased the total variance to 43% in combination with age. Adding the variable height further increased the variance (54%) for predicting RV wet. The addition of the variable weight explained 60% of the variance when combined with the three variables previously regressed. This value (60%) was the largest variance explained after conducting a step-wise multiple regression with all combinations of the variables. A standard error of estimation (S.E.E.) of 148 milliliters resulted from this developed formula.

Table 5 illustrates the development of the prediction formula using the four previously mentioned significant variables with their respective regression coefficient. A break down of each variable is provided as the use of the step-wise multiple regression formula manipulated each one singularly and collectively.

Table 5

Development of Prediction Formula for RV Wet Including Variables

| Formula | R Square | S.E.E. |
|---|---|---|
| .0162455(Age) | .35 | .186 |
| .0141427(Age) + .0343844(CD) - .0297162 | .43 | .175 |
| .0150168(Age) + .0205881(CD) + .0106820(HT) - 1.5662 | .54 | .158 |
| .0176556(Age) + .0399657(CD) + .0149732(HT) - .00747103(WT) - 2.20767 | .60 | .148 |

Note.

Age = years. CD = chest depth(cm). HT = height(cm). WT = weight(kg).

## Comparison of Prediction Formulas

The formula developed from this study was compared to the formulas developed by Crapo et al. (1982), Goldman and Becklake (1959), and Grimby and Soderholm (1963). The formula developed in this study resulted in a lower S.E.E. (148 ml) and a higher multiple correlation coefficient ($R^2$=.60) than the previously cited formulas. Table 6 depicts the comparison of the published formulas with the formula developed from this study.

Table 6

Comparison of Published Formulas to Developed Formula

| Formula | $R^2$ | S.E.E. |
|---|---|---|
| Crapo et al. (1982) | | |
| .0201(Age) + .0197(HT) - 2.421 | .48 | .381 |
| Goldman & Becklake (1959) | | |
| .009(Age) + .032(HT) - 3.90 | .30 | .360 |
| Grimby & Soderholm (1963) | | |
| .007(Age) + .0268(HT) - 3.42 | * | .326** |
| Present Study | | |
| .0176556(Age)+.0399657(CD)+.0149732(HT)- .00747103(WT)-2.20767 | .60 | .148 |

Note. * Not reported in study. ** Value reported as the "residual standard deviation" = 320 ml.

Age = years. HT = height(cm). WT = weight(kg). CD = chest depth(cm).

The raw data obtained in this study were inserted into the previously published formulas to predict RV (Prev RV). The results from each formula were compared to RV derived through the use of the newly developed formula (New RV). Residual volume obtained using the published formulas was then compared to RV wet. All three previously published formulas yielded significantly different ($P \leq .05$) predicted RV compared to New RV. These results are provided in Table 7.

Table 7

T-test of Previously Published Prediction Formulas to Newly Developed Prediction Formula

| Author | Mean | Standard Deviation | Standard Error Mean | T |
|---|---|---|---|---|
| Crapo et al. (1982) | 1.32 | .224 | .022 | 43.09* |
| Goldman & Becklake (1959) | 1.58 | .253 | .025 | 37.58* |
| Grimby & Soderholm (1963) | 1.15 | .211 | .021 | 15.38* |
| Present Study | .92 | .178 | .018 | --- |

Note. Data from present study was inserted into prediction formulas.

*$p<.05$

Results from a paired t-test indicated a significant difference ($p<.05$) between RV wet and Prev RV. The corresponding values of each RV determined using the prediction formulas reported are provided in Table 8.

Table 8

T-test of Predicted Residual Volume to Measured Immersed Volume

| Author | Mean | Standard Deviation | Standard Error Mean | T |
|---|---|---|---|---|
| Crapo et al. (1982) | 1.32 | .224 | .022 | 23.23* |
| Goldman & Becklake (1959) | 1.58 | .253 | .025 | 28.88* |
| Grimby & Soderholm (1963) | 1.15 | .211 | .021 | 11.05* |
| Present Study | .92 | .178 | .018 | .0000 |
| Measured RV (wet) | .92 | .230 | .023 | ---- |

Note. Data from present study was inserted into prediction formulas.
*$p<.05$.

