



**“FLOAT FIRST” AN ASSESSMENT OF THE BUOYANCY
PROVIDED BY SEASONAL CLOTHING ASSEMBLIES
BEFORE AND AFTER SWIMMING**

M. J. Barwood, V. Bates, G. Long & M. J. Tipton

Department of Sport and Exercise Science, University of Portsmouth,
U.K

MARCH 2010

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REPORT SUMMARY

Immersion represents a major cause of accidental death, a fact that underpins various learn to swim campaigns. It has been established that the responses evoked during the first minutes of cold water immersion (CWI) are responsible for a large proportion of immersion deaths (Golden & Tipton, 2002). It has further been established that attempting to swim on CWI increases the risk of drowning (Golden et al, 1986). This fact underpins the advice to “Float First” on immersion in cold water. However, the majority of those who are accidentally immersed are not prepared for such an event and are not therefore wearing specialist buoyancy aids. This raises the question of whether individuals who are not wearing such equipment are able to float on immersion. This report describes work that was undertaken to establish whether adults and children are able to float on immersion in water and, as a consequence, examines the utility of a “Float First” policy and campaign.

Study one determined the buoyancy and ability to “float first” of twenty four adults (12 males, 12 females) on immersion wearing winter, spring/autumn and summer clothing; these assemblies were compared to a control condition (bathing costume). The impact of resting and swimming for two minutes on the ability to float was also examined. The data indicated that up to 45 N more buoyancy was provided on initial immersion when the winter clothing assembly was worn compared to the Control. As the clothing layers were reduced the amount of inherent buoyancy was also reduced to 25 N and 7 N for spring/autumn and summer respectively. Buoyancy was reduced to a similar value irrespective of whether the participants swam or floated. In all clothing conditions, inherent buoyancy remained above that of the Control condition for the duration of the tests. When asked to float freely on their backs without paddling, the participants floated (i.e. the airway remained clear of the water) on 56 [19] % of occasions. However, this statistic was strongly influenced by gender being lower in males (24 [9] %) than females (88 [30] %); probably due to differences in body anthropometry (e.g. body fat levels).

Study two examined the ability of twenty nine (16 males, 13 females) children (average age: 12 years) to float on initial immersion and before and after two minutes of swimming in the winter clothing assembly; this assembly providing the most buoyancy. Irrespective of gender or whether the children rested or swam, their airways remained clear of the water on 94 [21] % of occasions just following entry to the water and 77 [30] % of occasions at the end of the experiment ($n=29$). These statistics did not vary with gender.

It is concluded that individuals should attempt to “Float First” on immersion for the following reasons:

- a. The risk of drowning is increased by swimming rather than resting on initial immersion in cold water and swimming accelerates cooling on immersion.
- b. Clothing, especially the type of clothing worn in winter, can trap air and help people float.
- c. Swimming or waving for help may release trapped air and reduce buoyancy.

For these reasons, floating should be taught as a survival skill for the first minutes of immersion. Those who are less able to float on immersion (adult males) should undertake the minimum amount of activity commensurate with staying afloat. The emphasis on “Float First” in no way removes the requirement for people to learn to swim or, where appropriate, to wear lifejackets.

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INTRODUCTION

Between 1993 and 2003 an average of 445 people per annum drowned in the UK (RoSPA U.K drowning statistics 2000-2003). The majority of these drowning incidents occurred in inland rivers and streams or in the relatively calm waters of lakes and reservoirs. Many of the victims were young, accidentally fell into the water, were fully or partially clothed and drowned within a short distance of the safe refuge of land. Data from the International Lifesaving Federation (ILSF: drowning facts and figures) suggest that approximately 40% of drownings occur within 2 metres of safety and a quarter in water less than 1 metre deep. These data appear to suggest that swimming performance in the early minutes of immersion is being impaired. This in part can be attributed to the low average annual water temperature in and around the U.K; even with the partial protection provided by clothing, immersion into water of this temperature impairs swimming performance (Tipton et al., 1999), may cause anxiety (Barwood et al., 2006) and induces hazardous cardio-respiratory responses (Tipton, 2003).

