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DEVICES BASED ON ANTHROPOMETRIC AND
BUOYANCY MEASUREMENTS.

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CRITERIA FOR CHILDREN'S WATER SAFETY DEVICES
BASED ON
ANTHROPOMETRIC AND BUOYANCY MEASUREMENTS

by
Charles Emilien Cotton

**A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Education)
in The University of Michigan
1976**

Doctoral Committee:

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Associate Professor Merle Foss
Professor Guy Reiff
Professor Richard Snyder

DEDICATION

This study is affectionately dedicated
to my wife Thérèse
and to my children
Marc, Marie-France and Pierre

ACKNOWLEDGEMENTS

I wish to acknowledge the many people who have made this dissertation a meaningful experience. My sincere appreciation is extended to the members of my committee, Dr. R.W. Harris, Dr. James A. Newman, Dr. G. Rieff, Dr. Merle Foss and Dr. R.G. Snyder, for their helpful suggestions whenever needed. Special thanks are offered to Dr. Newman, whose constant counselling, encouragement and guidance made this study possible. I would like to thank Dr. R.W. Harris for her helpful comments and cooperation during this study.

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CHAPTER I

STATEMENT OF THE PROBLEM

In recent years, due to increased interest in recreational activities, both on and in the water, there has been increased pressure to provide all persons, especially children, with water safety devices capable of minimizing the danger of drowning following a sudden fall in the water. Recent reports of several water-safety minded groups (Booz-Allen Report, 1969; Canadian Government officials, 1974; Canadian Safety Council, 1974; Red Cross representatives, 1974) have indicated that there is no good flotation device that fits young children and also meets rigorous safety standards. This difficulty of combining fit with adequate buoyancy is most evident with children who weigh 50 lb. (22.7 kg.) or less.

The lack of adequate fit and comfort can be explained by the fact that almost all the existing children's water safety devices have been designed solely according to weight without any regard for anthropometric data such as height, back length, chest circumference, etc. (Canadian Government officials, 1974; Canadian Safety Council, 1974; Red Cross representatives, 1974). Even the buoyancy

requirement of 7 lb. (3.2 kg.) built in the small size lifejacket for persons weighing less than 50 lb. (22.7 kg.) is not always sufficient. Some evidence even suggests that buoyancy requirements for certain children might be close in magnitude to adult requirements (Tom Taylor Company Ltd., 1974).

How can a single anthropometric parameter such as weight be used to measure the effectiveness of water safety devices? Weight alone seems to provide an inadequate basis for designing such equipment, because children under age twelve differ considerably in anthropometric and buoyancy measurements (Booz-Allen Report, 1969; Espenschade & Eckert, 1967; Whipple, 1966). Nevertheless, nearly all existing water safety devices manufactured and sold in Canada, the United States, and the United Kingdom, are sized solely according to weight.

Furthermore, in the United States and in Canada, approved water safety devices are marketed in only three sizes: (a) one designed to be worn by persons weighing over 90 lb. (41 kg.); (b) one for persons weighing between 45 lb. and 90 lb. (20 kg. and 41 kg.); (c) one for persons weighing 50 lb. (23 kg.) and under (Canadian Government, 1964; Canadian Government, 1972; Personal Flotation Devices Standard, 1971).

According to the above-mentioned sizing method, a one year-old boy or girl weighing 23.8 lb. (10.8 kg.)

and 21.9 lb. (9.9 kg.) respectively, would have to wear the jacket which fits the 6 year-old boy or girl who weighs 48.2 lb. (21.9 kg.) and 48.3 lb. (21.9 kg.) respectively (Lourey, 1973). The same unreasonable measures exist in the larger size, where a 12 year-old boy weighing 90 lb. (40.8 kg.) and a 250 lb. (113.4 kg.) adult would wear the same lifejacket. The only way to adapt such water safety devices would be to make them adjustable and the bulkiness makes such adjustment difficult in present models.

By adding a fourth category for infants, the Australian standards are more discriminating than the Canadian and American standards. The actual Australian standards for water safety devices require that jackets and vests be sold according to the following categories: 90 lb. (41 kg.) and over; from 50 lb. to 90 lb. (23 kg. to 41 kg.); from 25 lb. to 50 lb. (11 kg. to 23 kg.); and a last size which is labelled up to 25 lb. (11 kg.) (The Standard for Lifejackets, 1974).

Even if heavier people need a lifejacket with a greater buoyancy than lighter people, weight is not necessarily the best criterion to be used when classifying lifejackets. It was demonstrated (Carmody, 1965; Carter, 1956; Cureton, 1933; Whiting, 1965) that density is a more important factor than weight in floating ability; therefore,

$$\text{Floating ability} = \frac{\text{Volume of body}}{\text{Mass of body}}$$

Applying this to the human, we find that an endomorphic person "... not only displaces a larger amount of water thus experiencing a greater upward thrust, but his volume is composed of a high degree of fat tissue which, having a low specific gravity, gives him an even greater thrust" (Carmody, 1956, p. 16) and "The mesomorph on the other hand, will present a large volume, but his bulk will contain a high ratio of bone and muscle tissue which will tend to make him sink rather quickly." (Carmody, 1965, p. 16).

The actual sizing method which is not discriminating enough for children under age twelve brings about other secondary problems which limit the wearing of water safety devices by children. These problems are: the lack of comfort and fit which is accompanied by skin irritation around the neck and arms; the difficulty of donning; and the bulkiness of the buoyancy material which restricts the movement in and out of the water. In the last few decades, it has been demonstrated and accepted that children differ from adults in external dimension and shape, which illustrates the need to design children's lifejackets according to their own morphology (Whipple, 1966). It is evident that any improved personal flotation device for children should be based on appropriate physical characteristics (Swearingen, Badgley, Braden, and Wallace, 1965). This was emphasized in the statements in reports made by both the Canadian Red

Cross representatives (1974) and by Canadian Government Officials (1974).

It is, therefore, the purpose of this study to determine criteria for the design of children's water safety devices based on anthropometric and buoyancy characteristics of children.

Importance of the Problem

The recent increase in recreational activities on or near the water has led to an increasing number of drowning accidents, both in Canada and the United States (Cause of Death, 1974; National Safety League and Statistics Canada, 1974; Results of Boating Accidents, 1972). Of the 800 accidental drownings per year on an average over the past decade in Canada, one third were occupants of small boats or pleasure craft. In the United States, the six percent annual increase in drownings since 1966 has seemed to parallel the increased use of small boats.

Both the Canadian Ministry of Transport and the U.S. Coast Guard have stringent requirements relative to both the number and type of personal water safety devices required in small pleasure crafts and also flotation standards for those devices (Appendix A, page 172). In spite of the standards, the U.S. Coast Guard indicated "Flotation

devices were not available in 34 out of 100 drowning cases and they were not used even though available in 5 out of 100" (Coast Guard Recreational Boating Report, 1967, p. 98).

Of the total number of drownings, Canadian statistics (Cause of Death, 1974) indicate that approximately 40 percent are children between the ages of one and fourteen. Within this percentage, boys exceed girls by a ratio of three-to-one. The Canadian Red Cross Society (National Safety League and Statistics Canada, 1974) reported that children under 6 years of age represent 11.8 percent of the total drownings in Ontario for the year 1973. Of the 6,400 drownings recorded in the United States in 1962, 2,150 were children between 0 and 14 years old (Silvia, 1971). However, the statistics do not indicate if the children wore a life-jacket or not at the time of the accident, or if the water safety device was indeed available.

Statistics related to boating accidents indicate that the survival rate of those wearing water safety devices is increased to 60 percent as compared to only 30 percent survival of those not wearing a water safety device (Coast Guard Recreational Boating Report, 1972).

The statistics (Cause of Death, 1974; Results of Boating Accidents, 1972) seem to indicate that the constant wearing of a water safety device is necessary. Most fatalities happen during recreational boating

and without warning - boat capsizing - falls overboard, etc. United States boating statistics reported 1,318 drownings following boating accidents which represents approximately 6 percent of the total accidents involving reportable property damage. The majority of these victims were not wearing water safety devices and went into the water so suddenly that there was no time to reach out and grab one, let alone put one on (Recreational Boating Population Statistics, 1972). The Ontario Safety League (1972) found that 75 percent of their boating fatalities involved campers, fishermen, hunters, etc. "Ninety per cent of the drowning victims of boating accidents on whom data were available did not use a lifesaving device." (Silvia, 1970). These statistics clearly show the seriousness of the risk associated with boating. This problem becomes more drastic since it was shown that the average American could swim about 75 to 100 feet and/or stay afloat for only about 1 to 1.5 minutes (American Red Cross, 1967).

Logic suggests that the risk of drowning could be greater with children than with adults because they are less likely to be strong swimmers or even know how to swim, if under six years of age. Research also indicates two additional reasons which can affect the wearability and effectiveness of the existing water safety devices for children (Goodwin and Richardson, 1973; The Standards for Lifejackets, 1974). The reasons are:

1. The amount of buoyancy force needed to keep the children in a safe floating position, with face and neck out of the water at all times. This upward force should be so high as to oppose any sinking force caused by such movement as waving for help or stretching out for additional help. The present 7 lb. (3.2 kg.) buoyancy built in the present Canadian small size lifejacket (Size C) may not be sufficient for all children of this weight category, that is up to 50 lb. (22.7 kg.). In a study made for the U.S. Coast Guard, the Booz-Allen Applied Research Inc. has reported buoyancy requirements for children. The adequate buoyancy for a body weighing 30 lb. (13.6 kg.), 40 lb. (18.1 kg.) and 50 lb. (22.7 kg.) were 7.3 lb. (3.3 kg.), 8.4 lb. (3.8 kg.) and 9.8 lb. (4.4 kg.) respectively (Booz-Allen Report, 1969). These findings are supported by Little (1971), which reported buoyancy requirements of 7 lb. (3.2 kg.), 8 lb. (3.6 kg.), and 9 lb. (4.1 kg.) for the same body weights.

2. Rotation: the lifejacket should have a positive righting moment, and in no circumstances should it turn the wearer to a face-down position. It should be capable of turning almost everybody to a safe flotation position with the body inclined backward, face out of the water (Personal Flotation Devices Standard, 1971; Specification for Lifejackets, 1964; Standards for Personal Flotation

Devices, 1974; The Standard for Lifejackets, 1974). Nevertheless, this is not the case with many present models (Goodwin and Richardson, 1973; Personal Flotation Devices Standard, 1971). However, there are exceptional individuals for whom the righting moment will not work as designed. This turning effect is very important for children even when not unconscious, since they do not relax in the water, and will likely flail about until exhausted.

The reasons presented in the previous pages, as well as the quoted statistics, seem to reinforce the importance of including new features such as: better fit and comfort, good buoyancy force distribution, good righting moment, ease of donning, etc., in the design of a water safety device for children.

The Problem

The problem, therefore, is to provide criteria based on anthropometric and buoyancy measures of children which could provide more adequate bases for the future design and construction of children's water safety devices.

Sub-problems

This problem infers the following sub-problems:

1. to evaluate the aesthetic and functional features of present lifejackets;
2. to measure and analyse children's anthropometric characteristics;

3. to measure and analyse the buoyancy distribution of children;

4. to determine anthropometric variables which correlate highest with buoyancy, so that buoyancy can be predicted on the basis of these measurements;

5. to develop a buoyancy table which can be used and read easily by people responsible for the manufacturing and marketing of water safety devices;

6. to critically analyse the existing Canadian Standard 65-GP-11 as it applies to children's water safety devices;

7. to recommend possible changes for improvement in the Standard 65-GP-11 used to evaluate personal flotation devices.

Hypotheses

The following hypotheses were tested in this study:

1. The aesthetic and functional features of contemporary water safety devices are not suitable for young children.

2. Since the body shape and proportions of children differ from that of adults, buoyancy requirements for children cannot be determined by mere geometric scaling or by extrapolation on the basis of total body weight.

3. Buoyancy of a child can be predicted from a few anthropometric measurements.

Delimitations

1. Selection of subjects was a delimiting factor:
 - a) The original sample of two hundred boys and girls were volunteers from a single elementary school within the Ottawa/Hull region of Canada.
 - b) Only subjects weighing 90 pounds or less were selected and each was required to have parental consent.
 - c) Replacements for rejected subjects were chosen from the same area, but from outside that particular school, with some thought given to increasing the number at the lower end of the weight scale.

2. Each subject was tested wearing his/her swim suit which may have increased the net buoyancy score by as much as one-quarter pound.

3. Testing was limited to nine types of life-jackets and three types of personal flotation devices available and considered to meet minimum standards 65-GP-7 or 65-GP-11.

Limitations

1. The total buoyancy and buoyancy distribution was measured during normal respiration, since it seems unlikely that a young child could understand the sensation of complete exhalation or inhalation.

2. The actual buoyancy measurements were taken in calm warm water.

3. Precision of measurements could be affected by children's

- (a) lack of relaxation while submerged in water;
- (b) breathing irregularity due to physical tension affecting the quantity of air in the lungs;
- (c) instability when submerged;
- (d) unwillingness to listen to directives and remain in a given position for the time required to take the measurements.

4. The ease of donning and comfort of existing water safety devices were determined by subjective judgement.

Definition of Terms

1. Buoyancy: The resultant upward pressure of fluid on an immersed or floating body.

2. Center of Buoyancy: It is defined as a point about which the buoyant forces acting on an object or body in water are balanced.

3. Combined Buoyancy: Refers to a water safety device which has buoyant material and an air or compressed gas chamber that can be inflated if desired.

4. Net Buoyancy: This term indicates the weight of the subject when submerged up to his/her chin. It represents the amount of extra buoyant force which a child needs if he/she is to stay afloat head out of the water.

5. Net Buoyancy "down" or "arms at the side": both terms are used to define the buoyant force needed by

the subject to float when tested in the standing position arms at the side.

6. Net Buoyancy "up" or "arms over the head": these terms express the buoyant force needed by the subject to float when tested in the standing position, arms extended in the air.

7. Center of Gravity: It is the point at which the weight of the body may be considered to be concentrated.

8. Collar: That part of a lifejacket that moulds itself around the back of the neck and provides support to keep the back of the head at the surface of the water when the body is floating in a vertical or supine position.

9. Inherently Buoyant: Means that the flotation device is made of material that will float by itself without air or compressed gas.

10. Righting Moment: "Is used to indicate that the particular lifejacket is capable of turning the body within a certain time, to a safe flotation position with the body inclined backward from its vertical position and provide lateral and occipital support to the wearer's head" (Canadian Government Specification Board..., 1972).

11. Rotation: A roll around a horizontal axis or a pendulum-like motion around a frontal axis of the

body from a front float position to a back float. The face should be entirely out of the water in this final floating position.

12. Wearability: An attractive appearance with compact allocation of buoyant material to prevent discomfort, awkwardness, or difficulty in maneuvering in a boat, on water skis, or on land.

13. Specific Gravity: The ratio between the weight of a body and the weight of an equal volume of water. In other words:

$$\text{Specific Gravity} = \frac{\text{Weight of Body}}{\text{Weight of Equal Volume of Water}}$$

14. Lifejackets: Buoyant devices in the form of slab or vest used to keep a person safely afloat in water. They are approved by the Canadian Ministry of Transport. Their principal performance requirement is that they turn the wearer to a safe flotation position every time.

15. Personal Flotation Devices: Specifically used in Canada to refer to ski belts and other buoyant aids designed to meet the needs of persons engaged in water sports. These have no positive righting moment, but should not turn the wearer to a face-down position from a supine position. In the United States, all water safety devices are called personal flotation devices and are classified into five types, based on their performance.

16. The term "water safety device" refers to both lifejackets and personal flotation devices.

CHAPTER II

REVIEW OF RELATED LITERATURE

The degree of performance of a given lifejacket or personal flotation device is influenced by the functional characteristics of the material used and by the physiological and anatomical characteristics of the wearer. In the first case, the performance is dependent upon the amount, the kind and location of the buoyant material, as well as its position and fit on the body. As for the human, his floating characteristics depend on such parameters as: the density and the amount of bone, muscle and fat tissue, as well as the quantity of air in the lungs. This review has been organised so as to present the results of previous research pertaining to human buoyant characteristics followed by evidence pertaining to the performance characteristics of water safety devices.

Floating Ability

In this section, an attempt will be made to clarify such questions as: Why are certain persons better floaters than others? Is the degree of buoyancy of a person related to his sex?

At the beginning of the twentieth century, it was thought that all women could float. This belief was based

on the fact that in general women have smaller bone structure and a higher percentage of adipose tissue than men. This opinion was reinforced by the comments of Sandon (1924) who stated that all women could float since their body density was less than .9875. Because such writings seem to be contrary to practical experience, Rork and Hellebrandt in 1937 investigated the floating ability of women and concluded that not all women could float.

In an attempt to study the floating ability of the human body, Whiting (1963) subjected one thousand and forty males between the age of 9 to 24 years to four flotation tests. A description of these flotation tests appears in the section entitled "Tests For Determining Total Buoyancy" of the present chapter.

The results of these tests indicated that the highest percentage in both horizontal and tuck floating ability occurred between the ages of 10 and 13 years, with a decrease from then on. Horizontal floating became almost impossible from age 15 onward. As an explanation for these results, Whiting (1963) suggests that a decrease in specific gravity between 10 and 13 years of age is due to the distribution of body tissue, especially fat and its rate of growth in particular parts of the body.

Pursuing his study on the floating ability of humans, Whiting in 1965 submitted eight hundred and seventy-

seven females between the ages of 10 and 18 years to the same four floating ability tests. It was found that after the age of thirteen, females are superior to males in tuck floating ability after maximum inhalation and during normal breathing. The results of this later study also showed two peaks in the horizontal floating ability of the females, one between the ages of 10 and 13 years and another between 15 and 17 years, with a decrease in horizontal floating ability between the ages of 13 and 15 years and from 17 years upward.

When comparing his male (1963) and female (1965) studies, Whiting found a significant difference ($\chi^2 = 30.43$; $P < .01$) in favor of the 10 to 18 years old female group for the tuck floating ability test. The author also concluded that females were superior to males in horizontal floating ability between 15 and 17 years of age. This difference in floating ability in favor of the women was also found by Carmody (1965). The greater floating ability of some children and women could perhaps be explained in part by the amount and distribution of fat, muscle, and bone tissues in the body. Some of the studies dealing with the influence of the morphological factors on buoyancy will be reviewed in a later part of this chapter under the subheading "Factors Influencing Buoyancy".

It should be pointed out that in neither of these studies (Whiting, 1963; Whiting, 1965) did the author include subjects between 30 and 60 lb. (13.6 and 27.1 kg.). He did

use some young subjects, but their number represented only a small fraction of the total sample. (Only 2% of his subjects were less than 10 years old).

These results seem to indicate that floating ability varies with age and sex, in that children, ages 10 to 13, are better floaters than adults, and from age 13 onward, females have an advantage over males. Logically, it appears that the greater ability of women and children to float motionless in the horizontal position could have an influence on the rotation or righting moment of water safety devices. Since floating ability varies amongst individuals, it would perhaps be useful and practical if one could use certain physical parameters to predict buoyancy.

Buoyancy Prediction

Individual differences in buoyancy could be due to a number of factors such as age, sex, body build, etc. Accordingly, studies have been conducted with the purpose of studying the influence of these factors upon buoyancy.

In a study "An Experimental Study in Buoyancy: A Study of Buoyancy in Adult Women as Related to Body Proportions and to the Center of Weight", Lyman (1930) found that weight was the only physical parameter which had a statistically significant relationship with buoyancy. In another study on the floating ability of women, Rork et al. (1937) found a high relationship between surface area, vital

capacity, and specific gravity, as factors influencing buoyancy.

By measuring male subjects, Hunt (1940) found that the degree of buoyancy was influenced favorably by: excess fat, poor muscular development; a light skeleton and narrow shoulders and wide hips. These findings are supported by Carter (1956), Cureton (1933), Lyman (1930), Rork and Hellebrandt (1937), Whiting (1963), and Whiting (1965), who demonstrated that buoyancy is influenced by the density of the body which, in turn, is dependent upon the density and distribution of each main component: bone, muscle and adipose tissue.

Everette (1950), in trying to determine the relationship of body build to buoyancy in women, has shown that the best single measurement which can be used to predict buoyancy is the horizontal distance between the center of gravity and the center of buoyancy, and that no single anthropometric measurement could be used to predict buoyancy.

Using a larger amount of anthropometric variables than in previous studies, Lane and Mitchem (1964) tried to predict the buoyancy of 69 white and 52 negro subjects. The variables measured were: standing and sitting height, weight, chest, shoulder hip and knee widths, chest depth, chest circumference, arm and upper leg girth, breathing capacity, arm, chest, abdominal, back and supra iliac fat. The authors also used certain ratios in their analysis.

These ratios were: chest circumference divided by standing height, weight divided by standing height, sitting height divided by standing height and body area obtained by DuBois and DuBois formula ($\text{Area} = \text{Weight}^{0.425} \times \text{Height}^{0.725} \times 0.007184$) (Fulton, 1950). The buoyancy of their subjects was measured by the following technique. The subject had to maintain a tuck floating position after a deep breath for a time count of twenty. The subject was declared a floater if his back rose to the surface, and a non-floater if he sank.

Using a discriminating analysis, the authors found that standing height, breathing capacity, and sitting height were the greater contributors to the prediction of buoyancy of white subjects. Buoyancy of negro subjects could be predicted from nine variables: standing height, sitting height, knee width, chest circumference, arm girth, upper leg girth, breathing capacity, and back fat. They also concluded that negro subjects were anthropometrically different and would experience less buoyancy than white males.

Based on the repeated statement that women have greater buoyancy than men, and that caucasian are more buoyant than negro women, Mitchem et al. (1964) tried to predict buoyancy for women using anthropometric measurements. The testing was conducted on 74 caucasian and 81 negro women. The procedures and statistical analysis used in this study were the same as in the study by Lane and Mitchem (1964).

The study concluded that the discriminant equation to predict buoyancy as a dichotomy between floaters and non-floaters for the negro group was not significant at the .05 level. The lack of dichotomy between floaters and non-floaters made it impossible to compute a discriminate equation for the caucasian group. The authors also found that the greatest contributors to the prediction of buoyancy were: sitting height, breathing capacity, chest depth, chest circumference, chest fat and abdominal fat.

Most of the research to date on buoyancy prediction has been primarily concerned with the prediction of total buoyancy without any regard for the buoyant force needed when a person has to float with his head out of the water. Furthermore, this type of research using young subjects has not been reported in the literature. Therefore, these results cannot be applied directly in the design of adult and children water safety devices.

Factors Affecting Buoyancy

While there has been some investigation of the ability of floating and on buoyancy prediction, there has been extensive investigation of the factors which may influence the degree of buoyancy of a given individual.

Density of the Body

The location of the center of buoyancy as well as the righting or rotating moment of a submerged human body,

is influenced by the density of different body segments. The density of these segments, in turn, is influenced by the quantity and distribution of the bone, muscle, and fat tissues. Body density is also influenced by the amount of air in the lungs.

In Sandon's (1924) classic research on floating ability, he reported that a body will float in fresh water only if its specific gravity is .9875 or less. Based on these results, he also concluded that all women could float. However, this statement was rejected by Carter (1956), Cureton (1933), Davies (1930), Rork and Hellebrandt (1937), and Whiting (1965), all of whom demonstrated that some women will sink even if generally they are better floaters than men.

In a 1956 publication, Carter has stated that: "An increase in weight in the human body means an increase in bodily tissues or fluids. The effect of this increase on the density of body will, therefore, depend on the density of the tissue or fluid involved in the increase." (p. 10) All the tissues in the body can be divided into two groups according to whether the specific gravity is more or less than 1.000, the specific gravity of water.

Fat will have a positive influence on buoyancy since it is the only tissue in the body that has a specific gravity less than 1.000. In 1933, Cureton has found that body fat was a determining factor in specific gravity. Other

studies had arrived at the same conclusions: Behnke et al. (1942) stated that: "the amount of fat within a physique appears to be the most important single factor in determining the floating ability of the human body" (p. 496). This statement was also supported by Dupertius et al. (1951) which concluded that "Individual differences in specific gravity appear to depend primarily on varying degrees of the first component (endomorph) which is an anthropomorphic estimate of the amount of body fat" (p. 677).

The relative amount of fat tissue seems to be greater in females than in males. In 1948, Reynolds mentioned that girls will have a tendency to maintain more fat than boys and that from age 6 to early puberty, girls become slightly fatter than boys. He also found that at age $7\frac{1}{2}$, a boy's leg contains 14 per cent of fat in comparison to 18 per cent for girls. Stuart and Sabel (1946) and Tanner (1962) found that from one to six years, girls lose fat less rapidly than boys and will gain it more rapidly thereafter. This accumulation of fat in favor of girls has also been reported by Bugui (1972), Gray (1953), Malina et al. (1967), Maresh (1966), and Parizkova (1961).

Fat, because of its density (less than water), will help a person to float. However, the human physique is made of two other major components, muscles and bones, which will also influence the total density of the body.

Muscle tissue will influence the density of the body first, because of its specific gravity which is approximately 1.0 (Carter, 1956; Hay, 1973) and second, because it forms a major part of the body. From an experiment on the distribution of tissue components in the human leg, Reynolds and Groto (1948) concluded that at birth, muscles form 50 per cent of the total leg, at age $7\frac{1}{2}$, 51 per cent, at age $12\frac{1}{2}$, 54 per cent and at age $15\frac{1}{2}$, 59 per cent. As reported by Cole (1962) "at birth the muscles make up 27 percent of the total body weight. At age 15, they have become 32 percent and at age 16, 44 percent - or nearly half the weight of the body" (p. 21).

As indicated by Malina and Johnston (1967), the breadth of muscle tissue in the left upper arm, as measured by lateromedial radiographs, is slightly higher for boys than for girls. This difference was in the order of approximately 10 millimeters at age 6, 24 at age 9, and 12 at age 11. The same trend in muscle tissue in favor of the boys has been reported by earlier studies (Maresh, 1961; Reynolds et al., 1948; Tanner, 1962).

Bone which has a specific gravity between 1.5 and 2.0 (Carmody, 1965; Hay, 1973), is the tissue component that has the greatest influence on the total density of the body. Bone forms approximately 20 per cent of the total weight.

There are, however, sex differences in the rate of growth of bones. Reynolds et al., (1948) showed that boys

tend to have relatively more bone tissue than girls. The authors have reported that boys have approximately 10 per cent more bone tissue at birth than girls. This difference decreases gradually to 4 per cent at age 7. The same difference of 4 per cent will remain until 15 years old.

In a first study in 1955, Maresh has demonstrated that the mean length of long bones was greater by a few centimeters for boys than for girls from birth to 10 years of age, at which time the girls' bones seem to grow more rapidly. In measuring the width of four extremity bones (humerus, radius, femur and tibia) in boys and girls, Maresh (1966) found approximately the same values for both sexes until the age of five. After five years of age, boys have slightly larger bones than girls. This difference keeps increasing until 18 years of age. Comparative results were also reported by Malina et al., (1967) in their study on the "Significance of Age, Sex and Maturity Differences in Upper Arm Composition", in which the subjects' age varied between 6 and 16 years old.

Finally, the density of the body is influenced by the amount of air in the lungs. This influence of air on the total density of the body was found by Richer (1930) when he concluded that swimmers who do develop vital capacity will improve their buoyancy, therefore lowering their specific gravity scores. This was also supported by Cureton (1933) on his study of champion swimmers. The quantity of

air is of course influenced by the size of the lungs which varies with age and with sex. Shock et al., (1939) has reported that lungs grow slowly during childhood but in early adolescence, they increase rapidly, especially among boys. Girls have smaller lungs, possibly because they are less likely to participate in active games.

A relationship between the amount of air contained in a body and its specific gravity was found by Carter (1956). Inspiration will be accompanied by a large increase in volume with a negligible increase in weight. Carter also stated that: "The effect of inspiration will be to move the center of buoyancy toward the head; the upper half of the body will tend to rise and the lower half to sink" (p. 11).

From a study entitled "Relationship Between Human Buoyancy Measures, Specific Gravity, and Estimated Body Fat in Adult Males", Howell et al., (1961) reported that "... 45 percent of the subjects exceeded the specific gravity of water when weighed with lungs normally inflated, whereas 10.6 percent exceeded specific gravity of water when measured with lungs maximally inflated. All subjects were heavier than water when weighed with lungs minimally inflated after forced expiration" (p. 403). The authors reported that some adult males are not able to float regardless of air intake.

Ghesquire et al., (1970) found that the functional residual capacity has greater effect on buoyancy than the amount of fat. The authors explained this by using the

following example: The density of adipose tissue which contains water, protein and minerals, is approximately 0.950.

"It can be seen that an extra 5 kg. of adipose tissue provides only 0.25 kg. of buoyancy, while the effect of 0.80 liter difference in F.R.C. obviously gives three times as much floating power" (p. 177). This pulmonary function is related to body size and varies approximately as the cube of a linear dimension, such as body height, up to the age of twenty-five (Astrand et al., 1970).

In 1970, Little Inc. reported that the buoyancy requirements for an individual are determined by his submerged weight, state of inflation of lungs and the weight of the body part that remains outside the water.

Von Döbeln and Holmér (1974), working with adults, found a relationship between tidal volume and sinking force. An inspiration of 1.5 L. of air led to a reduction in the sinking force by about 1.5 Kg. (3.3 lb.). They also found that the residual volume was about the same in air and water; and that with a tidal volume of about 0.5 L., the functional residual capacity was about 2 L. less in water than in air. "The functional residual capacity was stated as the total residual volume of the subject plus the additional quantity of air which the subject could expire in a maximal effort after a few breaths at the respective V_t " (p. 57).

As indicated in the reviewed studies, the density of the body is affected by the amount of fat, muscle, and

bone tissues present in the body as well as by the quantity of air in the lungs. It is also shown that a girl's physique has a lower density than a boy's, because of a larger accumulation of fat, and a smaller amount of bone and muscle tissue. The lower density score obtained by the girls will facilitate floating. Since the amount of fat, muscle and bone tissues varies in different parts of the body, then the proportion of different body segments could influence the floating ability of an individual.

Body Proportions

The classification of children's body size and shape becomes very important since the proportions of different body segments, extremities, trunk and head, differ a great deal from adults and thus influence buoyancy and the effectiveness of the righting moment which could be incorporated in the design of flotation devices for children.

As shown by Kragman (1943) in his body proportion chart, the head of a two-year old corresponds to approximately one-quarter of the total body length, whereas in an adult, the head is about one-eighth of the total length. According to Cole (1959), "At age 6, it is already 90 percent of its adult size and equals one-sixth of the child's height" (p. 29). Aside from being large, "The skull is the heaviest bone in the body and it is feasible that in these cases, the fact that the skull is so large proportionally

makes that difference in specific gravity that distinguishes the non-floater from the floater" (Sackvill and Shaffery 1955-56, p. 231).

This difference in head proportion between children and adult was also reported by Breckenridge and Murphy (1969); Espenschade and Eckert (1967); Lourey (1973); Pariskowa (1961); and Whipple (1966). These authors also demonstrated that children are quite different from adults in all body proportions. The large head of the child as compared to the adult is due to differential growth rate. Smart and Smart (1972) reported that: "Development is at first more rapid in the head end of the body, with the tail end reaching maturity later. At age 2, the head is still large in relation to the trunk and legs" (p. 198).

The characteristics of the head are very significant because a) being the only part of the body which is not submerged, it will have a direct influence on the buoyant force that the water safety device must provide, and b) its size will have to be taken into consideration when developing a water safety device that will incorporate a key-hole design in its securing system.

The child's leg and hip region, on the other hand, remains comparatively short during childhood. Kragman (1943) indicated that legs equal approximately one-third of the total body height. At the age of 2, the lower limbs and trunk of the child are more or less equal in length (Reynolds

and Grote, 1948). From age 6 on, the legs grow rapidly and by age 12, they would comprise practically one-half of the total body height (Cole, 1959). This result is also supported by Breckenridge and Murphy (1969) which stated that: "by two years the legs are about 34 percent of total height, and by five years 44 percent" (p. 252).

Concerning the trunk, it makes up approximately half of the total body length of a 2-year-old (Cole, 1962). By age 4, it represents 45 per cent and at age 6, the trunk is about 40 per cent of the child's total height (Smart and Smart, 1967). As presented by Breckenridge and Murphy (1969) during its growth, the trunk will triple its original size, while the legs will grow 5 times longer.

The difference in the length of body segments for a 30 lb. (13.6 kg.) or a 90 lb. (40.8 kg.) child will influence the distribution of the buoyant force within the body. The large head as well as the short legs of the 30 lb. (13.6 kg.) child will likely cause his center of buoyancy to be closer to his center of gravity than the 90 lb. (40.8 kg.) subject, hence facilitating horizontal floating. The equal percentage length of trunk and legs could also explain in part the greater buoyant force of the very young child and its slower rotation or righting moment speed.

Assuming that the density of both the 30 lb. (13.8 kg.) child and the adult head is the same, one would tend to conclude that the head of the child, being larger in

proportion to the total body length, will have a greater influence on the net buoyancy score obtained when the bodies are submerged to chin level. This comparison will also hold for the 90 lb. (40.8 kg.) child when compared with an adult.

Center of Buoyancy - Center of Gravity

Differences in body proportions between children and adults as well as the distribution of bone, muscle, and fat tissues will have an influence on the location of both the center of gravity and the center of buoyancy.

There are two opposing forces acting on a submerged person. One of the forces which is its own weight will act as a sinking force through the center of gravity, while the second one is a buoyant force which keeps the body afloat. Consequently, there is a relationship between the two forces. "If the center of gravity of the swimmer and the center of buoyancy coincide, or lie vertically one above the other, the body will retain its horizontal position" (Hay, 1973, p. 174). This situation is uncommon with males (Whiting, 1963) but can be sometimes observed on females (Carter, 1955; Whiting, 1965). According to Whiting (1963 and 1965), horizontal floating is more commonly found in children between 10 and 13 years old. This ability of young children to float horizontally could be explained in part by body proportions and by the distribution of body tissues, fat, muscle and bone.

The large head of the child as well as his trunk which is relatively long in comparison to the legs, will place the center of gravity closer to the center of buoyancy, hence facilitating horizontal floating. The center of gravity of young children which is situated high in the abdomen will also favor horizontal floating (Smearengen and Young, 1969). The large fat accumulation, the relatively small muscle mass and the low density of bone will also influence the location of the center of gravity of the child (Carmody, 1965; Smart and Smart, 1972; Whipple, 1966).

However, for the great majority of persons, the center of buoyancy lies nearer the head than the center of gravity. In this case, the "weight and the buoyant force act as a couple that tends to force the legs and feet downward" (Hay, 1973, p. 175). Then from a horizontal position the legs will sink slowly until the center of gravity and the center of buoyancy lie along the same vertical line. The body will float in this position as long as the mouth and nose are outside the water permitting breathing (Hay, 1973; Whiting, 1970).

Considering this mechanical principle (turning moment), Whiting (1970) suggests the following body adjustment for improving horizontal floating: raise the center of gravity by stretching the arms above the head keeping them in the water; place the hand outside the water increasing the weight toward the head, thus raising the center of gravity;

and breathe normally since "Shallow breathing will prevent over-inflation of the lungs (which has the effect of raising the specific gravity toward the top part of the body increasing the tendency of the body to rotate)" (pp. 11-12).

Buoyancy and Other Parameters

Could the ability to float be influenced by factors other than the density of the body and the location of the center of buoyancy?

Height seems to have an influence on the floating ability of individuals (Carmody, 1965). Carter (1956) found that tall lean people were better floaters; however, he mentioned that this floating ability could be due to body build rather than height. The same conclusion was also reached by Highmore (1955) and by Loretz (1953). A more recent study on adults by Mitchem and Lane (1967) shows that standing height was one of the greatest contributors to buoyancy prediction.

The ability to float is not influenced by tension or relaxation (Carmody, 1965; Carter, 1956). When the body is tense, the muscles contract, change shape and change chemically, but these changes do not decrease or increase the overall mass. "The balance of a body in a relaxed position may be altered slightly when a tense position is assumed owing to the shifting of the center of gravity of the segment on contraction. However, the overall effect on the body would probably be an equalizing one" (Carter, 1956, p. 12).

This principle is also supported by Loretz (1953) who states that the change of volume of a 140 lb. person when in tension would equal approximately a half pound of fluid.

The net buoyancy of an individual could be influenced by the amount of gas bubbles or flatus in the gastrointestinal tract which has been estimated to be approximately 100 ml. (Buskirk, 1961). The amount of feces could also influence the buoyancy of a person. According to Davenport (1968), a person will eliminate approximately 5.5 ounces of feces daily. This value would be higher if a person is constipated and therefore have a greater effect on buoyancy.

Finally, the movements of different parts of the body (head, arms and legs) will influence the floating ability of a person even if this person wears a water safety device. A child that falls into the water will naturally use his arms and legs in trying to swim or to stay afloat. If he panics, he will increase the speed of his movements until exhaustion, at which time he becomes vulnerable. Furthermore, the panicky child could possibly neutralize any righting moment of a water safety device by his arm and leg movements.

The results of the research tends to show that a person's buoyancy is influenced by his/her body build which is dependent upon the amount and distribution of fat, muscle and bone tissues. The quantity of air in the lungs will also

contribute to floating ability. Buoyancy will also be influenced by uncontrollable factors such as the amount of gas bubbles in the gastrointestinal tract, by the amount of feces and by excessive movement of the body. As for the final floating position, it is determined by the relation which exists between the center of gravity and the center of buoyancy. This relationship is in turn influenced by body proportions. Finally, these factors could have an influence on the floating or rotating performance of the water safety device.

Distribution of Buoyant Material of Water Safety Devices

A large portion of the population could float with the body almost entirely submerged. However, no one could survive too long in such a position. To compensate for this shortage of natural buoyancy, the individual uses a water safety device that should keep his body in a safe floating position, with his head safely out of the water. To be effective, the quantity, distribution, and location of the buoyant material should comply to certain human and functional requirements. The following researchers have studied these requirements.

In testing lifejackets, Park (1962) found that: "excellent lateral support of the head and sufficiently high anterior buoyancy provided a vigorous self-righting moment" (p. 334). He also tried, using mobile flaps, to deflect the

oncoming waves. He found that when an inert man floats freely, his legs sink since they have a specific gravity greater than sea water. The upper part of the body, which is supported by the water safety device, is subject to the action of the wind and waves. The man thus comes to lie facing the oncoming waves in a face-up position.

According to the Booz-Allen Report (1969), the buoyant material for an adult personal flotation device should not be attached to the back of the wearer unless it is necessary to support his head and he is free-floating. The effect of buoyant material located on the person's back is to induce forces that tend to keep the person in a face-down orientation. Buoyant material located on the front of the person should be placed as high on the chest as possible to assist in achieving a safe attitude. Any material located more than 10 inches below the shoulders has a detrimental effect on the ability to achieve a safe attitude.

In 1973, the Consumers' Association of Canada tested 10 water safety devices in both adult and children's sizes. The results of the tests showed that the majority of the water safety devices did not always rotate the wearer into a safe floating position. Only two water safety devices turned the adult subjects to a safe flotation position every time. However, no child water safety device rotated the young subjects into a safe floating position every time.

In an attempt to develop a child's water safety device, Yeatman and Schellenberger (1975) studied the functional and human needs of young children. The investigators concluded that only $2\frac{1}{2}$ lb. (1.1 kg.) instead of the standard of 7 lb. (3.2 kg.) are required to rotate to a face-up position a child weighing up to 50 lb. (22.7 kg.); that the efficiency of the turning moment can be increased by asymmetry and by placing the buoyant material on the back of the head rather than on the neck. Furthermore, the design should have a ratio of five parts buoyancy on the front to one part buoyancy on the back, and the device should fit snugly and conform to the shape of the body.

Due to certain weaknesses of this study, some comments are in order. The $2\frac{1}{2}$ pounds of buoyancy suggested by Yeatman et al. (1975) contradicts previous buoyancy research such as Booz-Allen Report (1969) and Little, Inc. (1970). Furthermore, in the experiment with their prototypes, the authors have made and used two child size dummies which were not representative of a real child. The dummies' head and trunk were constructed with wire while water bags were used for the arms and legs. This would explain the lack of flexibility found by the authors. It seems that the dummies were built according to the material available with little regard for human resemblance. This could explain why the prototypes designed using the dummies did not function on live subjects.

Because of the weakness described above, the results of Yeatman et al. should not be used as guidelines in the construction of future water safety devices for children.

From the available information, one would tend to conclude that: The distribution of buoyant material in most available water safety devices does not always turn the wearer to a safe floating position, and that maximum buoyant force should be located in the chest and shoulder region with a minimum amount in the back and waist region.

Body Rotation as a Function of Water Safety Devices

To be effective, a water safety device should not only have the proper buoyant force, but it should also keep the wearer in a safe floating position with the face out of the water.

In a study on "The Testing of Lifejackets", MacIntosh and Park (1957) found that "when the forty-five degree position is assumed by the subjects, it is possible to make the self-righting from dangerous to safe position rapid and decisive. At its best, the twisting motion seen with this type of position was found more prompt and rapid than any other self-righting motion" (p. 175). The author tested only the three types of lifejackets which were available at that time.

The Booz-Allen Report (1969) indicates that when the human body falls into water, his natural body attitude in water is approximately 30 degrees face-down from the vertical. In the described position, the face is under water. It is also mentioned that the nose and mouth of an unconscious person are not out of the calm water until the body is at an angle of somewhere between 15 and 45 degrees, inclined backward from a vertical position in water. In choppy water, the body must be inclined backward more than 30 degrees and in extremely heavy swells, as much as 60 degrees to ensure sufficient freeboard to keep the mouth and nose out of the water.

Little, Inc. (1970) has reported that the turning moment or stability requirement is influenced by the density of water, the subject's orientation, state of inflation of the lungs, distance from the center of buoyancy to the center of gravity, and the submerged weight.

Little, Inc. (1970) also reported that to rotate 60 per cent of the population through the vertical, the distance from the body center line (halfway between head and feet) to the center of buoyancy of the personal flotation device, should be 7 in. (17.8 cm.) for adult females and 6 in. (15.2 cm.) for adult males.