One possible explanation for the noted differences among the obtained predicted RVs is the characteristics of the population from which each formula was developed. The previously published formulas used subject populations which had a different mean age value than did the population used during this investigation. This could stress the importance for using formulas developed on populations of the same sex, similar height, age, and weight parameters, as the desired test population. Table 9 illustrates the population characteristics from each study.

Table 9

Characteristics of Test Population from Previously Published Studies

| | Age (yr) | | Height (cm) | | |
|---|---|---|---|---|---|
| Author | Mean | S.D. | Mean | S.D. | n |
| Crapo et al. (1982) | 49.0 | * | 161.0 | 7.0 | 122 |
| Goldman & Becklake (1959) | 38.5 | 16.3 | 160.9 | 6.4 | 50 |
| Grimby & Soderholm (1963) | 40.1 | 13.8 | 164.0 | 6.0 | 58 |
| Present Study | 25.5 | 8.4 | 164.0 | 7.6 | 100 |

Note. *Not reported.

## Summary

A formula for predicting RV was developed through the use of a step-wise multiple regression formula based on the data collected in the investigation. The formula developed was derived from data gathered from female subjects, which may limit the use of the formula to only females falling within the test population parameters. Of the variables examined, chest diameter and smoking history did not show a significant effect in predicting RV and consequently, were not included in the final developed formula.

The square of the multiple correlation ($R^2$) indicates the proportion of the variation in RV attributed to the independent variables in the prediction formula. The $R^2$ value was used to compare the different prediction formulas. The newly developed formula had a higher $R^2$ (.60) than that reported by Crapo et al. (1982) of .48 and Goldman and Becklake (1959) of .30. Grimby and Soderholm (1963) did not report an $R^2$ value for their formula.

The newly developed formula was unable to explain 40% of the variance in RV. The author thought that possibly some physiological measurement of breathing muscle contractility could increase the adequacy of the prediction formula. Further investigation is needed as to what variables may enhance the adequacy of future prediction formulas.

The development of the new formula resulted in a lower standard error of estimate (148 ml) than the formulas developed by Crapo et al. (1982) (381 ml) and Goldman & Becklake (1959) (360 ml). There was a significant ($p<.05$) difference between RV wet and RV dry, necessitating the measurement of RV wet in order to increase the validity of values obtained.

There was a significant difference ($p<.05$) between Prev RV and RV wet. There also was a significant difference ($p<.05$) between Prev RV and New RV. This finding supports the need for using a formula that was developed on a population specific to the desired test population in order to increase validity in predicting RV. The newly developed formula would be most appropriate for females between the ages of 10 to 56, as this was the range of the test population age.

## CHAPTER V

## SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The intent of this study was to develop a formula for the prediction of RV. This study was unique in that RV wet measurements were used in the calculations as opposed to RV dry measurements. Also, all subjects were female.

### Summary

A test-retest correlation between the two RV wet measurements showed a significant correlation with an r of .97 resulting which would suggest that reliable measurements were taken.

A significant difference ($p<.05$) was found between RV dry and RV wet which would suggest the need for calculating body density by RV wet.

The physical characteristics of age, height, weight, chest depth, and chest diameter were examined through the use of a step-wise multiple regression process, to develop a prediction formula for RV. Smoking history did not add any significant ($\leq 05$) predictability to RV, and therefore was not included in the prediction. This may have been due to the small percentage of smokers (12%) in the test population. Chest diameter was also not included because of failure to improve predictability for RV.

The adequacy of the developed prediction formula was determined by the square of the multiple correlation coefficient ($R^2=.60$). This value was higher than that in formulas developed by Crapo et al. (1982) and Goldman and Becklake (1959) ($R^2$ =.48 and .30, respectively).