The physiological responses during the first few minutes of cold water immersion (CWI) are well understood and have been studied extensively by our research group (e.g. Tipton et al., 1998a & 1998b; Datta & Tipton, 2006; Barwood et al., 2007 & 2006). They have been described collectively as the ‘cold shock’ response (Tipton, 1989); characterised by an “inspiratory gasp,” hyperventilation, tachycardia, peripheral vasoconstriction and hypertension. The hyperventilatory component of the cold shock response makes co-ordinating breathing during swimming difficult and significantly decreases maximum breath-hold time. Thus, during the early minutes of immersion there is an increased risk of aspirating water and drowning (Tipton, 1995); this represents a further hazard in addition to that posed by the high cardiovascular strain (Tipton, 2003). The ‘cold shock’ response declines after the first 3 minutes of immersion as the cutaneous cold sensitive thermoreceptors adapt to the cold water (Mekjavic & Bligh, 1989). Following this adaptation, heart rate and breathing frequency return towards pre-immersion levels and swimming a short distance may become possible. Therefore, even in calm water, attempts to swim whilst experiencing ‘cold shock’ can result in drowning. The current experimental evidence supports the advice of not attempting to swim for a period of 2-3 minutes in order to re-gain control over breathing (Golden et al., 1986., Connolly., 2006., Ducharme & Lounsbury., 2007). Golden et al (1986) demonstrated that swim failure within ten minutes was more likely on cold water immersion (5°C) if participants began to swim immediately; it did not occur if participants rested in the water for two minute before beginning to swim.

Some drowning accidents are also attributable to a lack of basic swimming skills and survival behaviour. The existing standards for teaching people to swim are primarily focused on achieving the correct swimming technique for performance, and to a lesser extent achieve competency in the water and basic survival skills. Within the swim teaching curriculum, floating is encouraged to maintain buoyancy if accidentally immersed in water by means of making a flotation device from an item of clothing, i.e. tying knots in the legs of a pair of trousers. However there is currently no evidence-base for floating or the use of inherent buoyancy as survival strategies. It has been suggested that trapped air between clothing layers may provide some buoyancy to immersed victims (Golden & Tipton., 2002; Tipton et al., 1990), but swimming (or actions such as waving for help) may release the air trapped within the clothing, thereby reducing the buoyancy of the immersed victim and increasing the chances of submersion and drowning.

It can be concluded that behaviour during the initial minutes of accidental cold water immersion can be critical in determining survival prospects and a policy of “Float First” during this period could significantly improve survival prospects. One safety and survival organisation (the Irish Lifesaving foundation) already encourages the public to “float first” and to “float don’t swim” should accidental immersion occur (see ANNEX A for leaflets). However, this approach is counter-intuitive for many and has not been empirically investigated; it therefore currently lacks an evidence base.

This report describes a program of work undertaken to establish buoyancy on initial immersion and its reduction during swimming and floating whilst wearing different seasonal clothing assemblies. The results could support an educational program to raise public awareness of the appropriate behavioural response to accidental immersion. Two experiments were undertaken, one laboratory study to establish the buoyancy associated with three different seasonal clothing assemblies in adults, and one field-based (swimming pool) study to establish the practical significance of any clothing buoyancy for children and adolescents.

The null hypotheses tested for Study 1 were: a. There would be no significant buoyancy provided by air trapped between clothing layers b. The number of clothing layers would not influence the amount of inherent buoyancy and c. The buoyancy of the participant would be unaffected by the experimental condition of swimming in comparison with floating.

STUDY 1

METHODS

Participants

Prior to acceptance to the study each participant underwent a medical examination including, a 12 lead electrocardiogram (ECG) and a health history questionnaire. Twenty-four participants (12 male and 12 female) volunteered for this study and each provided written informed consent to participate. The mean (SD) participant characteristics are displayed in Table 1.

Table 1. Mean (SD) participant characteristics for the adults completing the laboratory studies.