The few studies which have reported data on the rotation function of water safety devices have only used adult subjects. Therefore, their conclusions cannot be

applied necessarily to children. The amount and distribution of buoyant material within different sizes of water safety devices should be based upon the different body proportions which characterize the children and the adults.

Evaluation of Existing Water Safety Devices

The increasing interest for the protection of individuals during water activities has stimulated a few research projects which have attempted to find new design criteria for children's water safety devices based on the evaluation of existing lifejackets and personal flotation devices.

In a study entitled "The Design of Lifejackets for Body Weights of One to One Hundred Twenty Pounds", Goodwin and Richardson (1973) evaluated the lifejackets available on the market at that time in an attempt to incorporate the findings in the design of a more functional lifejacket for children. The lifejackets tested did not rotate the majority of the subjects leaving 70 per cent of them in the front floating position, face in the water. During the testing in the supine position, the head of the subjects tended to fall back into the water so that the ears were partially submerged with minimum freeboard. The authors suggested the following steps in future research on lifejacket designs: Determine body weight and height; determine body fat sites peculiar to each age level; determine

body densities in order that the optimum buoyancy be allocated to jackets of different weight category; determine the mechanics of rotation; distribute the necessary buoyant material in order that the jacket be comfortable to wear; and develop a water safety device of the vest type to help conserve body heat.

In 1974, the Consumers' Association of Canada reported on 10 of the most popular children's water safety devices, 5 lifejackets and 5 personal flotation devices. The young subjects found all lifejackets difficult to put on either because of the keyhole shape opening or because of the long tapes which have to be wrapped twice around the waist. The personal flotation devices were found to be easy to don. Half of the water safety devices permitted the subjects to swim with ease. As a general rule, swimming on the back was considered the easiest. The subjects found that either type of water safety device worn over both the back and chest made them feel sticky and hot.

The Australian Consumer Association (1972) tested 25 lifejackets and 17 personal flotation devices. The two inflatable lifejackets were the only water safety devices that passed all tests including the righting of an unconscious person. Only one of the remaining 40 water safety devices was recommended but was given a 'provisional' pass for the unconscious position test.

Another water safety device evaluation was reported in the August edition of the Consumer Reports (1974). The report recommended the Type I devices as the only logical choice for high sea boating, and Type II devices for recreational boating. The Type III vests were not recommended for non-swimmers and young children because of the lack of a righting moment.

From these evaluations, one could conclude that the low 'passing' percentage of existing water safety devices would justify further research in this area. The buoyant characteristics, the righting moment, as well as all features that could influence wearability of the water safety devices should be examined carefully.

Buoyancy Measurement Techniques

Two techniques were and are being used to measure the floating ability of individuals. These techniques can be divided in two categories:

- 1) The total buoyancy technique, by which the individuals are classified as floaters or non-floaters without any intermediate grouping.
- 2) The partial buoyancy technique, by which one can determine the degree of buoyancy of a person. This technique will help to determine the amount of buoyant force that a person needs to float in a safe position.

The Total Buoyancy Technique

Following is a summary description of the tests used to differentiate the floaters from the non-floaters:

The tuck float: Standing in the shallow end of a pool or in a tank with water up to the waist, the subject is required to take a deep breath and bend forward face in the water. The subject is then asked to slide the hands down the legs, and bend the knees until the legs are encircled by the arms, chest touching thighs and forehead resting on the knees. The subject is asked to hold this tuck position for a 10 to 20 second time period. The subject is classified a floater if his or her back rises to the surface of the water and as a non-floater if he or she sinks. This technique was used by Highmore (1957), by Lane and Mitchem (1964), by Mitchem and Lane (1967), and by Whiting in both of his studies (1962 and 1964). This test is sometimes done after a maximum inspiration or expiration (Whiting, 1962; Whiting, 1964).

A variation of this test was used by Carter (1955). After a maximum breath, the subject was asked to dive down and hold on to a brick at a depth of seven feet. At that level, the subject was asked to assume a tuck position while holding on to the brick. At a signal, the hands move from the brick to the forelegs, the subject remained in this position holding maximum breath until the surface was reached.

The horizontal float: This test is specially used to determine the horizontal floating ability. The subject is required to adopt a horizontal floating position on the back during normal respiration "with arms sideways horizontal, palms upwards, legs straight (but relaxed) and together, feet adopting a natural position, head in line with the body" (Whiting, 1962, p. 86). The subject holds this position until the body reaches the vertical or remains stationary for a certain time (5 seconds or more).

The Partial Buoyancy Technique

Hunt, in 1940, measured the buoyant force of individuals by using two spring balances, one attached to a canvas helmet on the head of the subject and one secured to his ankles. The subject was then instructed to take a maximum inspiration and to slowly submerge face downward with his arms at his sides. The readings on both balances were taken and added algebraically and the score obtained constituted the buoyancy needed by the subject.

Another method was used by Highmore (1955) by which the subject was submerged in deep water holding a nine pound weight in his hands. The subject wore a belt around his waist which was attached to a hook suspended from a spring balance. Readings were taken before and after complete inspiration and expiration.

Hydrostatic weighing is a technique sometimes used

to measure buoyancy. Sitting in a chair, the subject is lowered into the water until totally submerged. His total body volume is equal to his loss of weight in water after a complete expiration. Some corrections are made for residual lungs volume and gas bubbles or flatus in the gastrointestinal tract (Behnke and Wilmore, 1974). This technique was used by Little (1972).

Body volume can be assessed by the water displacement technique. "This technique is nearly identical to that of hydrostatic weighing except that the actual volume of water displaced by the subject is measured rather than the loss of weight in water" (Behnke and Wilmore, 1974, p. 24). Residual lung volume is also taken into account in this technique.

The different techniques used to assess buoyancy cannot be directly applied in the case of young children. All the techniques necessitate complete submersion which frighten young children. Beside hydrostatic weighing, these techniques cannot be used to measure the buoyant force needed by an individual submerged to chin level. This is the measure needed to be incorporated in the design of water safety devices. Therefore, the technique used in the present study was developed in order to measure the buoyancy of young children while they felt secure in a comfortable position.

The procedures and techniques used in this study to take the different anthropometric measurements were based

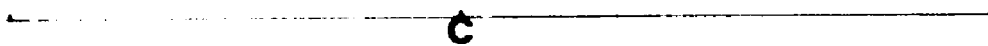
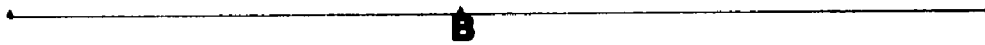
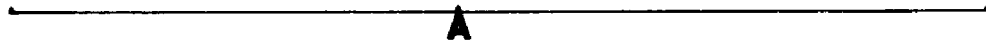
on the guideline suggested by Behnke and Wilmore (1974) and by a group of scientists presided over by J. Warlenwerler (1974). Procedures used in the Saskatchewan Growth and Development Study (1968) were also consulted.

To avoid repetition, the different anthropometric measurements, as well as the technique used to measure the variables, are presented in the Procedure Chapter of this present study, page 69.

Description and Specification For Water Safety Devices

The two main types of water safety devices, the inherently buoyant and combined buoyancy, are available in a variety of styles. There is the slab or keyhole style, and the vest or open-front style lifejackets, which are approved for commercial vessels and recreational boating. There are also the more attractive and comfortable styles which are manufactured especially for persons engaged in water sports. These latter styles are called (in Canada) personal flotation devices. A brief description of the different types and styles of water safety devices available in Canada and in the United States is presented below. This will be followed by a short summary of the Canadian and American water safety device standards.

FIGURE 1
CANADIAN WATER SAFETY DEVICES



Description of Water Safety Devices

Canadian Water Safety Devices

In Canada, water safety devices are divided into two types: Life Jackets and Personal Flotation Devices.

The lifejackets meet a federal government standard (65-GP-7) and are approved by the Canada Ministry of Transport. Approved small vessel lifejackets, approved personal flotation devices, or approved life-saving cushions are the only devices that by law can be carried on board pleasure craft, including rowboats and canoes. Racing shells or racing canoes that are being used in or prepared for competition and foreign registered craft in Canadian Waters, do not have to comply with this regulation (Canada Shipping Act, 1969; Canada Shipping Act, 1974). The personal flotation devices are not approved by the Canada Ministry of Transport. There is a government standard for such floatation devices, but compliance is purely voluntary.

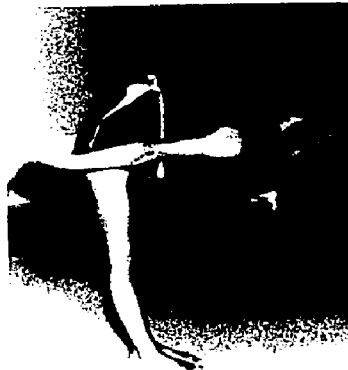
Lifejackets are manufactured in two styles and three types (Specifications for Lifejackets, 1964). The first style is described as a one-piece slab or keyhole (Fig. 1A) while the second style is referred to as open-front or vest (Fig. 1B). Both styles are divided into three types. Type I is made of unicellular foam covered with heavy red drill cloth. Type II is composed of three vinyl film envelopes filled with kapok enclosed within a heavy red drill. Type III is manufactured using a red or

FIGURE 2

CANADIAN WATER SAFETY DEVICES



A



B

yellow vinyl-coated unicellular foam.

The slab is characterized by a head opening which has the shape of a keyhole, thence its name. The bottom portion of the floatation device is tied around the wearer's waist by two long tapes.

The vest is made of three pieces with a shell fabric joining the front and back buoyancy elements forming an armhole. The vest is secured by at least two pairs of relatively short tapes, one at the chest and one at the waist. Some makes utilize a snap and ring securing device.

The personal flotation devices are classified according to Type I inherently buoyant (Fig. 2B) and Type II combined buoyancy (inflatable) (Fig. 3D).

Type I is usually made of red or yellow nylon cloth, rubber-lined fabric or canvas, filled with foam or lengths of plastic air cells. Some are manufactured with sleeves and with a collar filled with buoyant material. These vests are fitted by tying the tapes, by buttoning up, by zipping up or by a combination of these. Some of these personal flotation devices can be adjusted for fit by pulling up a tape through ring buckles situated on each side of the jacket. This type of water safety device is usually available in the three regular sizes.

Type II are made of buoyant material covered by air-tight rubber-lined fabric that can be inflated either by the release of carbon dioxide from a cylinder placed on

the side of the jacket, or by blowing into a tube having a one-way safety valve, and readily accessible to the mouth (Fig. 3). Even uninflated, these jackets should provide sufficient buoyant force to help support the indicated weight. The jackets can be adjusted by a neck opening and by a pair of long tapes at the waist. This kind of water safety device can be purchased in sizes A, B and C, or small, medium, and large. (These sizes were defined on page 3).

American Water Safety Devices

In the United States, all water safety devices are called personal flotation devices, and the many kinds of designs are grouped into five types which are approved by the U.S. Coast Guard.

Type I PFD: These are required for 'For Hire' vessels. These jackets are usually large, bulky, and uncomfortable and intended for the kind of emergencies that might develop with commercial vessels. Therefore, they are not generally recommended for recreational boating use. Nevertheless, they are legally qualified and acceptable as 'Approved' for recreational as well as for commercial use (Fig. 3A).

Type II Buoyant Vests: These are recommended for recreational boating activities. Their principal characteristic is positive righting moment. These vests are designed to turn an unconscious wearer from a face-down to a face-up position in water. However, there are always exceptional

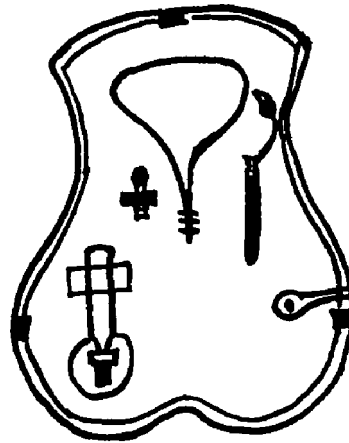
FIGURE 3

AMERICAN BUOYANCY DEVICES



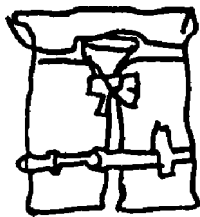
A

Type I PFD



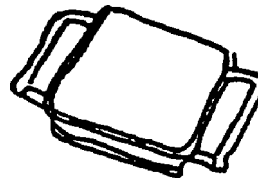
D

Inflatable



B

Type II
Buoyant Vests



E

Type IV
Throwable Devices



C

Type III
Buoyant Devices

individuals for whom the 'Righting Moment' will not respond as assigned (Fig. 3B).

Type III Buoyant Devices: These devices are specially recommended for persons engaged in water sports. They are comfortable and offer better mobility. These devices are described as providing for a stable, 'upright position' of the wearer in the water with no tendency to turn him to a face-down position (Fig. 3C).

Type IV Throwable Devices: This category includes buoyant cushion and ring lifebuoys. These throwable devices have sufficient buoyancy to support a person in the water. They are used as emergency lifesaving gear (Fig. 3E).

Type V PFD: Any device designed for specific use. "The exact specifications and performance of the Type V PFD will vary somewhat with each device." (Equipment Requirement, 1972, p. 2).

Canadian and American Standards

The Canadian Standards

Lifejackets, Inherently Buoyant Type (65-GP-7)

The following is a summary of the most important items of the standard. A copy of the complete specification is presented in Appendix A, page 172.

(1) Flotation: All the water safety devices included in this category should have a 'positive righting moment'. The total buoyancy and its distribution should be "... such as to provide support for the head so that the face of an unconscious person is held above the water position" (Specification for Lifejackets, 1964, p. 2). Also, there should be no tendency for the jacket to turn a body from a face-up to a face-down position. The total buoyancy should be at least 21 lb. (9.5 kg.) for type A, 13 lb. (5.9 kg.) for type B, and 7 lb. (3.2 kg.) for type C.

(2) Comfort: The jackets should provide reasonable comfort and should not interfere with the wearer's vision, either in or out of the water.

(3) Fastenings: "Jackets shall be designed so that they may be donned, secured and worn equally well inside-out or outside-in. One-piece jackets shall have no hardware, and shall be secured and adjusted by tie tapes only. Open-front jackets may have hardware" (Specification for Lifejackets, 1964, p. 3).

(4) Design: All styles and sizes of lifejackets should be made according to the figure and table shown on page 5 of the standard. If unicellular foam is used, there should not be more than three pieces per buoyancy unit. When kapok is used, no more than 40% of the total weight of kapok should be in any one envelope. All the material used in the fabrication of the lifejackets should comply with government

specifications (Specification for lifejackets, 1964).

Personal Flotation Devices (65-GP-11)

The following is a summary of the most important items of the standard. A copy of the complete specification is presented in Appendix A, page 172.

(1) Flotation: "All PFD's to this standard, whether inflated or deflated, shall provide flotation for a wearer of the size declared on the label with no tendency for the wearer to be turned face-down in the water" (Standard for Personal Flotation Devices, 1974, p. 3). Types I and II when inflated shall support and hold the wearer face up and out of the water. "Type II when inflated, shall be capable of turning the body within 10 seconds to a safe flotation position with the body inclined backward from its vertical position and provide lateral and occipital support to the wearer's head" (Standard for Personal Flotation Devices, 1974, p. 2). As for the amount of buoyant force, it varies according to the type. Type I 'inherently buoyant' should have a minimum of 15½ lb. (7.0 kg.) of buoyancy, while Type II should have a combined buoyancy of 9 lb. (4.1 kg.) minimum inherent plus a minimum of 20 lb. (9.1 kg.) inflatable (Standard for Personal Flotation Devices, 1974).

Because of certain similarities, and because of technical descriptions, all the other detailed requirements for both lifejackets and personal flotation devices, are presented in Appendix A of the present work.

The American Standards

The following is a summary of the most important items of the standards.

(1) Flotation: The Type I and Type II PFD's are approved devices "designed to turn an unconscious person from a face downward position in the water to a vertical or slightly backward position" (Equipment Requirement, 1972, p. 21262). The Type I PFD should have a minimum of 20 pounds of buoyancy, while the Type II PFD should have at least 15.5 pounds of buoyancy. Type III PFD is designed to maintain a conscious person in a safe vertical position and has a built-in buoyancy of 15.5 pounds. The Type IV PFD is a throwable device which should have at least 16.5 pounds of buoyancy. As for Type V PFD, its performance and specifications vary with each device.

(2) Model and Size: The model and size of the water safety device should be indicated in the following way: Adult, for a person weighing more than 90 lb. (40.8 kg.); child, medium size for children weighing from 50 to 90 lb. (22.7 to 40.8 kg.); and child, small for children weighing less than 50 lb. (22.7 kg.).

(3) Adjustment, Fit and Donning: These life preservers should be made: "with adjustments to: (1) fit a range of wearers for the type designed; and (2) facilitate donning time for an uninitiated person" (Equipment Requirement, 1972, p. 21268).

A copy of all the details concerning the manufacturing, the approval and the marking of the personal flotation devices can be obtained from the United States Coast Guard.

Summary

As shown in this chapter, the studies directly related to human buoyancy characteristics are not numerous. The main concern of these studies was to differentiate the floater from the non-floater which explains the use of the total submersion technique to measure buoyancy. Furthermore, with the exception of a few which used subjects of 9 years old, these studies were conducted on adult subjects. Therefore, the conclusions of these studies may not be directly applicable to younger subjects.

For multiple reasons, such as incapacity to swim, fear of water, etc., the complete submersion techniques (tuck, horizontal or vertical body positions) cannot be used with young subjects. Furthermore, these positions are not similar to the position in which the body should be if the subject is to float in a safe position, face out of the water.

However, these findings have tended to show that:

- a) children are more buoyant than adults and that females are superior to males in floating ability;
- b) buoyancy is dependent upon the density of the body, which in turn is influenced by the amount and the specific gravity of fat,

muscles and bones and the quantity of air in the lungs; c) buoyancy can be predicted for adults but it requires a large number of variables; d) the child's body proportions could have an influence on the righting moment as well as on the net buoyancy requirements; e) most available children's water safety devices do not fit or function properly; and f) added buoyant material should be distributed in the chest, shoulder and neck regions.

From the above-mentioned findings, one may conclude that: a) available water safety devices should be evaluated by children during actual water activities; b) with children, buoyancy should be measured using procedures and techniques which permit the young subjects to feel secure and relaxed; c) total buoyant force needed to keep a child safely afloat as well as the buoyancy distribution should be measured; d) a large number of anthropometric measurements should be taken in order to formulate a good prediction equation for children; and e) body proportions should be taken into consideration since they may affect the location of the center of gravity and the center of buoyancy, thence influence the rotation or righting moment.

The measuring techniques developed and used in the present research were based on these conclusions.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to determine a predictive buoyancy formula for children based on certain anthropometric measurements and to suggest possible improvements in the design of water safety devices for children. The objectives included:

- A) Evaluating children's water safety devices presently available on the market both with respect to comfort, ease of donning, freedom of movement, and skin irritation, and to their effectiveness in righting and supporting children in the water;
- B) determining certain anthropometric measurements of children as well as their buoyancy characteristics;
- C) deriving a predictive buoyancy formula using buoyancy measurements as the dependent variables, and selected anthropometric measurements as independent variables;
- D) testing the prediction formula derived by measuring the buoyancy and the selected anthro-

metric characteristics of a new sample population; and

- E) formulating recommendations to improve the design of children's water safety devices and to recommend improvements in the existing standard for water safety devices based on these findings.

Subjective Evaluation of Water Safety Devices During Water Activities

Subjects

One hundred and fifty (150) subjects were chosen from a summer camp. The age of the subjects varied between six and twelve years old. All subjects were swimmers. Their swimming ability varied from beginner to junior level. All subjects were enrolled in the 'Katimavic' summer camp, situated on McGregor Lake, 35 miles from Ottawa. The camp setting and programme permitted testing during swimming, rowing, sailing, and paddling activities. The evaluation took place during the months of July and August 1975.

Choice of Water Safety Devices

To gather the information, the instructors had each of the twelve existing and available water safety devices (9 lifejackets and 3 personal flotation devices) (list in Appendix B, page 195) assessed by each subject while he/she was performing in different water activities.

The water safety devices were representative of all types and styles, i.e. slab and vest styles, unicellular foam, kapok or air cell types.

In order not to disturb the daily camp schedule, no strict order of procedure was followed in the evaluation of the devices. However, even if the subjects were free to wear the jacket of their choice at a given time, the instructors made sure that each type and style of water safety device was worn at least once by each subject.

Activities

The subjective evaluation of each of the water safety devices was made immediately following each child's participation in either the swimming test or a boating class. Testing was continued until each child had had an opportunity to wear each of the twelve devices in each of the activities.

The swimming test consisted of swimming a total of 50 feet - 25 feet using either the crawl or breast stroke and 25 feet using either the elementary back stroke or back crawl. The second activity was boating. The children wore each of the devices during a two-hour instructional period in either rowing, canoeing, or sailing - whichever they were enrolled in.

Questions

After the swimming test and at the end of each of the boating classes, the children were asked a series of

questions pertaining to the particular water activity completed. These questions were:

- 1) Was the jacket cold ____, hot ____, very hot ____?
- 2) Was the jacket difficult to put on? Yes____ No____
- 3) Did the jacket interfere with your movements while swimming? Yes____ No____
- 4) Which swimming stroke did you prefer while wearing the water safety device? Back ____ Front ____ Side ____
- 5) Did the jacket interfere with your movements while rowing? Yes____ No____ Comment:
- 6) Did the jacket limit your maneuvers while sailing? Yes____ No____ Comment:
- 7) Did the jacket interfere with your movements while paddling? Yes____ No____
- 8) Any irritation around arms ____, neck ____?

The questions were asked, explained and checked by the instructors. The instructor also looked for possible irritation around the arms and neck as an objective indication of poor fit or poor choice of material. The instructor made sure that the subjects understood the meaning of each question.

It should be recognized that, although formal questions were asked to the subjects and responses recorded, the ratings are somewhat subjective. They are based on not only quantitative data but also reflect the general attitude

of the subjects toward the devices as interpreted by the author.

Selection of Subjects

The two hundred and three children (104 girls and 99 boys) involved in this part of the study were from the Ottawa/Hull region. The population from which the subjects were chosen was approximately half rural and half urban, representing a wide social economic stratum.

Weight was chosen as the one criterion for the selection of subjects for the simple reason that actual Canadian and American standards define a child's water safety device as one which fits a certain weight category. Both countries have two sizes of water safety devices in the children's range -- zero to 45 lb. (20.4 kg.) and from 45 to 90 lb. (20.4 to 40.8 kg.). Thus, it was important to select subjects who would represent both categories irrespective of age or other measurements. The weight of the subjects actually varied between 25 and 79 lb. (11.3 and 35.9 kg.).

This weight spread resulted in an age variation from two to twelve, and a height variation from 32.3 to 56.6 in. (82.0 to 143.7 cm.). Because of the wide range in age, weight and height of the subjects, a complete list of each of these variables is presented in Appendix C, page 197.

In selecting the subjects, there was no attempt to arrive at a 50/50 ratio between boys and girls.

Precautionary Measures

The sample was chosen on a voluntary basis for the following reasons:

The young age of the subjects, as well as the potential risk associated with part of the experiment, made it necessary to have the approval of the parents. First, the volunteer subjects had to weigh 90 pounds or less. Then, the tests were verbally explained to the children to determine whether they were willing to participate.

The parents were provided with a copy of the consent form (Appendix D, page 200) in which the anthropometric and buoyancy measurements were briefly explained. A copy of the medical questionnaire (Appendix D, page 200), as well as a description of the emergency procedures and lifeguard qualifications (Appendix D, page 200) were included. The parents who allowed their child or children to participate in the experiment had to sign the consent form and answer the first part of the medical questionnaire. Part Two of the medical questionnaire was completed by one of the university physicians following the medical examination.

The above-mentioned safety procedures were in conformity with the ones suggested by the Research Review Committee of the School of Education.

Subject Replacement

From the first 200 subjects chosen, 159 were tested and 41 were rejected. This last group of subjects

were replaced by 44 volunteers chosen from the same region. Of the subjects rejected, 31 were not tested because of parental refusal and/or the children's unwillingness to participate due to their fear of being submerged. A small number were rejected for medical reasons: two for heart murmur and three for some allergy problem. Finally, five other subjects were not included because of partial or total lack of buoyancy measurements. These children either refused to be submerged or panicked at some point during the submersion process.

Subjects for Testing Prediction Equation

An additional group of twenty young children was selected from the same geographical area to serve as subjects for the testing of the prediction equation. All subjects were volunteers. The safety precautions described for the larger group (203) were also applied for this group. A complete description of this group of subjects (20) is presented in Chapter IV, page 158.

Anthropometric Equipment

The following equipment was used to take the various anthropometric measurements:

Scale

A lever type 'Health-o-Meter' scale, manufactured by Continental Scale Corporation, Chicago, Illinois, was used to determine the weight of each subject in pounds. The scale measured to the nearest eighth of a pound.

Graduated Board

A white, two meter long by one centimeter wide tape was affixed to a plank fastened vertically to a wall to measure height. The tape was covered with a transparent material so that numbers would not be erased.

Set Square

The set square measured 20 by 20 centimeters and was made of rigid, clear plastic.

The graduated board and set square were used to measure the standing and sitting heights as well as the leg length (Fig. 4A).

Gulick Anthropometric Tape

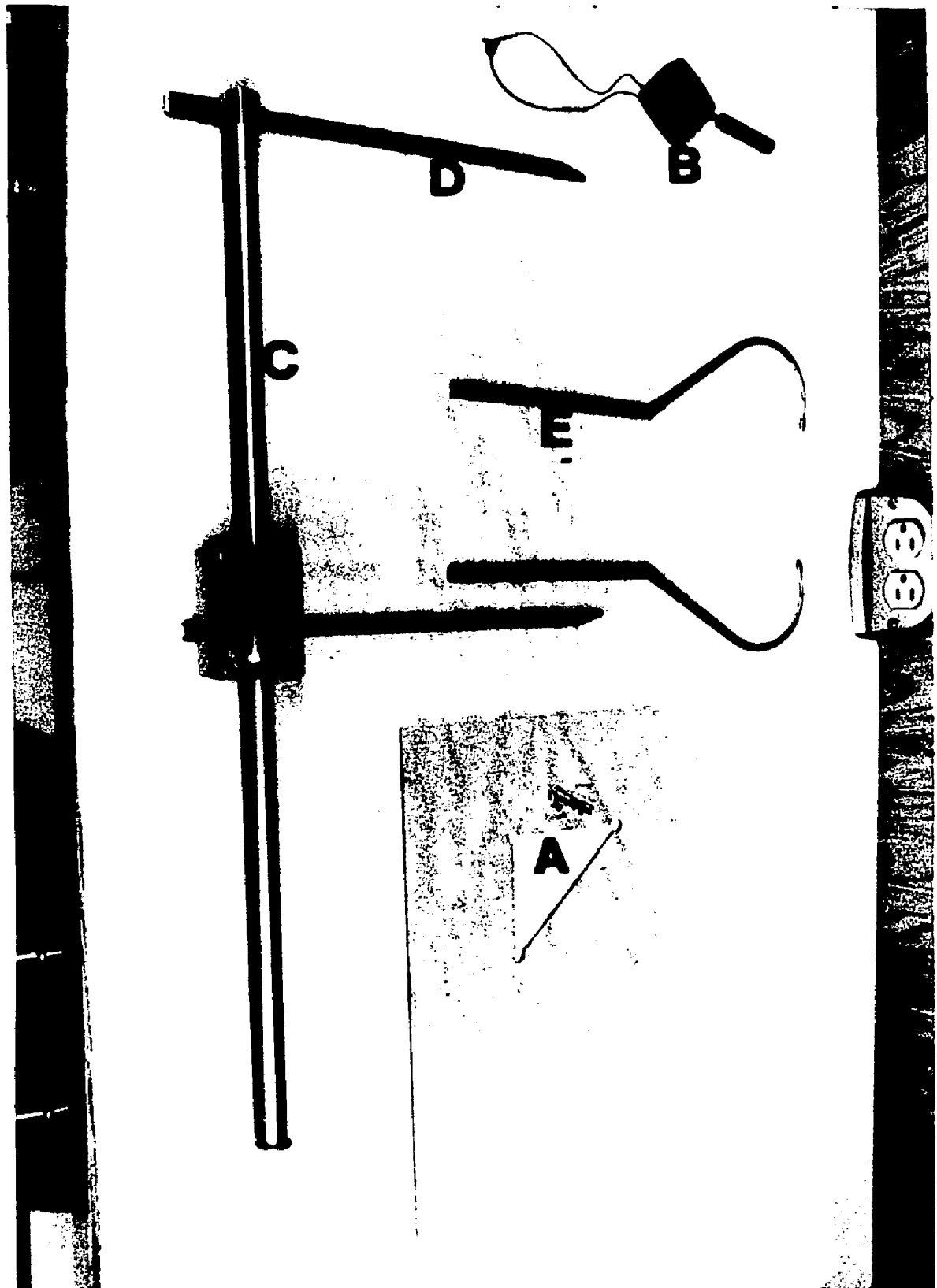
All girths, circumferences and arm size measurements were taken with this tape which includes a spring attachment which permits a slight amount of constant tension on the tape. The tape is graduated in both inches and centimeters. It is sold by J.A. Preston Corporation (Fig. 4B).

Harpenden Anthropometer

This instrument gives a direct and accurate reading to the nearest millimeter, over a range of 50 mm to 750 mm. It is constructed mainly of light alloy anodized to its natural colour. Its sliding member operates via miniature ball bearing rollers in order to ensure a movement which is free, yet without crossplay (Fig. 4C).

FIGURE 4

ANTHROPOMETRIC EQUIPMENT



This instrument mounted with straight branch attachments was used to measure chest breadth, shoulder width, back and trunk lengths (Fig. 4D). The recurved branches were used to measure chest depth (Fig. 4E).

Anthropometric Measurements

Prior to the actual assessment of the various anthropometric measurements, each subject was numbered and the age recorded to the nearest month. Also, weight was measured with a clinical scale to the nearest eighth of a pound, without shoes and wearing only a swimming suit. While measuring, care was taken so that the subject stood motionless in the center of the platform. Also, the balance was calibrated before each testing period using a 20 lb. (9.1 kg.) weight.

In addition to weight, seventeen anthropometric measurements were taken on each subject. The subject wore a swimming suit. Since certain of these measurements would probably be included in a prediction formula, and since the chosen measurements would eventually be taken by non-experienced adults in a non-scientific situation, data gathering was limited to measurements that could be taken at fairly accessible sites, using non-sophisticated equipment. All measurements were taken in the order in which they are described.

Standing Height

The child's height was measured to the nearest millimeter without shoes, the head in the Frankfort Plane, arms hanging at side, the back square against the wall, heels, buttocks, upper back and head touching, with a set square resting on the scalp and against a graduated board firmly attached to the wall. While taking this measurement, feet were kept flat on the floor, legs straight, and the set square firmly touching the head to compress the hair (Fig. 5).

Sitting Height

The subject sat on the floor with his back and head resting against the graduated board, legs straight, hands on his thighs. The perpendicular distance from the floor to the vertex was measured using a set square resting firmly on the scalp to compress the hair, and against the graduated board firmly attached to the wall. While taking this measurement, the subject's back was kept straight against the wall.

Head Circumference

The child stood erect, arms hanging at side. Maximum head circumference was measured to the nearest millimeter using a constant tension steel tape. The tape was placed horizontally at the level of the most posterior protrusion of the occipital bone and of a line above the brow ridges (Fig. 5).

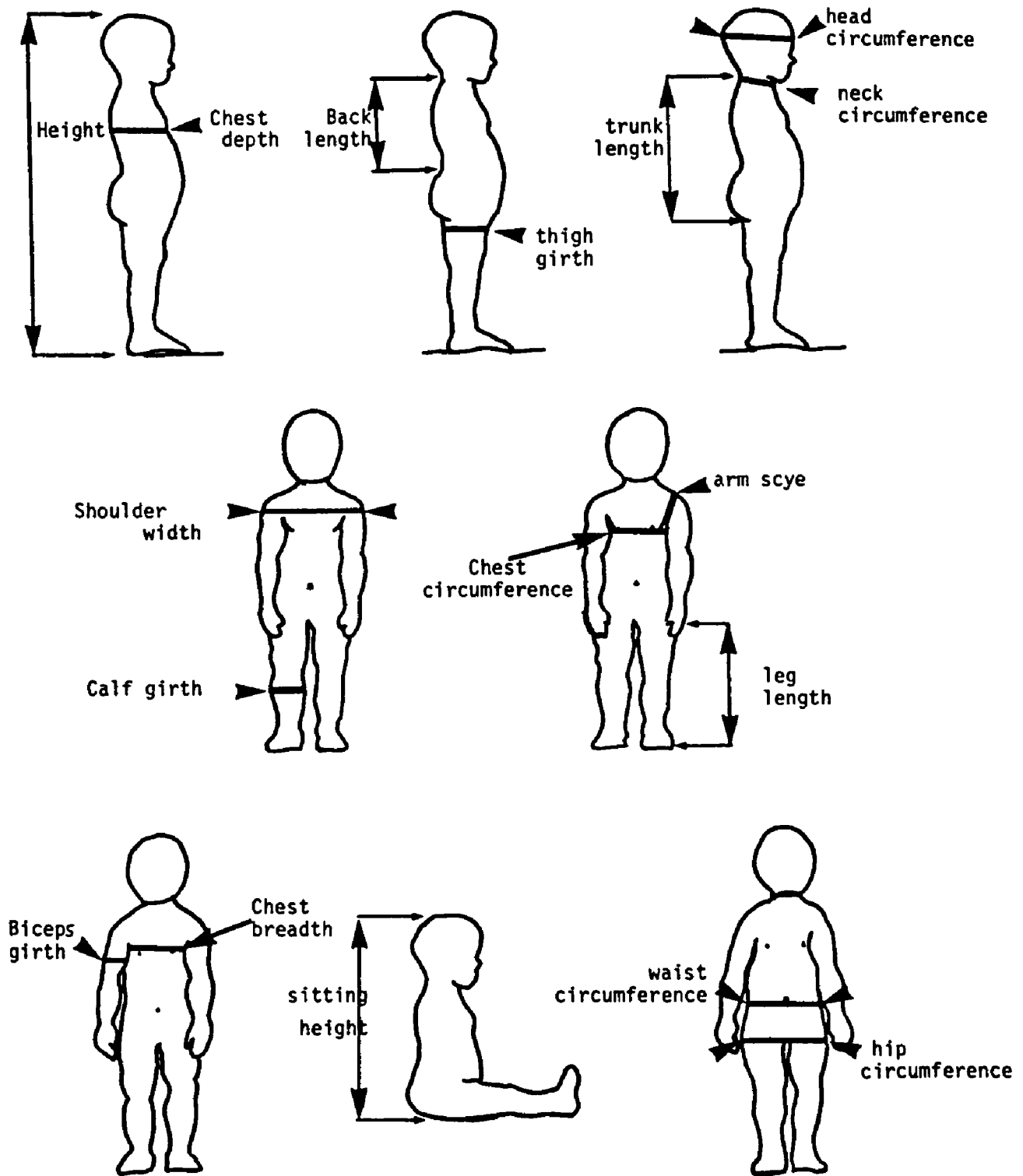


FIGURE 5

ANTHROPOMETRIC MEASUREMENTS

Neck Circumference

The child stood erect with the head in the Frankfort Plane, arms hanging at the side. The neck circumference was measured to the nearest millimeter by passing a constant tension steel tape around the neck, at the level of the Adam's apple. The tape was placed perpendicular to the long axis of the neck (Fig. 5).

Arm Scye

Child stood erect, arms extended slightly away from the body in the frontal plane. Arm scye was taken by measuring the circumference encompassing the highest point of the acromion process and the lower edge of the axilla. During this measurement, the subject kept his right arm slightly away from the body so as to eliminate possible wedging of the tape, which would increase the actual length of the measurement (Fig. 5).

Chest Circumference

The child stood erect, arms hanging slightly away from the side to allow clearance of the steel tape between the arms and trunk. The horizontal circumference of the chest was measured at nipple level. The measurement was recorded when the child momentarily stopped his breathing cycle as requested. During this measurement, care was taken to ensure a constant horizontal anterior-posterior level of the tape (Fig. 5).

Waist Circumference

The child stood erect, arms hanging slightly away from the side. Waist circumference was measured to the nearest millimeter with a constant tension steel tape on the unclothed abdomen at the level of the greatest lateral indentation of the trunk. While taking this measurement, the position of the tape was checked to ensure that it was entirely horizontal and that it was not touching any part of the swimming suit (Fig. 5).

Hip Circumference

The child stood erect, arms extended slightly away from the body in the frontal plane. Hip circumference was measured by placing the steel tape around at the level of the rearmost protrusion of the buttocks. During this measurement, care was taken as to ensure that the tape was horizontal (Fig. 5).

Chest Breadth

The child stood erect, arms slightly away from the side. Chest breadth was measured horizontally to the nearest millimeter at the level of the nipples with an anthropometer. While taking this measurement, minimum pressure was applied to the anthropometer to reduce the indentation. The subject's arms were always kept away from his body (Fig. 5).

Shoulder Width

The child stood erect, arms hanging at side, maximum width was taken by measuring the horizontal distance between shoulders using an anthropometer. During this measurement, the subject's arms were relaxed at his side to eliminate possible muscle contraction at the shoulder. Both blades of the anthropometer were kept horizontal (Fig. 5).

Chest Depth

The child stood erect, arms hanging at sides. The maximum horizontal depth (anterior-posterior distance) was measured to the nearest millimeter by placing one end of the caliper over the lower portion of the sternum (xiphoid process) and the other end at the same height on the spinous process of the vertebral column. During this measurement, both blades of the caliper must be kept in line horizontally (Fig. 5).

Biceps Girth

The child stood erect, the right arm extended. Biceps girth was measured at the level of the greatest circumference, with arm hanging slightly away from the body using a constant tension steel tape (Fig. 5).

Thigh Girth

The child stood erect, arms at sides, legs straight and slightly apart. Thigh girth was taken to the nearest millimeter on the right thigh at the level of maximum girth using a constant tension steel tape. While taking this

measurement, the weight of the subject was evenly distributed on both feet to eliminate greater contraction. The tape was kept perpendicular to the long axis of the thigh (Fig. 5).

Calf Girth

The child stood erect, arms at sides, legs straight and slightly apart. Calf girth was measured to the nearest millimeter on the right calf at the level of maximum girth. During this measurement, the weight of the subject was evenly distributed on both feet. The tape was kept at horizontal (Fig. 5).

Leg Length

The child stood erect, back against the graduated board, arms hanging at sides, and feet slightly apart. A set square was placed between the subject's legs and against the graduated board. The subject was asked to bring both feet together at which time the set square was raised to the crotch. The perpendicular distance from the floor to the crotch was measured. During this measurement, the subject's feet were kept flat on the floor with the legs straight (Fig. 5).

Trunk Length

The child stood erect, arms hanging at sides and weight distributed on both feet. Trunk length was measured to the nearest millimeter by recording the perpendicular distance between the crotch to the spine of the seventh

cervical using an anthropometer. During this measurement, the subject's neck and back were kept straight (Fig. 5).

Back Length

The child stood erect, arms hanging at side and weight distributed on both legs. Back length was taken by measuring to the nearest millimeter, the perpendicular distance between the waistline and the spinous process of the seventh cervical. During this measurement, the subject's head and back were kept straight (Fig. 5).

All anthropometric measurements were recorded to the nearest millimeter on an anthropometric data form presented in Appendix E, page 208.

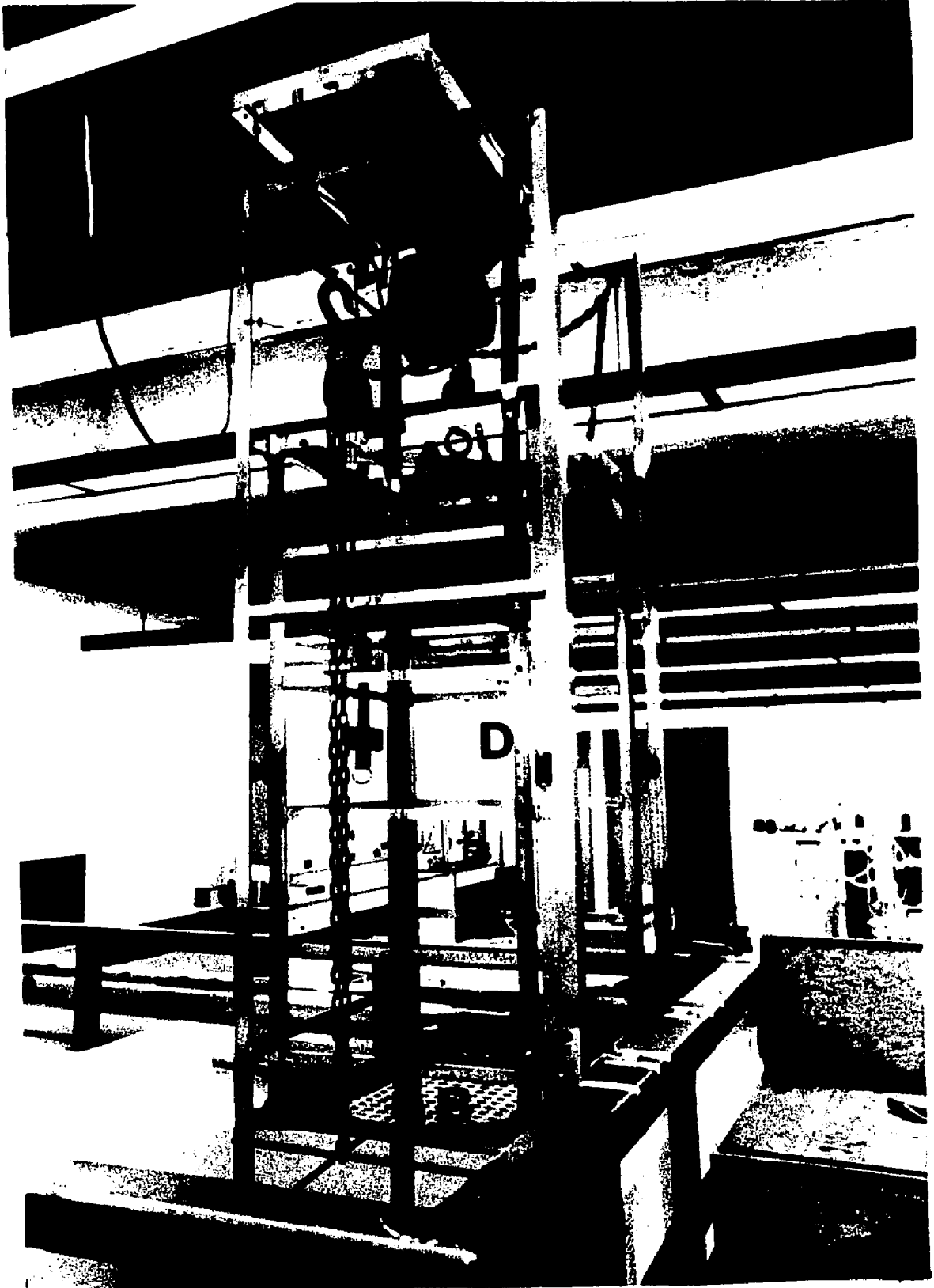
Buoyancy Measurements

During this phase of the data gathering, measurements were collected on the buoyant characteristics of the subject. Buoyancy and buoyancy distribution was measured by submerging each subject up to his/her chin. In stopping the submersion at this level, it was hoped to simulate the position in which the subjects would have to float in order to stay alive. Hence, the water safety device should have the necessary buoyant force to keep the subjects floating with head and neck out of the water.