The formula developed from this study had a lower standard error of estimate than the previously published formulas. There was a significant difference ($p<.05$) between Prev RV and New RV. This finding supports the need for using a formula that was developed on a population specific to the desired test population in order to increase validity in predicting RV. A significant difference ($p<.05$) was also found between Prev RV and RV wet. There was no significant difference ($p<.05$) found between RV wet and New RV which was expected considering New RV was derived from RV wet.

Equation 2 was the formula developed from this study for predicting RV.

$$\text{RV (liters)} = 0.0176536(\text{Age}) + 0.0399657(\text{CD}) + 0.0149732(\text{HT}) - 0.00747103(\text{WT}) - 2.20767 \quad (2)$$

Note.

Age = years. CD = chest depth(cm). HT = height(cm). WT = weight(kg).

## Conclusions

The results of this study support the following conclusions:

1. Of the physical characteristics examined, age, chest depth, height, and weight were the best significant predictors of RV. The null hypothesis was rejected.

2. Chest diameter and smoking history were not significant predictors of RV. The null hypothesis could not be rejected.

3. There was a significant correlation ($p<.05$) between trials for the closed-circuit oxygen-dilution technique of RV wet determination. The null hypothesis was rejected.

4. There was no significant difference between RV wet and New RV. The null hypothesis could not be rejected.

5. There was a significant difference between New RV and Prev RV. The null hypothesis was rejected.

6. There was a significant difference between RV wet and Prev RV. The null hypothesis was rejected.

7. There was a significant difference between RV wet and RV dry. The null hypothesis was rejected.

## Recommendations

Based on the findings of this study, the following recommendations were made:

1. Develop a prediction formula for RV wet for males.

2. Develop a prediction formula for RV wet for females over the age of 56 years.

3. Develop a prediction formula for females at the extremes of stature.

4. Test for significant differences in RV wet between female smokers and non-smokers.

5. Test for significant differences in body percent fat values using RV wet and RV dry, in body density calculations for women.

6. Select other physical characteristics, not already tested, for examination in the predictability of RV such as the physiology of the breathing muscles.

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Appendix A

Volunteer Subject Questionnaire

Name ________________________________ (please print)

Parent or Guardian's Name (if under 18 yrs.) ______________________

Address ________________________________________________________

Telephone Number (home) ______________ (work) __________________

Age (at last birthday) ______________ Height (total in.) _________

1. Date of birth ____________________ (month/day/year)

2. Do you suffer from any respiratory disorders such as bronchitis, asthma, or tuberculosis? Yes_____ No_____

3. Have you ever had heart surgery, experienced a cardiac indicent, or suffered a heart attack? Yes_____ No_____

4. Do you or have you ever smoked? Yes_____ No_____

   If yes, how many years have/did you and how many cigarettes per day?

   Numbe. of Years_____ Cigarettes/day_____

5. Are you apprehensive about holding your breath while submerged underwater? Yes_____ No_____

6. Do you suffer from any other conditions that the investigator should be aware of? If so, please explain.

   ______________________________________________________________

Appendix B

Experimental Consent Form

I, ____________________ have agreed to voluntarily participate in the residual volume study by being a subject. The requirements of the study involve breathing into a spirometer device, while immersed, used for measuring lung volume. This device measures the volume of gas remaining in the lungs after maximal exhalation. I have honestly completed a questionnaire regarding respiratory and cardiac disorders, age, and verifying smoking history. The purpose of this study is to determine the correlation between measured residual volume and residual volume determined from the study's prediction formula.

Possible risks of this study may include, light headedness, nausea, possible electrocardiographic (EKG) changes due to forced expiration or slight discomfort due to partial immersion while at the end of a maximal exhalation. Instruments will be sterilized and cleaned prior to subsequent trials, but the possibility of infection always exists.

I have read the above information and fully understand the procedures. I am aware of the possible risks and I am free to withdraw at any time.

By signing this document, I give my informed consent. In doing so I hereby release the University of Wisconsin - La Crosse, the Human Performance Laboratory employees and students involved in the evaluation process from any and all legal liability associated with the above described procedures.