	Age (years)	Height (m)	Mass (kg)	Skinfold (mm)	Body Fat (%)
Overall (<i>n</i> =24)	21.1 (3)	1.73 (0.1)	71.2 (11.4)	47.0 (18.4)	21.5 (8.4)
Males (<i>n</i> =12)	21.6 (3)	1.78 (0.1)	75.7 (9.7)	34.2 (8.6)	14.0 (3.0)
Females (<i>n</i> =12)	20.7 (3)	1.69 (0.1)	66.8 (11.6)	59.9 (16.5)	29.0 (4.0)

Experiment Design

Each participant visited the laboratory on one occasion, where they completed a total of seven submersions in a swimming flume (Figure 1) containing chlorinated thermoneutral water (35°C), six of the submersions took place in different clothing assemblies reflecting the ‘typical’ clothing worn in Summer, Winter, Spring/Autumn; for the remaining submersion the participants wore a bathing costume only; this acted as the Control condition. The participants completed two experimental conditions in each of the three clothing conditions; each was preceded and followed by subjective (observation) and quantitative (underwater

weighing) measurements of buoyancy. The two conditions were a two minute ‘float only’ condition and a two minute controlled swim. In the Control condition, it was assumed that buoyancy would be unchanged by floating compared to swimming and therefore only the ‘float’ condition was conducted.



Figure 1. Swimming flume in which participants in Study 1 completed their clothed submersions.

Experiment Procedure

Each participant undertook the test conditions (three clothing assemblies and Control condition) and experimental conditions (swimming or floating) according to a counter-balanced design to minimise any order effects. The timing of all data collection (i.e. initial buoyancy measurement, start and end of swimming period, second buoyancy measurement) was closely matched to avoid temporal variation between test conditions. Each test lasted approximately five and a half minutes in total. The participant dressed in their first clothing assembly and entered the environmental chamber and sat on an immersion chair attached to an electronic winch (CPM, F1-8; 2-8; 5-4, Yale, Shropshire, U.K) with a strain gauge (Biometrics Ltd, VA, USA) in series. The strain gauge was zeroed prior to each test with the chair attached. Therefore the participants’ weight and it’s change with submersion were recorded during each test.

The participant securely fastened a seat belt, equipped with a release button, prior to being winched above the swimming flume. The procedural requirements of the participant were then re-iterated and they were lowered, at a reproducible rate ($8\text{m}\cdot\text{min}^{-1}$), into still water to

the level of the most buoyant part of the clothing assembly above the head (i.e. hood); this took ~23 seconds. Following a maximal inhalation, the participant breath-held prior to entering the water; the volume of the maximum inhalation was measured prior to the first submersion test (see measurements section below). Following submersion, the chair was steadied and a measurement of mass was recorded for ~20 s. If the participants were unable to breath hold for 20 s a shorter duration was selected. At the end of the 20 s period the participant was winched back up to shoulder level and they released the seatbelt, moved away from the chair and lay on their back for 20 s. It was noted whether the airway remained clear of the water and if they needed to paddle to achieve a floating position (assessment of freeboard). Subsequently, and depending on the test condition, they either remained still and floated for a further 2 minutes, or turned on to their fronts and swam (breaststroke) for 2 minutes at a speed of $0.5\text{m}\cdot\text{s}^{-1}$ (a distance of 60 m). At the end of this 2 minute period the participant either remained still for a further 20 s (float condition) or moved on to their backs (swim condition) for a further assessment of freeboard. They then sat back on the immersion chair and a further measurement of their buoyancy was made (submersion to the same depth as in the buoyancy 1 measurement) by underwater weighing.

Finally, the participant was winched from the immersion pool and they undressed to their bathing costume. They dried themselves with a towel and re-dressed in dry clothes in preparation for the next condition. The difference in underwater weight before and after the interventions, and in comparison with the control (swim suited) submersions, was used to indicate the amount of air (buoyancy) retained in the clothing. On one occasion a measure of body composition was made (see below) in the period between submersions.

Each clothing assembly was based on the insulation required to keep an individual warm in the average temperature conditions of the different seasons. They comprised the following and are pictured in Figure 2:

- 1) Control condition: a normal bathing costume (i.e. trunks or female bathing costume).
- 2) Summer condition: running trainers, knee length shorts and a t-shirt tucked into the waistband of their shorts.
- 3) Spring/Autumn condition: running trainers, jeans, a t-shirt and a long sleeve cotton shirt tucked into the waistband of the trousers and a waterproof/windproof jacket.
- 4) Winter condition: running trainers, jeans, long-sleeve cotton shirt, a woollen jumper and a waterproof/windproof jacket with the hood up.