Equipment

The testing equipment was composed of a 2x2x5 foot cage, suspended by a load cell. The load cell was connected to a digital multimeter and was secured to a manually

FIGURE 6 BUOYANCY TESTING APPARATUS



operated chain hoist. The cage, guided by an aluminum shaft could be moved vertically within a large water tank. An overall view of the buoyancy test equipment is shown in figure 6.

Aluminum Cage and Guide Shaft

The 2x2x5 foot aluminum cage weighed 32 pounds. The four corners, as well as the top and bottom frames, were made of $1\frac{1}{2}$ inch angles. Three sides of the cage were reinforced by four 1 by $\frac{1}{2}$ -inch bars. The fourth or front side of the cage had no crossbars permitting the subject to step in or out without any obstruction.

A $1\frac{1}{2}$ by $\frac{3}{8}$ -inch aluminum bar was welded diagonally to the top frame. A 2-inch diameter ring was also welded at the center top of this bar, and was used to attach a load cell (Fig. 6A).

The bottom of the cage was made of a $\frac{1}{8}$ -inch thick aluminum plate. A series of 1-inch diameter holes were drilled through this plate (Fig. 6B). These holes served a dual purpose: first, they reduced the weight of the cage, and second, they permitted the water to flow more easily when the cage was submerged.

Three $1\frac{1}{2}$ -inch ball bearing wheels were attached at each corner (Fig. 6C), one at each end and one in the center. These wheels guided the cage through the shaft and minimized friction.

Two $1\frac{1}{2}$ -inch wide stainless steel meter scales, fitting end to end, were attached to the crossbars on the side of the cage where the chain hoist operator stood (Fig. 6D).

This cage moved up and down a shaft. The corners and bottom part of this shaft were made of $1\frac{1}{2}$ -inch aluminum angles. This frame was 12 feet in height and $28\frac{3}{4}$ inches square. The frame was also reinforced on three sides by four 1-inch crossbars. Only the top and underwater portions of the front side were reinforced. The top of the shaft was equipped with two removable crossbars which served to firmly fix the shaft to a 4x8 "H" beam attached to the ceiling. If needed, the shaft could be easily taken out of the water tank by removing the crossbars. An adjustable pointer indicated the level to which the cage was submerged (Fig. 6E).

The cage and shaft were mounted inside a 11x7x5 foot water tank. The side of the tank was made of $\frac{1}{2}$ -inch thick plate glass, held together by a 3-inch angle iron frame (Fig. 7A). The guide shaft was firmly anchored to the water tank frame by six "c" clamps. Four of these clamps were affixed on the part of the shaft. Of these four, two were placed under water and two on the top angle iron of the tank (Fig. 7B). The two other clamps were holding the top part of the shaft to the "H" beam (Fig. 7C).

FIGURE 7 BUOYANCY TESTING EQUIPMENT



Hoist and Attachments

The raising and lowering of the cage was accomplished by use of a one-half ton manually operated chain hoist. The hoist was centered using clamps and cables which kept it from moving. The hoist was secured to the "H" beam by a $\frac{1}{2}$ -ton C.M. Mercury roller bearing carriage (Fig. 7D). Both the hoist and carriage were manufactured by Columbus McKinnon Limited, St. Catharines, Ontario.

A 3-inch single pulley suspended 8 inches outside the shaft, kept the chain from touching the rig and facilitated the work of the operator (Fig. 7E). A weight arranged on a small pulley system kept the loose chain away from the cage (Fig. 7F).

Safety Equipment

An adjustable safety belt was suspended by a pulley system from the inside of the cage, to the right side of the stairs. The belt and rope combination permitted the lifeguard to pull the subject out of the water in case of an emergency (Fig. 7G).

In case of a failure in one of the load cell hooks, a 1/8-inch steel cable was looped through the cage ring and the second chain link (Fig. 8A).

Measuring Equipment

The cage was suspended by a load cell, capable of linear measurement up to 150 pounds (Fig. 8A). This load cell was made by Interface Inc., Scottsdale, Arizona. The

FIGURE 8

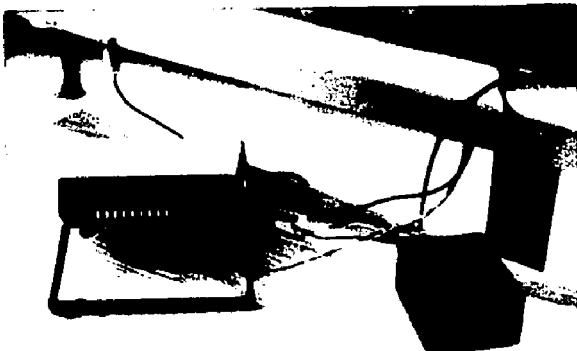
MEASURING EQUIPMENT



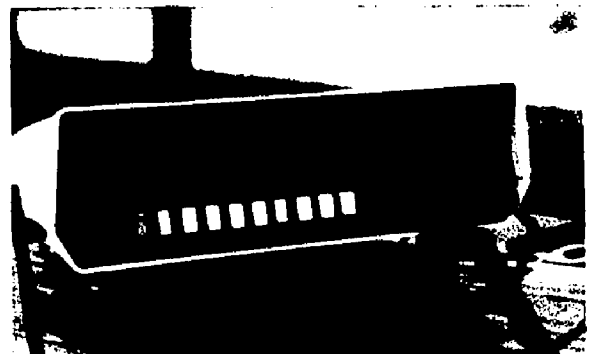
A



B



C



D

performance data of this load cell is presented in Appendix G, page 214. The load cell was specified and guaranteed to be repeatable within $< 0.01\%$ of full scale. To eliminate possible damage caused by humidity, the load cell was wrapped in a plastic bag containing a small silica gel bag (Fig. 8B).

The load cell was excited by a Saveco solid state DC power supply, Model AD-124. It had an input of 110 volts AC and an output of 12 volts DC (Fig. 8C).

The load cell was connected to a Keithley digital multimeter, model 168. As an autoranging DC voltmeter, it had a basic accuracy of $< 0.1\%$ of reading (Fig. 8D).

The load cell, the power supply, and the digital voltmeter, were all connected to each other by shielded wire. All this equipment was grounded to the water tank.

Problems in Equipment Design

The measuring and recording instruments chosen were used after more than three months of unsuccessful attempts with other types of equipment. Following is a list and short description of the instruments tried during this period, and some of the reasons for not using them in the final testing set-up.

To measure the weight of the submerged subjects, two strain gauges were built and tested in our laboratories. After multiple trials, it was realized that these instruments were unreliable due to non-linear calibration and

non-repeatable measurements. These inaccuracies in measurements could have been caused by weakness of the material and/or an alloy used in the fabrication of the proving ring or the improper gluing of the strain gauge, etc. For these reasons, it was decided to purchase an Interface load cell.

Some experimentation was conducted with different recorders before finding a proper, accurate and easy-to-read instrument.

First, a four channel Grass Model 5D Polygraph was used. Even if accurate, this recorder was impractical because of the short sweeping action of the ink needle, and the daubing on the paper. Because of these two defects, one could not read the different buoyancy measurements accurately.

As a second alternative, a 1125 Variplotter was used. This instrument has one ink needle that moves horizontally from left to right and vertically from bottom to top. It is designed to accept standard 8½ x 11-inch chart paper. The instrument was not used because of the uncleanness of the plotting. The subject's unstable position throughout the fifteen minutes of the testing period made the plotting dirty and very difficult to read.

The previously mentioned paper recorders having been proven unsuccessful, a voltmeter from which measurement can be directly read was tried. This instrument was also

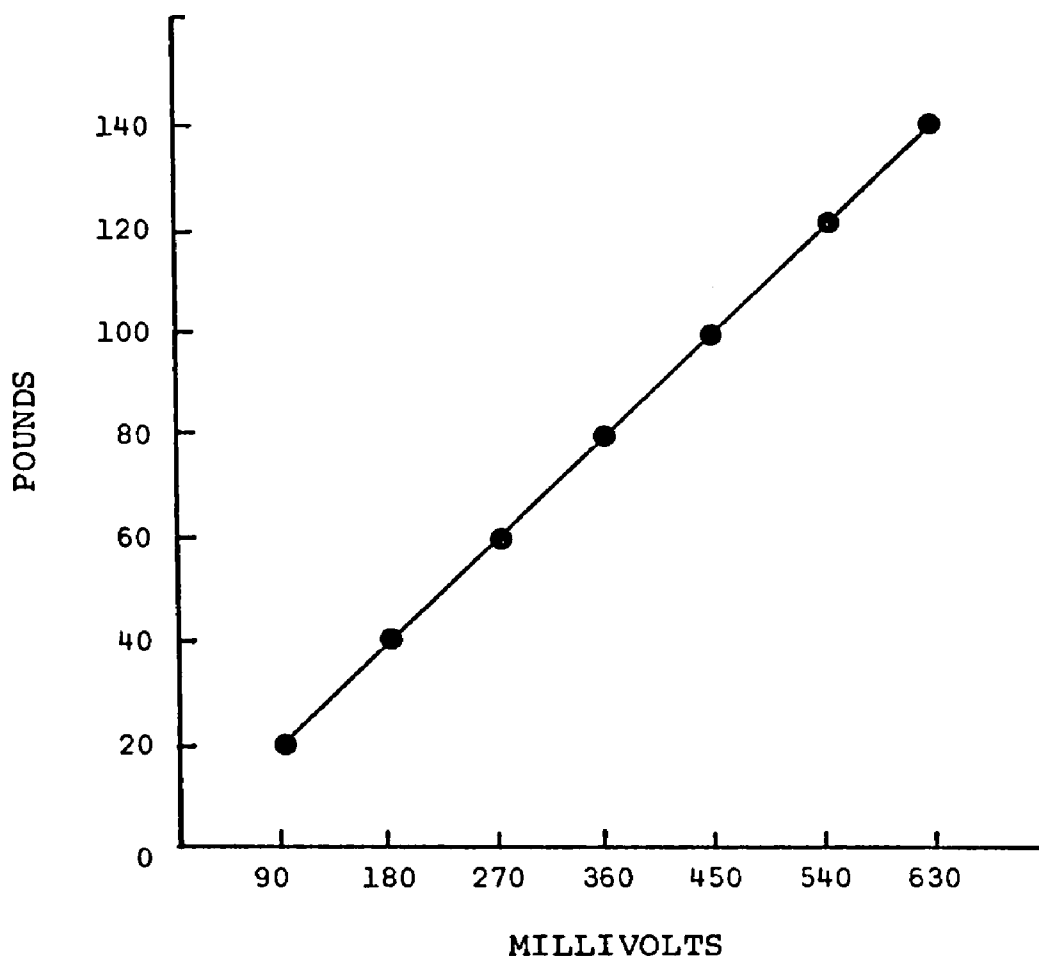
discarded because of the difficult task of reading the data accurately from a needle that fluctuated constantly.

Because of these unsuccessful experiments with different types of available recorders, a Digital Voltmeter was purchased and used to record the buoyancy measurements.

Measurements

The load cell was calibrated using known weights, by increments of 20 pounds, up to 140 pounds (Fig. 9).

Figure 9
Load Cell Calibration



It was found that 4.475 millivolts represented one pound of actual weight. This calibration was linear up to 140 pounds. The actual calibration data is presented in Appendix G, page 215. The calibration was repeated at different time intervals during the testing months.

To get the actual weight of the subjects at different heights submerged, one had to deduct the weight of the cage at that given height. To do this, the weight of the submerged cage was determined by increments of 5 cm. up to 125 cm. The actual calibration data is presented in Appendix G, page 217. The cage was calibrated periodically during the testing time.

Testing Procedures

The subjects were brought to the laboratory in groups of two to six. The parents were allowed to be present during the testing sessions if they so wished. All subjects of a given group were present in the laboratory while their comrades were being measured. The group testing method proved to be successful with young anxious subjects. By watching their older friends go through the tests, they became more aware of what to expect. This helped them to relax and enjoy the experience.

The children were asked to dress in a swimming suit. There was an adult to help the young subjects if they wanted. Their weight, height and other anthropometric measurements were taken individually. For consistency, all

measurements for all subjects were taken by the same investigator.

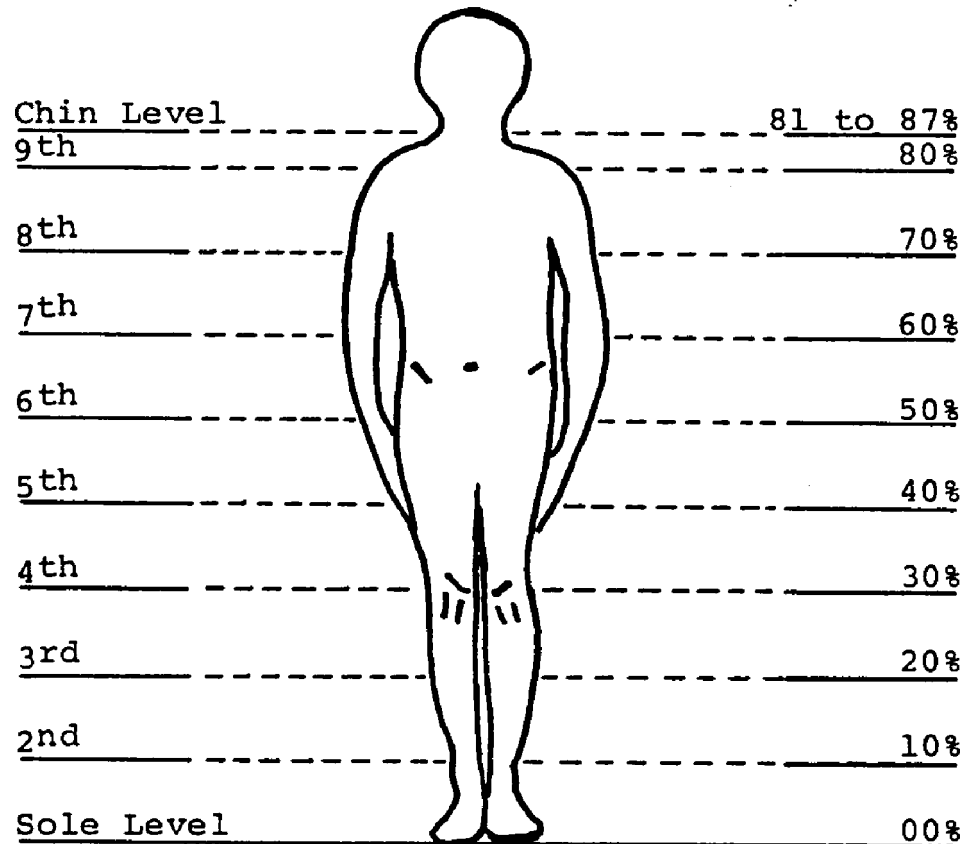
The water tank was filled before each testing day. The water temperature was kept between 85 and 90 degrees Fahrenheit and was treated with chemicals to eliminate possible bacteria. The water level was kept at a constant level by letting a faucet run and an overflow drain open during the testing sessions.

The standing height of each subject (as measured during the anthropometric measurement session) was divided into ten equal parts or percent and these numbers were written on the buoyancy test form in the column entitled 'cm. submerged'. This permitted the weight of the subject to be measured in water (buoyancy) at ten different levels of submersion. The first reading was recorded before the start of the descent when the subject's soles just touched the water. The second reading was recorded at 10 percent of submersion, the third reading at 20 percent.....until the ninth reading at 80 percent of body submersion. The tenth and last buoyancy reading was recorded when the subject was submerged at the level of the chin (Fig. 10).

The number of buoyancy measurement readings were limited to ten in order to keep the testing time within children's attention span while recording sufficient meaningful data.

Figure 10

Levels of Buoyancy Measurements



The individual groups of subjects were then gathered beside the water tank, where the buoyancy measurement procedures were explained. Once the explanation was completed and the questions answered, the first subject, usually the most confident of the group, was asked to walk up the stairs and stand on the top step in preparation for testing.

The lifeguard adjusted a safety belt around the child's waist. The safety belt, made of cotton drill, weighed approximately 2 ounces and was taken as a constant throughout the course of submersion. The weight of the belt was not deducted from the final buoyancy reading because of its change of weight when submerged which was difficult to assess accurately. In the meantime, the cage was placed at the proper height and its weight was recorded. This number was written at the top right of the buoyancy form beside the word calibration (Appendix E, page 208). The hoist operator adjusted the height pointer to 0.

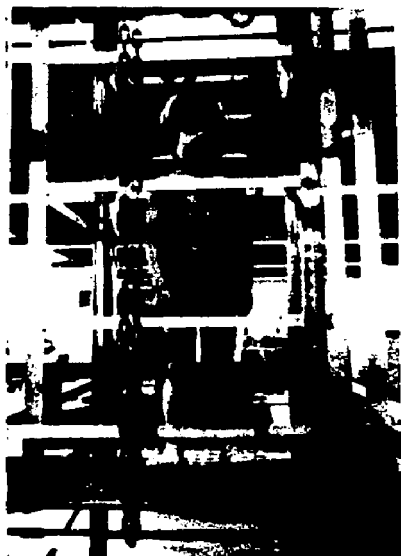
Then the subject was asked to step in the cage facing the hoist operator. The child stood straight in the middle of the cage, feet slightly apart with arms hanging at the sides, palms against his or her thighs (Fig. 11). The lifeguard stayed at the top of the stairs ready for an emergency during all the testing time.

The weight of both the subject and the cage was recorded in the top space of the column entitled 'total reading'. Then the subject was reminded to keep still during the descent. By looking at the subject through the glass tank, the investigator made sure that the child kept his original position with feet flat on the bottom.

During the descent, a "total reading" score with arms at the side was recorded at every tenth of the subject's height until his or her hands started to touch the

FIGURE 11

SUBMERSION TECHNIQUE



A



B



C



D

water. This usually happened at the fifth reading (Fig. 11B). From that point on, two readings were taken at each subsequent level, one with arms at the side (Fig. 11C) and one with arms over the head (Fig. 11D). By measuring the weight with arms over the head, the investigator tried to simulate a situation in which the subject would wave for help. These last readings were recorded in the 'total reading' column on the right side of the data form. The procedure continued through the ninth reading.

The last or tenth stage was different in that the subject was lowered down to his or her chin, and this distance was always less than one-tenth of the subject's height. These two last readings "arms up and arms down" were recorded when the investigator was sure that the subject was really submerged up to his chin level.

At that point, it was very important for the investigator to notice any anomalies in the subject's position such as: bending the head forward or backward, breathing normally, elevating the shoulders or standing up on the toes. The above-mentioned adjustments are instinctive when a child attempts to keep his or her head out of the water. Once the desired position was assumed, the reading as well as the height submerged as indicated by the pointer, were recorded. From this last reading, the investigator could calculate the exact percentage of total height to which a given subject was submerged. The cage was then

lifted out of the water and the subject guided out of the cage and down the stairs.

Data Conversion

To obtain the actual weight of the subjects when submerged at different levels as well as the net buoyancy in both positions (arms at the side and arms over head), the following conversions on the buoyancy data form were made.

The weight of the cage, as determined by the calibration (Appendix G, page 217), was subtracted from the "total reading score" and written in the "corrected reading" column. These readings were all recorded in millivolts. To get the weight in pounds, the number in the "corrected reading" column was divided by 4.475 which is the calibration of the load cell. This last number was then divided by the actual weight of the subject to give the percent weight as indicated in the column entitled "weight x 100". To facilitate the calculation, the ounces were converted to decimals. The same procedure was used to calculate the buoyancy with arms at the side and arms over the head. The last number at the bottom of both columns entitled "actual weight" represents the net buoyancy measurements of the subject.

The analysis and discussion of all the anthropometric and buoyancy measurements are presented in the next chapter.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to provide criteria based upon anthropometric and buoyancy measures of children which could be used in the design and construction of future children's water safety devices. Before making recommendations for changes in the design of existing water safety devices, it was judged necessary to conduct: a) a subjective evaluation of existing and available water safety devices; and b) an objective study of children's anthropometric and buoyancy characteristics. The analysis and discussion of the results will be presented in the order in which the hypotheses were stated.

Hypothesis 1 states: The aesthetic and functional features of contemporary water safety devices are not suitable for young children.

To test this hypothesis, the results of the subjective evaluation of existing water safety devices will be presented and discussed. These results will be presented in rating form followed by comments on their significance.

Hypothesis 2 states: Since body shape and proportions of children differ from that of adults, buoyancy requirements for children cannot be determined by mere

geometric scaling or by extrapolation on the basis of total weight.

To test this hypothesis, the buoyancy and anthropometric data will be analysed using the following statistical procedures: a) means and standard deviations of all anthropometric and buoyancy measurements for females, males and combined sexes; b) t-tests between boys and girls for all anthropometric and buoyancy measurements as well as for the different levels of submersion in both positions "arms at the side" and "arms over the head"; c) a correlation between all anthropometric and buoyancy measurements; and d) separate buoyancy curves for boys and girls in both positions "arms at the side" and "arms over the head" will be plotted.

Hypothesis 3 states: The maximum buoyancy force needed to support a submerged child with his head out of the water can be predicted by a few anthropometric measurements.

To test this hypothesis, the results will be analysed using the following statistical procedures: a) multiple regression analysis using separately "net buoyancy down" and "net buoyancy up" as dependent variables and all anthropometric measurements as independent variables; b) a prediction formula based on a small number of anthropometric measurements verified with a group of twenty subjects from the same population area; and c) a correlation and t-test

for this group (20 subjects) between the actual and predicted buoyancy scores.

Subjective Evaluation

During this phase of the study, 12 water safety devices were tested for comfort, freedom of chafing, ease of swimming as well as for wearability during paddling, rowing and sailing situations. The results are presented in Table 1.

The slab-type lifejackets were rated good in comfort while the vest types were found to be sticky and very hot. This discomfort was always present when the chest and back were covered on a hot and/or humid day (Fig. 12A). This inconvenience will increase with physical effort which is the case in almost all water activities. The personal flotation devices were found more comfortable (Fig. 12B). This superior rating in favour of the PFD's can be explained in part by their lightness, the softness and/or coolness of their inside lining, their lack of bulkiness, and their comfort and fit. The water-ski vest without collar was rated slightly lower than the water-ski vest with collar because of the rigidity of the edge around the neck opening.

Ease of floating and freedom of movement were the discriminating factors when the subjects swam different strokes using various types of water safety devices. The back stroke was found to be the easiest since floating

TABLE 1
SUMMARY OF THE SUBJECTIVE EVALUATION OF WATER
SAFETY DEVICES DURING WATER ACTIVITIES

Brand	Model	Style	Comfort	Freedom from Chafing	Ease of Swimming	Best Stroke	Padding	Row- ing	Sail- ing
Aqua Neptune	U	Slab	L.J.	G	P	Back	P	G	F
Aqua Neptune	K	Slab	L.J.	G	P	Back	P	G	P
Keep-a-Float	K	Slab	L.J.	G	P	Back	P	G	P
Mermaid	U	Slab	L.J.	G	P	Back	P	G	F
Foam Float	U	Slab	L.J.	VP	P	Back	P	P	P
Aqua Neptune	K	Vest	L.J.	G	F	Back	F	G	P
Aqua Neptune	U	Vest	L.J.	G	F	Back	F	G	P
Keep-a-Float	K	Vest	L.J.	G	F	Back	F	G	P
Mermaid	K	Vest	L.J.	G	F	Back	F	G	F
Stearns	U	Vest	PFD	G	F	Front	E	E	E
Water ski with collar	A	Vest	PFD	G	G	Front	E	E	E
Water ski with- out collar	A	Vest	PFD	F	G	Front	E	E	E

Legend:	L.J.	- Lifejacket	E	- Excellent
	PFD	- Personal Flotation Device	VG	- Very Good
	U	- Unicellular foam	G	- Good
	K	- Kapok	F	- Fair
	A	- Air	P	- POOR
			VP	- Very Poor

FIGURE 12

WATER SAFETY DEVICES



A



B



C



D



E



F

stability was at best when swimming on the back. The large buoyant force in the front section of the water devices is responsible for this great stability (Fig. 12C). However, all lifejackets were found cumbersome to various degrees in any swimming style. Once again, the personal flotation devices were rated good for swimming. The reasons for this high rating are the same as mentioned in the first evaluation, that is, the distribution of the buoyant force all around the trunk and the pliability of the vest or jacket materials.

The subjects encountered some difficulty in donning most lifejackets. The major problems were that the young children could not tie the tapes sufficiently tight to keep the slab or vest close to the body and they also had difficulty in pulling the keyhole type jackets over their head (Fig. 12D). Since these difficulties were experienced when donning the jackets or vest on dry land, one is led to believe that donning the water safety device for a child while in water is inconceivable following a sudden capsizing or fall overboard.

Almost all lifejackets ranked poorly in paddling situations. This could be explained by the following facts:

1. the bulkiness of certain slab and vest types (Fig. 12A, 12C). The front section, whether made of one or

two pieces of material, interfered with the side paddling movement. This was more pronounced with the inside arm or the arm opposite the paddling side.

2. The thickness of the front side buoyant pieces (Fig. 12A, 12C) rendered the rotation of the neck very difficult. If rotation of the neck is necessary, it is practically always accompanied by skin irritation (neck chafing).

3. The length and rigidity of the front section of the slab and vest made it difficult for the wearer to bend forward, to kneel or to sit in a crouched position (Fig. 12E, 12F). The positions mentioned above are the ones most commonly used in canoeing and vary with the ability and/or the preference of the paddler. The beginner will kneel and lean against the thwart while, in competition, the more advanced paddler will kneel and sit on his legs.

In paddling, the personal flotation devices were rated excellent. Their lightness, fit, and flexibility made them very popular among the children.

By contrast, all lifejackets except one were rated good or excellent for rowing. This could easily be explained by the fact that in rowing, the arms execute a side and out movement by flexing and horizontally extending the arms at the shoulder articulations in the transverse plane. In so doing, the front portion(s) of the slab or

vest does not come into contact with the arms. The length of the lifejackets did not limit or hinder the sitting position, usually taken for rowing. The foam float slab was rated poor not because it interfered with movement, but because of its total lack of comfort. The three personal flotation devices tested were classified as excellent in rowing situations. This high rating was due to their overall comfort.

All lifejackets tested were classified as poor or fair when used during sailing classes or practices. The reasons for such a low rating are the same as those indicated for paddling activities, with the added emphasis on the fact that the lifejackets appeared to hinder movement. In sailing, because of the sudden change in the position of the sail due to wind direction, one has to move quickly and execute rapid arm movements. These movements cannot be performed easily with these cumbersome lifejackets. Forward bending of the trunk, which is a frequent movement in sailing because of the quick rotation of the horizontal mast, is often hindered by these lifejackets. Being unable to move quickly to dodge the boom could be an actual hazard.

The three personal flotation devices were rated excellent for sailing. The reasons for such a high rating have been mentioned in the two previous sections (paddling and rowing).

As mentioned by the instructors, the personal flotation devices are more popular, not only with children but also with experienced sailors. These personal flotation devices, however, are often not approved because of their inability to meet and pass the established standards. These water safety devices emphasized comfort to the detriment of righting moment and flotation.

The subjective evaluation has shown that in ease of donning, overall comfort, and comfort during water activity, both on and in the water, the personal flotation devices are preferred to the lifejackets. Of the lifejackets tested, the vest type was rated higher than the slab type in all tests except comfort.

It appears from this analysis that the water safety devices tested are not as comfortable as they should be if children are to wear them for long periods of time. It is also shown that because of poor design of the water safety devices, it would be difficult or almost impossible for a child to swim rapidly to a boat or a wharf, or even to shore following a sudden fall or capsize. Time submerged may be an important factor if the water temperature is low. Furthermore, it was demonstrated that because of their bulkiness and poor fit, lifejackets limited and sometimes hindered the movement used during boating maneuvers. Not being able to execute the necessary movements properly could become an actual hazard or danger.

All these shortcomings of existing lifejackets could explain in part why children are unwilling to wear them during water activities. Some of these weaknesses also apply to personal flotation devices. From the previous remarks, one could concluded that, in general, the existing water safety devices are not suitable for young children.

Based on the present findings and within the limitations of this study, it is concluded that the hypothesis which states: "The aesthetic and functional features of contemporary water safety devices are not suitable for young children" is thus supported.

Anthropometric Measurements

The means and standard deviations for the weight of the combined groups as well as for boys and girls separately are presented in Table 2. The results of a t-test analysis has shown no significant difference between the mean weights of both groups.

TABLE 2

MEANS AND STANDARD DEVIATIONS FOR THE WEIGHT
AND t-VALUE FOR THE COMBINED GROUPS
AND FOR BOYS AND GIRLS

Groups	Means	S.D.	Means	S.D.	t
	kg.		lb.		
Combined (N= 203)	24.8	6.2	54.7	13.7	0.24*
Boys (N= 99)	24.7	6.0	54.4	13.2	
Girls (N= 104)	24.9	6.4	54.9	14.3	

*t= 2.57 - significant at the .01 level

Table 3 contains the means and standard deviations for all anthropometric measurements of the total population of 203 subjects. The seventeen variables are presented in both inches and centimeters.

In order to determine how the boys in this sample differed from the girls on the anthropometric variables measured, the means were obtained for each group and a t-test for the significance of the difference between means was then applied. The means and standard deviations for boys and girls on each variable and the t values for the difference between means are reported in Table 4.

Examination of this table indicates that a significant difference between the means at the .01 level was found for only three variables. These variables are head and neck circumferences and thigh girth. Within these differences, boys have greater head and neck circumferences while girls have greater thigh girth. From these findings, one may deduce that boys need more buoyant force than girls to keep their head in a safe floating position out of the water. Likewise, the larger thigh girth in favor of the girls could indicate that girls need less added buoyant force than boys.

The lack of significant differences between boys and girls for weight and fourteen other anthropometric variables would tend to imply that sex need not be taken into consideration when designing different sizes of

TABLE 3
MEANS AND STANDARD DEVIATIONS OF ALL
ANTHROPOMETRIC MEASUREMENTS (N= 203)

Variables	Means cm.	S.D.	Means in.	S.D.
Height	122.8	12.6	48.3	4.9
Head circumference	52.1	1.8	20.5	0.7
Neck circumference	26.6	1.8	10.5	0.7
Arm scye	29.5	3.7	11.6	1.4
Chest circumference	61.3	5.5	24.1	2.2
Waist circumference	55.3	5.2	21.8	2.0
Hip circumference	66.7	7.2	26.3	2.8
Chest breadth	20.9	1.9	8.2	0.8
Shoulder width	30.5	3.2	12.0	1.3
Chest depth	13.7	1.3	5.4	0.5
Biceps girth	18.5	2.1	7.3	0.8
Thigh girth	35.4	4.5	13.9	1.8
Calf girth	25.2	2.6	9.9	1.0
Leg length	55.6	8.0	21.9	3.2
Back length	28.9	3.5	11.4	1.4
Trunk length	45.9	4.7	10.1	1.9
Sitting height	64.6	5.4	25.4	2.1

TABLE 4

COMPARISON OF ALL ANTHROPOMETRIC MEASUREMENTS BETWEEN GIRLS AND BOYS

Variables	Female (N= 104)			Male (N= 99)			t
	Means	S.D.	in.	Means	S.D.	Means	
	cm.			cm.		in.	
Height	122.7	12.5	48.3	4.9	122.8	12.7	48.3 5.0 0.01
Head circumference	51.7	1.8	20.4	0.7	52.5	1.7	20.7 0.7 3.23*
Neck circumference	26.2	1.7	10.3	0.7	27.0	1.8	10.6 0.7 3.04*
Arm scye	29.3	3.7	11.5	1.5	29.7	3.6	11.7 1.4 0.67
Chest circumference	61.4	5.7	24.2	2.2	61.1	5.3	24.1 2.1 0.43
Waist circumference	54.9	5.2	21.6	2.0	55.7	5.1	21.9 2.0 1.16
Hip circumference	66.9	7.5	26.3	3.0	66.4	6.9	26.1 2.7 0.54
Chest breadth	20.9	1.8	8.2	0.7	21.0	2.1	8.3 0.8 0.50
Shoulder width	30.6	3.1	12.0	1.2	30.2	4.2	11.9 1.7 0.67
Chest depth	13.6	1.3	5.4	0.5	13.8	1.3	5.4 0.5 1.06
Biceps girth	18.7	2.4	7.4	0.9	18.3	1.8	7.2 0.7 1.32
Thigh girth	36.3	4.7	14.3	1.9	34.4	4.1	13.5 1.6 3.05*
Calf girth	25.3	2.7	10.0	1.1	25.1	2.6	9.9 1.0 0.51
Leg length	55.9	7.6	22.0	3.0	55.2	8.4	21.7 3.3 0.59
Back length	28.5	3.1	11.2	1.2	29.2	3.9	11.5 1.5 1.37
Trunk length	46.2	4.6	18.2	1.8	45.5	4.8	17.9 1.9 1.07
Sitting height	64.6	5.4	25.4	2.1	64.5	5.4	25.4 2.1 0.05

*Significant at .01 level

children's water safety devices. However, the head opening of the keyhole style design should be sufficiently large to accommodate boys and girls.

Comparison of Anthropometric Measurements

While the scope of this study includes a maximum of 203 subjects representing different age groups in both sexes, the question always arises concerning how representative is the sample of the population from which it was drawn. Therefore, this section compares means of anthropometric measures obtained in this study with those obtained from similar groups in other studies.

The Canadian data chosen for comparison was taken from the Saskatchewan Growth and Development Study initiated in 1968. It is the only Canadian study on children's anthropometric measurements for which some information on testing procedures could be obtained for males from 8 to 12 years old. Based on the available information, a t-test for significance between means of both groups (present study and Saskatchewan study) was computed. The measurements used for comparison were chosen because of their similarity with the measurements taken in the present study. The measuring technique used was also considered in the choice of variables. Six variables were chosen, namely standing height, weight, biceps girth, calf girth, thigh girth, and chest depth. The means of all measurements by

age are presented in Table 5.

A close look at Table 5 reveals that a significant difference between the means at the .05 level was found for the biceps girth of the 9 year old groups. The means for the chest depth for the 8 and 10 year old groups as well as the calf girth of the 8 year old groups were also different at the .05 level.

The small difference in means of anthropometric measurements between the two studies could be explained as follows. The difference in the size of the samples. It is known that test results obtained from a large sample will be more representative of the normal curve of the population from which it was drawn. The discrepancies in measurements could be due to variation in the technique used by a number of measurers. Being a longitudinal study, it is probable that different measurers were used thus influencing the results. Furthermore, the number of subjects varies from year to year. In the Saskatchewan study the loss is approximately 4 percent each year.

One of the objectives of the Saskatchewan research is to study whether or not changes with growth in the measurements taken are related to participation and proficiency in sports. Knowledge of this objective could motivate the subject to spend more time practising certain sports than the average child. As a result, the child involved in the study may develop his physical character-

TABLE 5

MEANS COMPARISON OF FIVE ANTHROPOMETRIC VARIABLES BETWEEN
SASKATCHEWAN AND PRESENT STUDY MALE SUBJECTS

Variables cm.	Study	Age by Years				
		8	9	10	11	12
Standing Height	S	122.2	129.2	133.1	138.5	143.4
	P	122.2	127.6	130.4	136.8	139.8
Biceps Girth	S	16.8	18.1 ^a	18.9	19.8	20.7
	P	17.8	18.9 ^a	19.1	19.9	19.2
Calf Girth	S	23.7 ^b	25.0	26.0	27.1	28.1
	P	25.4	25.8	26.7	27.0	27.1
Chest Depth	S	13.6 ^a	13.9	14.2 ^a	14.5	15.0
	P	13.9	14.1	14.7	14.6	15.0
Thigh Girth	S	33.3	35.6	37.1	39.9	41.6
	P	34.6	35.2	35.7	37.9	39.3
Weight kg.	S	23.2	25.7	28.7	31.7	35.3
	P	24.2	27.2	27.8	30.8	32.0

a= Significant at the .05 level

b= Significant at the .01 level

S= Saskatchewan Study
P= Present Study

istics to a greater extent than the other child.

The small differences observed between each group could be explained in part by the experimental discrepancies mentioned in the previous paragraphs. Consequently, one could conclude that the sample of both studies are fundamentally similar.

The results of the present study were also compared with the anthropometric measurements collected on 4027 infants and children of the United States (Snyder, et al., 1975). Standing height, chest breadth, waist, head and neck circumferences were the variables chosen for comparison. A t-test for significance between means of both groups was computed. The means as well as an indication of any significant difference found, are presented in Table 26, Appendix F, page 212.

The number of subjects in each age group of the present study varied from 2 to 51 compared to 63 and 674 for the American study. Also, to facilitate comparison, the subjects of the American study were arranged in one year groups as compared to the original 6 months grouping.

The instrument used in the American study to record chest breadth was made with pressure transducers while in the present study, the necessary pressure was applied manually by the measurer. The difference in equipment plus the amount of soft tissue in the chest region could account for the variation in the measurements

obtained in both studies. The small difference between means for neck circumference could also be attributed to the different ways by which measurements were obtained. In the present study, the tape was placed perpendicular to the long axis of the neck, at the level of the Adam's apple. Snyder placed the tape horizontally at the base of the neck.

Based on these explanations, one could conclude that the small difference between means of the two samples could be partly due to technical differences in experimental design. Nevertheless, one should be aware of the fact that the difference in means could possibly be due to a difference in subjects. However, the difference between the present samples is not greater than what would be anticipated when two groups of subjects chosen from different parts of a population are compared. Furthermore, this difference would be expected to decrease when larger samples are compared.

Buoyancy Measurements

The means and standard deviations for the net buoyancy "arms at the side" and "arms over the head" for the entire population (N= 203) is presented in Table 6. These two variables represent the amount of buoyant force required in order to keep a child afloat with his head completely out of the water while having his arms submerged or extended over his head. This buoyant force should be added around

the chest and shoulder regions.

TABLE 6
MEANS AND STANDARD DEVIATIONS OF NET BUOYANCY
ARMS AT THE SIDE, ARMS OVER THE HEAD

Variables	Means		S.D.	
	lb.	kg.	lb.	kg.
Arms at the side	7.02	3.18	1.22	0.55
Arms over the head	11.45	5.19	2.17	0.98

The big difference between the means is easily explained by the variation of the two positions in which the subjects were measured. In the position "arms at the side", the amount of displaced water was equal in volume to the size of the entire body less the head. In the second position "arms over the head", the volume of water displaced was less than in the first position since the subject had his head, his entire arms' length, and a part of his shoulders out of the water.

Buoyancy for Different Sexes

Since buoyancy is the most important single factor to be considered in the construction of water safety devices, it is essential to study its variation between sexes.

In order to determine if the boys in this sample differed from the girls on the buoyancy measurements taken,

the means were obtained for each group and a t-test for significance of the difference between means was applied. The means and standard deviations for boys and girls for both buoyancy measurements and the $|t|$ values for the difference between means are reported in Table 7.

TABLE 7
MEANS AND STANDARD DEVIATIONS AND t-RATIOS
FOR BOYS AND GIRLS ON NET BUOYANCY
ARMS AT THE SIDE, ARMS OVER THE HEAD

Variables	Means		S.D.		$ t $
	lb.	kg.	lb.	kg.	
Arms at the side					
Boys (N= 99)	7.29	3.31	1.10	0.50	3.15*
Girls (N= 104)	6.76	3.07	1.28	0.58	
Arms over the head					
Boys (N= 99)	11.73	5.32	2.22	1.01	1.82
Girls (N= 104)	11.18	5.07	2.09	0.95	

*Significant at the .01 level

As shown in Table 7, a significant difference between means at the .01 level was found for buoyancy "arms at the side". This difference between means indicates that boys are less buoyant than girls in the position "arms at the side". This difference in buoyancy in favor of the girls could be explained in part by the accumulation of adipose tissue which is greater in girls than in boys (Malina et al., 1967; Maresh, 1966; Reynold, 1948).