To my knowledge, I am not limited by any condition(s) that would affect my ability to participate in this study.

Signed ____________________ Date ____________________

Witness ____________________ Date ____________________

I, ____________________ (parent or guardian) of the above-named subject have read the experimental consent form and do hereby consent to said procedure.

Signed ____________________ Witness ____________________

Appendix C

<u>Subject Data Sheets</u>

Subject's Name ______________________ Age ______ Sex __________

Tester's Name ______________________ Date ____________________

Reason for Test ______________________________________________

Vital Lung Capacity: #1________ liters #2________ liters

| Residual Volume Data | Dry | Wet #1 | Wet #2 |
|---|---|---|---|
| Bag Volume of Oxygen (BV) | ______ L | ______ L | ______ L |
| Alveolar Nitrogen (AN) | ______ % | ______ % | ______ % |
| Impurity Nitrogen (IN) | ______ % | ______ % | ______ % |
| Equilibrium Nitrogen (EN) | ______ % | ______ % | ______ % |
| Final Nitrogen (FN) | ______ % | ______ % | ______ % |

Anthropometry - Subject in one piece bathing suit.

Dry Weight ________ kg

Height ____________ cm

Chest Diameter #1 ________ cm #2 ________ cm

Chest Depth #1 __________ cm #2 ________ cm

Densitometry - Subject immersed in hydrostatic weighing tank.

Immersed Weight of Apparatus (MY) ________ kg

Water Temperature ______________________ C

Immersed Weight of Subject and Apparatus (MX) _______ (heaviest)