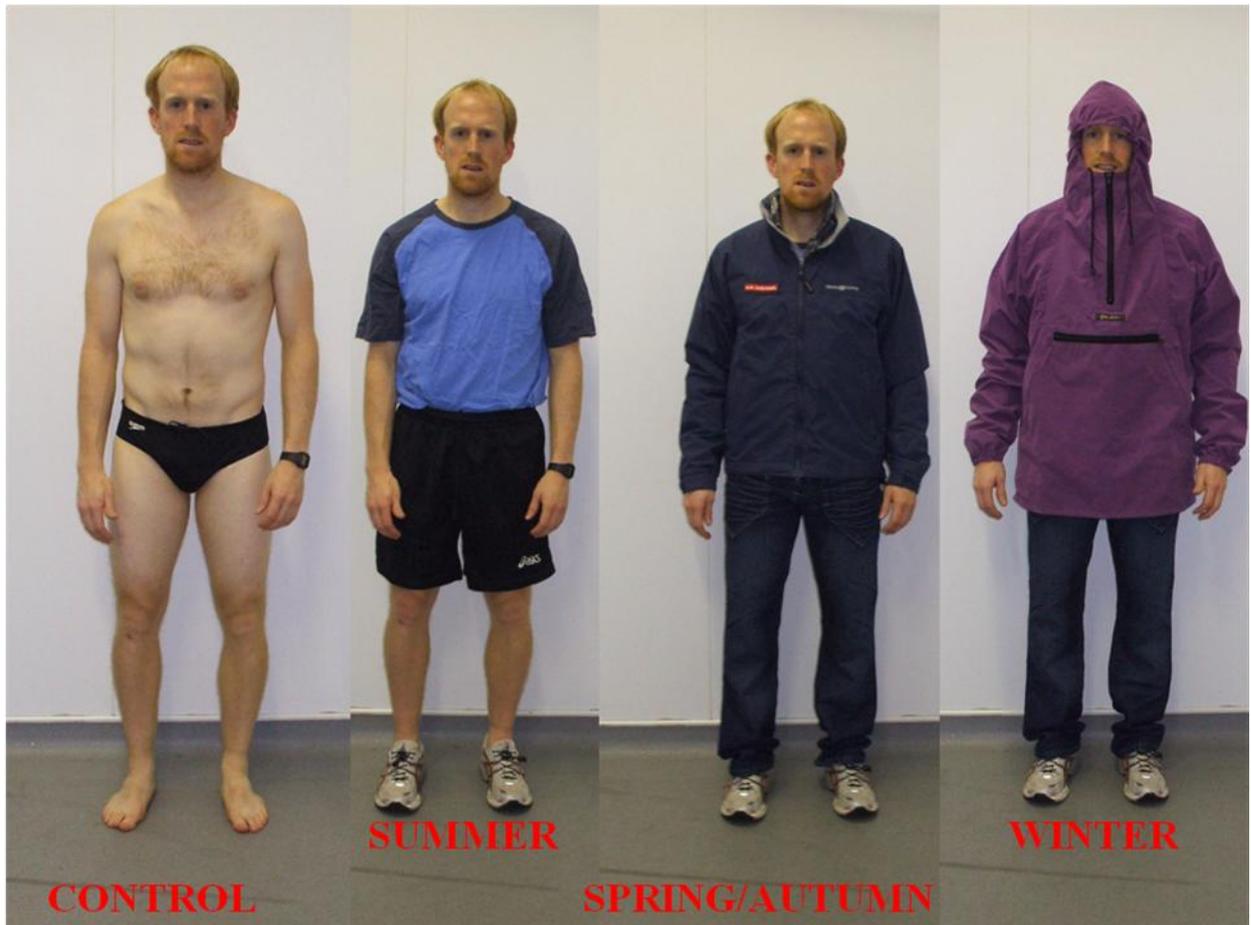


Figure 2. Examples of the clothing assemblies used in study 1.

Measurements

The primary measure was the underwater weight (UWW) of the participant on initial submersion and after the period of floating or swimming. The UWW was measured by a load cell (Biometrics Ltd, VA, USA) located in series with the winch support chain. The load cell was accurate to 100 g. The calibration process involved hanging certified weights from the load cell and checking accuracy.