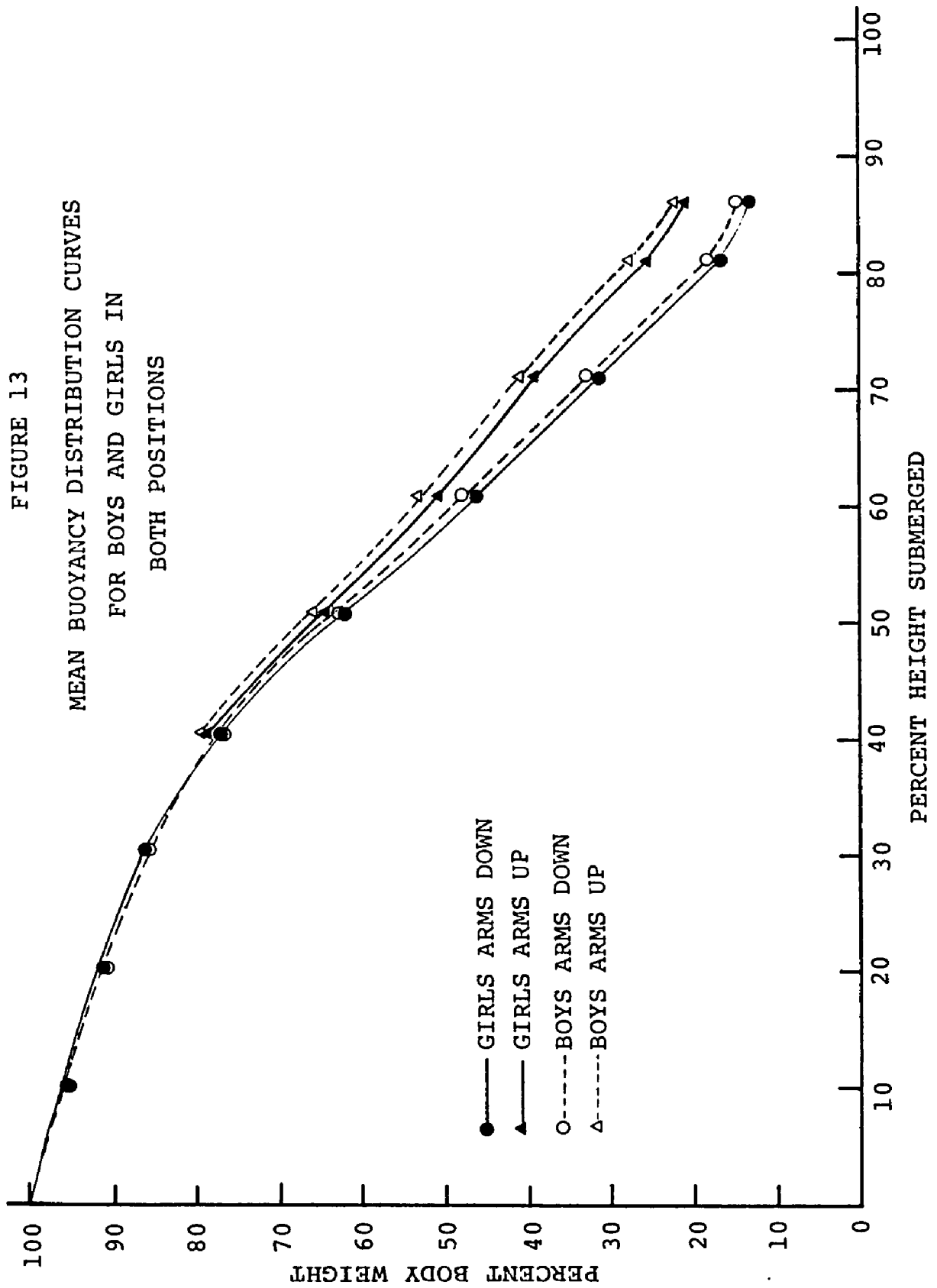
However, the lack of significant difference between means for the position "arms over the head" indicates that boys and girls have approximately the same body volume when measured with their head and arms out of the water. These results would also suggest that arms and any part of the shoulders which are out of the water while the measurements were recorded, are less dense for girls than for boys. This lower density in favor of the girls could be explained in part by the lower amount of muscle and bone tissues (Malina, 1967; Maresh, 1966) and by the higher amount of adipose tissue (Reynolds, 1948) found for girls. Furthermore, the smaller head of the girls ($\bar{X} = 51.7$ cm.) as compared to the boys ($\bar{X} = 52.5$ cm.) could also account for the lower buoyancy scores obtained by the girls.

Buoyancy Distribution

The distribution of buoyancy in both positions was studied, that is, how buoyancy values change because of the shape of certain parts of the body while submerged gradually from feet to chin.

Buoyancy Distribution for Boys and Girls

Figure 13 represents mean buoyancy distribution curves for boys and girls in the positions "arms at the side" and "arms over the head". A significant difference at the .01 level was found at the tenth reading or chin level for the position "arms at the side". The lack of



significant difference at the other levels of submersion indicates that the final difference in net buoyancy between boys and girls can be attributed almost entirely to the difference in head size. This is supported by the results of Table 4 which shows a significant difference in head size in favor of the boys. The actual mean differences in buoyancy between boys and girls at different levels of submersion as well as the t-test values are presented in Tables 8 and 9.

However, the mean buoyancy values at different levels of submersion and at the chin level did not differ significantly in the position "arms over the head". This lack of significant difference when arms are out of the water seems to indicate that the arms of the girls are slightly less dense than the arms of the boys, hence will help floating when they are submerged in the position "arms at the side".

Besides, the lack of difference in buoyancy values between boys and girls in the position "arms over the head" could also be explained by the small difference in arms and head measurements. The slightly larger arms of the girls ($\bar{X} = 18.7$ cm.) as compared to ($\bar{X} = 18.3$ cm.) for boys may compensate for the smaller head size of the girls. It is possible that the smaller head and larger arms of the girls equal in weight the larger head and smaller arms of the boys.

TABLE 8

MEANS, STANDARD DEVIATIONS AND t-VALUES FOR BOYS AND GIRLS ON ACTUAL
WEIGHT AT DIFFERENT LEVELS OF SUBMERSION ARMS AT THE SIDE

Percent Height Submerged	Boys (N= 99)				Girls (N= 104)				t
	Means		S.D.		Means		S.D.		
	lb.	kg.	lb.	kg.	lb.	kg.	lb.	kg.	
Sole Level	54.5	24.7	13.2	6.0	54.8	24.9	14.1	6.4	0.19
10	52.2	23.7	12.5	5.7	52.5	23.8	14.3	6.5	0.18
20	49.8	22.6	11.8	5.4	50.2	22.8	13.4	6.1	0.19
30	46.8	21.2	11.3	5.1	47.3	21.5	12.1	5.5	0.31
40	42.0	19.0	10.2	4.6	42.5	19.3	10.8	4.8	0.29
50	34.2	15.5	8.1	3.7	34.2	15.5	8.2	3.7	0.01
60	25.8	11.7	5.9	2.7	25.2	11.4	5.7	2.6	0.71
70	17.7	8.0	4.3	2.0	17.4	7.9	4.0	1.8	0.41
80	9.1	4.1	1.9	0.9	8.7	3.9	1.7	0.8	1.65
Chin Level	7.3	3.3	1.3	0.6	6.7	3.0	1.1	0.5	3.15*

*Significant at the .01 level

TABLE 9

MEANS, STANDARD DEVIATIONS AND t-VALUES FOR BOYS AND GIRLS ON ACTUAL
WEIGHT AT DIFFERENT LEVELS OF SUBMERSION ARMS OVER THE HEAD

Percent Height Submerged	Boys (N= 99)				Girls (N= 104)				t
	Means lb.	Means kg.	S.D. lb.	S.D. kg.	Means lb.	Means kg.	S.D. lb.	S.D. kg.	
40	42.5	19.3	10.2	4.6	42.7	19.4	10.7	4.9	0.17
50	35.4	16.1	8.2	3.7	35.3	16.0	8.5	3.9	0.13
60	28.3	12.8	6.3	2.9	27.6	12.5	6.1	2.8	0.83
70	21.8	9.9	5.1	2.3	21.3	9.7	4.7	2.1	0.79
80	14.4	6.5	3.1	1.4	13.9	6.3	3.0	1.4	1.34
Chin level	11.7	5.3	2.2	1.0	11.2	5.1	2.1	1.0	1.82

Although the difference between sexes is not significant before the last reading ($p < .01$) in the position "arms at the side", the small difference shown by the curves (Fig. 13) from the fifth reading on seems to indicate that girls are displacing a larger amount of water than boys. This small difference in favor of the girls will help floating.

Buoyancy Distribution for Different Weight Categories

Since buoyancy is the most important single factor to be considered in the construction of water safety devices, it is essential to study its variation in different body sizes more carefully.

Mean buoyancy distribution curves for different weight categories, namely by 10 pound intervals, for boys and girls are presented in Figures 14 and 15 respectively. The percent height submerged is presented on the abscissa, while the weight is given on the ordinate. The seven solid lines represent buoyancy distribution in the position "arms at the side" whereas the two dotted lines illustrate the buoyancy distribution of the smallest and larger group of subjects when weighed in the water in the position "arms over the head".

These curves show that children of different body weight do differ in body shape and proportions. This difference keeps increasing with weight. For example, when

FIGURE 14
BUOYANCY DISTRIBUTION CURVES
FOR BOYS BY DIFFERENT
WEIGHT CATEGORIES

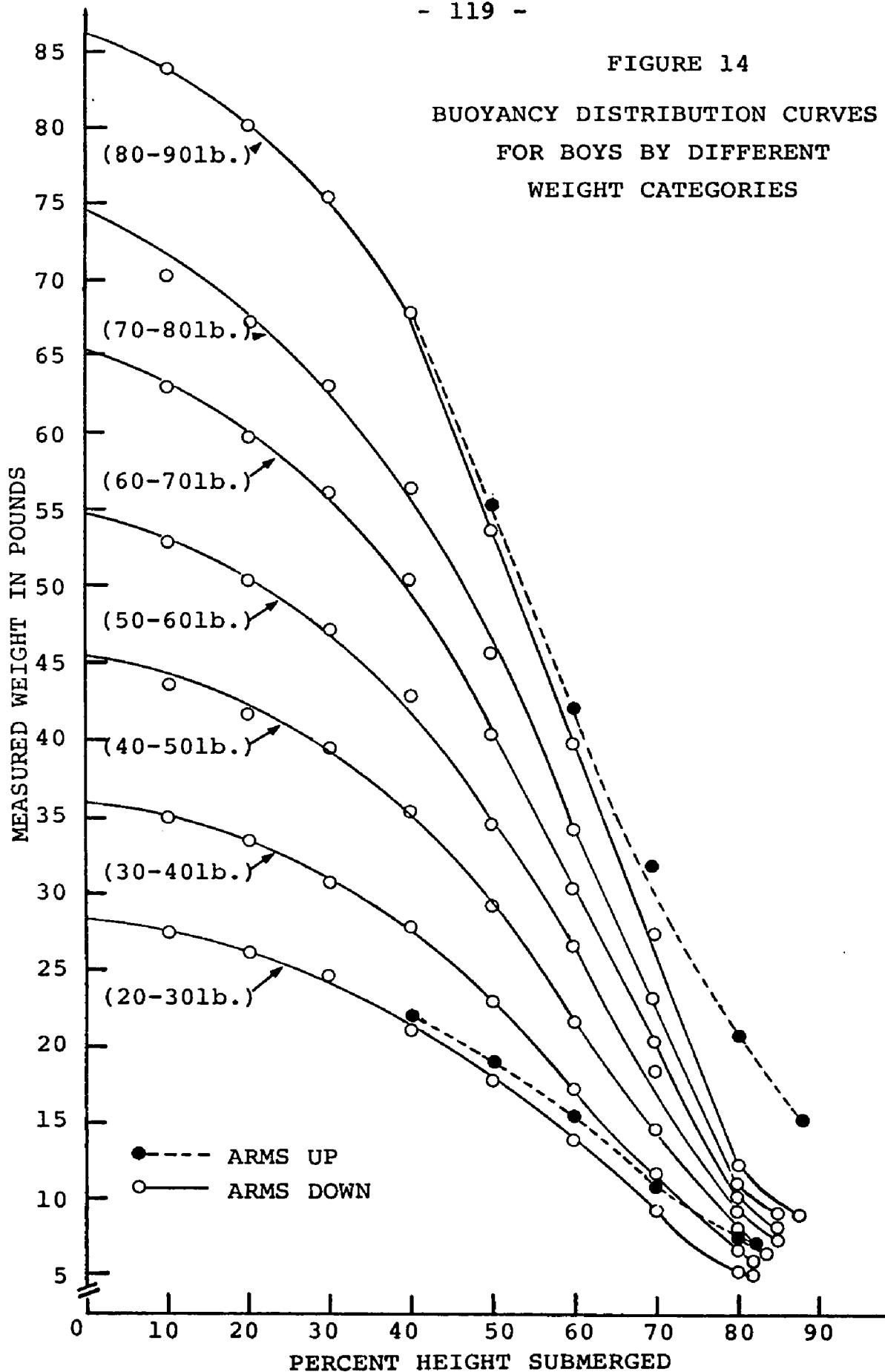
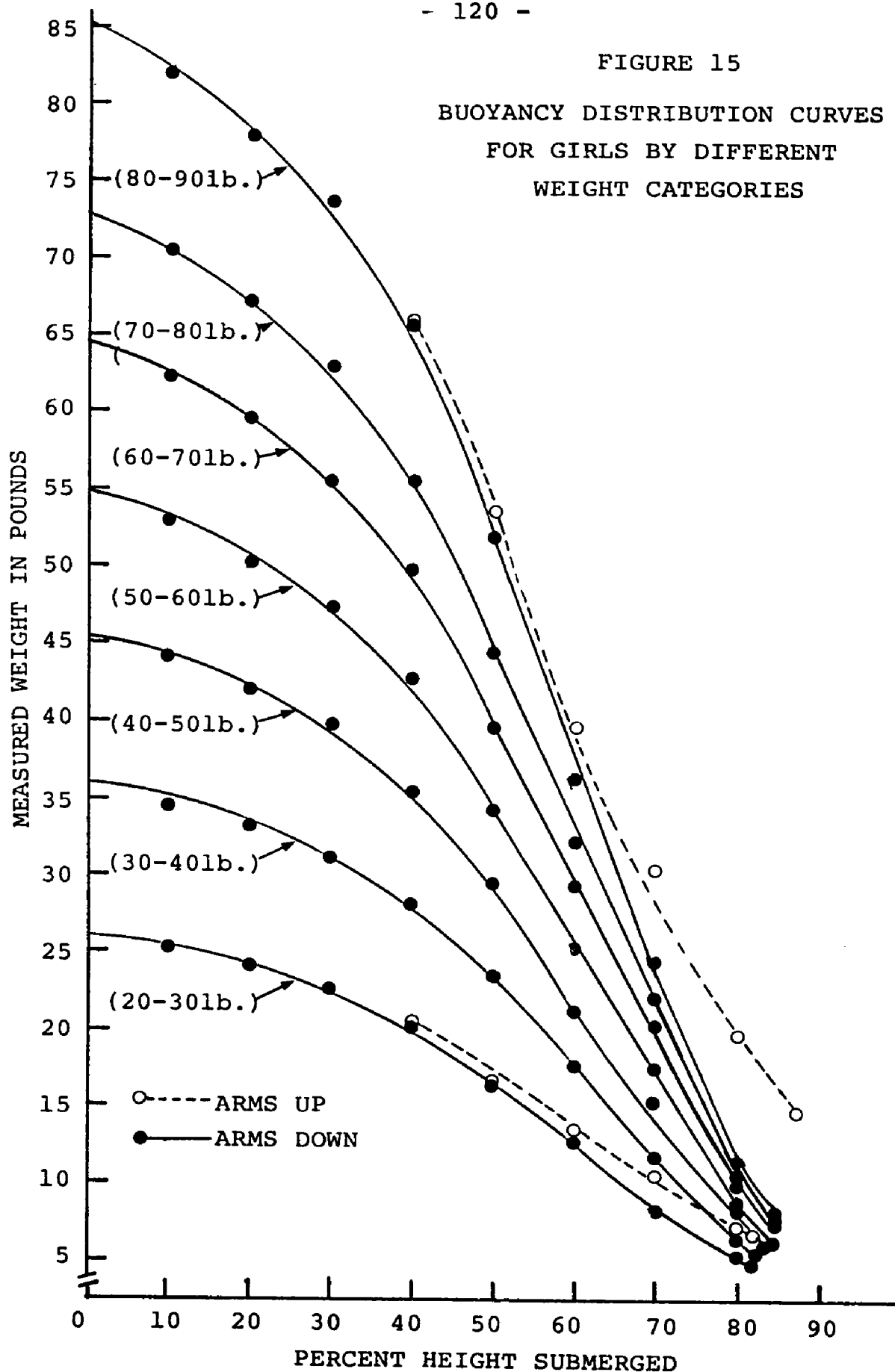


FIGURE 15
BUOYANCY DISTRIBUTION CURVES
FOR GIRLS BY DIFFERENT
WEIGHT CATEGORIES



a 28 pound (12.7 kg.) boy is submerged to 40 percent of his total height, his body weight in water has decreased by approximately 7.5 pounds (3.4 kg.) compared to nearly 18 pounds (8.2 kg.) for the 74 pound (33 kg.) boy. This difference in body weight represents respectively 26.8 and 24.3 percent of the total body weight. The same general trend in body shape and proportions can be observed for girls in Figure 14.

The difference in maximum height submerged between groups varied from 82 to 88 percent for the 28 (12.7 kg.) and 86 (39 kg.) pound boy, compared to 82 and 85 percent for the 26 (11.8 kg.) and 85 (38.5 kg.) pound girls respectively. This difference in height submerged indicates that the head of the smaller child is proportionally larger than the head of the heavier child. These head size differences were reported by a great number of growth and development specialists (e.g. Espenschade, 1967; Lourey, 1972).

The difference in head length between boys and girls will not only influence the height submerged but also the amount of buoyant force needed to support the body with the head safely out of the water. This variation in buoyancy between boys and girls has been reported in the preceding section on page 107. The girls were found to be more buoyant than the boys. However, because of possible difference in the density of body segments between boys and

girls, this difference in net buoyancy cannot be totally attributed to the size of the head.

The dotted lines in Figures 14 and 15 show that the difference between the net buoyancy "arms at the side" and "arms over the head" also increases with body weight. When measured "arms over the head", the net buoyancy of the smaller boy is 2.7 pounds (1.2 kg.) more than when taken in the position "arms at the side". For the heavier boy, this difference in buoyancy is in the order of 7 pounds (3.2 kg.). Figure 14 shows a difference of 1.3 pounds (0.6 kg.) and 7.3 pounds (3.3 kg.) for the smaller and heavier girls respectively. These findings indicate that the smaller boy has heavier arms than the smaller girl. However, this difference in the weight of the arms between sexes keeps decreasing until it is almost equal for the heavier groups.

The variation in the inclination of the different slopes shows that the density and volume change according to the weight of the child.

Comparison of Buoyancy Curves

Because of the variation in the amount and density of different body tissues throughout the human body, it is possible that a boy and a girl may have the same total body volume without having the same buoyancy distribution. Therefore, an analysis between paired subjects was performed

in order to find at what level of submersion boys and girls differed in body volume, hence in buoyancy distribution.

A comparison of buoyancy distribution curves between boys and girls of approximately the same weight and height is presented in Figure 16. The actual weight and height from which those curves were plotted are presented in Table 10.

TABLE 10

WEIGHTS AND HEIGHTS OF BOYS AND GIRLS USED IN THE
BUOYANCY DISTRIBUTION CURVES COMPARISON

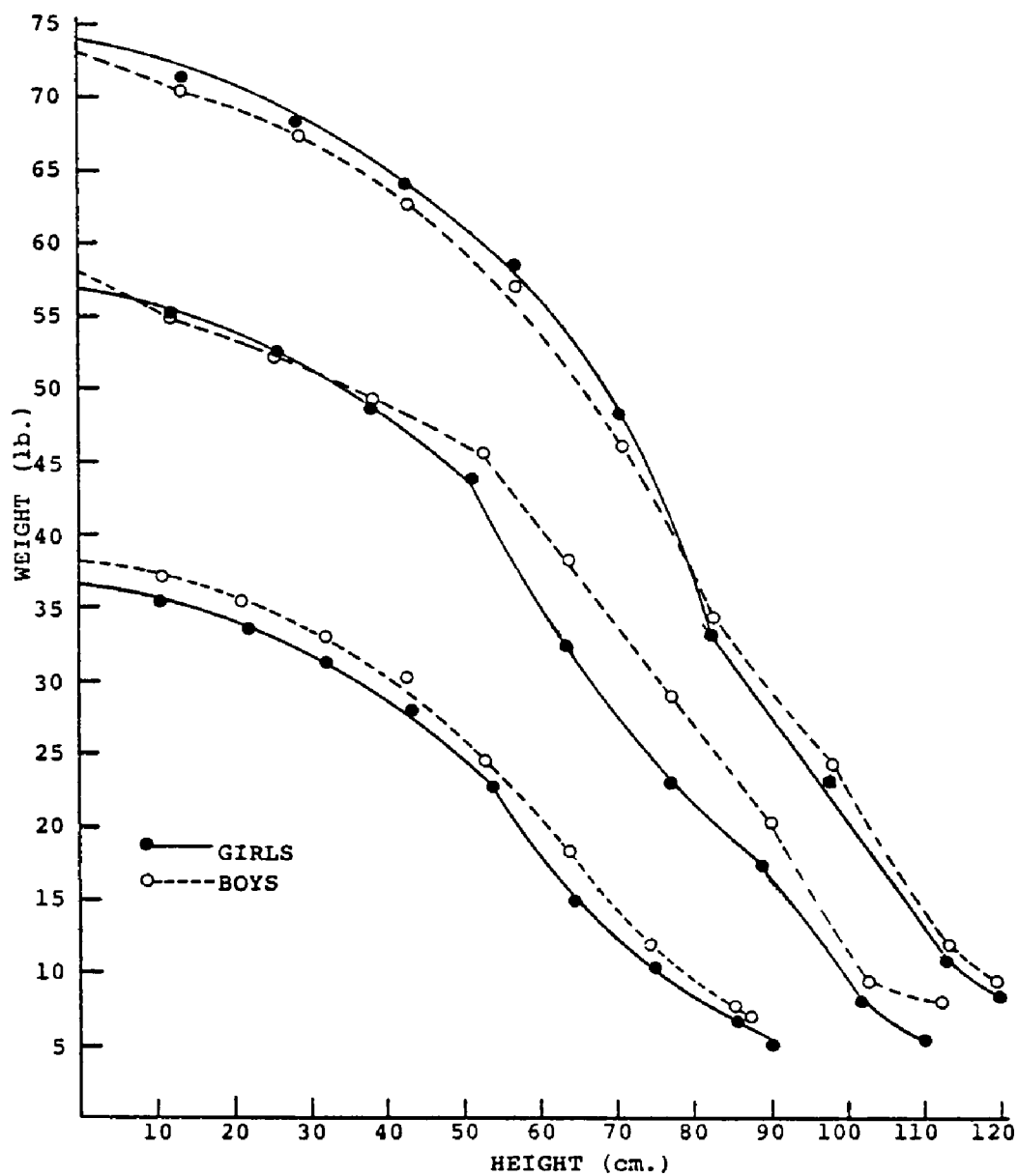
Subjects	WEIGHT				HEIGHT			
	Males		Females		Males		Females	
	lb.	kg.	lb.	kg.	in.	cm.	in.	cm.
1	37.8	17.1	36.3	16.5	41.2	104.7	41.8	106.1
2	56.3	25.5	57.8	26.2	49.8	126.4	49.8	126.6
3	72.0	32.7	73.7	33.4	55.0	139.6	54.6	138.8

When the actual weight and height of two subjects used in a comparison are almost equal, one can conclude that both individuals have approximately the same volume and the same density. Furthermore, one may even assume that the buoyancy distributions of both individuals are the same.

However, a look at Figure 16 shows that the compared curves are not parallel, therefore, the volume is not

FIGURE 16

BUOYANCY DISTRIBUTION CURVES OF
OF A BOY AND A GIRL, PAIRED BY HEIGHT
AND WEIGHT, SELECTED FROM EACH OF
THREE AGE GROUPS



equally the same throughout the total height of both subjects in each comparison.

A further analysis of these curves reveals that the paired boys and girls have approximately the same buoyancy or volume distribution for the first 30 percent of their total height. This level represents the mid-thigh region. The variation between the compared curves starts to increase when the subjects are submerged at 40 percent of their total height. From that point on, the girls are more buoyant than the boys, with the maximum difference being in the hip, waist and upper trunk regions.

Although not significant, the slightly larger hip, chest and biceps anthropometric measurements obtained by the girls (Table 4) will permit them to displace a larger volume of water which facilitates floating. This difference in buoyancy as shown by the curves could also be influenced by the more muscular shoulders of the boys and by the greater accumulation of fat in girls. As stated by Cole (1959), "During childhood girls often have a slight deposit of fat on their arms, legs, chest and abdomen - just enough to give them a curved rather than a flat appearance. Boys have much less" (p. 31).

The present results tend to show that the volume of certain parts of the body are different for boys than for girls. Furthermore, by displacing a larger amount of water, the girls will be better floaters than boys.

The discussion on buoyancy and buoyancy distribution could be summarized in the following manner: a) The girls are more buoyant than the boys in the position "arms at the side" ($p < .01$); b) The buoyancy distribution is approximately the same for both sexes for the first 40 percent of their total height. From that level on, girls are more buoyant than boys; c) The buoyancy distribution curves for different weight categories show that children of different weight differ in body shape and proportions; and d) The volume of body segments are different for boys than for girls.

Extrapolation of Children's Anthropometric and Buoyancy Requirements

Specialists in growth and development such as Cole (1959); Espenschade (1967); Lourey (1973); Tanner (1961) and Smart and Smart (1959), have already established that children differ from adults in body shape and proportions. These variations are due to the fact that various parts of the body grow at different rates and reach their maximum development at different times. Since the growing process is not linear for every part of the body, it is evident that adult clothing should not simply be scaled down to fit children. This matter has been disregarded entirely by water safety device manufacturers.

This lack of linearity between children and adults also exists in buoyancy measurements. In order to

study the possibility of extrapolation, a regression analysis was conducted for two sets of data, one representing children's buoyancy values and one representing adult buoyancy measures. From the values found, a regression line or line of best fit was traced for both sets of data. The lower and higher values from which the regression lines were traced are given numerically in the figures.

Figures 17 and 18 represent buoyancy required to float children and adult subjects when they are submerged up to chin level. The data for children was taken from the present study. The adult data is that of Little (1972). Each plotted point represents a mean value found for a given number of individual scores. Height measurements were grouped by intervals of 5 centimeters for children and adults. Children's weight measurements were arranged in 5 pound intervals while adult weight measurements were arranged by intervals of 10 pounds.

An examination of Figure 17 reveals that extrapolation of children's values from adult data will underestimate the buoyancy requirement for children. Besides, the plotted data for adults is so scattered that it is impossible to even extrapolate specific buoyancy requirements for groups of adults.

From Figure 18, it is obvious that extrapolation from adult data will over-estimate the necessary buoyancy

FIGURE 17

BUOYANCY REQUIRED TO FLOAT SUBJECTS
TO THE LEVEL OF THE CHIN
ACCORDING TO HEIGHT

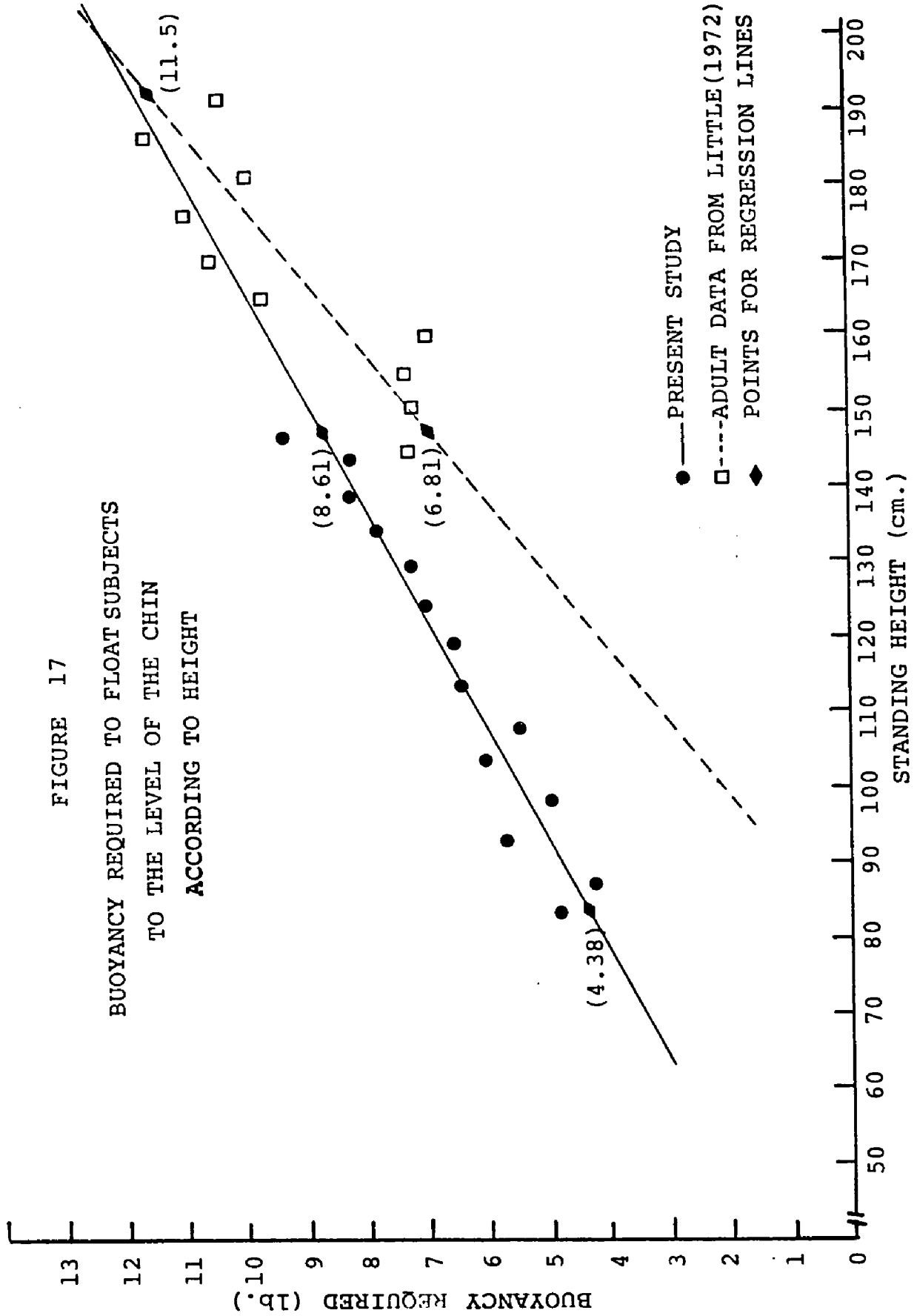
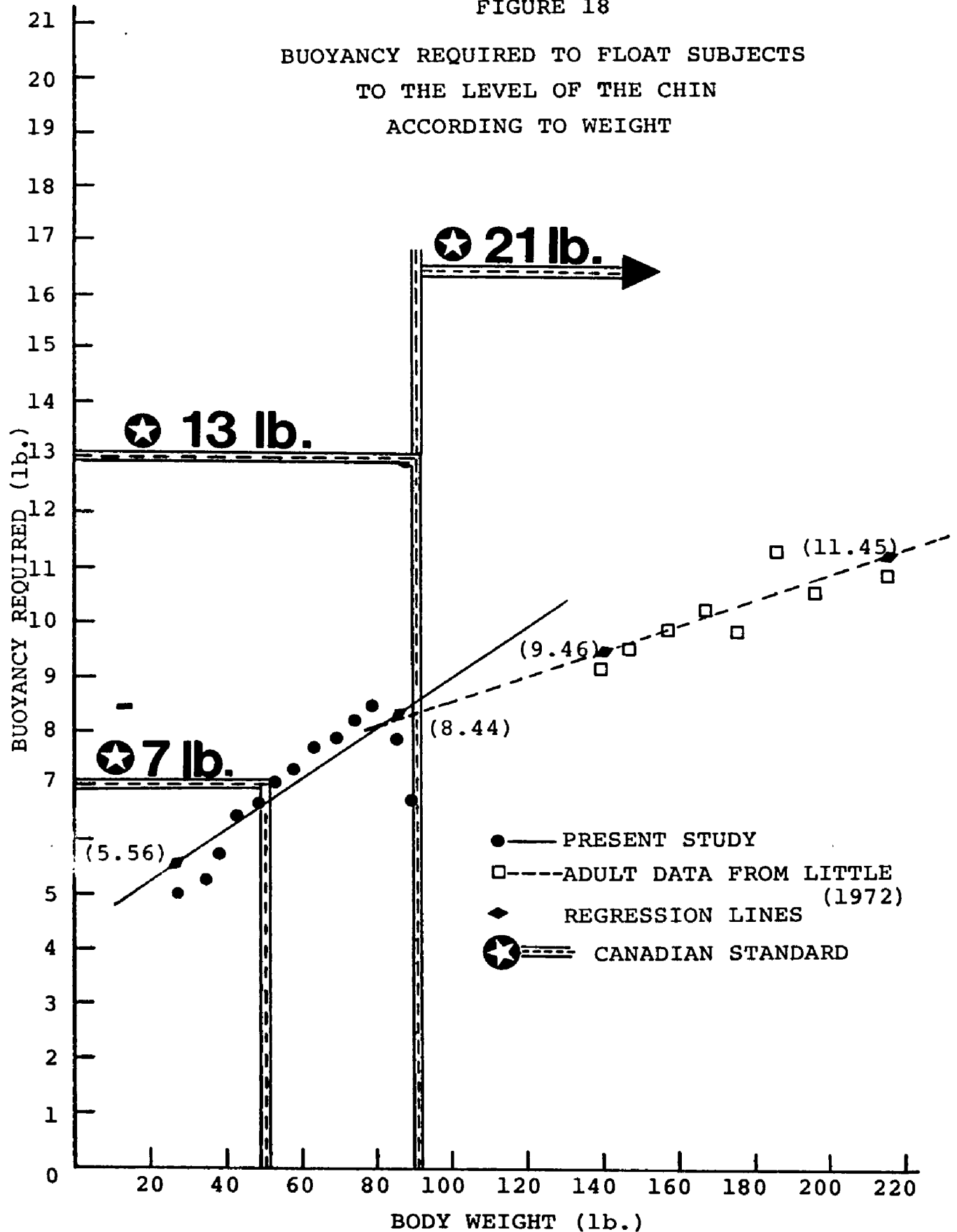


FIGURE 18

BUOYANCY REQUIRED TO FLOAT SUBJECTS
TO THE LEVEL OF THE CHIN
ACCORDING TO WEIGHT



values of children. This partly explains the large buoyancy values recommended in the Canadian standards (lifejacket: 7 pounds for persons weighing less than 50 pounds, 13 pounds for body weight between 45 and 90 pounds and 21 pounds for persons weighing more than 90 pounds; 15½ pounds for personal flotation devices). Furthermore, these large buoyancy requirements also contribute toward the bulkiness of the current lifejackets for children.

Recommendations concerning the amount of buoyant force to be included in different sizes of children's water safety devices are presented in Chapter 5. Recommendations as to the distribution of the buoyant material are also included in Chapter 5.

From the previous discussion, it is obvious that proper sizing as well as the necessary buoyant force needed to be incorporated in the design of children's water safety devices cannot be determined by simply scaling down the values obtained from adult experiments. The poor fit of children's water safety devices was also demonstrated by the Canadian Consumer (1974) and by Goodwin et al. (1973). Discomfort and restriction of movement which are indications of poor sizing were also found in the subjective evaluation of the present study.

Based on the present findings and within the limitations of this study, and according to available

information from adult experiments, it is concluded that anthropometric and buoyancy requirements for children cannot be determined by simply scaling down adult requirements. The hypothesis which states that: "Since body shape and proportions of children differ from that of adults, buoyancy requirement for children cannot be determined by mere geometric scaling or by extrapolation on the basis of total body weight" is thus supported.

Interrelationship Between Body Measures and Buoyancy

Correlation coefficients were computed first to find out the degree of relationship that exists between the two measures of buoyancy "arms at the side" and "arms over the head" and the anthropometric measurements taken, and second, to observe any relationship that may stand out in anthropometric measurements themselves. Because of the quantitative nature of the variables, a Pearson Product Moment Correlation Coefficient was used.

As shown in Table 11, the correlation between "buoyancy down" and "buoyancy up" was in the order of .83. The high correlation between these two variables can be explained in part by the consistently positive difference that existed between the two values obtained for net buoyancy for each subject. Furthermore, the higher net buoyancy requirement scores obtained for the position "arms over the head", is influenced by the weight of the arms

TABLE 11
CORRELATION COEFFICIENTS BETWEEN ANTHROPOMETRIC AND
BUOYANCY MEASUREMENTS FOR BOTH SEXES (N= 203)

Variables	Age	Weight	Height	Head Circum.	Neck Circum.	Arm Scye	Chest Circum.
Age	1.000						
Weight	0.780	1.000					
Height	0.902	0.888	1.000				
Head Circum.	0.429	0.567	0.527	1.000			
Neck Circum.	0.558	0.791	0.654	0.623	1.000		
Arm Scye	0.684	0.747	0.719	0.397	0.576	1.000	
Chest Circum.	0.751	0.912	0.801	0.508	0.774	0.722	1.000
Waist Circum.	0.535	0.830	0.621	0.526	0.737	0.602	0.829
Hip Circum.	0.729	0.936	0.831	0.537	0.698	0.741	0.858
Chest Breadth	0.718	0.840	0.773	0.484	0.690	0.679	0.858
Shoulder Width	0.756	0.878	0.813	0.465	0.679	0.692	0.818
Chest Depth	0.611	0.796	0.645	0.398	0.706	0.622	0.837
Biceps Girth	0.522	0.843	0.622	0.454	0.725	0.628	0.800
Thigh Girth	0.611	0.847	0.707	0.428	0.662	0.570	0.772
Calf Girth	0.648	0.897	0.751	0.509	0.705	0.689	0.801
Leg Length	0.898	0.837	0.966	0.467	0.584	0.668	0.753
Back Length	0.706	0.743	0.788	0.438	0.556	0.664	0.675
Trunk Length	0.782	0.826	0.881	0.462	0.581	0.714	0.736
Sitting Length	0.838	0.889	0.954	0.522	0.672	0.725	0.794
Net Buoyancy Down	0.599	0.633	0.686	0.615	0.642	0.525	0.559
Net Buoyancy Up	0.703	0.869	0.812	0.648	0.791	0.662	0.777

TABLE 11--Continued

Variables	Waist Circum.	Hip Circum.	Chest Breadth	Shoulder Width	Chest Depth	Bicep Girth	Thigh Girth
Age							
Weight							
Height							
Head Circum.							
Neck Circum.							
Arm Scye							
Chest Circum.							
Waist Circum.							
Hip Circum.	1.000	1.000	1.000		1.000		
Chest Breadth	0.782	0.788	0.712	1.000	0.749	1.000	1.000
Shoulder Width	0.775	0.835	0.694	0.682	0.663	0.802	0.787
Chest Depth	0.733	0.753	0.686	0.714	0.737	0.815	0.647
Biceps Girth	0.753	0.786	0.688	0.728	0.592	0.500	0.534
Thigh Girth	0.781	0.783	0.735	0.782	0.574	0.624	0.660
Calf Girth	0.717	0.866	0.728	0.776	0.579	0.646	0.743
Leg Length	0.753	0.772	0.667	0.687	0.447	0.427	0.448
Back Length	0.556	0.714	0.716	0.756	0.652	0.701	0.696
Trunk Length	0.567	0.807	0.768	0.802			
Sitting Length	0.619	0.832	0.583	0.543			
Net Buoyancy Down	0.633	0.557	0.730	0.780			
Net Buoyancy Up	0.431	0.786					
	0.678						

TABLE 11--Continued

Variables	Calf Girth	Leg Length	Back Length	Trunk Length	Sitting Length	Net Buoyancy Down	Net Buoyancy Up
Age							
Weight							
Height							
Head Circum.							
Neck Circum.							
Arm Scye							
Chest Circum.							
Waist Circum.							
Hip Circum.							
Chest Breadth							
Shoulder Width							
Chest Depth							
Biceps Girth							
Thigh Girth							
Calf Girth	1.000						
Leg Length	0.679	1.000					
Back Length	0.651	0.725	1.000				
Trunk Length	0.727	0.816	0.685	1.000			
Sitting Length	0.770	0.892	0.788	0.880	1.000		
Net Buoyancy Down	0.513	0.650	0.580	0.569	0.671	1.000	
Net Buoyancy Up	0.778	0.686	0.719	0.719	0.804	0.833	1.000

which increase in size normally parallel to the increase in body size and weight.

The correlations between all anthropometric variables and "net buoyancy up" were higher than the relationship which existed between these same variables and "net buoyancy down". This higher correlation in favor of "buoyancy up" is explained in part by the greater variation in individual buoyancy scores obtained under this condition. The variation in individual scores for "buoyancy down" was between 5.0 and 8.4 lb., whereas for "buoyancy up", the measures varied from 7.0 to 15.2 lb. This large variation in the scores obtained for "buoyancy up" will permit a better rank order. Also, the error in measurement due to the difficulty of determining precisely the optimum level of the chin for the last buoyancy reading would have a lesser effect on these large scores.

Of all the variables, weight, height and sitting height had the highest correlation with both measures of buoyancy. (Buoyancy down and weight = .663; height = .686; sitting height = .671: Buoyancy up and weight = .869; height = .812; sitting height = .803). Height and sitting height were two variables which contributed the most to the prediction of adult buoyancy in both studies by Lane and Mitchem (1964) and Mitchem and Lane (1967). The comparatively high relationship between sitting height and both buoyancy measurements (.671 and .804) could be explained by

the volume of displaced water since of all parts of the body, it is the trunk that tends to displace the greatest amount of water in relation to its weight. The same inter-relationship could be used to explain the correlation between weight and buoyancy readings (.633 and .869).

Although weight was the single variable which correlated most highly with "buoyancy up" (.869), height had the larger relationship with "buoyancy down" (.686). Biceps girth had the lowest correlation with "buoyancy down" (.427) and head circumference had the lowest relationship with "buoyancy up" (.648). This low correlation between head and net buoyancy up could be explained in part by the net buoyancy up values which are related not only to the weight of the head, but also to the arms and part of the shoulder which were out of the water.

Other variables such as chest and hip circumferences, chest breadth and shoulder width, which represent to a certain degree measures of volume, correlate also positively with both measures of buoyancy (between .543 and .559 for buoyancy down, and between .730 to .786 for buoyancy up).

The highest relationship between two anthropometric variables was found to be between height and leg length (.966), while the lowest correlation involved head circumference and arm scye (.397).

Weight showed the best correlation with almost all other anthropometric variables, while head circumference had the lowest relationship with practically all anthropometric measurements.