Trial #1______ Trial #2______ Trial #3______ Trial #4______

## Appendix D

Raw Data

| SUBJECT NUMBER | DRY RV | WET1 RV | WET2 RV | C.DI CM | C.DE CM | HT IN | WT LB | PK YR | AG YR |
|---|---|---|---|---|---|---|---|---|---|
| 001 | 1.15 | 1.12 | 1.18 | 25.4 | 17.5 | 60.3 | 132.75 | 20 | 35 |
| 002 | 0.71 | 0.69 | 0.70 | 23.3 | 15.0 | 59.6 | 93.00 | 00 | 20 |
| 003 | 0.93 | 0.80 | 0.85 | 26.3 | 17.5 | 67.9 | 134.75 | 00 | 23 |
| 004 | 1.12 | 1.02 | 1.00 | 26.9 | 17.0 | 68.0 | 140.00 | 00 | 21 |
| 005 | 0.57 | 0.54 | 0.54 | 23.0 | 15.0 | 59.5 | 107.50 | 00 | 19 |
| 006 | 0.79 | 0.71 | 0.71 | 25.3 | 16.5 | 60.5 | 116.50 | 00 | 20 |
| 007 | 0.73 | 0.72 | 0.69 | 26.5 | 17.0 | 64.1 | 125.00 | 00 | 21 |
| 008 | 0.89 | 0.83 | 0.81 | 24.4 | 15.0 | 66.7 | 124.50 | 00 | 22 |
| 009 | 0.94 | 1.01 | 0.97 | 26.8 | 17.5 | 62.2 | 141.00 | 00 | 30 |
| 010 | 0.95 | 0.82 | 0.82 | 26.4 | 17.0 | 62.7 | 130.75 | 00 | 22 |
| 011 | 0.77 | 0.85 | 0.86 | 26.0 | 16.5 | 68.4 | 137.00 | 00 | 20 |
| 012 | 1.07 | 1.07 | 1.11 | 25.7 | 20.0 | 64.7 | 159.00 | 00 | 31 |
| 013 | 0.70 | 0.52 | 0.55 | 20.9 | 14.0 | 63.6 | 89.00 | 00 | 11 |
| 014 | 1.32 | 1.25 | 1.22 | 24.4 | 15.5 | 65.7 | 140.00 | 00 | 41 |
| 015 | 1.04 | 0.97 | 0.88 | 27.3 | 15.0 | 63.6 | 126.25 | 00 | 18 |
| 016 | 0.84 | 0.83 | 0.85 | 25.0 | 15.5 | 65.0 | 131.25 | 00 | 28 |
| 017 | 0.93 | 0.86 | 0.83 | 28.8 | 18.0 | 67.7 | 146.00 | 00 | 18 |
| 018 | 0.77 | 0.77 | 0.77 | 25.2 | 14.5 | 65.1 | 120.50 | 00 | 18 |
| 019 | 0.76 | 0.69 | 0.70 | 26.0 | 15.0 | 62.5 | 105.00 | 00 | 19 |
| 020 | 0.85 | 0.83 | 0.81 | 26.3 | 17.5 | 65.5 | 131.25 | 20 | 28 |
| 021 | 0.56 | 0.58 | 0.55 | 24.9 | 14.0 | 59.7 | 117.00 | 00 | 23 |
| 022 | 0.75 | 0.69 | 0.68 | 25.6 | 17.5 | 65.8 | 136.50 | 03 | 28 |
| 023 | 0.90 | 0.93 | 0.99 | 28.9 | 18.0 | 65.5 | 146.50 | 00 | 18 |
| 024 | 0.88 | 0.89 | 0.93 | 33.7 | 22.0 | 62.6 | 241.50 | 00 | 40 |
| 025 | 0.89 | 0.86 | 0.89 | 27.8 | 19.0 | 66.1 | 179.25 | 00 | 22 |
| 026 | 1.14 | 1.13 | 1.12 | 29.4 | 16.0 | 66.9 | 145.00 | 00 | 27 |
| 027 | 0.93 | 0.92 | 1.13 | 27.3 | 19.0 | 67.3 | 151.00 | 00 | 31 |
| 028 | 0.70 | 0.84 | 0.79 | 26.8 | 19.5 | 60.5 | 130.00 | 00 | 23 |
| 029 | 0.92 | 0.92 | 0.95 | 26.1 | 19.0 | 58.0 | 177.00 | 01 | 38 |
| 030 | 1.47 | 1.42 | 1.51 | 26.0 | 19.5 | 67.8 | 160.00 | 00 | 32 |
| 031 | 0.65 | 0.67 | 0.64 | 29.4 | 22.0 | 68.0 | 217.75 | 00 | 25 |
| 032 | 1.12 | 0.99 | 0.99 | 25.4 | 17.5 | 64.6 | 123.00 | 00 | 19 |