A qualitative measurement of the consequence of any inherent buoyancy was made on two occasions during each test. The final method involved assigning a fixed value of 1 to participants whose airway remained clear of the water without paddling, 0.5 if the airway remained clear of the water with minimal paddling and zero if the participant's airway was consistently submerged requiring significant paddling to float.

Participants completed an anthropometric profile of skinfold thickness at four different sites (bicep, tricep, subscapular, iliac crest). Measures were taken in duplicate by an accredited anthropometrist. These data were used to estimate body composition (body fat percentage) and a sum of four skinfolds which will contribute, in part, to inter-individual buoyancy.

The volume of each participant's maximum inhalation was measured in air whilst adjacent to the swimming flume, and assumed to be the same volume as the breath taken just before the

participants were submerged. It was measured whilst seated in a chair and breathing through a two-way Hans-Rudolph mouthpiece connected to a piece of respiratory tubing attached to a spirometric transducer (Spirometric transducer module, KL Eng. Co, Northridge, USA). After breathing normally the participant took a maximal inhalation and the volume was recorded. Each participant performed this manoeuvre on three consecutive occasions. After this, their vital capacity (VC; the maximum amount of air that could be expelled from the lungs after a maximal inhalation) was also measured using the same equipment. The average of three attempts was again calculated.

DATA ANALYSES

A mean (SD) value for buoyancy was calculated for the 20 s period preceding and following resting and swimming for each clothing condition. Data were then compared using an analysis of variance (ANOVA) with repeated measures for buoyancy change a. As a consequence of swimming compared to floating b. Between genders and c. Between clothing assemblies. Assumptions of sphericity were checked using Mauchley's test. Where non-spherical data sets were evident a Greenhouse-Geisser adjustment was used.

To establish the practical significance of any inherent buoyancy, the freeboard data were converted to a percentage by dividing the value assigned (0, 0.5 or 1) by the total number of occasions the participants were asked to float (6 clothing assemblies, 2 conditions plus two control floats = 14). Percentage floats were calculated using all the data and the data for males and females separately.

To assess the relationship(s) between the freeboard data following the first buoyancy measurement and the measured respiratory and anthropometric variables that may influence buoyancy, a Pearson's correlation was calculated for the Winter and Control conditions

The alpha level for all statistical tests was set at 0.05, $P < 0.05$ indicates a statistically significant result.

RESULTS

The data indicated that: a. A significant amount of air (buoyancy) was trapped underneath the layers of clothing during submersion ($P=0.001$; see Figure 3) b. This buoyancy reduced over time ($P=0.001$; see Figure 4) and c. The amount of air released over time varied between the clothing assemblies ($P=0.001$; Figure 5), but did not differ between floating and swimming ($P > 0.05$; Figures 4 and 5). With the exception of the Control condition (no difference observed), the buoyancy was always significantly lower in the second buoyancy measurement than the first, irrespective of whether swimming or floating had been undertaken. Overall, females were significantly more buoyant than males ($P=0.001$) but the statistical observations between clothing assembly, condition and across time (submersion 1 vs. submersion 2) were the same in males and females.

Freeboard

Irrespective of the clothing condition, experimental condition (floating or swimming) or gender, the participants floated (i.e. the airway remained clear of the water) on 56 [19] % of occasions just following the first buoyancy measurement and 52 [20] % of occasions just before the second buoyancy measurement 2 ($n=24$). Males floated on 24 [9] % of occasions

just after the first buoyancy measurement and 22 [13] % of occasions just before the second buoyancy measurement ($n=12$). Females floated on 88 [30] % of occasions just after the first buoyancy measurement and 83 [28] % of occasions just before the second buoyancy measurement ($n=12$). The freeboard statistic for each clothing assembly and condition (float compared to swim) are displayed for all participants ($n=24$), males ($n=12$) and females ($n=12$) in Figures 6, 7 and 8 respectively.