In summary, "net buoyancy arms over the head" shows a consistently higher relationship with other body variables (r varies between .64 and .86) than does "net buoyancy down" (r varies between .42 and .68). The correlation between the two net buoyancy measures is .83 which one might expect on the basis of the similarity in which both buoyancy measures were taken.

Buoyancy Prediction

In the previous section, the buoyancy and anthropometric measurements were submitted to a correlation coefficient analysis. This type of statistical analysis allows the researcher to measure or observe the linear relationship between one independent variable and a dependent variable. However, to be more practical, one often studies the relationship between a group of variables in the hope that any relationship that is found can be used to help in making "estimates" or "predictions" of a particular variable from one or more of the variables of the same group. The methods that have been designed to handle these types of problems are known as regression methods.

Multiple regression is a method by which one important variable can be predicted by means of several

other variables. Multiple regression allows the investigator to study the linear relationship between a set of independent variables and a number of dependent variables while taking into account the interrelationship among independent variables (Nie et al., 1975).

The basic concept of multiple regression is to provide a linear combination of independent variables which will correlate as high as possible with the dependent variables. This linear combination can then be used to predict values of the dependent variables (Nie et al., 1975).

In this particular research, an attempt was made to predict net buoyancy at chin level by using anthropometric measurements. In this case, the dependent variable is the buoyancy measurements taken in the position "arms at the side" or "arms over the head", while the anthropometric measures and age are the independent variables. Written in an equation form, this would equal:

$$D = W_1I_1 + W_2I_2 \dots\dots\dots W_NI_N + C$$

Where "D" is the dependent variable or net buoyancy, the I's are the independent variables or anthropometric measures and age, the W's are the regression coefficients or the weight which for a given variable within a certain group is constant, and "C" is a constant. This value changes with the number of independent variables considered.

There is more than one regression program and each one has some advantages and some disadvantages. The regression program chosen for this study is called "stepwise multiple regression". This procedure permits independent variables to be entered on the basis of some pre-established statistical criteria. This procedure allows the investigator to isolate a subset of available "predictor" variables that will yield an optimal prediction equation with only a few terms (Nie et al., 1975).

One objective of this study was to attempt to predict net buoyancy requirements using only a few anthropometric measurements. To do this, the forward stepwise regression equation analysis constructs a prediction equation, one independent variable at a time. First, it will choose the single variable which is the best predictor; next, it will pick the second independent variable which provides the best prediction in conjunction with the first variable and so on. This process will go on until the desired number of independent variables to be included in the prediction formula is reached, or until the independent variables do not make a significant contribution to the prediction equation (Nie et al., 1970).

Prediction of Buoyant Force Needed to
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Tables 12, 13 and 14 contain a summary of the regression analysis for the total group of subjects (N= 203)

TABLE 12

SUMMARY OF THE MULTIPLE REGRESSION ANALYSIS BETWEEN
NET BUOYANCY DOWN AND ANTHROPOMETRIC MEASURES
FOR BOYS AND GIRLS (N= 203)

Variables	Multiple r	Square r	Change in r	Simple r
Height	0.686	0.471	0.471	0.686
Head Circumference	0.750	0.563	0.092	0.621
Neck Circumference	0.763	0.582	0.019	0.642
Waist Circumference	0.784	0.614	0.032	0.432
Chest Breadth	0.789	0.622	0.008	0.583
Thigh Girth	0.793	0.628	0.006	0.448
Chest Circumference	0.794	0.631	0.003	0.560
Back Length	0.796	0.633	0.002	0.580
Calf Girth	0.797	0.635	0.002	0.512
Weight	0.799	0.638	0.003	0.633
Hip Circumference	0.801	0.641	0.003	0.558
Arm Scye	0.802	0.643	0.002	0.524
Biceps Girth	0.803	0.645	0.002	0.427
Trunk Length	0.804	0.646	0.001	0.568
Sitting Height	0.804	0.647	0.001	0.672
Age	0.804	0.648	0.001	0.599
Shoulder Width	0.804	0.647	0.001	0.543
Chest Depth	0.804	0.647	0.000	0.448
Leg Length*	0.804	0.647		
Constant				

*Not computed because of insufficient F-level

TABLE 13

SUMMARY OF THE MULTIPLE REGRESSION ANALYSIS BETWEEN
NET BUOYANCY DOWN AND ANTHROPOMETRIC MEASURES
FOR BOYS (N= 99)

Variables	Multiple r	Square r	Change in r	Simple r
Height	0.701	0.492	0.492	0.701
Neck Circumference	0.751	0.563	0.072	0.691
Head Circumference	0.773	0.598	0.035	0.634
Waist Circumference	0.793	0.629	0.031	0.453
Chest Breadth	0.812	0.660	0.030	0.649
Calf Girth	0.816	0.667	0.007	0.517
Weight	0.822	0.676	0.010	0.690
Biceps Girth	0.827	0.684	0.007	0.512
Chest Circumference	0.830	0.688	0.005	0.670
Age	0.834	0.695	0.007	0.617
Trunk Length	0.836	0.699	0.004	0.542
Chest Depth	0.839	0.703	0.005	0.500
Sitting Height	0.840	0.705	0.002	0.693
Back Length	0.841	0.707	0.002	0.545
Shoulder Width	0.841	0.708	0.001	0.527
Leg Length	0.842	0.708	0.000	0.655
Thigh Girth	0.842	0.709	0.001	0.547
Arm Scye	0.842	0.709	0.000	0.541
Hip Circumference*				
Constant				

*Not computed because of insufficient F-level

TABLE 14

SUMMARY OF THE MULTIPLE REGRESSION ANALYSIS BETWEEN
NET BUOYANCY DOWN AND ANTHROPOMETRIC MEASURES
FOR GIRLS (N= 104)

Variables	Multiple r	Square r	Change in r	Simple r
Height	0.708	0.501	0.501	0.708
Head Circumference	0.759	0.577	0.076	0.575
Waist Circumference	0.774	0.600	0.023	0.399
Back Length	0.787	0.619	0.019	0.620
Neck Circumference	0.796	0.633	0.014	0.551
Chest Circumference	0.802	0.643	0.010	0.498
Leg Length	0.808	0.652	0.009	0.702
Arm Scye	0.811	0.658	0.006	0.515
Thigh Girth	0.813	0.662	0.004	0.499
Weight	0.816	0.665	0.004	0.622
Hip Circumference	0.820	0.673	0.008	0.562
Age	0.821	0.674	0.001	0.627
Calf Girth	0.821	0.675	0.000	0.554
Sitting Height	0.822	0.675	0.000	0.689
Chest Breadth	0.822	0.675	0.000	0.513
Biceps Girth	0.822	0.675	0.000	0.435
Shoulder Width*				
Chest Depth*				
Trunk Length*				
Constant				

*Not computed because of insufficient F-level

for boys (N= 99) and for girls (N= 104) respectively. For these three groups, the dependent variable was "net buoyancy down" or "arms at the side".

The numbers in the column entitled "Multiple r" represent the correlation between the dependent variable and one or more independent variables. The "r-square" can be interpreted as being the proportion of the variance in the dependent variable which is accounted for by the regression equation. The "r-square change" is the change in r-square from the value of the previous step. "Simple r" is the correlation between the independent variable and the dependent variable.

By examining Tables 12, 13 and 14, it is apparent that height, head and neck circumferences are the three most important contributors to the prediction of buoyancy "arms at the side" for boys and girls combined and for boys alone. The three most important variables for the prediction of buoyancy for girls are height, head and waist circumferences. Hence, height and head circumference appear within the first three variables in each prediction equation.

From Table 12, where boys and girls are combined, it is apparent that there is only a small increase in the multiple correlation coefficient from the third variable onward. Numerically, this multiple correlation increases

from .763 for three variables to .804 for eighteen variables. As shown in Table 13, the multiple correlation calculated for the boys extends from .773 to .842 for three and eighteen anthropometric measures respectively. The same tendency is shown in Table 14, which presents the data for girls only. The calculated multiple correlation extends from .774 for the first three variables to .822 for sixteen measures.

The r-square or the prediction number also shows the same trend for the three groups of subjects. For the combined group, the increase in the prediction is in the order of 11.1 percent for the first three variables comparatively to 6.5 percent for the remainder of the variables. The first three variables increase the boys' prediction by 10.6 percent while the last fifteen measures increase it by only an additional 11.1 percent. The girls' prediction equation increases by 9.9 percent when calculated from the first three variables. The last fifteen variables will increase the prediction accuracy by only an additional 7.5 percent.

These comparatively small increases in multiple regression and in the prediction percentage after the first three independent variables suggest that the amount of precision obtained by adding more variables in the prediction equation a) does not justify the work involved in taking all anthropometric measurements; and b) increases the risk

of error associated with a great number of calculations.
The prediction equation can be written:

$$F_{BD} = W_1H + W_2h + W_3n + C$$

Where F_{BD} = Required buoyancy in the position
"arms at the side"

H = Standing height in centimeters

h = Head circumference in centimeters

n = Neck circumference in centimeters

C = Constant (Y intercept)

W's = Unstandardized regression
coefficients.

Prediction of Buoyant Force Needed to
Support the Body when Submerged at
Chin Level with Arms Over the Head

Tables 15, 16 and 17 present a summary of the regression analyses calculated for the combined groups of subjects (N= 203), for the boys (N= 99) and for the girls (N= 104) respectively. The dependent variable for these three analyses was "net buoyancy up" or "arms over the head".

An examination of Tables 15, 16 and 17 reveals that weight, head and neck circumferences are the three best predictors of "net buoyancy up" for the combined groups and for boys alone. When the prediction equation for "buoyancy up" is calculated from the girls' data, weight,

TABLE 15

SUMMARY OF THE MULTIPLE REGRESSION ANALYSIS BETWEEN
NET BUOYANCY UP AND ANTHROPOMETRIC MEASURES
FOR BOYS AND GIRLS (N= 203)

Variables	Multiple r	Square r	Change in r	Simple r
Weight	0.869	0.756	0.756	0.869
Head Circumference	0.891	0.794	0.038	0.657
Neck Circumference	0.898	0.806	0.012	0.791
Waist Circumference	0.906	0.821	0.015	0.680
Shoulder Width	0.908	0.824	0.003	0.780
Hip Circumference	0.909	0.827	0.003	0.787
Back Length	0.910	0.829	0.002	0.685
Chest Depth	0.911	0.830	0.001	0.652
Thigh Girth	0.912	0.832	0.002	0.697
Calf Girth	0.912	0.832	0.000	0.778
Height	0.913	0.833	0.001	0.812
Trunk Length	0.913	0.833	0.000	0.720
Arm Scye	0.913	0.834	0.001	0.662
Leg Length	0.913	0.834	0.000	0.760
Chest Circumference	0.913	0.834	0.000	0.778
Chest Breadth	0.914	0.835	0.001	0.730
Sitting Height	0.914	0.835	0.000	0.806
Age	0.914	0.835	0.000	0.704
Biceps Girth	0.914	0.835	0.000	0.701
Constant				

TABLE 16

SUMMARY OF THE MULTIPLE REGRESSION ANALYSIS BETWEEN
NET BUOYANCY UP AND ANTHROPOMETRIC MEASURES
FOR BOYS (N= 99)

Variables	Multiple r	Square r	Change in r	Simple r
Weight	0.871	0.758	0.758	0.871
Neck Circumference	0.890	0.792	0.034	0.833
Head Circumference	0.899	0.809	0.017	0.692
Waist Circumference	0.905	0.819	0.010	0.683
Chest Circumference	0.907	0.822	0.003	0.829
Age	0.910	0.829	0.007	0.686
Biceps Girth	0.913	0.833	0.004	0.725
Chest Depth	0.913	0.834	0.001	0.685
Leg Length	0.914	0.835	0.001	0.726
Back Length	0.914	0.835	0.000	0.655
Sitting Height	0.914	0.835	0.000	0.794
Height	0.914	0.835	0.000	0.789
Shoulder Width	0.914	0.835	0.000	0.734
Trunk Length	0.914	0.835	0.000	0.677
Arm Scye	0.914	0.835	0.000	0.678
Chest Breadth	0.914	0.836	0.001	0.725
Thigh Girth	0.914	0.836	0.000	0.717
Hip Circumference	0.914	0.836	0.000	0.793
Calf Girth*				
Constant				

*Not computed because of insufficient F-level

TABLE 17

SUMMARY OF THE MULTIPLE REGRESSION ANALYSIS BETWEEN
NET BUOYANCY UP AND ANTHROPOMETRIC MEASURES
FOR GIRLS (N= 104)

Variables	Multiple r	Square r	Change in r	Simple r
Weight	0.890	0.793	0.793	0.890
Chest Depth	0.908	0.825	0.032	0.615
Head Circumference	0.919	0.845	0.020	0.613
Waist Circumference	0.926	0.857	0.012	0.672
Shoulder Width	0.930	0.866	0.009	0.850
Hip Circumference	0.933	0.870	0.004	0.810
Back Length	0.935	0.874	0.004	0.733
Neck Circumference	0.937	0.878	0.004	0.741
Calf Girth	0.939	0.881	0.007	0.840
Age	0.941	0.885	0.004	0.747
Chest Breadth	0.943	0.888	0.003	0.741
Trunk Length	0.943	0.890	0.002	0.802
Thigh Girth	0.944	0.892	0.002	0.779
Chest Circumference	0.945	0.892	0.000	0.755
Height	0.945	0.893	0.001	0.851
Sitting Height	0.946	0.894	0.001	0.833
Biceps Girth	0.946	0.895	0.001	0.738
Arm Scye	0.946	0.895	0.000	0.647
Leg Length*				
Constant				

*Not computed because of insufficient F-level

chest depth and head circumference are the most important variables.

From Tables 15, 16 and 17, it is apparent that the multiple correlation and the prediction numbers do not increase significantly beyond the third variable. The multiple correlation for the total group of subjects is .898 after the first three variables compared to .914 for nineteen variables. When calculated for the group of boys, the multiple correlation coefficient increases from .899 at the third variable to .914 at the eighteenth variable. The multiple correlation coefficients calculated after three and eighteen variables were .919 and .946 respectively.

The percentage of prediction or r-square also shows a comparatively small increase from the fourth variable on. As shown in Table 16, "buoyancy up" can be predicted at 80.6 percent using three variables compared to 83.5 percent with nineteen measures. This is an increase of 2.9 percent. The first three variables increase the boys' buoyancy up prediction by 5.1 percent (75.8 to 80.9) while the last fifteen variables increase it by 2.7 percent (80.9 to 83.6). The girls' "buoyancy up" can be predicted at 84.5 percent accuracy with three variables compared to 89.6 percent with eighteen measures, therefore an increase of 5 percent. The equation for buoyancy "arms over the head" can be written:

$$FB_U = w_1W + w_2h + w_3n + C$$

Where F_{BU} = Required buoyant force in the position
"arms over the head"

W = Weight of the body in pounds

h = Head circumference in centimeters

n = Neck circumference in centimeters

C = Constant (Y intercept)

w's = Unstandardized regression
coefficients.

Selection of Equations to Predict Buoyancy

The difference between regression equations developed for boys and girls was not sufficient to warrant two separate equations. Therefore, the regression equations for boys and girls combined were retained for prediction of buoyancy "arms at the side" and "arms over the head". Also, because of the small increase of the multiple correlation coefficient after the first three variables, it was decided to compute both prediction equations using only the top three variables.

Tables 18 and 19 show the variables that were retained for the prediction equations as well as a statistical summary of the total prediction equations and individual variables. The multiple "r" represents the correlation coefficient between the buoyancy position and the group of three independent variables. The "r-square" is the percentage of prediction, and the standard error is

TABLE 18

STATISTICAL SUMMARY FOR NET BUOYANCY DOWN
PREDICTION EQUATION AND INDEPENDENT
VARIABLES USED FOR ALL SUBJECTS
(N= 203)

Multiple R	0.76284		
R-Square	0.58192		
Standard Error	0.79489		
Variables in the Equation			
Variables	W	Standard Error of W	F
Height	0.03946	0.00601	43.128
Head Circumference	0.19539	0.04201	21.632
Neck Circumference	0.13643	0.04512	9.142
Constant	-11.62319		

TABLE 19

STATISTICAL SUMMARY FOR NET BUOYANCY UP PREDICTED
EQUATION AND INDEPENDENT VARIABLES USED
FOR ALL SUBJECTS (N= 203)

Multiple R	0.89750		
R-Square	0.80551		
Standard Error	0.96321		
Variables in the Equation			
Variables	W	Standard Error of W	F
Weight	0.09712	0.00823	139.145
Head Circumference	0.23563	0.05048	21.786
Neck Circumference	0.22563	0.06501	12.044
Constant	-12.12616		

the standard deviation of the residual. Since the residual is the difference between predicted and actual value, the standard error is the true error in prediction.

As for each variable, in the regression equations the "w" represents the unstandardized regression coefficients. The "F" ratios are used in tests of significance for the individual w's.

Sample Calculations

For a better understanding of the prediction equation, the buoyancy of a child (subject No. 4) is calculated for the positions "arms at the side" and "arms over the head". The subject chosen had a weight of 56.25 lb. (25.5 kg.), a standing height of 49.8 in. (126.4 cm.), and a head and neck circumference of 21.2 in. (53.8 cm.) and 11.2 in. (28.4 cm.) respectively.

Buoyancy "arms at the side" (Table 18)

$$\begin{aligned} F_{BD} &= w_1H + w_2h + w_3n + C \\ &= (0.03946)(126.4) + (0.19539)(53.8) + (0.13643) \\ &\quad (28.4) - 11.62319 \\ &= 7.75 \pm 0.795 \text{ lb.} \end{aligned}$$

Buoyancy "arms over the head" (Table 19)

$$\begin{aligned} F_{BU} &= w_1W + w_2h + w_3n + C \\ &= (0.09712)(56.25) + (0.23563)(53.8) + (0.22563) \\ &\quad (28.4) - 12.12612 \\ &= 12.42 \pm 0.963 \text{ lb.} \end{aligned}$$

The actual net buoyancy of the subject as measured during the experiment was 7.9 lb. for buoyancy "arms at the side" and 11.9 lb. for buoyancy "arms over the head".

Significance of the Variables Chosen

How can one explain that the combination of height and head and neck circumferences is the best predictor of "buoyancy down", whereas the combination of weight and head and neck circumferences is the best predictor of "buoyancy up"?

The importance of weight and height in the prediction of buoyancy could be partly explained by the fact that height is the variable that has the highest correlation (.686) with buoyancy "arms at the side", whereas weight has the highest correlation (.869) with buoyancy "arms over the head" (Table 11). This relationship of weight and height to buoyancy could also be explained by the fact that these two variables are good indicators of the morphology or body build of the child.

As for the influence of the second variable, it could be explained in part by the fact that the head is fairly large in comparison to the whole body (one-sixth to one-eighth of body weight), and that it was outside the water when net buoyancy readings were recorded. Since it was not submerged, its size would have a direct influence on the last or chin buoyancy reading. In fact, the buoyant force needed to support the body when submerged up to the

chin would be directly proportional to the weight of the part(s) of the body which is outside the water.

Of the first three parameters, neck circumference is the variable that has the lowest influence on the buoyancy prediction. When it is added to the prediction equation for "arms at the side", it increases the prediction by 2 percent compared to 9 percent for the head. For the prediction of buoyancy "arms over the head", the neck increases the prediction accuracy by 1 percent in comparison to 4 percent for the head.

The influence of the neck on the prediction of buoyancy could be partly explained by the fact that a portion of the neck was outside the water when net buoyancy was recorded. The length of the neck unsubmerged depends on the total length of the neck and also on the shape of the chin which influences the total height of submersion.

In the previous discussion, an attempt was made to explain the selection of weight, height, head and neck circumferences as good predictors of buoyancy. The explanations used were based on morphological characteristics and on statistical findings. The choice and number of variables were also based on practical aspects such as the use of simple and non-expensive equipment, and on the objectivity and reliability of measurements.

Comparison Between Prediction Equations

An examination of Tables 18 and 19 reveals that head and neck circumferences appear in both prediction equations. However, height is included only in the equation predicting buoyancy "arms at the side", whereas weight is the best predictor of buoyancy "arms over the head". All the reasons why height was selected as the best predictor in one equation and weight in the other equation, and why one equation predicts more accurately than the other, are not known. Nevertheless, some possible explanations are presented in the following paragraph.

Statistically, height is the single variable that has the highest relationship ($r = .686$) with the buoyancy scores obtained in the position "arms at the side". As for weight, it is the single variable that has the highest relationship ($r = .869$) with buoyancy "arms over the head". Since the first independent variable chosen in each equation is the one that correlates the highest with the dependent variable, therefore, the variables height and weight came out first in their respective equation.

The possible variation in height of the chin level could also be an explanation for having different variables in the prediction equations. If the ninth buoyancy reading taken at a level corresponding to 80 percent of the child's total height is used as the dependent variable instead of the tenth or chin level buoyancy reading, weight is

selected as the best predictor of buoyancy in both equations.

The following explanations, which are also related to the previous discussion, illustrate some possible reasons why the prediction of buoyancy "arms at the side" is less accurate ($r^2 = .582$) than the prediction for buoyancy "arms over the head" ($r^2 = .806$).

As explained above, when the ninth buoyancy reading is used as the maximum height submerged, the buoyancy prediction accuracy for the position "arms at the side" increases by 17 percent (from 58.2 to 73.2). The buoyancy prediction accuracy for the position "arms over the head" also increases by almost 10 percent (from 80.6 to 90.2). This would indicate that even with all the precautions taken (feet flat, legs and trunk straight, head at horizontal), the exact level at the chin was less precise than the level of the pre-determined ninth readings. This inconsistency in measurement can be explained first, by the variation in the distance of submersion between the ninth and tenth buoyancy readings. This distance varied from 2 centimeters for smaller subjects to over 10 centimeters for the tallest subjects. Second, the shape of the chin will influence the height of submersion. A child with a projected chin would have been lowered less than a child with a short and round chin, since submersion was stopped when the water touched the bottom of the chin. Third,

a slight forward or backward rotation of the neck around a frontal axis would also have influenced the total height of submersion.

When looking at absolute numbers, it is logical to suppose that the same amount of error, if any, will have less influence if it applies to a larger total score. For example, a one pound error would have a greater influence if it is distributed on a net buoyancy score of 7 lb. for "arms at the side" than if it was distributed on a net buoyancy score of 14 lb as measured in the position "arms over the head".

In summary, the choice of these two prediction equations is based on:

- a) the small increase in the correlation and the small difference recorded in the prediction accuracy when using individual equations do not justify the need for separate prediction equations for boys and girls;
- b) the inconvenience of having to take different anthropometric measurements for boys and girls, and the possibility of making errors when using a different series of numbers in each calculation; and
- c) the elimination of special instruments that must be handled with extra care to obtain accurate readings, e.g. chest depth.

Testing the Prediction Equation

The last section of this research analysis consisted of the testing of the prediction equations. The results of this small sample should yield pertinent information on the accuracy of the prediction formulae.

Subjects

A group of twenty subjects, 11 boys and 9 girls, who were not measured in the original sample (N= 203), were tested. The subjects' weight varied between 28.5 lb. (12.7 kg.) and 87.25 lb. (39.6 kg.). Their height varied from 37.6 in. (95.5 cm.) to 58.3 in. (148 cm.).

Measurements

Height, weight, head and neck circumferences were the only anthropometric measurements taken. The scores for "net buoyancy down" and "net buoyancy up" were also recorded for each subject. The means and standard deviations of the anthropometric measurements are presented in Table 20.

Buoyancy Test

The buoyancy test consisted of submerging the subjects once up to their chin, at which point buoyancy measurements were recorded in both positions. The predicted buoyancy was calculated by placing the proper anthropometric values into the prediction formulae.

Actual and Predicted Values

The actual and predicted values for the positions "arms at the side" and "arms over the head" are presented in

TABLE 20

MEANS AND STANDARD DEVIATIONS OF THE FOUR
ANTHROPOMETRIC MEASUREMENTS (N= 20)

Variables	Means		S.D.	
	lb.	kg.	lb.	kg.
Weight	50.73	23.0	16.61	7.53
	cm.	in.	cm.	in.
Height	119.39	47.0	17.04	6.7
Neck Circumference	26.69	10.5	1.72	0.7
Head Circumference	52.15	20.5	1.90	0.8

Tables 21 and 22 respectively. Table 23 contains the results of the correlation between the actual and predicted buoyancy, as well as the t-test values.

As shown in Table 23, there is a very high relationship between actual and predicted buoyancy, which would tend to indicate a high prediction capability. Also, the results of the t-tests show no significant difference between the actual and predicted buoyancy. This means that the regression equations predict buoyancy beyond simple chance.

Summary

From the previous discussion, it can be concluded that the amount of buoyant force needed by a child in order to float safely with his/her head and arms out of the water

TABLE 21

ACTUAL AND PREDICTED MEASURES FOR NET
BUOYANCY ARMS AT THE SIDE (N= 20)

Actual Values		Predicted Values		Percent Difference
lb.	kg.	lb.	kg.	
9.39	4.26	8.32	3.77	-12.6
6.93	3.14	6.77	3.07	-02.3
4.02	1.82	5.56	2.52	38.3*
7.37	3.34	8.05	3.67	09.2
8.27	3.75	7.44	3.37	-11.2
4.69	2.13	4.73	2.15	00.8
6.70	3.04	6.08	2.76	-10.2
6.26	2.84	6.30	2.86	00.6
8.49	3.85	8.14	3.69	-04.3
8.27	3.75	7.57	3.43	-09.2
6.48	2.94	6.78	3.07	04.6
7.60	3.45	7.26	3.29	-04.7
6.70	3.04	6.93	3.14	03.4
6.26	2.84	5.63	2.55	-11.2
9.76	4.43	8.67	3.93	-12.6
9.16	4.15	8.87	4.02	-03.3
6.70	3.04	6.34	2.88	-05.7
7.37	3.34	6.54	2.97	-12.7
6.59	2.99	6.37	2.89	03.5
5.81	2.63	5.59	2.54	-03.9

*A re-examination of the anthropometric and buoyancy data in this case suggests that a possible error in measurement may have occurred.

TABLE 22

ACTUAL AND PREDICTED MEASURES FOR NET
BUOYANCY ARMS OVER THE HEAD (N= 20)

Actual Values		Predicted Values		Percent Difference
lb.	kg.	lb.	kg.	
14.02	6.36	13.94	6.32	-00.5
10.73	4.87	10.23	4.64	-04.9
6.93	3.14	8.79	3.99	21.2*
12.50	5.67	13.18	5.98	04.6
13.20	5.99	12.10	5.49	-09.1
7.37	3.34	7.23	3.28	-01.9
9.83	4.46	9.94	4.51	01.1
9.39	4.26	9.92	4.50	05.6
13.40	6.08	13.35	6.05	-00.4
13.51	6.13	12.43	5.64	-08.7
10.73	4.87	10.59	4.80	-01.3
12.51	5.67	11.42	5.18	-09.5
10.95	4.97	10.99	4.98	00.4
9.16	4.15	8.54	3.87	-07.3
16.54	7.50	15.21	6.90	-08.7
14.30	6.49	15.84	7.18	10.8
9.61	4.36	9.57	4.34	-00.4
10.73	4.87	10.38	4.71	-03.4
9.27	4.20	9.57	4.34	03.2
8.27	3.75	8.97	4.07	08.5

*A re-examination of the anthropometric and buoyancy data in this case suggests that a possible error in measurement may have occurred.

TABLE 23

CORRELATIONS AND t-TEST VALUES BETWEEN ACTUAL
AND PREDICTED BUOYANCY IN BOTH POSITIONS

Variables	r	t
Arms at the side	.916	1.61
Arms over the head	.941	.20

can be predicted through the use of a few anthropometric measurements. It can also be concluded that buoyancy "arms over the head" can be predicted with more accuracy than buoyancy "arms at the side".

Based on the present findings and within the limitations of this study, the hypothesis which states: "Buoyancy of a child can be predicted from a few anthropometric measurements", is thus supported.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

Summary

The results of this study may be summarized as follows:

Hypothesis One stated and subjective evidence supported the idea that "the aesthetic and functional features of contemporary water safety devices are not suitable for young children".

Based on the results obtained from the subjective evaluation, it is concluded that, in general, existing children's water safety devices are disliked and not worn by children because of:

- a) bulkiness and poor fit;
- b) overheating; and
- c) difficulty in moving around in a boat and/or swimming while wearing them.

Children also experience difficulty in donning and wearing the lifejackets because of:

- a) the long tapes which must be secured in the back; and
- b) the difficulty in pulling the keyhole type jacket over the head.

Children preferred the personal flotation devices to the lifejackets because of their flexibility, lightness, and aesthetic look. However, their shape and fit need definite improvement.

Hypothesis Two stated that "since the body shape and proportions of children differ from that of adults, buoyancy requirements for children cannot be determined by mere geometric scaling or by extrapolation on the basis of total body weight".

When adults' and children's buoyancy values are compared and a linear regression line traced for both sets of data, it is evident that:

- a) extrapolation of children's buoyancy values from adult data will under-estimate the buoyancy requirement for children when standing height is used as the basis of comparison; and,
- b) extrapolation from adult data will over-estimate the necessary buoyancy values of children when weight is used as the basis of comparison.

The range of values for each anthropometric variable necessitates the manufacturing of several size water safety devices or a few which are highly adjustable.

Hypothesis Three stated that "the buoyancy of a child can be predicted from a few anthropometric measurements". A multiple regression equation was derived by using net buoyancy measures as the dependent variables and various combinations of anthropometric measures as the independent variables.

The formula for "net buoyancy up" using weight and head and neck circumferences as independent variables resulted in a higher buoyancy prediction of $r^2 = .80$, than the formula for "net buoyancy down" which predicted at $r^2 = .58$ using height and head and neck circumferences as independent variables.

When both formulae were used to predict the buoyancy values of a group of twenty subjects, it was demonstrated that the formula predicting "net buoyancy up" is more accurate than the "net buoyancy down" formula.

Discussion of the Limitations and Value of this Study

It was the purpose of this study to find criteria based on anthropometric and buoyancy measures of children which could provide a more satisfactory basis for the future design and construction of water safety devices.

Limitations

1. The sample in this study was neither stratified

nor randomized thus preventing generalization to a national population of Canadian children.

2. The anthropometric measuring devices, although adequate, might have been more precise if equipment used by Snyder et al. (1975) had been available at the time of the study.

Values and Recommendations

Even with the above weaknesses in the design and measurement procedures, this study does lay the ground work for future research. It illustrates that:

1. The 65-GP-7 and 65-GP-11 standards are strictly performance standards which regulate only the total buoyancy and material requirements. Sizing, comfort, and other characteristics are problems which are not dealt with in the standards. However, these factors are too important to be left entirely to manufacturers if children are to be encouraged to wear water safety devices.

2. Water safety devices should probably be made in at least three sizes - size A for those under 30 lb. (13.6 kg.); size B for children weighing 30 to 60 lb. (13.6 to 27.2 kg.); and size C for children weighing 60 to 90 lb. (27.2 to 40.8 kg.) - rather than the two sizes now recommended in the standard which are size C for body weight up

to 50 lb. (19.7 kg.) and size B for body weight between 45 and 90 lb. (17.7 and 40.8 kg.).

3. The inherently buoyant type should be preferred to the combined inherent and inflatable type for the following reason. When inflated, the water safety devices are big and cumbersome. Although not a result of this research, it would seem that more flexible and highly buoyant materials have been developed which would make the manufacture of this type of device for children unnecessary.

4. The type and amount of buoyant material used is greatly responsible for the bulkiness and poor fit of the majority of existing water safety devices. Also, the actual buoyancy requirement of 7 and 13 lb. (3.2 and 5.9 kg.) of the 65-GP-7 standard as well as the 15.7 lb. (7 kg.) requirement of the 65-GP-11 standard, are partly responsible for this shortcoming in presently available water safety devices. In order to be capable of holding the body in a safe floating position with the mouth and nostrils clearly out of the water, and to possibly reduce the bulkiness of the existing water safety device, the buoyancy requirement should probably be 6 lb. (2.7 kg.) for size A, 8 lb. (3.6 kg.) for size B, and 10 lb. (4.5 kg.) for size C.

5. Most of the water safety devices tested were too difficult for young children to don by themselves.

Adults should take the responsibility to see that the child is wearing one correctly at all times when on or near the water. The procedure for donning should be clearly indicated for the adult who, in turn, will help the child don it. Thus, no modifications need be specified for children.

6. For comfort and fit, the water safety device should be adjustable in neck, chest and waist circumferences, as well as in arm scye and body length. It should provide ease of motion at the neck around a vertical and horizontal axis. Arms should be free to move in the three planes. It should not interfere with flexion of the trunk in the frontal and sagittal planes. The jacket should not interfere with the wearer's vision, either in or out of the water. It should not cause skin irritation, especially around the neck and arms.

7. Future children's water safety devices should be sized and constructed according to the anthropometric measures found in this study. Table 24 indicates the actual dimensions.

Material requirements such as shell fabric, webbing, tapes and thread, should be consistent with the existing standards (4-GP-105, 4-GP-85, 4-GP-131, 4-GP-139) with added aesthetic values.

TABLE 24

WATER SAFETY DEVICES DESIGN DIMENSIONS

Variables	Unit	Size A	Size B	Size C
	lb. jg.	20 - 30 9.1 - 13.6	30 - 60 13.6 - 27.2	60 - 90 27.2 - 40.8
Head	cm.	43 - 53	47 - 56	50 - 53
Circum.	in.	16.9 - 20.9	18.5 - 22.0	19.7 - 20.7
Neck	cm.	20 - 27	22 - 31	25 - 34
Circum.	in.	7.9 - 10.6	8.7 - 12.2	9.8 - 13.4
Arm Scye	cm.	17 - 26	19 - 36	26 - 42
	in.	6.7 - 10.2	7.5 - 14.2	10.2 - 16.5
Chest	cm.	40 - 55	45 - 71	55 - 85
Circum.	in.	15.7 - 21.7	17.7 - 28.0	21.7 - 33.5
Chest	cm.	13 - 19	16 - 24	19 - 27
Breadth	in.	5.1 - 7.5	6.3 - 9.4	7.5 - 10.6
Back	cm.	18 - 25	23 - 32	28 - 35
Length	in.	7.1 - 9.8	9.1 - 12.6	11.0 - 13.8

At the present time, all these recommendations could be incorporated in an amendment to the present life-jacket 65-GP-7 and personal flotation device 65-GP-11 standards. However, with the results of further research on

the performance of water safety devices as a flotation device and as a garment, all recommendations could be included in a new standard specially used to evaluate children's water safety devices.

Suggestions for Further Research

Before applying the anthropometric and buoyancy values suggested in the above recommendations, it would be desirable to select a sample of boys and girls from all areas of Canada, urban and rural; from all races; from all weight categories under 90 lb. (40.8 kg.); and from the range of age from infancy to young teenagers which would embrace the 20 to 90 lb. (7.9 to 40.8 kg.) weight range. Such a sample would contribute to our knowledge of the anthropometry of Canadian children, permit comparison with children of other countries, and become the basis for designing water safety devices which would meet buoyancy requirements for safety and be sufficiently comfortable to be worn for extended periods of time. This could then become the basis for other safety devices for children.

Detailed considerations should be given to the development of suitable test methods and procedures for certification testing. These procedures should incorporate testing of the performance of the device, both as a garment and as a safety device. The testing procedures should make use of quantitative methods to the greatest possible degree.

Because of the great diversity in weight distribution and shape of children, research could be undertaken to study the optimum buoyancy distribution required for children of different body type categories.

APPENDIX A

CANADIAN STANDARD FOR
WATER SAFETY DEVICES



Specifications Board Office des Normes

Supply and services
Canada

Approuvé par le ministre de l'Industrie
et du Commerce

Standard for : Personal Flotation Devices

This standard applies to personal flotation devices (PFDs) intended for constant wear to increase the safety of adults who are required to be physically active in situations where drowning hazard exists.

65-GP-11

October 1972

(Reprinted Feb., 1974, with
metric conversions updated).

Price Code A

Pour l'édition française commander (F)65-GP-11

CANADIAN GOVERNMENT SPECIFICATIONS BOARD

Standard
for

PERSONAL FLOTATION DEVICES

1. SCOPE

1.1 This standard applies to personal flotation devices (PFDs) intended for constant wear to increase the safety of adults who are required to be physically active in situations where a drowning hazard exists.

NOTE: *Personal flotation devices conforming to this standard provide varying degrees of assistance in the water. PFDs increase the chances of survival but do not guarantee it. It is recommended that each individual secure a PFD suitable for his body type and size, and the kind of activity in which he is to be engaged.*

2. APPLICABLE PUBLICATIONS

2.1 The following publications are applicable to this standard:

2.1.1 Canadian Government Specifications Board (CGSB)

1-GP-12 Standard Paint Colors
1-GP-71 Method of Testing Paints and Pigments
4-GP-2 Canadian Standard Textile Test Methods
4-GP-85 Thread, Nylon (Continuous Multifilament)
4-GP-97 Thread, Polyester (Continuous Multifilament)
4-GP-105 Textile Components of Life Jackets (Inherently Buoyant Type)
4-GP-131 Thread, Polyester Cotton Covered
4-GP-139 Thread, Polyester Staple
41-GP-8 Plastic Material: Cellular, Elastomeric
41-GP-28 Macro-Cellular Plastic Buoyancy Elements

2.1.2 American Society for Testing and Materials (ASTM)

D 413 Methods of Test for Adhesion of Vulcanized Rubber
D 751 Methods of Test for Coated Fabrics
D 882 Methods of Test for Tensile Properties of Thin Plastic Sheeting
D 1004 Method of Test for Tear Resistance of Plastic Film and Sheeting

2.1.3 U.S. Military (MIL) Specifications

C-401 Cylinders, Carbon Dioxide Filled, Technical
C-19002 Cloth, Coated, and Tape, Coated Cloth-polychloroprene on Nylon, Pneumatic Life Preserver
C-19377 Cloth, Twill, Nylon
I-25369 Cylinders, Carbon Dioxide for Inflation of Pneumatic Life Preservers
I-23145 Inflation Assemblies, Life Preserver
O-81375 Oral Inflation Assemblies.

2.1.4 U.S. Federal Specifications

191 Textile Test Methods

2.2 Reference to the above publications, or to test methods therein, is to the issue in effect on the date of invitation to tender, unless otherwise specified.

65-GP-11

3. CLASSIFICATION

3.1 This standard applies to devices of two types.

3.1.1 Types

Type I - Inherently Buoyant (minimum 15½ lbs. (7.05 kg) buoyancy)

Type II - Combined Buoyancy (minimum 9 lbs. (4.1 kg) inherent plus minimum 20 lbs. (9.1 kg) inflatable)

4. GENERAL REQUIREMENTS

4.1 Performance as Flotation Device

4.1.1 All PFDs to this standard whether inflated or deflated shall provide flotation for a wearer of the size declared on the label with no tendency for the wearer to be turned face down in the water.

Par. 7.2.3

4.1.2 Type I PFDs, and Type II PFDs when inflated, shall support and hold the wearer face up and face clear of the water.

Par. 7.2.4

4.1.3 Type II PFDs when inflated shall be capable of turning the body within 10 seconds to a safe flotation position with the body inclined backward from its vertical position, and provide lateral and occipital support to the wearer's head.

Par. 7.2.5

4.2 Ease of Donning and Adjustment for Fit - PFDs shall be of such a design that the proper method of donning is obvious to an untrained person and shall incorporate such strapping or means of attachment as may be necessary to ensure ease of donning and size adjustment (within the limits of size declared on the label) and secure fastening.

Par. 7.2.2

4.3 Hardware and Fastenings - Hardware and fastenings shall be of a size and strength consistent with the webbing, tape or fabric with which they are to be engaged and shall be of corrosion resistant material.

Par. 7.2.6

4.4 Strength of Assembly - The strength of the PFD, its fastenings and adjustments, shall be sufficient to allow the wearer to be assisted from the water by grasping any part of the PFD by hand.

Par. 7.2.6

4.5 Design - PFDs shall be as comfortable, nonrestrictive of motion and nonbulky as is consistent with their performance. They shall have a minimum number of protrusions that might be subject to snagging.

4.6 Workmanship - PFDs shall be free from all defects in workmanship or materials that might affect serviceability or appearance.

5. DETAIL REQUIREMENTS

5.1 Materials

5.1.1 Shell Fabric, Webbing and Tapes - Shell fabrics, webbing and tapes, where used, shall comply with the requirements of CCSB 4-GP-105.

8. NOTES

8.1 The publications referred to in par 2.1.1 are available from the Canadian Government Specifications Board.

8.2 The publications referred to in par. 2.1.2 are available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa., 19103, U.S.A.

8.3 The publications referred to in par. 2.1.3 and 2.1.4 are available from the Superintendent of Documents, U.S. Government Printing Office, Washington D.C. 20402, U.S.A.

8.4 Système International (Metric) Units - The SI (Metric) equivalents for customary inch/pound units are shown in this standard. Since the equivalents are not exact, the SI values are provided for information only to familiarize readers with units that are expected ultimately to be adopted nationally.



FOREWORD

Standards issued by the Canadian Government Specifications Board are prepared by committees in which representatives of government, industry and research organizations participate on a voluntary basis. Although intended to serve the needs of government, CGSB standards are available for general use.