| 033 | 1.02 | 1.00 | 0.93 | 25.1 | 17.0 | 65.7 | 127.50 | 00 | 24 |
| 034 | 1.64 | 1.50 | 1.69 | 18.0 | 28.4 | 68.6 | 141.00 | 00 | 19 |
| 035 | 0.70 | 0.67 | 0.67 | 26.8 | 17.0 | 61.4 | 135.00 | 00 | 20 |
| 036 | 0.91 | 0.91 | 0.89 | 26.5 | 17.0 | 65.0 | 141.75 | 00 | 18 |
| 037 | 1.10 | 1.14 | 1.10 | 26.9 | 15.8 | 68.7 | 150.50 | 00 | 32 |
| 038 | 0.88 | 1.42 | 1.26 | 28.4 | 17.5 | 66.9 | 148.25 | 02 | 27 |
| 039 | 1.18 | 1.13 | 0.96 | 26.0 | 18.0 | 63.1 | 116.50 | 00 | 32 |
| 040 | 0.56 | 0.62 | 0.67 | 19.6 | 14.0 | 53.5 | 62.50 | 00 | 10 |
| 041 | 0.82 | 0.80 | 0.82 | 27.1 | 17.5 | 67.0 | 142.00 | 00 | 21 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 042 | 0.76 | 0.75 | 0.73 | 26.3 | 16.5 | 66.1 | 153.00 | 00 | 20 |
| 043 | 0.86 | 1.25 | 1.22 | 24.2 | 18.5 | 62.2 | 153.50 | 00 | 56 |
| 044 | 0.80 | 0.77 | 0.85 | 23.1 | 16.0 | 64.4 | 120.00 | .5 | 21 |
| 045 | 0.86 | 0.86 | 0.89 | 25.7 | 17.0 | 67.1 | 139.50 | 02 | 27 |
| 046 | 1.16 | 1.01 | 1.00 | 27.1 | 16.0 | 66.5 | 133.00 | 00 | 22 |
| 047 | 0.61 | 0.65 | 0.63 | 25.6 | 17.5 | 65.2 | 141.50 | 04 | 19 |
| 048 | 0.95 | 1.25 | 1.22 | 24.9 | 15.0 | 67.1 | 111.25 | 00 | 19 |
| 049 | 0.94 | 0.86 | 0.87 | 26.4 | 17.5 | 67.0 | 133.75 | .8 | 31 |
| 050 | 1.70 | 1.61 | 1.55 | 30.3 | 20.0 | 66.3 | 159.00 | 00 | 49 |
| 051 | 1.26 | 1.26 | 1.25 | 25.1 | 19.0 | 62.7 | 159.00 | 00 | 38 |
| 052 | 0.60 | 0.70 | 0.68 | 24.7 | 18.0 | 63.1 | 123.25 | 00 | 19 |
| 053 | 1.01 | 1.01 | 0.97 | 27.8 | 16.8 | 66.9 | 145.00 | 00 | 19 |
| 054 | 1.33 | 0.97 | 0.92 | 24.8 | 17.0 | 65.5 | 130.25 | 00 | 19 |
| 055 | 1.32 | 1.33 | 1.26 | 24.3 | 19.0 | 64.6 | 129.50 | 18 | 42 |
| 056 | 1.15 | 1.19 | 1.15 | 24.0 | 17.0 | 62.9 | 123.50 | 08 | 33 |
| 057 | 0.85 | 0.75 | 0.73 | 24.1 | 16.0 | 62.0 | 115.00 | 00 | 21 |
| 058 | 0.82 | 0.87 | 0.85 | 25.8 | 17.0 | 63.9 | 130.50 | 00 | 22 |
| 059 | 1.16 | 1.12 | 1.12 | 28.0 | 17.5 | 65.3 | 150.00 | 00 | 22 |
| 060 | 1.08 | 0.91 | 0.88 | 26.2 | 16.5 | 65.5 | 130.25 | 00 | 19 |
| 061 | 1.25 | 1.22 | 1.24 | 29.4 | 21.0 | 69.3 | 219.00 | 00 | 36 |
| 062 | 1.06 | 1.07 | 1.08 | 23.3 | 18.1 | 55.1 | 119.00 | 00 | 20 |
| 063 | 0.66 | 0.62 | 0.61 | 27.0 | 16.5 | 60.6 | 127.50 | 00 | 23 |
| 064 | 1.12 | 1.17 | 1.05 | 24.6 | 16.0 | 62.3 | 121.50 | 00 | 33 |
| 065 | 0.72 | 0.67 | 0.66 | 23.9 | 15.8 | 61.4 | 111.50 | 00 | 25 |
| 066 | 0.61 | 0.70 | 0.69 | 27.4 | 15.0 | 63.5 | 135.00 | 00 | 20 |