Correlation Data

In the winter clothing assembly the initial freeboard value (i.e. just after the first buoyancy measurement) was correlated with: the first buoyancy measurement ($P=0.048$, $r=0.407$); the sum of skinfolds ($P=0.001$, $r=0.738$); the body fat percentage ($P=0.001$, $r=0.859$); and the vital capacity ($P=0.001$, $r=0.647$). Relationships were also found between the freeboard value generated just before the second buoyancy measurement and: the second buoyancy measurement ($P=0.001$, $r=0.622$); the sum of skinfolds ($P=0.001$, $r=0.748$); the body fat percentage ($P=0.001$, $r=0.879$); and the vital capacity ($P=0.001$, $r=0.649$). These relationships were not as strong in the Control condition as they were when clothing was worn; the initial freeboard value was correlated with: buoyancy measurement ($P=0.046$, $r=0.411$); sum of skinfolds ($P=0.002$, $r=0.595$); body fat percentage ($P=0.002$, $r=0.595$); and vital capacity ($P=0.034$, $r=0.435$).

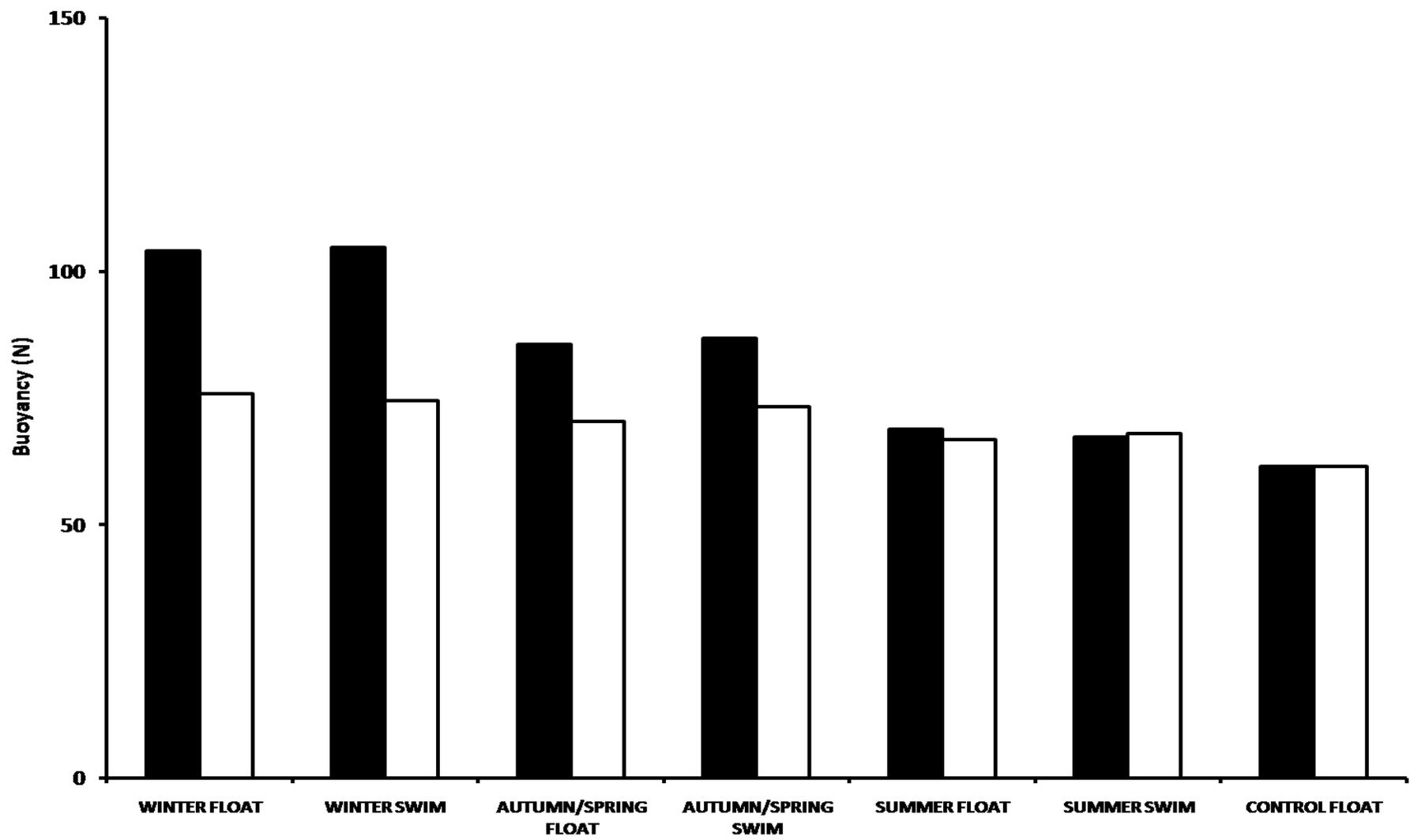


Figure 3. Average positive buoyancy provided by each clothing assembly in the first buoyancy measurement (black bars) compared to second buoyancy measurement (white bars) ($n=24$).