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Canadian Government Specifications Board
c/o Department of Supply and Services
88 Metcalfe St.
Ottawa, Canada
K1A 0S5

65-CF-11

- 7.2.7 *Breaking Strength and Elongation of Foam Coating Material* - shall be determined in accordance with ASTM D 882, Method B, using 1 x 6 inch (25 x 150 mm) specimens and a rate of travel of the power-activated grip of 20 inches (508 mm/sec) per minute. Specimens shall be obtained as described below*. The average breaking strength expressed as lbf/in. of width, and the average elongation at break expressed as a percentage of the original gauge length, shall be reported.
- 7.2.8 *Tear Resistance of Foam Coating Material* - shall be determined in accordance with ASTM D 1004 on "as received" and artificially weathered specimens obtained as described below*. The average resistance to tearing shall be reported.
- 7.2.9 *Adhesion of Coating to Foam* - shall be determined in accordance with ASTM D 413 using the machine method, except that the average of 5 specimens from different parts of the jacket shall be used to determine compliance with the specification. Specimens that do not separate cleanly from the foam but show an adhesion in excess of 2 lbf/in. (9N/25mm) shall be acceptable.
- 7.2.10 *Strength of Seam Seams* - Specimens shall be 4 inch (100 mm) wide and not less than 6 inches (150 mm) long, with the seam to be tested at right angles to the length and approximately equidistant from each end of the specimen. Ten specimens shall be tested by CGSB 4-CF-1, Section 9.A.1 of Method 9. Specimens shall be tested after thorough wetting by immersion in water at room temperature to which has been added not more than 0.5 gram per litre of a neutral wetting agent.
- 7.2.11 *Aging* - Place the complete PFD, in the uninflated condition for Type II, in a circulating air oven maintained at $140 \pm 5^\circ\text{F}$ ($60 \pm 3^\circ\text{C}$) for 168 hours, after which it shall be removed and cooled at room temperature for at least 12 hours. Vinyl coatings, where used, shall not become soft or sticky, nor develop blisters, checks or other defects that might affect serviceability. Subject the PFD to the buoyancy test described in par. 7.2.12. In no case shall the change in buoyancy from the original determination exceed 6 per cent.
- 7.2.12 *Buoyancy* - Place the PFD inside a cage of sufficient weight to hold the PFD under water. Suspend the assembly from a suitable scale or balance in fresh water at room temperature with the top of the cage two inches below the surface of the water. Determine the buoyancy after any trapped air has been released. Calculate the buoyancy of the PFD as the weight in water of the empty cage minus the weight in water of the cage-plus PFD-assembly. Test Type II PFDs in both the inflated and uninflated conditions, inflation shall be by means of the carbon dioxide cylinder.
- Par 5.5 and 5.6
- 7.2.13 *Leakage Test (Type II)* - Inflate the PFD with air to a pressure of 2 lbf/in² (13.8 kN/m²). After a minimum of 15 minutes the pressure shall be checked and adjusted to the original pressure. The pressure source shall then be removed. A minimum of 24 hours after the adjustment, the pressure shall be measured and corrected for any change in temperature or barometric pressure. The corrected pressure shall be not less than 1.5 lbf/in² (10.3 kN/m²). Every Type II PFD manufactured shall be subjected to this test. Failure to meet the test shall be cause for rejection.
- Par. 5.7
- 7.2.14 *Proof Pressure* - Inflate Type II PFDs with air through the oral inflation valve to a pressure of 10 lbf/in² (68.9 kN/m²) and allow to stand for a minimum period of 5 minutes. The pressure drop shall be not greater than 0.4 lbf/in² (2.75 kN/m²). Examine the PFD while held under pressure. There shall be no evidence of failure of the material in any respect. All seams and sealed area shall remain perfectly intact and shall show no signs of separation.

Par. 5.8

Sufficient specimens for the breaking strength and tear resistance tests (10 specimens 6 x 1 inches (150 x 25 mm) and 10 specimens 5 x 2 inches (125 x 50 mm) shall be taken from the jacket by elitting with a razor blade and stripping from the foam.

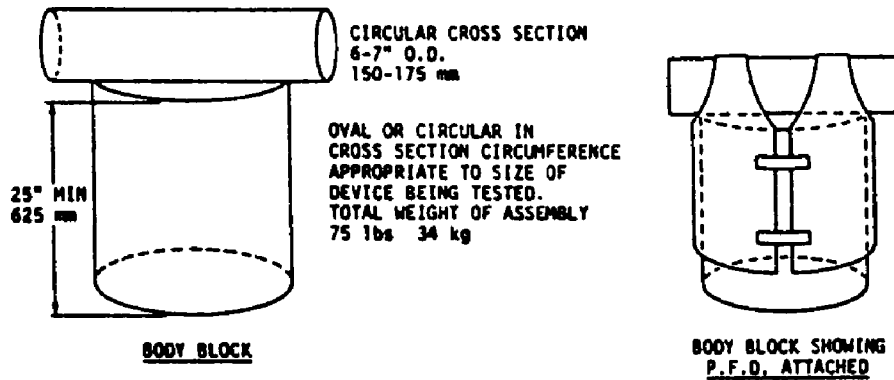


FIGURE 1

- (b) Collar style PFDs shall be suspended as shown in Figure 2 for five minutes and note made of any sign of damage.

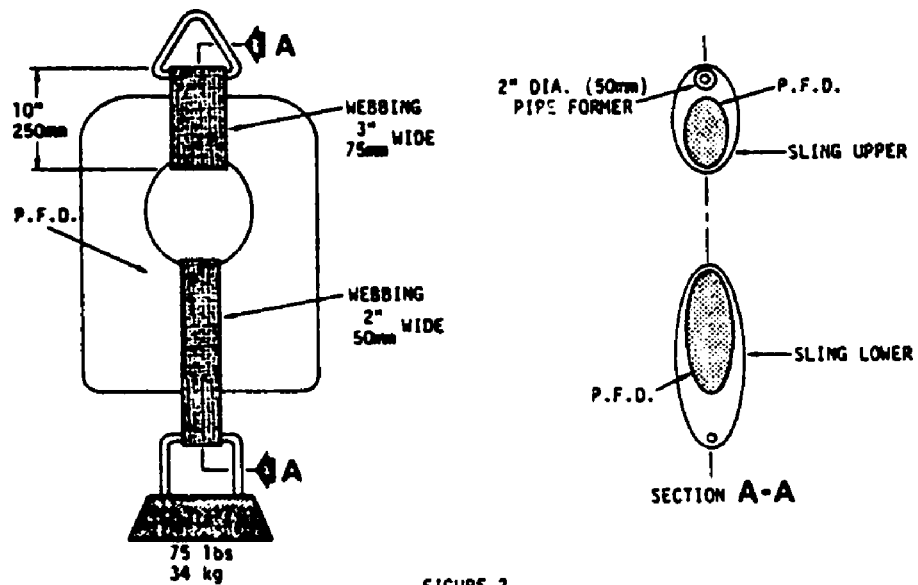


FIGURE 2

65-GP-11

- 6.2.5 The instructions shall also include words to the following effect: "If it is intended to wear a harness in conjunction with a PFD, users are advised to try them on together to ensure that one does not interfere with the function of the other."

(NOTE: These requirements are minimum. It is strongly recommended that the user be provided with the fullest information to enable him to choose the PFD most appropriate to his activities and also to maintain it in effective condition.)

7. INSPECTION

- 7.1 PFDs shall be examined for compliance with the requirements of this standard by the following procedures:

7.2 Performance as a Flotation Device

- 7.2.1 For the following tests, several male and/or female subjects shall be chosen of different body types and sizes appropriate to the chest size of the device being tested as stated on the label.
- 7.2.2 Each subject shall don the jacket over attire customary to the intended activity, and note shall be made of any difficulties in donning or adjusting. If necessary, the jackets shall then be properly adjusted to the wearer by the tester, before carrying on with water tests.

Par. 4.2

- 7.2.3 Each subject stands with his feet as near as possible to water level and falls back into the water, and upon entry relaxes completely; the subject swims on his side and relaxes; the subject swims on his back and relaxes. After each phase, falling, swimming on side and swimming on back, note shall be made of any tendency for the PFD to turn the wearer to a face down position. This applies to all PFDs. Type II PFDs shall be tested before and after inflation.

Par. 4.1.1

- 7.2.4 Each subject wearing a Type I or a Type II PFD inflated shall relax face up in calm water. When equilibrium has been attained note shall be taken of the position of the face relative to the water.

Par. 4.1.2

- 7.2.5 Each subject wearing an inflated Type II PFD shall assume a face downward position in calm water with his arms forward and relaxed simulating unconsciousness or exhaustion. Note shall be made of the time required for the PFD to turn the body to a safe flotation position.

Par. 4.1.3

NOTE: For the assessment of performance as a flotation device, it is desirable that a number of independent trained observers be employed and that the number of subjects be as large as possible.

7.2.6 Strength of Assembly

- (a) Vest style PFDs shall be adjusted to fit snugly a body block (Figure 1). A grip 5 in. (125 mm) long curved to a radius of 3 inches (75 mm) shall be inserted at points of the PFD likely to be grasped by hand, and the PFD suspended by the grip for five minutes at each point. The PFD shall then be examined for signs of damage and slipping of fastenings.

6. PREPARATION FOR DELIVERY

6.1 Labelling and Marking - All PFDs shall have a permanent and legible label or marking including in both official languages as a minimum, the following information:

PERSONAL FLOTATION DEVICE

Designed for chest size _____ in. to _____ in.
Manufactured by (Manufacturer's Name) _____
on (month and year of mfg) Lot Number _____
to conform to CGSB Standard 65-GP-11, Type _____
Buoyancy _____ lb. minimum.

(* For Type II PFDs state buoyancy as:
_____ lb. min. inherent
_____ lb. min. inflated)

DIAGRAM OR SKETCH

Showing how the PFD is to be worn and for Type II operated

This PFD is designed to be worn
WEAR IT!

VETEMENT DE FLOTATION INDIVIDUEL

Tour de poitrine, de _____ à _____ po.
Fabriqué par (nom du fabricant) _____
en (mois et année de fabrication) _____
Lot n° _____ conforme au type _____
de la norme 65-GP-11 de l'O.N.C.C.
Flottabilité, _____ lb au minimum*

(* Pour les V.F.I. de type II, déclarer ainsi la flottabilité:
non gonflés, _____ lb au minimum,
gonflés, _____ lb au minimum)

DIAGRAMME OU DESSIN

Expliquant comment porter le V.F.I. et, dans le cas du type II, comment le gonfler

Ce vêtement est conçu pour votre sécurité.
PORTEZ-LE!

6.1.1 For uncoated fabric covered PFDs, the label shall be made of fabric attached to the covering by stitching along the four edges of the label.

6.1.2 For vinyl coated or coated fabric covered PFDs, the information above shall be marked on the coating or coated fabric.

6.2 Information Sheet and Maintenance Instructions - In addition to the brief instructions marked permanently on the PFD, each PFD offered for sale shall have attached a sheet or booklet readily accessible to the purchaser which contains the following minimum information in both official languages.

6.2.1 Personal flotation devices conforming to the Canadian Government Specifications Board Standard 65-GP-11 are of two types: Type I provides a minimum of 15½ lbs. inherent buoyancy and Type II, which provides a minimum of 9 lbs. inherent buoyancy and a minimum 29 lbs. when inflated. Type II devices using the inherent buoyancy element alone provide limited assistance in the water. Type II devices using both the inflatable and inherent buoyancy elements provide substantial assistance for the majority of individuals under most circumstances. Type I devices provide greater assistance than Type II using inherent buoyancy only and less assistance than Type II using both inherent and inflatable elements. The wearing of a PFD increases the chances of survival in the water, but does not guarantee it. It is recommended that you choose a PFD meeting CGSB 65-GP-11 which fits you comfortably and is suitable for your intended activities. Try the PFD on and familiarize yourself with the method of fastening and adjustment.

6.2.2 For Type II PFDs the user shall be provided with instructions on the maintenance of the PFD and in particular on the check weighing of carbon dioxide cylinders and the correct type of replacement cylinder. Instructions, where appropriate, that the oral inflation device should be kept closed when not in use shall be included together with a warning of the danger of partial oral inflation followed by subsequent gas inflation.

6.2.3 Instructions on general care and maintenance shall be provided for all PFDs, covering methods of drying (avoiding direct heat), method of storage, avoidance of abuse by use as a cushion or boat-fender, etc.

6.2.4 Full instructions shall be provided on the method of donning and adjustment together with a warning in the case of Type II PFDs that they must not be worn under clothing.

65-GP-11

- 5.1.7 **Manual Inflation Device** - Type II PFDs shall be fitted with an inflation device consisting of a cylinder of compressed carbon dioxide discharged by a manually operated triggering device. The mechanism shall be protected against snagging, and shall be readily and readily accessible to either hand. It shall be operated at a load of not more than 15 lbf (67N) and shall fully inflate the PFD in not more than 5 seconds. Devices conforming to MIL-I-23145 fitted with the appropriate carbon dioxide cylinder conforming to MIL-C-601 or MIL-C-25369, Type II, are deemed to comply.
- 5.1.8 PFDs using other materials may be considered as complying with this standard provided the manufacturer supplies evidence from a properly qualified test laboratory that they meet the specified requirements for strength, durability and performance. Kapok or other natural fibre shall not be permitted as a buoyancy medium. In the case of alternative manual inflation devices or carbon dioxide cylinders evidence shall be supplied that the levels and type of inspection in respect to operation of the device and weight of the filled carbon dioxide cylinder are equivalent to those required by MIL-I-23145 and MIL-C-601 or MIL-C-25369.
- 5.2 **Seaming** - All sewn seams shall be made with locked stitches. The ends of all thread breaks during seaming shall be securely backstitched.
- 5.2.1 **Strength of Sewn Seams** - The design of all seams shall be such that the strength of the seam shall be not less than 80 per cent of the lower of the specified strengths of the materials being joined. Seams shall be located so as to assist in developing the full strength of the covering and shall be of a type that shall not expose any raw edges.
- 5.3 **Color** - When wet, PFDs shall be bright yellow, orange or red in color preferably approximating Orange 508-101 of CCGS 1-GP-12.
- 5.4 **Retention of Buoyancy** - The difference in the buoyancy before and after aging shall not exceed 6 per cent expressed as a percentage of the aged buoyancy.
- Par. 7.2.11 and 7.2.12
- 5.5 **Buoyancy** - The total buoyancy after aging in accordance with Par 7.2.11 shall not be less than:
- | | |
|-------------------------|--------------------|
| Type I | 15½ lbs. (7.05 Kg) |
| Type II (inherent only) | 9 lbs. (4.1 Kg) |
| (combined) | 29 lbs. (13.2 Kg) |
- Par. 7.2.11
- 5.6 The center of buoyancy of the inherent buoyancy portion of Type II devices shall be on the front and above the base of the sternum of a 5th percentile male model.
- 5.7 **Leakage Test** - The inflatable portion of a Type II PFD shall pass a leakage test at a pressure of 2 lbf/in² (13.8 kN/m²) with a pressure drop not greater than 0.5 lbf/in² (3.45 kN/m²) after 24 hours. The manufacturer shall submit every Type II PFD to this test.
- Par. 7.2.13
- 5.8 **Proof Pressure** - At a temperature between 60 and 90°F the inflatable portions of a Type II PFD shall be capable of withstanding for five minutes an internal pressure of 10 lbf/in² (68.9 kN/m²).
- (NOTE: PFDs which are tested in this manner shall not be offered for sale).

- 3.1.2 **Air Bladder** - The air bladder portion of Type II PFDs shall be made from material conforming to MIL-C-19002 or to MIL-C-19377 coated one side with NF available polyurethane. This material may also serve as the shell fabric. Polyurethane coated fabric shall conform to the following requirements:

Property	Requirement	Test Method
Weight of Coated Fabric	6 ± 0.3 oz per sq yd (204 ± 10 g per sq m)	4-GP-2 Method 3A
Tensile Strength	Warp minimum 200 lbf per in. (900N per 25 mm) Weft minimum 200 lbf per in. (900N per 25 mm)	ASTM D 751
Tear Strength	Warp Minimum 5 lbf (22.5N) Weft Minimum 5 lbf (22.5N)	4-GP-2 Method 12.2
Coating Adhesion	Minimum 8 lbf per inch (36N per 25 mm)	ASTM D 751
Blocking	No blocking	Federal Standard Test Methods 191, Method 5872
Hydrostatic Resistance	No leaks	MIL-C-19002

- 3.1.3 **Thread** - The thread used for all sewing shall be nylon or polyester conforming to one of the standards listed in paragraph 2.1.1.
- 3.1.4 **Inherent Buoyancy Materials** - shall be unicellular foam conforming to CGSB 41-GP-8, or macro-cellular plastic buoyancy elements conforming to CGSB 41-GP-28P,
- 3.1.5 **Coating Material** - Type I PFDs and the inherently buoyant part of Type II PFDs, may consist of unicellular foam coated with a fully cured compound of poly(vinyl chloride) or poly(vinyl chloride acetate) and complying with the following requirements:

Requirement	Limit		Test Method
	as received	after* aging	
Breaking strength lbf/in. width, min.	10.00 (45N per 25 mm)	9.5 (43N per 25 mm)	Par. 7.2.7
Elongation % min.	220	200	
Tearing strength, lbf min.	1.6 (7.2N)	1.3 (5.9N)	Par. 7.2.8
Adhesion to Foam, avg of 5 specimens, lbf min.	1.5 (6.8N)	1.5 (6.8N)	Par. 7.2.9
any single specimen lbf min.	1.1 (5.0N)	1.1 (5.0N)	Par. 7.2.9

- 3.1.6 **Oral Inflation Device** - Type II PFDs shall be fitted with a smoothly finished oral inflation device readily accessible to the mouth and to either hand when the PFD is either uninflated or inflated. At a pressure of 1 lbf/in² (6.89 kN/m²) applied to the mouthpiece the air flow through the device shall be not less than 1.7 ft³/min. (0.79 litre/sec). At a pressure of 0.6 lbf/in² (4.13 kN/m²) the valve shall be fully open. Any metallic functional component of the device shall be corrosion resistant. Devices conforming to MIL-Q-81375 are deemed suitable.

* Aging shall be in accordance with Par. 7.2.11

SPECIFICATION
FOR
LIFE JACKETS; INHERENTLY BUOYANT TYPE

65-GP-7
3 JULY 1964
(CORRECTED)

SUPERSEDES 65-GP-1A
65-GP-2A
65-GP-4
65-GP-6

**THIS SPECIFICATION APPLIES TO INHERENTLY BUOYANT DEVICES INTENDED TO BE WORN ON
THE BODY TO PROVIDE FLOTATION**

Price
Code B

FOREWORD

The CANADIAN GOVERNMENT SPECIFICATIONS BOARD under whose auspices this standard has been developed is a federal government agency engaged in the production of voluntary standards in a wide range of subject areas through the medium of technical committees and the consensus process. The technical committees are representative of relevant interests including producers, consumers and other users, retailers, governments, educational institutions, technical, professional and trade societies, and research and testing organizations. The CGSB has been accredited by the Standards Council of Canada as a national standards writing organization. The standards that it develops and offers as National Standards of Canada conform to the criteria and procedures established for this purpose by the Standards Council of Canada. In addition to standards it publishes as National Standards, CGSB produces standards to meet particular needs, in response to requests from a variety of sources in both the public and private sectors.

Although the intended primary application of each standard is stated in its Definition or Scope clause, it is important to note that it remains the responsibility of the user of the standard to judge its suitability for his particular purpose.

CGSB standards are subject to periodic review to ensure that they keep abreast of technological progress. Suggestions for their improvement, which are always welcome, are brought to the notice of the technical committees concerned. Changes to standards are issued either as separate amendment sheets or in revised editions of the standards.

An up-to-date listing of CGSB standards, including details on latest issues and amendments, and ordering instructions, will be found in the Catalogue of Standards which is published annually with cumulative supplements, and is available without charge upon request.

Further information on the CGSB and its services and standards may be obtained from:

Canadian Government Specifications Board
6th Floor, 88 Metcalfe Street
Ottawa, Ontario
Canada
K1A 0S5

65-GP-7 (Corrected)
3 July 1964
Supersedes 65-GP-1a
65-GP-2a
65-GP-4
65-GP-5

CANADIAN GOVERNMENT SPECIFICATIONS BOARD

Specification
for

LIFE JACKETS; INHERENTLY BUOYANT TYPE

1. DEFINITION

1.1 This specification applies to inherently buoyant devices intended to be worn on the body to provide flotation.

2. APPLICABLE PUBLICATIONS

2.1 The following publications are applicable to this specification:

- 2.1.1 CGSB 1-GP-12, Standard Paint Colors.
- 2.1.2 CGSB 1-GP-71, Method 122.2, Accelerated Weathering of Paints, General Procedure.
- 2.1.3 CGSB 4-GP-2, Canadian Standard Textile Test Methods.
- 2.1.4 CGSB 4-GP-80, Thread: Cotton, Sewing, Untreated or Rot Resistant.
- 2.1.5 CGSB 4-GP-105, Textile Components of Life Jackets (Inherently Buoyant Type).
- 2.1.6 CGSB 41-GP-8, Foam: Elastomeric, Unicellular, Sheet and Molded Shapes.
- 2.1.7 CGSB 41-GP-10, Film and Sheeting Flexible, Vinyl.
- 2.1.8 CGSB 54-GP-1, Stitches, Seams and Stitchings.
- 2.1.9 Department of National Defence - PSNL 9-2-1, Thread, Nylon, Twisted, Machine.
- 2.1.10 ASTM D413, Methods of Test for Adhesion of Vulcanized Rubber.
- 2.1.11 ASTM D882, Methods of Test for Tensile Properties of Thin Plastic Sheeting.
- 2.1.12 ASTM D1004, Method of Test for Tear Resistance of Plastic Film and Sheeting.

2.2 Reference to the above publications, or to test methods therein, is to the issues in effect on the date of invitation to tender, unless otherwise specified.

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3. CLASSIFICATION

3.1 This specification applies to jackets of three sizes, three types and two styles, as follows:

3.1.1 Types

- Type I - Unicellular Foam Filled
- Type II - Kapok Filled
- Type III - Unicellular Foam Filled, Vinyl Coated

3.1.2 Styles

- Style 1 - One-piece (slab or keyhole)
- Style 2 - Open-front (vest)

3.1.3 Sizes

- Size A (for body weight more than 90 lb.)
- Size B (for body weight more than 45 lb. and up to 90 lb.)
- Size C (for body weight up to 50 lb.)

4. GENERAL REQUIREMENTS

4.1 Flotation

4.1.1 The jacket shall be capable of turning the body on entering the water to a safe flotation position with the body inclined backwards from its vertical position.

Method par. 7.2.1

4.1.2 The total buoyancy and the distribution of buoyancy shall be such as to provide support for the head so that the face of an unconscious person is held above the water with the body inclined backwards from the vertical position.

Method par. 7.2.1

4.1.3 There shall be no tendency for the jacket to turn a body from any other position to a face-down position.

Method par. 7.2.1

NOTE: It is considered that jackets conforming to this specification provide reasonable protection for the majority of individuals under most circumstances. It must be realized that no single design can provide protection for all individuals under all circumstances. Life jackets are intended to increase the chances of survival, but do not guarantee survival. It is recommended that each individual secure a jacket suitable for his particular physique. In the final analysis, the responsibility to ensure that a jacket is adequate and satisfactory for the particular user must rest with the person concerned.

4.2 Comfort - Jackets shall be designed to provide reasonable comfort and ease of motion, and shall not unduly interfere with the wearer's vision both in and out of the water.

Method par. 7.2.2

4.3 Fastenings - Jackets shall be designed so that they may be donned, secured and worn equally well inside-out or outside-out. One-piece jackets shall have no hardware, and shall be secured and adjusted by tie tapes only. Open-front jackets may have hardware.

Method par. 7.2.3

4.4 Ease of Donning - Jackets shall be easy to put on over clothing.

Method par. 7.2.3

4.5 Adjustment for Fit - Jackets shall be capable of simple and extensive adjustments for fit.

Method par. 7.2.3

4.6 Odor - Jackets shall not have, nor develop, an objectionable odor when wet or dry.

Method par. 7.2.2

4.7 Workmanship - Jackets shall be free from all defects in material or workmanship that might affect appearance or serviceability.

5. DETAIL REQUIREMENTS

5.1 Materials

5.1.1 Shell Fabric - The shell fabric shall comply with the requirements for Type I material of CGSB Specification 4-GP-105.

5.1.2 Unicellular Foam - Type I jackets shall be filled with material conforming to CGSB 41-GP-8.

5.1.3 Kapok - Type II jackets shall be filled with new, well-tressed, clean kapok, free from foreign matter, enclosed in heat-sealed vinyl envelopes.

5.1.4 Vinyl Film - The kapok-containing envelopes for Type II jackets shall be made from vinyl film conforming to CGSB 41-GP-10, 0.008 inch minimum in thickness.

5.1.5 Thread - The thread used for all seaming shall be nylon Size C conforming to specification PSNL 9-2-1, or 4-cord No. 12, glazed finish, rot resistant cotton thread conforming to CGSB 4-GP-80.

5.1.6 Hardware - All hardware on Type II jackets shall be of a size and strength consistent with the webbing or tape with which it is to be used, and shall be of corrosion resistant material or suitably protected against corrosion by plating. All rings used for adjustment shall be circular; "D" rings are not permitted.

5.1.7 Tapes, Webbing and Cords - All tapes, webbings and cords shall comply with the requirements of CGSB 4-GP-105. Tapes and webbings shall be at least 1-1/4 inches wide for Size A jackets and at least 1 inch wide for Sizes B and C jackets, unless the design is such that they are prevented from coming in contact with the body by a draw cord channel, in which case cord, or narrower tape or webbing, may be used. The ends of all tapes, webbings and cords shall be treated to prevent unravelling. Tapes, webbings and cords shall be secured to the jacket, or shall be tipped, knotted, or folded and sewn, in such a manner that they cannot readily be separated from draw-cord channels, hardware, etc.

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5.1.8 Coating Material - Type III jackets shall be coated with a fully cured compound of poly (vinyl chloride) or poly (vinyl chloride-acetate), bright yellow, orange or red in color, preferably approximating Orange 6-2 of CGSB 1-GP-12, and complying with the following requirements:

<u>Requirement</u>	<u>Limit</u>		<u>Test Method</u>
	<u>as received</u>	<u>after aging</u>	
Breaking strength, lb. /in. width, min.	10.00	9.5)	par. 7.2.4
Elongation, % min.	220	200)	
Tearing Strength, lb. min.	1.6	1.3	par. 7.2.5
Adhesion to foam, lb. min.	2.0	2.0	par. 7.2.6

5.2 Design

5.2.1 Style 1, Sizes A and B, shall be in accordance with Figure 1 and the dimensions shown in the table.

5.2.2 The lower portion of the buoyancy pad of Style 1 jackets shall be secured to the waist strap in such a manner as to allow 4 to 6 inches between the waist strap and the midthickness of the buoyancy element.

Method par. 7.2.3

5.2.3 Style 1, Size C, and Style 2, Sizes A, B and C, shall follow the design principles shown in Figure 1, particularly with respect to:

(a) Support for the head and chin.

(b) General proportions and buoyancy distribution.

5.2.4 Style 2 shall have shell fabric joining the front and back buoyancy elements forming an armhole. The width of the fabric shall be not less than 4 inches for Size A and 2 inches for Sizes B and C.

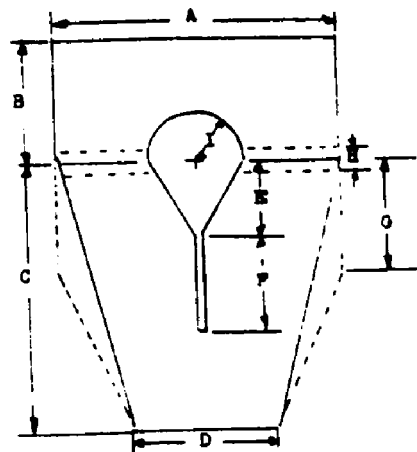
5.2.5 Detachable collars shall not be used.

5.3 Buoyancy - The total buoyancy shall be not less than:

Size A	21 lb.
Size B	13 lb.
Size C	7 lb.

For Types I and III jackets this measurement shall be made after heat aging in accordance with par. 7.2.8.

• Aging shall be in accordance with par. 7.2.7.



(Dimensions in Inches)

	TYPES I AND II		TYPE II	
	SIZE A	SIZE B	SIZE A	SIZE B
A	14 ± 1	11 ± 1	15 ± 1	13 ± 1
B	7 ± 1	6 ± 1	7 ± 1	5 1/4 ± 1
C	14 ± 1 1/2	12 ± 1	13 1/2 ± 1	12 ± 1
D	7 ± 1	6 ± 1	8 ± 1	7 ± 1
E	3 1/2 ± 1	2 to 3	3 1/2 ± 1	2 to 2 1/2
F	7 ± 1	6 ± 1	7 ± 1	6 ± 1
*G	7 ± 1	3 1/2 ± 1	-	-
H	1 1/2 max.	1 max.	-	-
I	2 1/2 ± 1	2 to 2 1/2	2 1/2 ± 1	2 to 2 1/2

* Optional

NOTES:

1. Dimension F may extend to the bottom of the jacket if the waist strap is designed to ensure that the two portions stay together and the buoyancy elements cannot spread to the sides.
2. The portion of the life jacket included in dimension C shall have not less than 75 nor more than 80 per cent of the total buoyancy.
3. Body tie tapes shall pass completely through the life jacket approximately at the bottom of the slot.
4. Neck tie tapes shall be positioned so that the chin cannot fall through the jacket and the reversibility of the jacket is maintained.

FIGURE 1

65-GP-7

- b -

5.4 Filling

5.4.1 Type I jackets shall be filled with unicellular foam material, with not more than three pieces per buoyancy unit. When more than one piece is used in a buoyancy unit, the design shall be such that there is no likelihood of the foam pieces being grossly displaced.

5.4.2 Type II Jackets - Each buoyancy element in Type II jackets shall contain one or more vinyl envelopes evenly filled, without compression, with kapok. Not more than 40 per cent of the total weight of kapok shall be in any one envelope. After filling, excess air shall be removed by firm pressing, and the envelope closed by heat sealing. Heat-sealed seams shall have a strength of not less than 8 lb. per inch of width.

Method par. 7.2.10

5.5 Weight of Kapok - In Type II jackets the minimum weight of kapok shall be:

Size A	24 oz.
Size B	15 oz.
Size C	8 oz.

5.6 Seaming - All seams shall be made with 7 to 10 lockstitches per inch (CGSB 54-GP-1, Type 301). The ends of all thread breaks during seaming shall be securely backstitched.

5.6.1 Strength of Sewn Seams - The design of all seams shall be such that the strength of the seam shall be not less than 80 per cent of that of the material being joined. Seams shall be located so as to assist in developing the full strength of the covering and shall be of a type that shall not expose any raw edges.

Method par. 7.2.11

5.7 Strength of Assembly - The strength of any part of the jacket that could be grasped by hand shall be sufficient to allow the wearer to be assisted from the water.

Method par. 7.2.12

6. PREPARATION FOR DELIVERY

6.1 Labelling and Marking

6.1.1 Each Type I and II life jacket shall have a fabric label or labels attached to the covering material by stitching along the four edges of the label, and printed in indelible ink in English and French as follows:

SMALL VESSEL REGULATION LIFE JACKET

For a person weighing.....pounds

Manufactured to Canadian Government Specification 65-GP- 7

by.....
(name of company)

Date Lot No.

Department of Transport, Canada, approval number

BRASSIERE DE SAUVETAGE POUR PETITES EMBARCATIONS

Pour une personne pesant.....livres

Fabriquée selon la norme 65-GP-7 du gouvernement canadien

par.....
(nom de la compagnie)

Date.....No. du lot

No. d'approbation du ministère des Transports du
Canada

6.1.2 Each Type III (vinyl coated) life jacket shall be indelibly marked in accordance with the requirements of par. 6.1.1.

6.1.3 Labels shall include a diagram or jackets shall be stamped with a diagram demonstrating how the life jacket shall be worn.

6.1.4 Labels shall include the statement:

Approval void if jacket not maintained in serviceable condition.

L'approbation est nulle si la brassière de sauvetage n'est pas en bon état

7. INSPECTION

7.1 Jackets shall be examined for compliance with all the requirements, general and detail, of this specification.

7.2 Test Methods

7.2.1 Flotation (see par. 4.1.1, 4.1.2 and 4.1.3)

Adult test subjects shall, while wearing the life jacket, be required to fall into the water, first sideways and then forwards. In each case, and with the test subjects simulating unconsciousness, the position at which the body comes to rest, the amount of freeboard at the mouth, and the amount of head support shall be noted.

A children's size life jacket shall be tested on a child of appropriate size, but it shall only be necessary for the child to wade or be lowered into the water; falling-in need not be attempted. The child shall float in the required position.

7.2.2 Comfort - The test subject shall be required to swim, walk and sit while wearing the life jacket over a bathing costume. It shall provide reasonable comfort and ease of motion and shall not unduly interfere with the vision of the wearer, both in and out of the water. Note shall be made of any objectionable odor.

7.2.3 Ease of Donning, Adjustability and Reversibility - Test subjects shall, after an allowance of one minute to familiarize themselves with the life jacket, be required to don and properly secure the life jacket in darkness within 30 seconds without assistance. Sizes B and C life jackets whose designs are the same as Size A life jackets that comply, need not be tested. Other Size B and C life jackets shall be fitted to a child by an adult, under the same conditions. Note shall be made of the ease and extent of adjustments for fit, of the reversibility of the jacket, and of the slack between waist strap and buoyancy element in Style 1 jackets.

7.2.4 Breaking Strength and Elongation of Coating Material (Type III Jackets) - shall be determined in accordance with ASTM Method D882, Method B, using 1 x 6 inch specimens and a rate of travel of the power-activated grip of 20 inches per minute. Specimens shall be obtained as described in 7.2.7 below. The average breaking strength expressed as lb./in. of width, and the average elongation at break expressed as a percentage of the original gauge length, shall be reported.

7.2.5 Tear Resistance of Coating Material (Type III Jackets) - shall be determined in accordance with ASTM D1004 on "as received" and artificially weathered specimens obtained as described in par. 7.2.7. The average resistance to tearing shall be reported.

7.2.6 Adhesion of Coating to Foam (Type III Jackets) - shall be determined in accordance with ASTM D413 using the machine method, except that the average of 5 specimens from different parts of the jacket shall be used to determine compliance with the specification. Specimens that do not separate cleanly from the foam but show an adhesion in excess of 2 lb./in. shall be acceptable.

7.2.7 Aging of Coating Material (Type III Jackets) - Sufficient specimens for the breaking strength and tear resistance tests (10 specimens 6 x 1 inches and 10 specimens 5 x 2 inches) shall be taken from the jacket by slitting with a razor blade and stripping from the foam. The specimens shall be aged for 15 cycles in a twin arc weatherometer complying and operated in accordance with CGSB 1-GP-71 Method 122.2. After weathering, specimens shall be conditioned 40 hours at $23 \pm 1^\circ\text{C}$ and 50 ± 2 per cent RH and examined for legibility of markings, gross changes of color, or the development of surface defects. Specimens for the breaking strength and tear resistance tests shall be cut, a razor blade or die being used for the breaking strength test, and a die for the tear resistance test.

7.2.8 Aging of Jacket (Types I and III) - The complete life jacket shall be placed in a circulating air oven maintained at $140 \pm 5^\circ\text{F}$ for 168 hours, after which it shall be removed and cooled at room temperature for at least 12 hours. The vinyl coating (Type III) shall not become soft or sticky, nor develop blisters, checks or other defects that might affect serviceability. The life jacket shall then be subjected to the buoyancy test described in par. 7.2.9 and in no case shall the change in buoyancy from the original determination exceed 6 per cent.

7.2.9 Buoyancy - The life jacket shall be placed inside a cage of sufficient weight to hold the jacket under water. The assembly shall be suspended from a suitable scale or balance in fresh water at room temperature with the top of the cage two inches below the surface of the water, and the buoyancy determined. The buoyancy of the life jacket shall be calculated as the weight in water of the empty cage minus the weight in water of the cage-plus-jacket assembly.

7.2.10 Strength of Heat Seals - Five 1 x 6 inch specimens shall be cut at right angles to the heat-sealed seams with the seam in the middle. The breaking load of the seam shall then be determined by Method B of ASTM Method D882. All specimens shall pass.

7.2.11 Strength of Sewn Seams - Specimens shall be 4 inches wide and not less than 6 inches long, with the seam to be tested at right angles to the length and approximately equidistant from each end of the specimen. Ten specimens shall be tested by Section 9.A.1 of Method 9 of CGSB 4-GP-2. Specimens shall be tested wet.*

* The specimens shall be immersed and thoroughly wetted in water at room temperature to which has been added not more than 0.5 gram per liter of a neutral wetting agent.

7.2.12 Strength of Assembly

7.2.12.1 Waist Strap Assembly - With the life jacket suspended horizontally and the waist tape or harness adjusted to a medium position, and hanging freely, a weight of 200 lb. in the case of a Size A, or 125 lb. in the case of a Size B or C jacket shall be suspended from the bottom of the waist strap loop for 5 minutes and the life jacket examined for signs of damage and slippage of adjusting devices.

7.2.12.2 Strength of Neck Opening - The neck opening of a life jacket shall be statically loaded with a weight, first vertically and then horizontally, by grips curved to a radius of 3 inches. The load shall be applied for 5 minutes and the jacket examined for signs of damage after removal. The weights and grip sizes shall be:

Size A - 140 lb., grips 5 in. long, 3 in. wide,
Sizes B and C - 125 lb., grips 3 in. long, 3 in. wide

8. NOTES

8.1 The CGSB publications listed in Section 2 may be obtained from the CGSB Secretary.

8.2 The ASTM publications listed in Section 2 may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia 3, Pa., U.S.A.

8.3 This specification is subject to annual review.

Correspondence regarding this specification should be addressed to the Secretary, Canadian Government Specifications Board, National Research Council, Ottawa 2, Canada.

APPENDIX B

LIST OF WATER SAFETY DEVICES EVALUATED

LIST OF TESTED WATER SAFETY DEVICES

Branch	Model	Buoyant Material	L.J./PFD
Turner's Life Preserver	Vest	Kapok in vinyl sacks	x
Aqua Neptune	Slab	Unicellular foam	x
Aqua Neptune	Vest	Unicellular foam	x
Aqua Neptune	Vest	Kapok in vinyl sacks	x
Aqua Neptune	Slab	Kapok in vinyl sacks	x
Keep-a-Float	Vest	Kapok in vinyl sacks	x
Keep-a-Float	Slab	Kapok in vinyl sacks	x
Mermaid	Slab	Unicellular foam	x
Mermaid	Vest	Kapok in vinyl sacks	x
Stearns	Vest	Closed cell foam pad	x
Water Ski Vest with Collar	Vest	Vinyl envelopes filled with air	x
Water Ski Vest without Collar	Vest	Vinyl envelopes filled with air	x

APPENDIX C

MEAN WEIGHT AND HEIGHT OF
THE SUBJECTS PER AGE

TABLE 25

SUBJECTS' WEIGHT AND HEIGHT PER AGE

Age	N (203)	Weight				Height			
		M Kg.	M Lb.	SD Kg.	SD Lb.	M cm.	M in.	SD cm.	SD in.
1	3	11.9	26.25	0.6	1.30	83.8	33.0	1.6	0.6
2	2	14.2	31.38	1.8	4.07	92.4	36.4	0.1	0.0
3	6	14.8	32.72	2.3	4.97	97.6	38.4	6.2	2.4
4	12	16.7	36.75	1.7	3.79	103.9	40.9	4.9	1.9
5	13	19.9	43.77	3.4	7.47	111.3	43.8	7.1	2.8
6	28	20.8	45.81	2.6	5.76	116.3	45.8	4.4	1.7
7	29	24.4	53.86	3.4	7.52	122.2	48.1	5.9	2.3
8	51	27.2	60.08	5.0	11.33	128.3	50.5	6.2	2.4
9	42	28.9	63.75	4.6	10.09	131.4	51.7	5.4	2.1
10	11	31.3	68.95	4.5	9.89	137.4	54.1	4.6	1.8
11	5	29.7	65.45	3.5	7.64	136.0	53.5	5.7	2.2
12	1	35.9	79.25	0.0	0.00	145.0	57.1	0.0	0.0

APPENDIX D

CONSENT AND MEDICAL FORMS AND BRIEF
EXPLANATION OF TESTS TO PARENTS

UNIVERSITÉ D'OTTAWA



UNIVERSITY OF OTTAWA

ÉCOLE D'ÉDUCATION PHYSIQUE ET DE RÉCRÉATION
DÉPARTEMENT DE KINANTHROPOLOGIE

OTTAWA ONTARIO
CANADA K1N 6N6

SCHOOL OF PHYSICAL EDUCATION AND RECREATION
DEPARTMENT OF KINANTHROPOLOGY

LIFEJACKET EXPERIMENT

Dear Parents:

It is the intention of the University of Ottawa during the coming year to develop, in collaboration with the Product Safety Branch of the Ministry of Consumer & Corporate Affairs, safety standards which should prove to be essential to the manufacturing of lifejackets for children.

To develop these standards, some 300 children between the ages of 2 and 10 years will be acquired. Various anthropometric and buoyancy measurements will be taken on each participant prior to being tested with a prototype vest. The anthropometric buoyancy measurements and testing with prototype vests will be conducted at the University of Ottawa's laboratory and pool. A complete description of these tests have been included on the "consent form" for your information.

Since both the buoyancy measurements and the prototype testing will not be conducted during school hours but after 1600 hrs on week days and all day on weekends, the transportation to and from the University will be the responsibility of those conducting the experiments.

All of the testing will be done by and under the supervision of qualified personnel so as to assure the safety of all participants. Furthermore, all children will receive a verbal explanation of the tests being conducted. Thus, it is hoped that their participation in this experiment will provide them with a learning situation in which they can become familiar with various biomechanical concepts.

Parents who wish to have their child (children) participate in this experiment should complete the first part of the enclosed "Medical Questionnaire" and sign the "Consent Form" before returning them. The other two forms "Lifeguard Qualifications" and "Emergency procedure" have been enclosed for your own information. If you wish to receive additional information with regard to the experiment, please feel free to communicate with Mr. Charles Cotton at one of the following telephone numbers:

(1) 684-3705 - (2) 231-5929 - (3) 231-5928.

Hoping that you will respond favorably to this request by allowing your child (children) to participate in this experiment.

Yours truly,

Charles E. Cotton

DEPARTMENT OF KINANTHROPOLOGY
SCHOOL OF PHYSICAL EDUCATION & REC.
UNIVERSITY OF OTTAWA
LIFEJACKET EXPERIMENT

CONSENT FORM

TEST DESCRIPTION

1. Anthropometric measurements.

In addition to height and weight, the following measurements will be taken using a metric nylon tape or a Harpenden metal caliper :

Head Circumference - Arm Scye - Chest Circumference -
Waist Circumference - Chest Breadth - Shoulder Width -
Chest Depth - Bicep Girth - Thigh Girth - Calf Girth -
Leg Length - Back Length - Trunk Length - Sitting Height.