| 067 | 1.06 | 0.76 | 0.76 | 26.4 | 17.5 | 62.5 | 128.50 | 00 | 34 |
| 068 | 0.74 | 0.62 | 0.63 | 24.0 | 17.0 | 61.6 | 117.00 | 00 | 19 |
| 069 | 1.41 | 1.46 | 1.36 | 27.8 | 15.5 | 69.9 | 161.00 | 00 | 30 |
| 070 | 1.06 | 1.03 | 1.04 | 23.7 | 16.5 | 60.0 | 113.00 | 00 | 39 |
| 071 | 1.01 | 1.12 | 1.13 | 22.8 | 15.5 | 63.5 | 101.00 | 00 | 42 |
| 072 | 0.67 | 0.71 | 0.67 | 26.0 | 16.0 | 64.0 | 127.50 | 00 | 19 |
| 073 | 0.82 | 0.86 | 0.84 | 26.0 | 17.8 | 68.5 | 146.50 | 00 | 21 |
| 074 | 0.81 | 0.91 | 0.84 | 26.8 | 15.0 | 66.0 | 134.25 | 00 | 31 |
| 075 | 0.79 | 0.94 | 0.90 | 24.8 | 18.0 | 65.2 | 130.50 | 00 | 18 |
| 076 | 0.92 | 0.79 | 0.77 | 24.9 | 15.5 | 64.9 | 124.00 | 00 | 21 |
| 077 | 0.77 | 0.84 | 0.75 | 23.8 | 17.5 | 65.9 | 132.00 | 00 | 21 |
| 078 | 0.89 | 0.77 | 0.77 | 24.2 | 19.0 | 64.4 | 132.25 | 00 | 18 |
| 079 | 0.92 | 0.98 | 0.93 | 27.8 | 16.5 | 66.3 | 153.00 | 00 | 22 |
| 080 | 1.11 | 0.87 | 0.81 | 26.1 | 15.5 | 63.9 | 121.50 | 00 | 21 |
| 081 | 0.92 | 0.90 | 0.88 | 28.7 | 19.0 | 64.5 | 152.25 | 00 | 25 |
| 082 | 0.63 | 0.58 | 0.55 | 25.0 | 16.0 | 61.9 | 136.50 | 00 | 20 |
| 083 | 1.00 | 1.01 | 1.09 | 27.2 | 15.5 | 64.2 | 132.50 | 00 | 30 |
| 084 | 1.29 | 1.18 | 1.30 | 28.4 | 18.0 | 65.7 | 151.00 | 00 | 32 |
| 085 | 0.91 | 0.80 | 0.78 | 28.9 | 18.5 | 72.0 | 165.00 | 00 | 20 |
| 086 | 0.73 | 0.74 | 0.71 | 22.9 | 16.5 | 61.0 | 109.50 | 00 | 23 |
| 087 | 1.21 | 1.21 | 1.11 | 26.5 | 19.0 | 65.6 | 163.00 | 00 | 38 |
| 088 | 0.51 | 0.58 | 0.56 | 23.6 | 16.0 | 60.5 | 90.50 | 00 | 13 |
| 089 | 0.74 | 0.77 | 0.74 | 25.8 | 18.0 | 65.0 | 147.00 | 00 | 19 |
| 090 | 0.89 | 0.90 | 0.90 | 23.5 | 16.0 | 63.1 | 110.50 | 00 | 20 |
| 091 | 1.41 | 1.25 | 1.23 | 25.7 | 17.0 | 62.6 | 132.00 | 03 | 44 |
| 092 | 0.94 | 0.85 | 0.83 | 23.7 | 16.0 | 60.1 | 106.25 | 00 | 22 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 093 | 0.89 | 0.91 | 0.93 | 27.4 | 19.0 | 65.5 | 172.00 | 00 | 27 |
| 094 | 0.79 | 0.78 | 0.77 | 25.7 | 15.1 | 66.2 | 139.00 | 00 | 20 |
| 095 | 1.23 | 1.10 | 1.06 | 27.2 | 16.5 | 65.1 | 139.00 | 00 | 26 |
| 096 | 1.07 | 0.81 | 0.79 | 28.3 | 19.0 | 67.5 | 180.00 | 00 | 19 |
| 097 | 1.33 | 1.17 | 1.16 | 27.8 | 18.0 | 70.8 | 168.50 | 00 | 31 |
| 098 | 0.97 | 0.77 | 0.91 | 24.1 | 17.0 | 62.0 | 131.25 | 00 | 40 |
| 099 | 1.65 | 1.29 | 1.29 | 28.7 | 18.5 | 70.6 | 149.00 | 00 | 23 |
| 100 | 1.01 | 1.01 | 1.05 | 26.2 | 17.5 | 64.1 | 153.25 | 00 | 40 |