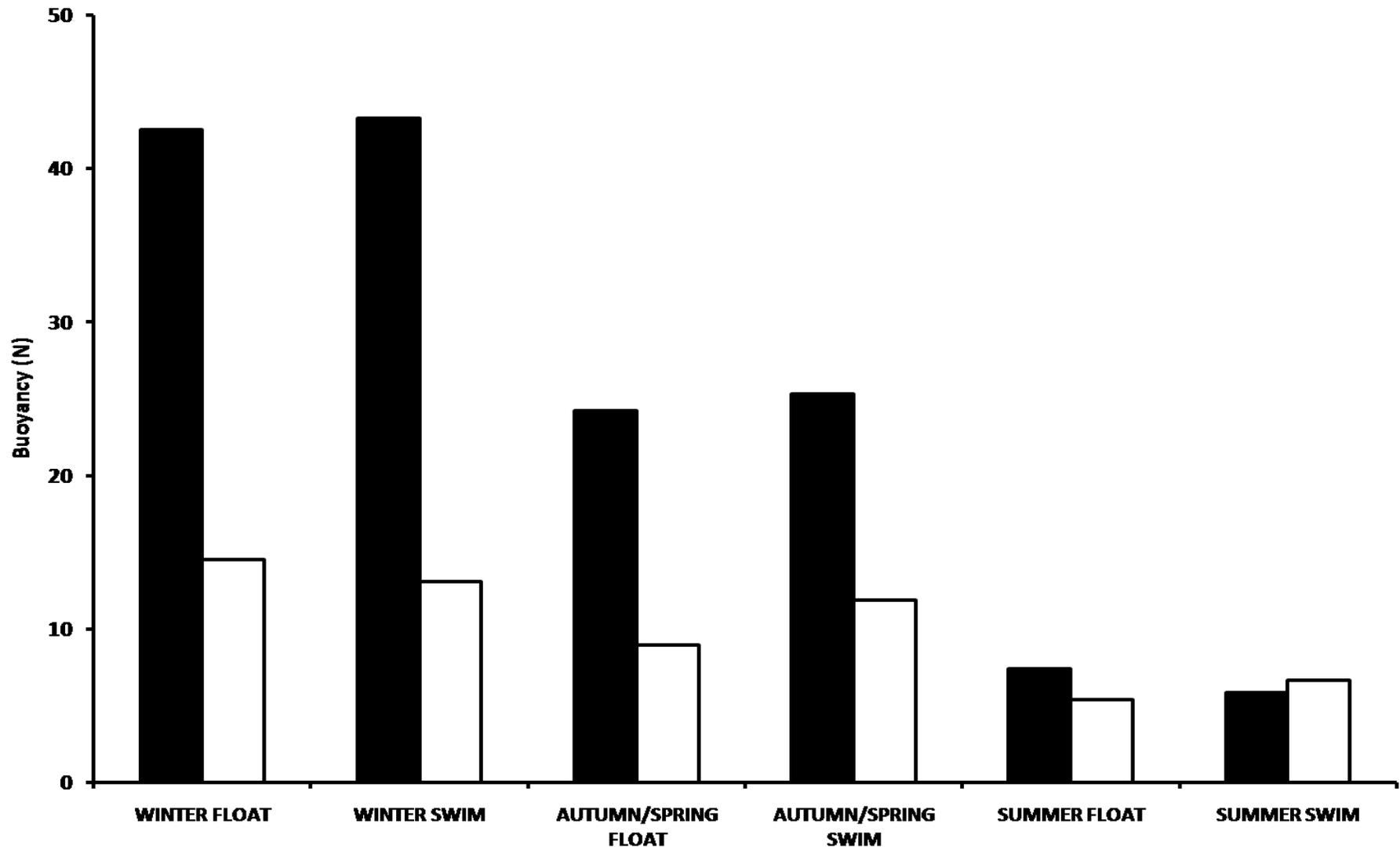


Figure 4. Average positive buoyancy provided by each clothing assembly in the first buoyancy measurement (black bars) compared to second buoyancy measurement (white bars) in all participants adjusted against the buoyancy measured in the Control condition ($n=24$).