2. Buoyancy Distribution Measurement.

The child standing upon the instrumented suspended platform will be gradually lowered into the water tank. At each one tenth interval the total load on the platform will be measured. This procedure will be continued until the subject is submerged to his chin. At each location, measurement will be taken with the subject's arms at his sides and raised above his head. Weight measurement will be recorded on a EAl 1125 Variplotter.

The hoist apparatus is fail-safe and it is guaranteed for a 1/2 ton load. The platform and the child combined weight will never exceed 140 pounds.

3. Prototype testing in the pool

Each subject will evaluate each prototype by submitting them to the following test:

1. The subject will be asked to don the jacket in the water.
2. They will be asked to float on the jacket for a short period of time (1/2 to 1 minute).
3. While wearing one lifejacket the subject will be pushed into the water, and will be asked to relax upon submersion and let the jacket control his final position.
4. The subject will be asked to swim in the lifejacket on a given distance, once on the side, once on the front and once on the back.
5. From a horizontal position wearing a lifejacket, the subject will be asked to take a deep breath before allowing his faces to fall into the water at the same time his arm and legs to limp. The subject will keep this position until he rotates or his out of air (voluntary).
6. The subject will also be asked to float face-up in the lifejacket and remain completely relaxed, simulating a lifeless body.

All these tests will be done by swimmers in deep water and by non-swimmers in shallow water.

There will be at least two qualified lifeguards trained in first-aid, emergency procedures and in cardio-pulmonary resuscitation at all time.

There will also be a parent or adult present whose sole purpose will be to watch and look after the child while in the tank or pool.

NAME OF SUBJECT: _____ AGE: _____

ADDRESS: _____ PHONE: _____

In addition to reading the descriptions above I have received an explanation of the procedures to be used in the present study, and the potential risk involved has been outlined. The purpose and design of the experiment has been explained to the child and to myself. I understand that my child or protégé is free to withdraw from the study at any time and that his/her name will in no way appear in any disclosure of the experimental results.

I have read the above statement, and agree to have my child or protégé participate as a subject in this experiment.

Signature of Parent or Guardian

Signature of the Experimenter

DATE : _____

DEPARTMENT OF KINANTHROPOLOGY
SCHOOL OF PHYSICAL EDUCATION & REC.
UNIVERSITY OF OTTAWA
LIFEJACKET EXPERIMENT

MEDICAL QUESTIONNAIRE

CHILD'S NAME: _____

PART I

To be answered by parent or guardian.

Is your child suffering from:

	YES	NO
CHRONIC BRONCHITIS.....	___	___
CHRONIC EAR INFECTION....	___	___
CHRONIC SINUSITIS.....	___	___

Is your child ALLERGIC to :

	YES	NO
POLLENS	___	___
MEDICATIONS.....	___	___
CHLORINE.....	___	___
BROMIDE.....	___	___

Have YOUR CHILD EVER HAD:

	YES	NO
RHEUMATIC HEART DISEASE?	___	___
ANY LONG LASTING DISEASE AT ALL ?	___	___

Have your child ever been limited in physical activity by a PHYSICIAN?
YES _____ NO _____

If YES, Please give Detail: _____

Has your child been sick, at home within the last two weeks?

YES ____ NO ____

Details: _____

PART II

To be filled by the Physician:

Remarks: _____

Physician's signature: _____

Date: _____

DEPARTMENT OF KINANTHROPOLOGY
SCHOOL OF PHYSICAL EDUCATION & REC.
UNIVERSITY OF OTTAWA
LIFEJACKET EXPERIMENT

EMERGENCY PROCEDURE

1. Remove child from water.
2. Apply first aid required.
3. Phone 2222 (University of Ottawa emergency number)
and say : What the emergency is
Where the emergency is
Who is reporting the emergency .
An ambulance will be sent if required.
4. Keep involved person quiet, warm, as reassured as possible.
5. Notify the parent or guardian if not present.
6. Do not DISCUSS situation with anyone as there may be factors
that you do not fully understand.

DEPARTMENT OF KINANTHROPOLOGY
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UNIVERSITY OF OTTAWA
LIFEJACKET EXPERIMENT

LIFEGUARD QUALIFICATION

The lifeguardson duty during the experiment hold a certificate of the Canadian National Lifeguard Service and are regular lifeguards at the University of Ottawa.

REGULATION
made under
The Public Health Act
respecting
PUBLIC SWIMMING POOLS
Ontario Regulation 113/71
as amended by
O.Reg. 323/71 and O. Reg 1/72

JANUARY 1973

Each of the lifeguards used in this experiment is:

1. at least seventeen years of age; and
2. in possession of a lifeguard certificate issued to him and dated not more than two years prior to the date on which he acts as a lifeguard.

Lifeguard certificates means any one of:

- a) the Royal Life Saving Society's Bronze Medallion;
- b) the Canadian Red Cross Society's Water Safety Leader Award;
- c) the Canadian Red Cross Society's Water Safety Instruction Certificate;
- d) the National Lifeguard Service's Certification;
- e) the Young Men's Christian Association's Senior Lifesaving Award;
- f) the Senior Resuscitation Award

APPENDIX E

ANTHROPOMETRIC AND BUOYANCY

RAW DATA FORMS

ANTHROPOMETRIC DATA FORM

1. NAME: _____ No. _____
2. AGE: _____ mths
3. WEIGHT: _____ lbs
4. STANDING HEIGHT: _____ cm
5. HEAD CIRCUMFERENCE: _____ cm
6. NECK CIRCUMFERENCE: _____ cm
7. ARM SCYE: _____ cm
8. CHEST CIRCUMFERENCE: _____ cm
9. WAIST CIRCUMFERENCE: _____ cm
10. HIP CIRCUMFERENCE: _____ cm
11. CHEST BREADTH: _____ cm
12. SHOULDER WIDTH: _____ cm
13. CHEST DEPTH: _____ cm
14. BICEP GIRTH: _____ cm
15. THIGH GIRTH: _____ cm
16. CALF GIRTH: _____ cm
17. LEG LENGTH: _____ cm
18. BACK LENGTH: _____ cm
19. TRUNK LENGTH: _____ cm
20. SITTING HEIGHT: _____ cm
-
21. CONSTIPATED: YES _____ NO _____
22. TESTING TIME OF THE DAY: _____ hr

BUOYANCY TEST RAW DATA FORM

HEIGHT: _____ CALIBRATION _____
 WEIGHT: _____ lbs _____ NAME _____ NO. _____ TIME OF TEST _____

COMMENTS		ARMS ON THE SIDE				ARMS OVER THE HEAD			
HEIGHT SUBMERGED	CM SUBMERGED	TOTAL READING	CORRECT READING	ACTUAL WEIGHT	WEIGHT X 100	TOTAL READING	CORRECT READING	ACTUAL WEIGHT	WEIGHT X 100
SOLE									
0.1									
0.2									
0.3									
0.4									
0.5									
0.6									
0.7									
0.8									
CHIN									
HEIGHT SUBMERGED		NET BUOYANCY				NET BUOYANCY			

APPENDIX F

ANTHROPOMETRIC MEASUREMENTS OF
UNITED STATES CHILDREN

TABLE 26

MEANS COMPARISON OF FIVE ANTHROPOMETRIC MEASUREMENTS BETWEEN UNITED STATES
POPULATION AND PRESENT STUDY FOR COMBINED SEXES BY AGE

Variables cm.		Age by Years							
		2		3		4		5	
Study		US	(N= 106)	(N= 167)	(N= 556)	(N= 684)	(N= 416)		
		P	(N= 3)	(N= 2)	(N= 6)	(N= 12)	(N= 13)		
Standing Height	US	84.7	90.9	98.3	105.4	111.7			
	P	83.8	92.4	97.6	104.0	111.3			
Chest Breadth	US	16.4	17.1	17.5	18.2 ^b	18.9 ^b			
	P	16.5	17.9	17.5	18.9 ^b	19.5 ^b			
Waist Circum.	US	44.3	46.9	48.4	49.6	50.7			
	P	47.7	48.4	49.6	50.4	53.2			
Head Circum.	US	48.8	49.5	50.3	51.1	51.5			
	P	49.4	49.1	50.8	50.7	51.6			
Neck Circum.	US	24.3	25.1	25.6	26.4	26.9 ^b			
	P	25.1	24.3	25.1	26.0	25.7 ^b			

a= Significant at the .05 level

b= Significant at the .01 level

US= United States Study

P= Present Study

TABLE 26--Continued

Variables cm.	Study	Age by Years				
		7	8	9	10	11
		US (N= 346) P (N= 28)	(N= 278) (N= 29)	(N= 276) (N= 51)	(N= 263) (N= 42)	(N= 209) (N= 17)
Standing Height	US P	117.8 116.3	124.3 122.2	130.1 128.3	134.7 131.5	141.5 137.4
Chest Breadth	US P	19.6 19.7	20.3 ^b 20.9 ^b	21.8 ^b 21.1 ^b	21.6 21.9	22.6 22.7
Waist Circum.	US P	52.2 51.9	53.1 55.4 ^a	55.3 57.2	56.7 57.5	59.9 58.7
Head Circum.	US P	51.7 51.6	52.1 52.1	52.6 ^b 52.3 ^b	52.8 52.8	53.5 53.5
Neck Circum.	US P	27.5 ^b 26.5 ^b	28.4 ^b 26.8 ^b	28.7 ^b 27.6 ^b	29.8 28.3	30.6 28.2

a= Significant at the .05 level
b= Significant at the .01 level

US= United States Study
P= Present Study

APPENDIX G

PERFORMANCE AND CALIBRATION DATA
OF THE LOAD CELL AND CAGE

CALIBRATION OF THE LOAD CELL

Lbs	mv	mv	mv	mv
20	0.00945	0.00955	0.00945	0.00950
40	0.01835	0.01845	0.01845	0.01850
60	0.02725	0.02745	0.02745	0.02745
80	0.03625	0.03635	0.03645	0.03645
100	0.04515	0.04535	0.04535	0.04545
120	0.05415	0.05425	0.05435	0.05445
140	0.06315	0.06325	0.06335	0.06345
ave.	89.5	89.3	89.6	89.6

$$\frac{89.5 \text{ mv}}{201 \text{ Lbs}} = 4.475 \text{ mv/lb}$$

OUNCES TO DECIMAL

1	.06
2	.13
3	.19
4	.25
5	.31
6	.38
7	.44
8	.50
9	.56
10	.63
11	.69
12	.75
13	.81
14	.88
15	.94
16	1.00

Used to convert
body weight scores

LIST OF THE PERFORMANCE DATA
OF THE LOAD CELL

Input Resistance	350 ± 3.5 ohms
Output Resistance	350 ± 3.5 ohms
Recommended Excitation	10 VDC or VAC
Maximum Excitation	15 VDC or VAC
Non-Linearity (terminal)	$< 0.03\%$ FS
Hysteresis	$< 0.02\%$ FS
Compensated Temperature Range	0°F to 150°F
Thermal Zero Shift	$< \pm 0.0008\%$ FS/°F
Zero Balance	$< \pm 1\%$ FS

ACTUAL WEIGHT OF THE CAGE WHEN
SUBMERGED AT DIFFERENT LEVELS

cm. SUBMERGED	ACTUAL WEIGHT OF THE CAGE (mv)	cm. SUBMERGED	ACTUAL WEIGHT OF THE CAGE (mv)
0	151.0	60	136.0
-	149.5	-	134.5
5	148.0	65	133.0
-	147.0	-	133.0
10	146.0	70	133.0
-	145.0	-	131.5
15	145.0	75	130.0
-	144.5	-	130.0
20	140.0	80	131.0
-	144.0	-	130.0
25	144.0	85	130.0
-	144.0	-	130.0
30	144.0	90	129.0
-	142.5	-	127.5
35	141.5	95	126.0
-	140.5	-	126.0
40	139.0	100	126.0
-	138.5	-	126.0
45	138.0	105	125.0
-	138.0	-	125.0
50	138.0	110	125.0
-	137.5	-	125.0
55	137.0	115	124.0
-	136.5	-	124.0

APPENDIX H

RAW DATA FOR ANTHROPOMETRIC MEASUREMENTS

APPENDIX H

RAW DATA FOR ANTHROPOMETRIC MEASUREMENTS

The anthropometric measurements raw data are presented for all subjects in the order in which they were taken. The age is presented in months, the weight in kilograms and the anthropometric measurements in centimetres.

The subject's identification number is presented first, followed by a sex differentiation number in column two. Numbers 0 or 1 designate a girl or a boy respectively. The number in the third column represents the age of the subject, while the weight is given in the fourth column. Columns five through twenty-one represent the anthropometric measurements in the following order: standing height, head circumference, neck circumference, arm scye, chest circumference, waist circumference, hip circumference, chest breadth, shoulder width, chest depth, biceps girth, calf girth, leg length, back length, trunk length and sitting height.

001	0	68	19.6	117.3 22.0	54.3 52.8	27.0 27.3	24.5 42.3	65.8 62.7	49.7	58.6	20.1	27.6	13.0	16.8	29.7
002	0	76	17.5	110.2 21.0	48.5 50.0	24.7 25.8	22.0 40.0	56.3 58.5	50.2	60.4	18.4	26.9	12.8	15.3	31.5
003	0	54	14.6	96.3 20.9	51.1 39.2	25.4 24.0	22.8 36.4	51.8 56.5	48.2	54.1	19.0	25.2	12.5	15.2	27.6
004	1	122	25.5	126.4 25.7	53.8 58.8	28.4 29.7	30.5 45.0	65.0 65.2	57.2	65.0	22.6	31.7	14.7	18.3	36.3
005	0	99	27.9	131.6 26.3	53.2 58.9	28.0 33.3	30.1 52.2	63.8 69.7	55.5	70.2	21.9	33.0	14.1	17.8	39.2
006	0	102	26.2	126.6 25.7	50.2 59.8	26.3 30.5	34.0 49.3	63.0 65.6	57.3	69.5	20.6	31.7	14.9	19.6	33.6
007	1	97	21.7	120.2 23.8	51.0 56.5	26.3 26.8	28.8 43.0	59.9 63.0	52.7	61.2	21.0	39.9	13.9	17.3	34.2
008	1	109	23.6	126.6 24.6	50.2 60.8	27.8 26.7	32.7 42.0	62.5 64.6	52.4	63.7	21.7	29.9	13.0	17.3	33.7
009	0	97	23.1	127.6 23.7	50.2 59.1	24.1 26.2	25.8 45.4	59.3 65.8	52.4	63.6	19.6	29.9	12.8	16.8	34.2
010	1	109	21.8	121.8 23.7	50.7 58.3	26.5 25.0	27.8 37.1	65.3 59.3	52.0	64.2	20.6	30.2	15.9	21.3	28.5
011	1	82	19.7	116.5 23.0	50.1 52.1	26.5 30.0	30.0 45.7	58.1 61.1	50.9	60.2	19.0	29.2	12.5	17.2	31.2

012	0	121	40.1	143.7 31.0	55.2 69.2	28.5 28.4	29.0 52.2	69.5 74.6	68.6	84.3	22.6	35.8	15.1	24.2	46.5
013	1	95	24.0	123.8 24.1	52.3 56.8	26.2 28.0	32.2 45.0	61.8 63.6	55.2	66.8	20.7	30.7	14.9	17.5	35.4
014	0	118	27.0	131.6 26.2	53.1 61.0	26.5 29.9	33.0 48.3	63.1 64.0	55.4	70.1	21.6	32.5	12.9	19.2	38.9
015	0	103	33.6	133.8 28.9	52.4 62.2	26.4 33.1	35.1 51.5	64.5 71.5	62.3	79.1	22.9	34.9	14.5	20.7	42.6
016	0	84	16.2	112.4 21.3	49.7 47.8	22.8 25.5	29.5 42.6	52.4 59.2	48.5	56.4	18.2	27.5	10.9	14.5	29.3
017	1	136	31.5	139.8 27.6	53.6 67.8	28.5 34.8	31.3 50.5	68.7 72.2	58.4	68.5	23.2	34.4	14.6	18.4	37.9
018	0	107	28.6	136.5 25.7	52.4 66.8	27.2 31.0	24.3 49.4	62.7 67.4	51.6	72.8	21.1	32.3	14.5	18.7	38.7
019	0	107	38.5	138.5 31.1	55.3 65.3	29.0 30.1	30.1 50.1	66.18 72.3	56.5	80.6	22.2	35.7	14.9	23.8	43.3
020	0	110	23.6	126.4 25.3	50.8 58.4	25.7 26.1	29.6 46.9	61.2 65.5	52.2	66.4	21.5	31.7	13.7	17.0	34.9
021	0	111	21.4	122.8 23.9	52.2 56.0	27.1 25.3	27.0 44.4	62.2 61.3	56.5	66.4	18.9	27.9	13.2	17.3	31.8
022	0	103	22.6	122.8 23.4	49.4 57.8	25.9 33.5	29.8 48.7	63.2 62.1	58.4	67.6	22.0	30.4	14.0	18.3	29.8

023	1	103	23.0	123.7 24.2	52.5 58.2	26.8 25.7	28.2 44.0	62.1 62.4	53.3	65.2	19.9	29.5	13.9	16.8	33.5
024	1	78	20.7	119.0 22.8	49.5 55.5	25.5 28.8	26.0 42.5	58.3 62.2	54.2	62.3	20.3	29.0	13.9	16.0	32.3
025	0	117	31.9	132.8 28.4	53.6 62.2	28.0 31.6	29.6 50.5	67.8 68.6	59.9	74.1	24.1	34.9	15.5	20.7	41.3
026	1	93	26.0	127.0 26.5	54.5 56.5	26.5 27.0	29.6 47.3	62.1 65.1	56.4	70.9	20.8	31.8	12.9	18.1	31.5
027	1	116	26.6	126.2 36.5	53.3 56.0	27.4 32.0	30.2 48.5	62.0 66.8	56.0	67.5	31.8	31.0	15.5	19.2	32.0
028	0	84	20.2	116.6 23.8	49.5 51.2	24.5 27.3	28.2 44.5	59.1 59.5	49.6	62.2	20.6	28.8	13.1	17.0	34.3
029	0	79	18.5	108.3 22.5	51.7 45.0	24.3 28.4	27.0 43.9	57.0 56.5	51.5	60.0	19.0	27.6	12.6	15.9	25.5
030	0	92	25.7	125.5 25.7	50.6 55.2	26.7 30.2	31.4 48.0	68.5 68.0	57.1	71.6	24.1	22.4	14.2	19.2	37.8
031	1	109	29.7	133.1 27.8	55.5 60.2	26.9 33.3	38.7 50.9	63.3 71.2	59.0	73.6	21.6	31.8	14.5	20.1	36.2
032	1	76	20.8	119.0 22.8	51.2 52.1	25.8 31.6	33.5 45.1	58.5 67.2	52.0	63.4	19.9	29.9	12.5	16.0	30.3
033	0	101	26.7	128.8 25.0	51.9 58.6	25.5 30.0	28.6 48.2	62.6 68.2	56.0	68.1	22.1	32.8	12.3	19.0	37.5

034	0	66	19.3	108.5	51.8	25.4	27.1	56.0	55.5	60.1	20.0	29.0	12.5	17.4	34.1
				23.0	49.0	28.2	42.9	60.7							
035	0	118	34.1	140.5	51.6	28.2	33.0	68.0	55.6	74.0	22.4	33.6	13.9	22.1	41.6
				31.0	66.0	33.5	54.4	71.8							
036	1	107	27.7	135.5	53.0	25.6	31.8	62.7	55.8	73.2	23.1	31.4	12.9	19.0	37.8
				26.5	61.6	34.1	51.7	70.2							
037	0	97	20.7	120.1	52.7	25.4	29.0	60.2	58.1	61.9	19.9	28.3	12.6	16.1	33.2
				22.5	54.8	29.2	45.2	65.0							
038	1	105	37.2	138.3	56.0	30.9	31.5	72.1	63.2	80.0	24.9	34.9	15.8	24.2	44.2
				29.8	65.0	32.4	52.4	71.8							
039	0	100	23.7	126.6	51.3	25.7	30.7	59.0	51.8	67.7	20.7	29.9	12.6	17.9	35.0
				24.6	58.0	31.1	49.5	66.0							
040	0	90	22.4	129.1	52.0	24.9	28.0	56.0	51.4	64.7	19.6	28.7	11.5	16.7	32.8
				24.6	59.6	31.3	48.6	67.3							
041	1	103	29.8	136.7	51.8	28.5	32.1	64.8	61.9	69.0	23.4	35.1	14.0	18.8	35.9
				26.0	63.4	30.9	48.9	68.6							
042	1	86	31.2	130.2	53.8	27.8	30.2	67.2	62.0	77.2	23.2	33.5	14.6	20.2	39.7
				29.0	57.9	31.2	50.3	69.1							
043	0	113	27.5	129.4	52.6	26.4	33.8	66.7	58.7	69.2	24.1	34.1	14.0	18.7	37.3
				26.2	59.7	30.1	47.7	66.8							
044	0	96	32.7	135.1	51.3	29.5	29.0	68.6	56.5	77.0	22.2	34.2	15.3	20.8	43.5
				28.2	62.0	31.4	50.8	72.8							

045	0	100	25.4	121.5 26.0	51.7 53.0	26.5 32.1	31.4 47.3	63.0 65.8	57.7	68.0	21.5	31.4	14.2	19.1	37.5
046	1	81	23.7	118.2 25.4	52.7 51.5	27.5 29.0	30.0 45.1	61.1 64.1	54.9	65.7	19.4	29.0	13.6	18.5	35.0
047	1	115	25.1	124.8 24.5	52.8 56.7	26.8 28.6	29.2 45.4	66.3 65.2	59.5	70.2	21.9	31.2	15.0	18.8	35.0
048	0	102	27.8	129.0 27.6	49.7 60.5	26.4 28.5	31.0 45.6	61.3 67.5	54.8	68.8	21.5	32.7	13.9	18.5	40.2
049	0	104	23.7	121.6 24.5	49.5 58.8	25.6 27.0	31.0 48.0	62.5 64.2	54.4	67.0	21.8	31.4	14.0	18.3	36.8
050	0	113	24.1	132.4 23.6	49.2 61.8	25.5 31.4	29.0 49.7	58.5 68.7	52.4	63.5	19.4	30.9	13.2	16.4	33.1
051	0	121	26.4	136.2 24.5	50.2 64.2	23.1 33.5	32.0 51.0	57.6 71.0	48.7	65.3	21.2	31.6	12.8	18.1	34.8
052	0	103	24.5	124.9 26.5	50.7 58.0	25.7 29.0	31.2 48.0	59.5 64.9	53.0	70.0	21.1	29.5	14.2	18.4	37.0
053	1	88	20.4	113.1 23.3	51.6 51.4	26.2 24.0	28.8 42.3	56.7 59.2	53.9	59.5	19.8	29.4	12.9	17.6	34.0
054	1	105	30.1	130.6 27.2	53.3 59.0	27.5 28.8	33.3 50.0	68.2 68.7	60.0	75.2	23.6	34.5	14.5	19.9	38.3
055	1	94	26.9	122.8 26.8	52.8 55.3	28.2 28.4	29.7 47.0	63.6 67.6	56.5	67.5	21.9	32.7	13.9	19.2	36.2

056	1	104	30.3	136.6 27.5	54.6 63.6	28.0 31.4	33.0 49.4	64.3 71.1	56.0	76.1	21.6	33.8	13.9	18.5	35.5
057	1	88	29.9	128.4 28.0	53.6 57.4	28.2 32.9	31.8 50.0	66.2 69.1	60.5	73.1	21.9	33.7	14.8	21.4	35.2
058	1	116	24.0	127.8 24.7	52.7 57.6	25.6 29.9	29.2 50.6	60.7 68.6	54.0	68.7	21.8	33.5	13.2	17.3	31.6
059	1	126	28.1	142.1 25.9	52.8 79.5	26.8 33.4	29.0 50.5	59.9 67.9	58.3	71.4	22.0	32.7	11.9	18.2	33.0
060	1	107	23.3	123.6 23.8	53.5 58.5	25.8 29.1	29.3 47.8	61.0 64.5	55.3	68.7	21.8	30.0	14.2	18.4	30.5
061	0	117	33.4	133.9 28.5	53.8 61.5	29.6 29.7	37.2 51.7	70.6 70.3	62.0	76.4	22.9	33.7	15.9	28.0	40.7
062	0	104	40.5	130.2 30.5	53.3 56.8	31.1 33.5	32.3 50.7	82.2 67.8	81.0	80.5	26.3	37.6	18.6	25.1	45.2
063	1	79	23.7	121.1 24.3	54.5 49.8	29.6 29.7	31.9 47.1	62.2 67.1	55.3	66.4	20.8	31.6	13.2	19.2	30.5
064	0	104	32.8	136.8 27.9	55.1 61.3	28.3 32.7	32.5 52.0	68.0 71.7	63.7	72.5	23.7	33.6	15.8	22.6	40.5
065	1	107	41.2	128.6 31.2	53.4 58.7	30.6 32.8	34.5 50.2	76.8 69.1	84.3	87.5	27.0	39.9	17.4	23.9	45.0
066	1	100	26.9	132.5 25.6	53.6 59.9	27.5 30.0	33.3 48.5	64.0 67.9	56.8	69.2	30.6	21.5	13.4	18.5	34.9

067	1	126	30.9	135.5 26.9	54.2	30.4	31.6	65.4	60.0	69.2	22.6	33.6	14.4	20.9	39.3
068	1	95	23.7	122.8 24.5	51.9	25.5	27.1	59.5 63.7	54.3	68.0	20.2	30.2	13.4	17.3	32.2
069	1	97	23.8	124.2 26.7	52.3	26.0	31.1	60.5 66.5	54.2	65.2	19.9	30.7	13.5	17.2	32.0
070	1	122	26.5	135.1 24.0	52.3	26.3	30.0	60.4 68.9	54.2	71.3	22.3	32.2	13.0	18.7	36.6
071	1	118	25.6	135.2 25.0	53.5	26.6	24.6	59.0 67.0	55.2	67.9	21.6	31.9	12.6	16.3	31.2
072	1	59	13.7	97.9 19.1	49.6	24.4	22.5	50.9 54.8	47.4	52.5	18.2	25.3	11.4	15.9	27.3
073	0	70	19.7	114.5 23.8	53.0	24.9	26.8	54.2 58.3	52.6	60.3	18.9	27.5	12.3	16.8	30.0
074	0	110	30.3	135.8 27.5	50.6	26.1	34.0	70.1 68.5	63.0	57.2	23.0	33.5	15.0	22.7	42.2
075	1	138	30.4	138.1 26.6	51.3	28.8	31.2	67.8 69.8	59.2	70.4	22.6	33.0	14.9	18.6	38.3
076	1	151	35.9	145.0 28.5	53.4	29.7	34.9	70.5 74.4	60.0	74.8	25.6	35.9	14.6	20.7	42.6
077	1	125	32.7	139.6 28.1	53.8	28.6	33.8	67.7 72.0	56.4	76.3	22.6	34.0	15.6	19.2	39.6

078	0	104	23.0	124.2 23.2	50.0	24.0	29.4	60.2	53.2	66.2	21.3	32.2	14.0	17.5	33.2
079	0	114	31.2	126.0 30.7	51.5 60.6	29.9 30.9	38.5 47.9	63.5 65.9	59.9	76.0	22.9	33.5	14.7	21.3	41.0
080	0	62	17.8	100.8 23.5	48.7 44.6	24.8 23.3	24.5 37.8	58.0 55.8	52.0	61.7	20.0	28.3	12.7	18.4	33.6
081	0	116	33.4	138.8 28.9	51.9 65.9	27.8 32.7	32.8 52.0	67.3 70.5	58.0	78.1	22.9	35.1	15.3	20.2	39.5
082	0	91	19.9	113.1 23.7	51.5 51.5	24.5 26.4	28.1 42.6	59.4 59.3	51.1	62.7	19.8	29.0	11.9	16.2	32.0
083	0	97	26.2	130.7 25.7	52.7 62.5	26.0 27.0	30.4 45.1	59.9 65.8	55.1	67.5	20.0	30.4	12.7	18.6	35.3
084	0	96	25.0	120.9 24.9	53.4 56.3	27.3 29.9	31.3 45.1	66.2 63.2	56.5	71.5	22.5	32.9	11.9	18.3	36.6
085	0	116	30.7	138.3 26.0	54.4 67.1	27.6 30.0	32.1 50.6	64.6 70.7	56.9	71.3	22.2	33.3	13.6	18.3	36.8
086	1	116	29.1	137.1 25.7	52.5 63.9	27.9 33.4	31.1 50.1	61.2 69.6	57.8	71.3	20.9	32.6	13.8	17.9	37.9
087	0	119	25.3	127.6 26.0	49.0 58.7	24.6 28.1	30.0 48.5	60.8 68.4	51.2	69.3	19.9	31.4	13.2	19.0	39.7
088	0	98	20.2	116.5 23.1	50.2 53.2	24.2 26.6	27.5 44.3	59.1 60.2	50.7	63.2	19.4	27.4	14.1	17.5	34.5

089	0	73	17.0	111.2 22.8	49.3	25.0	25.0	25.0	52.5	47.2	59.3	18.4	26.9	12.0	15.4	27.0
090	1	87	27.0	132.0 26.4	50.9	26.2	30.5	60.2	51.5	70.2	19.8	32.0	13.0	18.2	37.5	
091	0	118	38.3	133.4 29.0	51.3	29.0	33.2	72.1	61.0	80.3	23.1	33.1	17.3	23.9	45.8	
092	0	102	32.4	134.7 28.4	54.2	26.5	32.2	70.0	62.2	77.0	24.1	35.0	14.2	20.6	39.8	
093	0	117	28.4	128.5 27.6	51.9	26.0	29.5	63.4	54.5	69.2	21.5	32.3	14.2	20.0	37.0	
094	0	101	25.2	127.8 26.8	51.3	25.8	32.5	58.7	54.2	71.2	19.5	29.5	13.7	18.8	36.2	
095	1	75	21.0	116.8 23.3	49.8	25.0	30.0	58.5	51.5	64.6	19.9	29.5	12.9	16.0	32.0	
096	1	82	21.4	122.2 24.2	51.1	25.6	27.0	59.8	51.3	65.0	20.5	28.7	13.9	17.5	33.4	
097	0	75	19.4	114.3 23.8	50.2	25.0	27.0	55.2	51.1	60.2	18.8	28.3	11.6	16.8	32.8	
098	0	101	28.0	126.5 26.8	51.6	26.1	32.6	62.3	60.0	72.3	21.3	32.3	14.4	20.0	37.5	
099	1	93	25.0	122.8 25.2	52.2	26.5	31.0	61.3	52.5	71.2	19.7	29.8	15.9	18.0	36.0	

100	1	108	27.1	133.0	53.2	26.7	31.0	62.6	53.0	71.5	20.7	32.0	13.4	18.2	32.6
				25.8	61.1	31.2	49.9	69.9							
101	1	108	33.4	130.3	51.7	28.4	38.3	66.5	57.0	72.4	22.1	34.4	15.5	20.3	32.7
				27.1	63.3	35.5	52.9	67.9							
102	0	96	25.3	122.8	51.6	27.1	30.5	61.3	53.4	64.6	21.9	32.2	13.1	18.6	34.2
				25.7	56.4	29.1	45.1	63.7							
103	1	131	33.3	136.7	54.1	30.4	34.4	71.9	61.8	70.5	24.5	35.2	15.5	21.1	38.9
				28.6	66.0	32.1	49.0	69.5							
104	1	107	22.9	128.6	53.0	26.5	29.2	59.8	52.2	65.0	20.9	29.2	14.3	17.2	28.5
				23.2	61.0	30.9	46.9	62.9							
105	1	108	30.7	133.5	51.9	28.9	38.4	67.8	50.3	72.5	23.2	33.9	15.0	20.8	36.2
				26.3	62.0	31.8	49.5	68.5							
106	1	74	22.2	116.8	53.3	26.0	28.5	59.0	55.2	64.6	21.2	29.2	12.7	17.0	32.0
				23.5	52.8	27.0	43.0	61.8							
107	0	109	34.8	134.7	51.1	26.8	33.0	68.3	60.3	79.2	21.8	32.7	15.5	22.2	43.3
				29.0	63.0	32.5	52.2	69.1							
108	0	82	17.4	112.4	49.8	23.9	28.3	53.6	46.7	58.2	18.8	28.5	11.9	15.5	30.1
				21.7	49.6	22.6	41.6	61.1							
109	0	99	27.9	129.2	50.9	26.1	35.9	66.0	55.8	72.0	19.9	31.0	14.6	19.5	39.8
				28.0	60.2	28.5	47.5	68.0							
110	0	100	28.5	136.3	51.2	26.6	32.2	65.8	58.3	72.3	21.6	31.5	15.9	18.8	32.5
				26.8	62.5	32.8	51.5	71.4							

111	1	83	25.4	120.1 26.8	52.6 52.3	26.8 27.9	31.9 46.0	61.2 63.7	56.0	70.4	20.7	30.9	14.2	19.3	35.0
112	0	86	23.2	118.7 25.2	49.5 55.2	25.2 29.0	28.5 43.5	60.1 63.1	54.6	67.1	21.4	31.7	13.8	18.4	33.2
113	0	99	32.3	126.9 29.3	53.2 56.8	27.3 30.8	36.3 48.5	67.4 67.8	62.3	80.5	23.6	33.9	15.0	22.5	46.4
114	0	111	19.5	118.2 23.7	49.5 51.2	24.1 27.5	33.8 48.2	57.0 63.8	49.5	64.0	20.5	29.0	13.3	16.4	32.2
115	0	118	36.8	136.8 31.2	52.3 60.6	29.9 31.3	31.4 52.5	68.5 71.0	63.4	79.5	24.0	35.3	14.2	22.7	45.6
116	1	114	20.7	120.5 23.0	52.5 54.7	26.7 29.9	28.7 44.4	59.7 63.8	51.5	64.2	20.3	31.4	13.4	16.6	29.2
117	1	122	35.4	137.6 29.4	54.2 61.1	30.5 34.5	33.1 51.8	66.5 73.4	62.5	76.8	23.3	35.0	15.4	22.3	40.1
118	0	106	24.7	126.2 26.2	51.7 56.8	27.3 31.0	31.2 49.3	61.0 66.1	54.6	70.5	20.9	30.5	14.5	19.5	36.9
119	0	86	20.6	114.9 23.6	52.9 51.0	25.3 25.3	32.6 44.6	61.4 60.5	53.6	64.8	20.0	29.8	13.8	17.4	34.3
120	0	63	23.3	121.0 25.3	53.1 52.5	27.8 30.0	28.0 48.0	59.8 66.2	56.5	65.0	20.0	29.2	12.7	18.5	36.8
121	1	84	24.1	118.3 25.2	52.5 51.6	28.1 26.8	27.0 46.9	63.8 62.5	51.4	67.3	19.7	30.5	13.9	18.5	33.8

122	1	86	26.6	122.7 27.5	54.0 53.5	29.7 32.4	33.2 47.7	63.0 64.1	62.1	70.1	21.9	32.0	14.0	19.3	37.2
123	1	72	27.5	124.8 25.7	53.2 56.1	28.5 29.2	28.1 48.4	59.4 63.4	59.5	71.5	21.9	30.9	13.6	18.6	36.0
124	0	112	29.9	130.1 27.3	52.6 60.9	27.7 31.2	31.3 49.0	66.2 68.9	55.8	72.5	22.5	31.6	15.5	19.5	41.9
125	1	120	29.3	131.9 26.8	54.2 58.3	28.3 32.4	28.6 51.2	62.2 67.8	56.4	71.8	20.9	31.5	15.0	19.1	34.8
126	1	88	18.9	109.8 23.9	51.0 48.8	24.2 27.0	26.9 40.4	58.5 59.1	50.8	59.7	19.9	28.4	13.5	16.8	31.2
127	1	88	21.2	116.3 23.6	53.8 50.5	24.4 27.6	29.0 43.3	56.8 62.4	55.0	64.3	19.4	29.0	13.4	16.8	31.0
128	0	120	38.1	137.0 28.7	54.3 65.0	30.4 31.0	34.1 50.0	74.3 70.4	65.5	80.3	23.8	36.8	15.1	23.2	43.5
129	1	113	32.3	134.7 27.2	55.0 64.7	28.9 31.6	34.7 47.9	63.6 67.5	61.1	76.0	21.3	32.9	15.0	20.5	36.2
130	1	88	21.0	116.6 24.0	52.0 52.8	25.4 28.0	33.1 43.0	60.8 60.0	52.8	63.1	19.7	30.4	14.0	16.7	30.6
131	1	83	21.7	118.2 23.8	51.7 55.2	24.8 28.0	28.2 42.0	59.7 59.0	53.2	65.0	20.9	28.9	14.5	16.2	31.0
132	0	115	29.6	131.1 26.5	55.5 62.1	28.8 27.8	34.6 46.5	66.0 66.6	56.2	73.5	21.9	33.7	13.9	20.3	39.9

133	0	99	18.0	113.2 22.3	51.0 52.7	24.2 25.1	24.5 41.0	58.0 59.4	49.8	58.1	19.9	27.3	12.8	16.2	28.1
134	1	92	25.0	124.6 26.2	53.8 55.2	26.9 29.5	31.5 47.4	62.5 65.0	56.7	69.5	20.9	30.0	13.8	17.9	34.2
135	1	60	17.5	107.8 21.8	49.0 47.8	25.2 25.4	25.2 40.0	58.1 57.7	52.3	55.5	19.7	27.6	13.6	16.6	30.0
136	0	96	26.2	128.3 24.9	49.8 59.5	26.2 27.8	28.5 45.5	64.5 67.0	56.3	68.5	20.5	30.9	14.7	19.1	40.3
138	0	94	26.7	121.4 26.1	49.5 55.8	26.8 29.0	28.5 44.4	63.9 63.1	59.7	70.8	22.7	33.0	14.4	18.5	36.1
139	0	94	26.2	119.5 27.3	49.7 54.3	25.7 26.2	28.8 43.4	61.8 63.3	56.1	71.1	21.2	32.0	14.4	19.3	33.8
140	1	120	33.6	124.6 29.8	54.0 55.8	29.4 30.9	32.0 47.3	69.6 66.0	68.3	80.5	23.3	34.9	16.7	21.1	42.8
141	1	103	18.5	110.9 21.1	51.0 48.0	25.3 27.8	33.5 43.4	58.0 59.7	52.5	61.3	19.3	28.4	13.1	17.6	29.7
142	1	84	25.3	122.6 24.3	55.1 55.5	25.3 29.2	24.8 44.4	61.5 62.8	59.2	67.2	21.6	30.9	14.0	17.5	33.2
143	0	82	21.9	116.8 25.2	53.2 53.0	26.1 27.0	29.0 44.1	58.5 62.5	51.2	65.4	19.9	29.2	12.2	18.2	33.2
144	1	132	34.3	141.5 27.3	54.4 69.5	30.3 30.9	35.0 49.6	71.4 72.2	59.2	72.5	24.2	34.5	16.5	20.8	39.5

145	1	60	16.1	104.3 22.0	52.3 45.5	24.2 23.4	22.9 37.4	52.0 56.6	50.5	53.0	18.5	27.4	12.0	16.1	29.4
146	0	120	27.4	131.5 26.1	54.9 60.7	30.5 27.8	30.9 48.2	62.5 70.0	55.5	67.3	20.8	31.9	14.3	19.2	39.1
147	0	107	22.2	122.8 23.3	53.5 56.3	26.6 28.6	26.6 44.4	60.5 65.6	53.8	60.6	21.8	29.9	13.5	16.8	35.2
148	1	64	21.7	113.5 24.6	51.4 46.0	29.2 26.0	27.4 43.0	58.7 62.2	56.0	61.4	20.1	28.6	14.0	19.3	35.8
149	0	40	16.1	99.6 21.4	51.4 45.6	25.1 23.3	23.8 37.9	52.1 54.7	50.0	54.5	17.5	24.8	12.0	16.6	31.2
150	1	82	19.0	111.5 23.4	50.5 48.0	26.3 26.7	26.7 41.0	57.2 60.5	50.5	58.2	19.4	28.7	12.8	16.0	32.1
151	1	59	17.0	106.9 22.4	49.4 45.6	26.0 22.8	23.2 37.4	54.8 58.3	50.0	55.9	19.1	27.7	12.3	17.0	30.8
152	1	89	23.1	121.9 23.2	53.2 52.8	28.4 27.0	29.7 44.6	59.0 65.2	54.6	62.4	20.5	29.3	14.4	18.0	33.8
153	0	75	22.0	123.1 23.2	51.5 55.8	26.5 26.8	26.2 44.8	56.1 65.7	50.6	62.5	20.0	29.9	13.4	17.9	35.9
154	0	118	23.8	130.9 22.3	51.6 61.7	26.3 29.2	29.5 48.6	62.0 67.5	53.4	64.6	21.2	31.2	13.9	17.6	36.4
155	0	61	15.1	105.7 20.9	49.8 44.9	24.7 26.1	21.3 40.1	53.3 57.1	52.4	56.5	18.6	26.8	12.2	16.8	30.6

156	0	66	22.7	111.0 26.0	52.7	26.8	27.5	58.9	55.2	69.2	19.9	29.3	13.9	20.6	37.4
157	1	39	13.0	91.5 19.6	52.2	24.9	19.8	50.3	48.1	51.0	17.1	24.2	12.2	15.1	25.9
158	0	60	15.2	97.7 22.2	50.3	23.6	23.3	52.9	48.0	54.8	19.3	26.6	11.0	16.9	31.8
159	0	120	29.4	136.5 27.2	54.6	27.2	29.6	63.5	59.2	68.8	22.0	31.9	13.2	20.3	41.3
160	0	133	25.3	127.5 24.3	52.8	26.6	28.6	61.5	52.5	67.9	20.2	31.3	13.7	18.4	40.8
161	1	119	29.6	135.6 25.2	53.1	29.1	31.3	65.8	57.8	70.3	21.1	32.0	15.0	19.8	38.7
162	1	86	19.1	119.3 23.7	50.5	26.5	26.2	59.8	55.7	63.8	20.4	29.7	13.4	18.2	39.2
163	1	67	18.0	107.5 22.9	49.4	23.8	25.2	54.2	51.0	60.1	18.4	27.5	11.6	17.8	32.2
164	1	140	34.0	141.6 27.2	53.1	29.7	33.6	67.8	62.3	71.4	24.0	33.9	15.4	20.2	41.7
165	1	112	32.3	133.4 28.1	55.1	29.9	32.7	67.9	66.9	72.8	22.6	35.1	16.0	20.2	41.6
166	1	115	31.4	136.0 27.6	51.3	28.5	32.7	65.7	61.0	71.2	22.2	34.0	16.1	21.5	41.8

167	1	116	29.3	137.0 27.3	55.2 63.9	28.2 30.9	31.5 48.6	61.3 68.8	56.5	69.0	21.1	32.3	14.2	19.3	40.4
168	0	21	11.6	82.0 20.8	48.6 31.5	24.4 22.6	25.5 34.6	53.0 48.7	48.9	49.8	16.8	23.5	12.1	17.3	29.1
169	1	50	17.1	104.7 22.3	50.5 42.4	25.0 25.1	25.2 39.9	54.2 59.5	54.1	56.2	19.0	25.5	12.7	17.3	29.7
170	0	118	29.5	137.0 28.2	51.6 63.9	27.0 30.4	32.1 51.7	63.2 71.4	57.1	69.7	22.2	32.7	14.6	20.2	40.8
171	1	85	23.2	121.2 25.2	55.9 52.6	27.1 29.1	27.0 43.8	59.2 62.4	58.3	63.2	20.5	20.6	14.2	17.5	33.9
172	0	22	11.6	84.2 20.8	49.1 27.5	25.5 19.6	23.2 33.8	50.5 49.0	45.9	50.0	16.0	21.5	12.6	16.1	25.5
173	0	52	17.7	104.1 24.0	52.4 44.3	26.1 24.4	24.2 39.0	55.5 57.5	50.3	57.5	19.0	29.5	12.7	17.2	33.6
174	0	101	25.6	127.7 25.8	52.6 60.1	25.6 29.3	28.2 46.2	62.5 63.7	55.8	66.8	19.4	31.2	14.0	19.8	38.9
175	1	24	12.6	85.2 21.5	50.4 31.0	23.5 20.9	25.0 32.6	49.1 51.4	48.5	51.6	16.6	22.3	11.5	16.2	30.5
176	0	68	16.0	102.8 21.8	50.4 44.5	24.2 23.4	25.4 39.2	54.3 55.2	48.0	55.9	18.8	26.9	11.6	15.7	32.0
177	1	60	19.3	113.6 23.8	50.2 50.3	26.5 27.9	25.8 42.7	54.3 61.5	49.5	58.9	18.4	27.8	12.8	17.8	33.9

178	1	106	25.1	132.2 22.8	52.8	28.0	28.5	59.0	54.5	64.2	21.6	29.1	13.0	17.6	32.9
179	0	36	12.9	92.5 20.5	48.9	23.3	21.4	49.5	45.1	51.6	17.1	23.9	11.5	15.6	30.5
180	1	84	21.1	120.1 23.7	51.1	26.2	26.6	56.5	53.6	61.1	19.4	29.0	13.0	17.3	34.2
181	1	102	23.3	126.8 23.1	52.6	26.1	25.0	59.4	52.5	68.5	20.5	30.5	12.9	17.2	30.4
182	0	114	31.1	133.2 28.2	51.4	25.9	30.8	65.4	57.2	75.3	22.2	32.6	14.6	21.8	40.2
183	0	106	30.3	134.3 27.0	53.6	27.9	35.5	64.6	57.5	73.5	22.1	33.0	14.3	18.7	37.5
184	0	78	15.4	107.5 20.8	50.8	23.5	21.0	55.2	46.8	54.8	18.4	25.9	11.7	14.2	32.5
185	0	102	26.3	125.7 25.7	52.7	26.6	30.4	63.2	57.0	67.6	21.3	31.2	13.8	19.5	39.9
186	0	136	27.2	133.2 25.8	51.8	27.2	29.5	68.8	56.4	68.3	22.0	30.7	13.6	18.2	38.9
187	1	54	16.0	101.7 21.2	50.9	24.2	25.4	54.1	50.5	55.5	18.7	25.2	11.5	17.0	32.1
188	0	85	22.2	118.3 24.1	51.3	25.9	27.7	62.0	52.1	62.5	19.7	28.4	13.6	18.8	36.6

189	0	63	16.8	104.9 22.4	50.2 46.2	24.8 24.2	23.2 37.8	50.2 57.1	51.0	58.0	18.3	26.8	12.0	17.6	33.5
190	1	100	26.8	126.5 26.8	53.1 55.7	29.1 30.0	28.7 45.8	61.5 68.6	58.7	65.4	22.2	31.5	14.1	19.0	37.7
191	1	45	12.2	92.3 19.8	49.6 37.6	22.5 21.8	22.4 35.6	48.1 52.6	47.8	50.9	17.2	20.4	11.0	14.5	27.0
192	1	71	20.6	114.0 23.4	53.2 47.3	26.4 26.3	27.4 42.1	56.5 62.7	52.8	60.4	19.0	27.9	12.9	18.1	34.5
193	1	45	17.9	104.3 22.4	50.1 43.8	25.3 25.0	26.3 41.4	54.6 59.3	51.6	58.7	18.0	26.0	12.9	16.8	31.9
194	0	82	23.1	118.3 24.5	56.8 52.0	26.4 26.7	26.3 45.2	58.9 62.8	52.7	68.5	19.9	29.2	13.9	18.6	38.5
195	1	30	15.5	92.3 22.2	49.3 35.6	26.8 22.6	22.5 36.1	54.2 52.5	53.6	57.3	18.6	24.7	12.6	16.6	31.0
196	0	122	30.9	136.9 25.4	53.2 64.0	28.1 31.9	30.5 50.6	66.2 69.9	58.3	70.6	21.9	34.0	13.2	18.8	40.5
197	0	79	21.3	114.2 23.6	51.8 51.0	27.2 27.1	26.4 43.1	57.0 60.1	52.6	61.0	19.8	28.4	12.0	18.4	36.5
198	1	98	29.9	132.6 27.3	54.2 61.1	27.9 30.2	31.1 50.4	62.5 69.5	57.8	69.6	20.8	33.3	13.3	18.8	40.7
199	1	78	22.4	120.6 24.5	53.1 53.9	25.8 28.4	27.2 44.9	58.5 64.3	51.4	60.2	20.0	28.8	13.7	17.8	38.3

200	0	48	16.4	104.9 23.0	51.1 40.1	24.5 27.1	27.3 43.0	53.5 59.3	51.1	59.0	18.5	26.9	11.6	17.2	28.4
201	1	37	13.4	92.8 22.4	50.1 33.8	23.3 24.9	23.4 35.9	50.1 51.4	49.2	57.5	16.4	25.4	11.6	15.5	27.6
202	0	54	16.5	106.1 22.5	50.2 43.8	22.5 26.1	26.8 42.6	51.8 59.2	48.8	58.1	18.8	27.3	21.4	16.8	31.3
203	1	60	19.4	106.3 24.3	53.0 43.5	27.8 25.3	29.0 42.5	56.5 53.2	55.4	62.2	18.9	29.2	12.0	21.1	32.2

APPENDIX I

RAW DATA FOR BUOYANCY MEASURES

APPENDIX I

RAW DATA FOR THE ACTUAL WEIGHT OF THE
SUBJECTS AT DIFFERENT LEVELS OF SUBMERSION

The actual weight raw data is presented for all subjects in the "arms at the side" and "arms over the head" positions. The data is presented in two blocks: the first block consists of ten measurements taken in the position "arms at the side", the second block consists of six measurements taken in the position "arms over the head". The measurements are listed in the order in which they were taken. The scores are given in inches since they were originally recorded in this system.

The subject's identification number is presented first. This number is followed by the ten measurements in the position "arms at the side", followed by the six measurements in the position "arms over the head".

001	43.3	41.4	40.5	38.1	34.2	29.0	21.4	16.9	8.3	7.2	34.6	29.5	23.6	18.2	11.9	10.1
002	36.9	36.4	34.8	33.3	30.1	24.3	18.0	12.1	6.3	5.6	30.3	25.2	20.2	15.5	9.9	8.8
003	32.4	31.5	30.3	27.9	24.8	20.5	17.2	11.9	6.1	4.0	25.4	21.4	17.6	13.7	8.8	8.1
004	56.0	54.4	51.7	49.1	45.2	37.9	28.5	20.0	9.4	7.9	45.4	38.8	30.6	24.3	15.1	11.9
005	61.3	59.1	55.1	51.7	46.6	35.3	26.7	17.4	8.5	6.7	46.9	37.3	29.7	22.6	14.4	11.5
006	57.1	54.4	51.2	48.8	43.4	32.0	22.9	17.3	8.1	5.8	43.6	33.6	24.7	21.4	14.2	10.3
007	47.2	44.9	44.2	41.2	37.1	30.8	22.1	15.6	7.6	6.5	37.3	31.5	23.9	18.8	11.8	8.9
008	50.9	49.4	46.3	43.0	39.6	33.0	26.1	17.9	9.2	6.9	40.0	33.9	27.9	21.5	13.6	11.4
009	49.8	47.4	44.9	41.9	38.4	30.1	21.0	15.0	6.7	5.8	38.2	31.3	23.5	19.1	11.2	10.3
010	46.9	44.7	42.5	39.9	36.2	31.1	20.6	10.7	7.6	6.7	37.1	33.1	23.4	13.4	12.1	9.8
011	42.2	40.2	37.1	35.3	32.8	26.9	19.0	14.5	7.3	6.3	33.1	28.0	22.6	17.9	12.2	10.7
012	86.9	82.7	78.7	73.6	65.6	53.0	36.9	25.5	12.5	7.2	66.3	54.0	40.0	31.1	21.0	14.5
013	52.7	50.1	47.4	44.6	40.4	32.3	26.1	17.4	8.7	7.2	40.9	34.2	28.6	21.9	14.7	12.3
014	59.0	56.3	52.7	50.7	45.1	36.9	27.7	19.0	10.3	7.2	45.8	38.2	29.9	23.2	16.1	12.5
015	73.1	69.5	68.6	62.8	55.5	43.6	31.3	21.8	10.1	8.3	56.0	44.9	33.7	26.6	16.3	11.2
016	35.8	34.4	32.3	32.1	28.8	24.6	19.2	13.2	8.3	6.0	29.1	25.3	20.8	15.9	10.9	9.4

017	70.6	66.8	64.4	61.5	55.6	46.0	34.6	24.8	12.7	9.8	56.1	47.8	37.5	29.1	19.9	15.4	
018	63.7	61.7	58.5	56.1	50.5	40.9	29.0	21.5	11.2	8.3	50.5	42.2	32.4	25.7	17.0	13.6	
019	84.7	81.1	76.6	72.4	64.8	50.9	35.5	26.1	13.0	8.9	64.8	52.3	38.7	30.8	21.2	17.2	
020	51.6	49.8	47.8	44.8	40.9	34.3	25.9	18.5	9.2	6.9	41.1	35.0	27.7	22.1	13.6	11.2	
021	45.8	45.1	42.9	40.1	36.4	30.5	22.5	16.1	8.1	6.5	36.6	31.4	24.2	18.8	11.8	9.8	
022	48.5	47.8	46.7	44.6	39.6	32.4	24.5	17.0	8.0	6.3	40.0	34.2	26.9	20.3	13.0	9.8	
023	50.1	48.0	45.8	43.0	40.4	34.0	26.0	18.1	9.2	7.4	40.9	35.1	28.8	21.5	14.3	11.6	
024	45.1	43.8	42.0	39.2	36.0	30.3	23.5	16.3	7.8	6.0	36.0	31.4	25.0	19.0	12.3	10.1	1
025	70.6	68.2	64.8	60.7	54.2	43.8	31.8	22.2	10.7	7.8	54.6	44.5	34.7	25.6	16.5	12.3	2
026	57.0	55.0	52.3	48.8	44.7	37.0	27.3	19.2	10.5	7.8	44.9	38.5	30.4	23.0	16.5	12.3	2
027	58.8	56.8	53.9	50.6	44.7	35.2	27.3	17.9	7.8	6.0	44.9	36.5	29.9	21.9	13.9	11.8	1
028	44.5	42.9	41.1	38.5	34.4	28.3	21.2	14.7	6.8	4.9	35.1	29.4	23.5	18.1	11.7	9.4	
029	40.4	39.3	37.5	35.3	32.0	26.7	20.3	14.5	8.0	5.7	31.8	27.4	22.3	17.0	11.6	9.3	
030	56.3	55.2	52.5	49.3	43.6	34.7	26.6	17.9	7.6	6.3	44.0	35.9	28.6	22.1	12.7	9.6	
031	65.4	63.2	59.7	56.2	50.5	40.4	30.6	21.1	10.7	7.8	50.5	41.8	33.3	25.4	17.0	13.9	
032	45.9	43.6	41.8	39.0	34.9	28.7	23.0	16.5	8.9	6.3	35.3	29.6	25.0	19.2	13.0	10.1	

033	58.8	56.5	54.5	50.6	45.4	36.3	28.4	19.9	9.8	6.7	45.6	37.2	29.9	23.2	14.7	11.2
034	42.5	40.9	39.1	37.0	33.6	26.0	20.3	14.3	7.4	6.7	33.9	27.2	22.3	16.5	10.9	9.8
035	75.1	73.3	67.9	63.5	57.2	44.2	33.3	23.2	10.7	8.5	57.2	45.8	35.8	27.7	18.8	16.3
036	60.0	57.9	55.2	52.7	47.5	37.5	28.8	19.3	9.8	6.9	47.7	38.7	31.1	29.9	15.6	11.2
037	45.7	44.5	41.8	39.4	36.9	29.1	21.7	15.4	7.4	6.9	37.1	29.9	23.9	18.1	11.4	10.5
038	82.1	79.1	76.2	71.7	63.9	50.9	38.7	27.0	13.0	10.3	64.4	52.1	41.3	32.2	21.9	17.0
039	52.3	50.5	48.0	45.0	41.6	32.5	24.8	17.0	8.0	6.7	41.8	33.6	27.0	20.3	12.7	10.3
040	49.5	48.3	46.0	43.0	39.8	32.3	25.0	17.7	9.6	6.7	39.6	33.0	26.4	20.6	13.4	10.5
041	65.6	63.2	60.3	57.4	52.8	44.5	33.3	24.4	12.7	8.5	52.8	45.6	36.0	28.4	18.1	14.3
042	68.8	65.9	58.0	53.7	51.6	39.6	30.2	16.3	6.5	6.3	51.2	40.9	32.2	23.0	13.9	13.2
043	60.6	58.8	56.3	52.8	48.5	38.8	29.9	20.6	9.6	7.4	48.5	39.9	32.0	24.1	15.2	11.8
044	72.1	70.4	65.7	62.3	54.9	42.5	30.6	20.9	9.8	8.0	55.1	43.6	33.5	26.0	17.2	12.7
045	55.9	53.9	51.6	48.6	44.2	34.6	25.4	17.9	8.6	7.6	44.5	36.0	28.0	22.1	14.3	11.4
046	52.3	50.3	48.0	45.9	40.4	32.5	25.0	17.4	9.5	7.5	40.7	33.9	27.7	21.7	13.7	12.1
047	55.4	53.6	52.3	48.2	44.0	34.4	28.0	18.8	9.4	7.8	44.2	36.9	30.3	23.5	15.4	11.8
048	61.0	59.2	56.3	53.3	46.7	37.0	28.6	19.7	9.4	7.6	47.2	38.8	31.1	23.5	15.4	12.1

049	52.2	50.5	47.6	44.8	40.7	32.8	24.7	16.1	8.0	6.5	40.7	33.7	26.9	18.1	13.6	9.8
050	52.2	50.3	48.0	45.5	41.2	33.7	25.0	18.2	9.2	6.5	41.2	35.1	27.3	21.3	13.6	10.9
051	58.0	56.1	54.1	50.5	45.3	37.3	27.0	18.8	9.4	7.8	45.7	38.2	29.7	23.0	14.3	12.3
052	54.1	52.4	51.1	47.2	42.0	33.0	24.3	17.1	7.6	6.7	42.0	34.6	26.5	20.7	12.6	10.1
053	45.0	44.0	42.5	41.6	36.4	29.9	23.2	16.2	8.8	7.4	36.9	30.8	24.9	19.6	13.5	10.6
054	66.4	63.0	60.3	56.9	50.6	40.7	29.7	20.6	10.5	9.2	51.2	42.0	33.1	26.1	16.8	14.1
055	59.4	56.1	53.4	50.2	45.4	36.0	27.4	18.5	9.6	7.6	45.6	37.5	30.7	23.9	15.9	13.0
056	66.8	63.5	60.6	57.9	52.0	41.3	31.3	22.8	11.8	8.7	52.0	42.7	34.0	27.5	17.7	13.9
057	65.9	63.5	60.3	56.6	50.1	39.2	29.5	19.7	9.6	8.0	50.5	41.0	33.1	24.6	16.8	14.3
058	52.9	51.2	48.9	45.9	41.6	33.6	26.7	18.1	8.9	8.0	41.8	34.7	28.2	21.9	14.7	12.1
059	62.0	58.5	55.2	52.0	45.1	34.9	25.9	16.8	7.6	7.2	45.6	36.4	29.1	21.4	13.0	12.1
060	51.3	48.9	47.2	43.5	39.8	33.1	26.6	18.5	10.3	8.3	40.4	34.4	28.5	22.6	15.2	12.7
061	73.7	71.1	67.9	63.7	56.4	44.7	32.4	22.5	10.7	8.0	56.6	46.0	35.5	27.6	17.7	13.6
062	89.4	86.7	83.1	78.1	70.2	56.3	40.2	25.7	11.2	6.5	69.7	58.1	43.6	31.1	18.5	14.1
063	52.2	50.3	48.5	45.7	40.9	34.0	27.8	19.0	9.8	8.5	41.6	35.5	29.2	22.3	15.9	13.6
064	72.3	69.9	67.7	62.8	55.8	44.9	33.5	23.0	10.9	9.2	56.2	46.5	36.6	25.7	17.7	14.3

065	90.9	88.5	84.0	80.0	71.7	56.6	40.4	27.7	11.6	6.7	71.7	58.0	43.4	31.7	20.8	14.7
066	59.3	57.4	55.0	51.2	46.4	38.7	28.8	20.9	10.7	9.4	46.6	39.3	31.5	25.1	17.2	12.5
067	68.1	65.7	62.8	58.5	52.2	42.9	33.1	22.5	11.4	8.5	53.3	44.2	35.3	28.0	18.8	14.5
068	52.3	50.3	47.6	44.4	40.9	34.2	26.7	18.8	10.5	6.5	40.9	35.1	28.3	22.3	14.3	10.1
069	52.5	50.1	47.4	44.6	40.2	32.4	24.9	16.8	9.2	8.0	40.4	33.7	27.8	21.9	13.9	12.1
070	58.4	56.5	54.3	51.2	46.4	38.7	29.5	20.4	10.5	7.4	47.0	40.0	31.3	23.8	15.4	10.9
071	56.4	54.1	51.8	49.4	44.8	37.5	28.8	20.4	9.8	6.9	45.3	38.9	30.8	22.9	14.5	10.7
072	30.2	29.1	28.9	26.8	24.0	20.3	15.9	11.2	6.7	6.0	24.0	21.5	17.7	13.6	9.4	9.4
073	43.4	41.3	39.8	37.4	33.5	28.8	21.5	14.7	8.0	7.6	34.0	29.3	23.5	17.4	11.4	10.3
074	66.9	64.8	62.1	58.5	52.4	41.8	29.9	21.0	9.4	6.0	52.8	43.4	32.8	25.7	16.8	12.3
075	67.1	64.4	61.7	58.5	52.7	43.1	32.2	21.5	9.6	8.3	53.2	44.2	35.1	25.5	16.5	14.3
076	79.3	75.1	71.7	67.4	61.1	49.8	37.3	26.6	13.2	9.4	61.8	51.2	39.8	31.7	20.6	15.9
077	72.0	69.5	66.4	62.1	56.8	46.3	34.4	24.8	12.1	9.6	57.0	47.6	37.5	29.3	18.8	14.7
078	50.8	48.3	46.7	43.9	40.4	33.3	24.5	17.2	8.5	6.7	40.7	34.2	26.5	20.8	13.6	9.6
079	68.8	66.1	62.1	58.9	52.7	41.2	31.1	20.8	10.3	7.8	52.7	42.8	33.5	25.7	17.7	13.2
080	39.3	38.0	36.2	34.4	30.4	25.0	18.1	12.5	6.2	5.4	30.4	25.9	20.6	15.4	10.9	8.9

081	73.7	71.1	67.5	63.5	57.7	47.8	33.3	23.9	11.8	8.5	57.9	49.2	36.6	28.4	17.9	15.6
082	43.9	42.7	40.9	38.8	34.9	29.1	21.2	14.5	8.7	6.5	35.1	29.5	23.2	18.3	12.5	10.7
083	57.8	56.1	53.0	49.7	45.8	37.1	27.9	19.2	9.6	7.6	45.8	38.2	30.4	23.7	15.4	12.1
084	55.2	53.2	51.2	47.9	43.8	35.5	26.5	18.8	9.4	6.7	44.0	36.6	28.9	22.8	14.7	11.8
085	65.8	63.2	60.1	56.5	51.6	42.0	31.3	21.9	10.5	9.4	52.1	43.6	34.2	27.0	17.7	14.3
086	64.3	61.7	59.0	56.3	50.4	40.9	30.6	21.7	11.6	8.0	50.6	42.0	33.1	26.1	17.7	13.4
087	55.8	53.9	50.7	47.9	42.5	34.1	25.3	17.0	8.3	6.7	42.7	35.3	27.7	21.2	14.1	10.9
088	44.6	42.9	40.7	37.7	33.7	28.3	20.8	14.5	7.9	7.2	34.2	29.2	23.0	18.1	12.4	11.2
089	37.4	36.0	34.6	32.1	28.7	24.1	17.9	13.2	6.9	5.7	29.2	25.0	20.3	16.3	11.2	9.2
090	59.4	56.1	53.4	50.2	44.6	36.2	27.3	18.8	9.8	5.6	45.7	37.8	30.2	23.2	16.1	13.0
091	84.4	81.8	78.0	73.3	65.1	51.4	35.1	23.4	10.3	6.7	65.1	52.1	38.4	29.2	18.8	12.7
092	71.4	69.7	65.5	62.8	56.2	44.7	32.4	22.7	10.1	7.6	56.4	45.8	35.1	26.9	17.4	13.6
093	62.6	61.0	57.0	53.5	47.8	37.7	27.9	19.4	9.4	7.6	48.3	39.0	31.3	24.1	15.4	12.3
094	55.6	53.9	50.5	47.0	42.5	34.7	25.5	17.7	9.2	6.7	43.1	35.6	27.9	22.1	15.0	11.2
095	46.3	44.5	42.7	39.9	35.1	28.0	22.1	14.7	7.9	7.2	35.8	29.4	23.9	18.1	12.2	9.8
096	47.1	44.9	42.7	40.1	37.3	30.4	23.6	16.4	9.2	6.9	37.5	31.5	25.8	20.3	13.6	10.7

097	42.8	41.6	39.8	37.4	33.5	28.2	21.0	14.5	7.6	6.7	34.0	29.1	23.5	18.1	12.5	10.7	
098	61.6	60.1	57.2	53.3	47.4	38.1	28.8	20.1	10.5	8.0	47.8	39.4	32.2	25.5	17.4	13.4	
099	55.1	52.3	51.2	46.4	41.3	32.6	24.5	16.5	8.7	7.4	41.6	33.7	27.6	20.8	13.6	11.4	
100	59.8	57.4	54.7	51.5	47.0	38.7	30.2	21.1	10.7	8.5	47.7	40.4	33.1	26.3	17.4	13.4	
101	73.6	61.5	58.1	54.6	49.6	41.3	32.0	22.3	13.2	7.8	50.1	43.1	34.9	27.0	18.8	13.4	
102	55.7	53.0	50.7	47.5	43.6	35.3	26.7	18.8	9.6	8.5	43.8	36.6	29.2	22.6	15.2	13.2	
103	73.4	70.2	66.8	63.7	57.3	48.0	36.0	25.5	12.5	10.1	58.2	49.6	39.6	32.0	20.6	16.8	
104	50.5	49.2	46.9	43.9	40.2	33.4	24.6	19.0	9.8	7.4	40.4	34.5	27.0	23.0	14.5	11.6	1
105	67.8	64.8	61.5	58.1	52.4	42.5	32.0	21.8	10.1	7.2	52.8	43.8	35.3	26.9	17.2	13.4	2
106	48.9	47.2	45.6	43.2	38.2	30.5	23.5	16.3	8.4	7.4	38.9	31.8	26.1	20.1	13.5	11.2	4
107	76.8	74.4	70.2	65.9	58.4	46.3	33.5	22.0	9.4	7.2	58.9	47.8	36.4	27.4	17.2	13.4	7
108	38.4	37.3	35.3	33.2	29.5	24.6	19.4	14.3	7.2	6.4	29.9	25.9	21.2	16.8	10.3	9.3	
109	61.6	60.3	56.5	52.0	46.9	37.4	26.8	17.9	8.3	6.7	47.4	38.8	29.9	22.8	14.7	12.1	
110	62.9	60.6	59.2	54.5	48.8	38.7	27.9	20.1	9.2	7.6	48.8	40.0	31.1	24.1	15.0	11.6	
111	56.1	55.4	52.1	48.2	44.2	34.6	26.1	17.9	9.6	8.0	44.5	36.0	28.6	22.1	15.2	12.1	
112	51.1	49.2	46.7	43.5	40.2	32.1	23.7	15.9	6.7	4.7	40.2	33.0	25.5	19.7	11.8	8.9	

113	71.1	67.7	64.4	60.0	52.3	40.1	29.3	19.9	7.8	5.8	52.5	41.5	32.0	23.9	15.2	12.3
114	43.0	41.3	38.7	36.5	33.7	26.7	20.3	14.5	7.5	6.5	34.2	27.8	22.8	17.4	11.5	9.6
115	81.1	77.5	74.0	69.3	61.8	48.3	24.2	23.0	10.5	6.9	62.0	49.6	37.5	28.8	17.7	14.3
116	45.8	44.2	42.0	39.4	36.0	29.5	22.6	16.1	8.0	5.6	36.4	30.6	24.8	19.9	12.5	9.6
117	78.1	75.5	72.0	67.5	59.2	47.2	34.9	23.9	10.1	7.4	59.9	48.7	38.4	29.9	18.8	14.5
118	54.5	51.2	48.0	45.5	41.1	34.1	25.7	17.7	8.7	7.6	41.1	35.2	27.0	21.0	13.6	11.6
119	45.5	43.6	41.6	39.2	36.0	29.5	22.6	14.7	7.6	6.0	36.4	30.5	24.6	19.2	12.1	9.6
120	51.4	48.9	47.2	42.8	38.0	30.6	22.9	15.4	8.5	6.7	38.4	31.5	26.3	19.9	13.4	10.7
121	52.1	51.4	48.9	46.1	40.4	33.6	24.1	16.3	8.2	7.2	41.3	34.3	27.9	20.8	13.3	11.2
122	58.8	57.0	54.1	50.4	45.6	37.5	28.5	19.2	9.6	7.2	45.8	38.7	29.4	23.9	14.7	12.1
123	60.6	59.4	56.1	52.6	47.4	37.8	28.0	19.9	10.1	7.6	47.8	39.1	31.4	24.4	16.3	13.4
124	65.9	63.7	60.6	56.9	51.2	40.2	29.1	20.1	10.7	7.4	51.2	41.8	32.2	24.6	16.8	13.0
125	64.6	62.6	59.2	55.5	50.4	39.8	29.9	20.6	11.2	7.8	50.4	41.6	33.5	25.7	17.2	13.4
126	41.7	40.2	37.8	36.3	32.1	26.1	20.1	13.6	7.6	5.6	32.5	27.5	22.6	17.4	12.3	9.2
127	46.7	45.4	42.9	40.6	36.4	29.6	22.3	15.0	6.6	5.4	36.9	30.5	24.4	17.9	11.5	8.7
128	83.8	81.6	77.1	73.1	65.8	51.2	36.9	25.0	11.8	6.7	66.5	54.5	40.2	30.6	20.1	15.2

129	71.0	67.7	65.0	61.2	55.1	43.6	31.5	21.6	10.5	8.0	54.9	45.4	35.1	26.9	18.1	13.6
130	46.3	42.7	41.1	38.3	35.1	28.7	23.0	14.1	7.0	5.6	35.5	30.1	24.4	18.1	11.1	9.8
131	47.9	45.6	44.0	41.2	38.0	31.2	23.9	15.6	7.9	6.9	38.0	32.3	26.4	19.9	13.0	10.9
132	65.3	63.0	60.8	57.3	51.6	41.3	29.9	20.1	10.7	7.2	52.3	43.1	32.6	25.3	16.5	13.0
133	39.8	38.2	36.4	35.5	32.6	26.8	20.1	13.4	6.7	6.3	32.6	27.3	21.9	16.3	10.3	8.9
134	55.1	52.7	50.3	46.6	41.8	33.3	25.4	17.0	9.4	7.8	42.5	34.6	28.3	21.5	14.5	12.1
135	38.5	36.0	35.1	32.2	29.8	24.5	18.2	12.3	6.0	4.7	30.1	25.1	20.6	15.9	10.3	8.0
136	57.7	55.0	53.0	49.3	44.7	36.2	26.9	18.8	9.4	5.1	44.5	36.9	28.5	21.9	14.1	9.8
137	58.9	56.3	54.5	50.2	45.1	35.1	26.3	17.2	7.8	6.0	45.6	36.6	29.6	23.0	15.0	12.1
138	57.8	54.7	52.1	48.4	43.1	33.5	24.1	17.4	7.4	5.6	43.6	35.3	26.6	21.7	14.1	10.3
139	74.1	70.6	67.9	62.9	55.6	43.6	32.3	21.0	10.1	7.8	55.9	45.1	35.2	26.8	18.1	14.3
140	40.7	38.9	37.5	36.1	31.4	26.4	19.4	13.0	6.9	6.1	31.6	27.0	21.5	15.6	11.2	9.3
141	55.8	53.4	51.6	47.7	43.4	35.1	25.6	17.7	8.5	6.9	44.0	36.2	28.5	21.0	14.1	11.2
142	48.3	45.8	43.6	40.6	36.6	30.1	22.3	14.7	8.2	7.6	37.1	30.9	24.6	18.8	12.8	11.6
143	75.6	71.5	69.1	65.3	59.7	49.6	37.8	27.0	14.3	11.4	60.1	51.4	40.9	32.6	20.6	18.5
144	43.3	41.8	40.2	37.7	33.9	28.4	20.1	14.1	7.8	6.8	33.9	29.3	22.6	18.1	12.3	10.4

145	35.5	34.4	32.8	30.6	27.9	23.2	17.7	12.6	6.7	6.5	28.6	24.1	20.1	15.3	10.5	9.6
146	60.5	58.3	56.3	53.3	47.5	38.7	29.7	19.9	11.6	8.9	47.7	40.2	32.0	24.1	16.8	14.3
147	49.1	47.6	45.6	42.8	38.9	31.7	24.0	17.9	8.9	7.4	39.1	33.3	26.7	21.0	13.6	11.2
148	47.8	44.9	43.1	39.2	35.5	28.4	20.3	13.0	6.7	6.4	35.5	29.7	23.2	17.0	11.4	10.7
149	35.5	33.1	31.6	29.1	24.9	21.5	14.9	8.9	5.8	5.6	26.0	22.3	17.5	12.7	8.9	8.7
150	41.5	39.8	38.0	36.1	31.6	26.8	20.3	13.4	7.6	6.5	32.3	27.5	22.1	16.8	11.4	10.1
151	37.5	36.0	34.4	31.7	28.9	22.9	17.3	11.7	6.7	6.0	29.2	24.0	19.7	14.9	10.1	9.2
152	51.0	49.6	47.6	44.8	40.2	32.2	24.5	17.4	8.9	8.3	40.7	34.0	27.8	21.5	12.7	12.1
153	48.5	46.9	44.9	41.9	37.5	29.9	22.0	15.2	8.5	6.9	37.8	31.1	24.5	18.8	12.7	11.2
154	52.5	51.2	48.9	45.5	42.0	35.1	26.6	17.7	9.6	7.2	42.5	36.4	28.8	21.2	14.3	11.2
155	36.2	34.4	33.1	30.8	27.7	22.7	16.6	10.2	6.3	5.4	28.4	23.4	18.4	13.5	9.4	8.3
156	50.1	48.7	46.5	43.5	38.8	30.2	22.8	16.3	7.6	5.6	38.8	32.2	25.7	20.3	12.1	10.3
157	28.8	27.9	27.2	25.5	22.9	19.7	15.1	10.2	6.8	6.0	23.6	20.3	16.6	12.6	8.8	8.5
158	33.4	32.1	30.9	28.8	24.2	22.3	16.4	10.9	6.7	4.2	24.5	22.8	18.2	14.1	9.8	8.7
159	64.8	61.9	59.0	56.3	50.4	40.7	29.1	20.1	9.4	8.0	50.4	41.8	32.0	24.1	14.7	13.9
160	55.8	53.2	50.5	47.5	42.0	32.5	24.8	15.9	7.4	7.2	42.2	33.4	27.3	19.7	13.4	12.3

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161	65.3	61.7	59.2	55.6	49.9	40.9	29.1	20.8	9.8	8.3	50.6	42.0	32.4	25.7	16.1	12.7
162	49.0	46.3	44.2	41.2	37.1	29.4	22.1	15.2	8.3	6.5	37.8	30.9	24.6	19.0	13.0	10.7
163	39.8	37.8	36.0	33.1	29.6	23.8	17.1	12.1	6.5	5.1	29.8	24.5	19.1	14.7	9.8	8.0
164	75.0	72.0	68.8	65.3	58.1	46.9	34.4	23.7	10.7	6.9	59.2	48.9	38.7	29.3	19.0	9.6
165	71.3	68.6	64.8	61.2	54.0	43.1	31.3	20.4	9.4	8.3	54.6	44.9	34.4	25.1	16.8	14.5
166	69.3	66.6	63.2	59.7	53.1	41.8	29.9	19.9	8.7	5.8	53.7	43.1	33.5	24.8	15.2	12.3
167	64.5	61.0	58.1	54.5	48.7	37.8	27.9	18.8	9.8	8.7	48.8	39.3	31.3	24.1	16.1	14.5
168	25.9	24.6	23.7	21.9	20.0	16.8	12.3	8.7	6.0	4.9	20.2	16.1	13.2	10.9	7.2	6.5
169	37.8	37.1	35.3	32.8	30.2	24.4	18.2	12.2	7.6	7.2	30.4	25.0	20.2	15.3	11.6	9.2
170	65.0	61.0	58.1	55.0	49.5	39.3	29.1	20.6	9.6	6.5	49.7	40.0	31.5	24.1	15.0	12.3
171	51.2	48.3	47.4	43.2	38.9	32.4	24.7	15.6	8.5	7.8	39.1	33.7	26.5	19.9	13.0	12.1
172	25.5	23.9	23.5	21.5	19.1	15.0	11.2	6.8	5.4	4.9	19.1	15.9	12.7	8.8	6.5	5.4
173	39.0	37.1	35.1	32.8	29.7	24.1	18.3	12.0	6.5	6.0	29.7	25.3	21.0	15.8	10.7	9.4
174	56.4	53.6	50.7	47.9	44.2	35.9	25.9	17.9	9.2	6.9	44.5	36.8	28.2	22.1	13.9	12.3
175	27.8	27.3	25.9	24.4	21.1	16.1	12.5	8.8	4.7	4.2	21.6	17.8	14.7	11.5	7.8	7.8
176	35.3	32.6	31.5	29.9	27.3	22.8	18.1	12.1	7.6	5.8	27.3	23.5	19.7	14.7	11.2	8.7

177	42.6	42.0	38.9	37.9	33.5	26.1	19.9	14.3	7.8	6.0	33.5	27.3	22.6	17.7	12.1	9.4
178	55.3	52.5	50.7	47.7	43.0	35.1	27.0	18.3	10.7	8.0	43.5	37.1	29.7	22.6	16.1	12.7
179	28.5	27.3	26.0	24.4	22.0	18.1	15.0	10.2	5.6	4.9	22.2	18.5	15.6	12.4	8.6	6.7
180	46.5	45.4	43.8	41.0	36.6	30.2	21.7	15.9	7.8	6.9	36.9	31.3	24.1	19.4	12.5	9.4
181	51.3	49.8	47.8	44.8	41.6	33.6	25.0	18.1	10.9	7.4	41.8	34.7	27.5	22.1	15.4	11.4
182	68.5	66.6	62.8	58.5	52.0	40.9	29.1	20.0	9.4	6.3	52.2	42.0	32.4	24.9	16.5	12.3
183	66.8	64.1	61.0	57.9	52.2	41.8	29.5	21.6	11.8	7.4	52.4	42.7	32.8	25.6	17.9	12.3
184	34.0	34.0	32.0	30.2	27.4	22.9	16.9	11.8	6.3	4.7	27.6	23.4	18.7	14.1	9.2	7.8
185	58.0	55.9	53.6	49.9	44.2	35.4	26.1	18.3	8.0	6.7	44.9	36.8	28.8	22.6	13.4	11.8
186	60.0	57.7	54.3	51.4	45.9	36.6	27.1	18.7	8.5	7.2	45.7	37.8	29.5	22.9	13.6	10.9
187	35.3	34.4	32.8	30.6	27.3	22.1	16.5	11.2	6.5	5.4	27.3	23.0	18.3	13.9	8.9	7.8
188	49.0	46.7	45.1	42.6	38.2	30.7	21.9	14.7	7.5	6.5	38.4	31.8	24.4	19.0	12.0	9.4
189	37.7	36.9	35.1	32.2	29.9	23.5	17.1	11.7	6.5	6.0	29.9	24.4	19.3	14.4	9.6	9.2
190	59.6	58.3	55.2	51.7	45.8	37.2	27.9	19.0	10.1	9.6	46.5	38.3	30.6	23.5	16.1	13.6
191	27.0	26.6	25.6	24.6	21.1	17.0	14.3	9.5	5.9	5.6	21.3	18.1	15.6	11.5	7.7	7.6
192	45.5	44.0	41.6	38.5	34.6	27.5	21.0	13.0	7.4	6.6	35.1	28.6	23.5	17.4	11.2	10.8

193	39.5	39.3	36.9	34.2	31.1	24.6	19.1	13.5	8.5	6.0	31.3	25.9	21.7	17.2	12.1	10.3
194	51.0	48.9	46.9	44.4	39.6	31.4	23.0	15.9	8.4	6.5	40.4	31.8	25.3	19.9	13.5	10.5
195	34.3	32.2	31.4	29.3	25.6	20.8	16.1	9.9	7.3	7.3	25.8	21.5	17.4	12.8	10.8	10.6
196	68.1	65.9	64.1	59.9	53.7	42.7	31.5	22.8	12.3	9.8	54.0	44.0	34.0	27.0	17.9	13.6
197	47.1	45.6	43.8	40.8	36.6	29.9	23.5	17.0	8.0	6.7	36.9	30.8	25.0	19.7	12.1	10.3
198	65.9	63.2	60.3	56.0	47.1	39.6	29.5	20.2	10.9	8.9	50.2	41.1	32.2	24.7	16.8	13.0
199	49.5	46.9	46.6	41.9	38.2	31.5	23.5	16.5	8.2	6.3	38.4	32.0	25.7	19.4	13.3	10.9
200	36.1	34.0	32.8	30.4	27.3	21.9	16.6	11.5	6.7	6.0	27.5	23.0	19.0	14.9	10.5	8.5
201	29.5	27.9	26.7	24.4	21.1	18.5	13.6	7.8	4.8	4.8	21.3	19.2	15.4	10.5	7.3	7.3
202	36.3	35.1	33.5	31.1	27.7	22.9	15.0	11.5	7.4	5.4	28.2	23.6	17.2	14.4	9.4	8.0
203	42.8	40.9	39.1	36.0	33.5	27.2	20.2	14.0	7.8	6.5	33.7	28.3	22.7	18.0	13.0	10.7

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2
3

APPENDIX J

PERMISSION OBTAINED



Consumer and
Corporate Affairs

Consommation et
corporations

Consumer
Standards
Directorate

Direction
générale
des normes

Your file votre référence

Our file notre référence 7305-1

Product Safety Branch
18th Floor, Zone 1
Place du Portage
Ottawa/Hull
K1A 0C9

April 23, 1976.

Professor Charles E. Cotton,
Dept. of Kinanthropology,
School of Physical Education
and Recreation,
University of Ottawa,
Ottawa, Ontario.
K1N 6N5

Dear Professor Cotton:

In respect of the research project on
Children's Water Safety Devices with which you have
been associated over the past two years, this will be
your authorization to utilize results and findings,
as necessary, in the preparation of a degree dissertation.

Yours very truly,

R.D. Bennett
Chemical and Fire
Safety Programs



COLLEGE OF
PHYSICAL EDUCATION

UNIVERSITY OF SASKATCHEWAN

SASKATOON, CANADA
S7N 0W0

May 17, 1976.

Dr. Guy Metivier,
School of Physical Education
and Recreation,
University of Ottawa,
Ottawa, Ontario.

Dear Dr. Metivier:

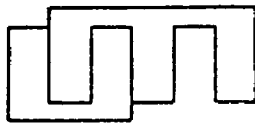
CHARLES COTTON'S THESIS

Just a note to let you know that I am happy, Professor Cotton
has been able to use the growth data from the Sask. Growth Study. I
hope his thesis will prove useful and I wish him well.

Sincerely,


D. A. Bailey,
Professor.

DAB:dmv



THE UNIVERSITY OF MICHIGAN

HIGHWAY SAFETY RESEARCH INSTITUTE

Institute of Science and Technology

Huron Parkway and Baxter Road

Ann Arbor, Michigan 48109

June 3, 1976

Permission is granted to Mr. Charles Cotton to
utilize anthropometric data for comparative analysis
purposes relative to our published report to the
Consumer Product Safety Commission of physical
measurements of United States infants and children.

Richard G. Snyder, Ph.D.
Head, Biomedical Department
Research Scientist
Professor of Anthropology

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