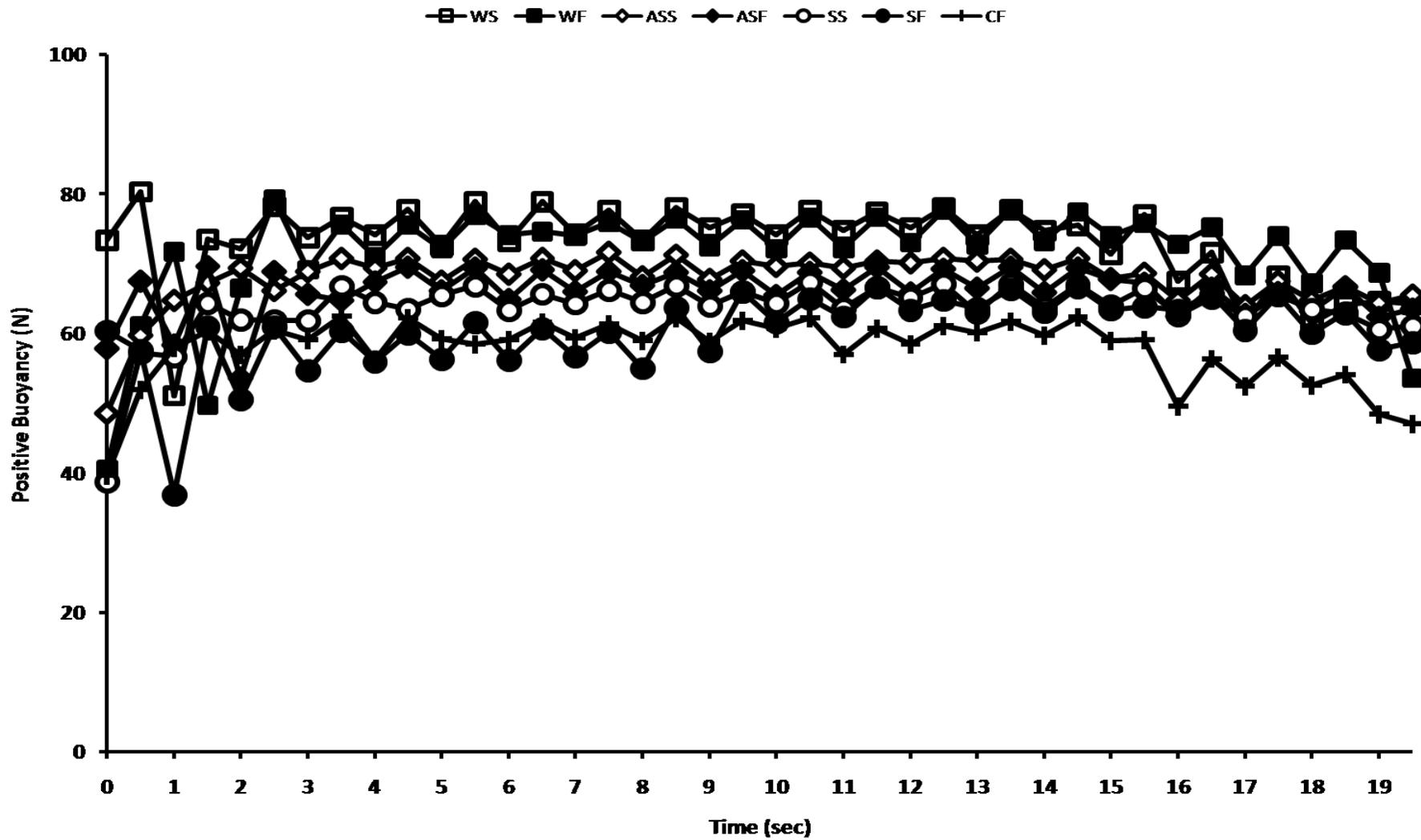


Figure 5. Average buoyancy (y axis) provided by each clothing assembly in the second buoyancy measurement (see figure legend) over a 20 second period (x axis) in all participants ($n=24$).

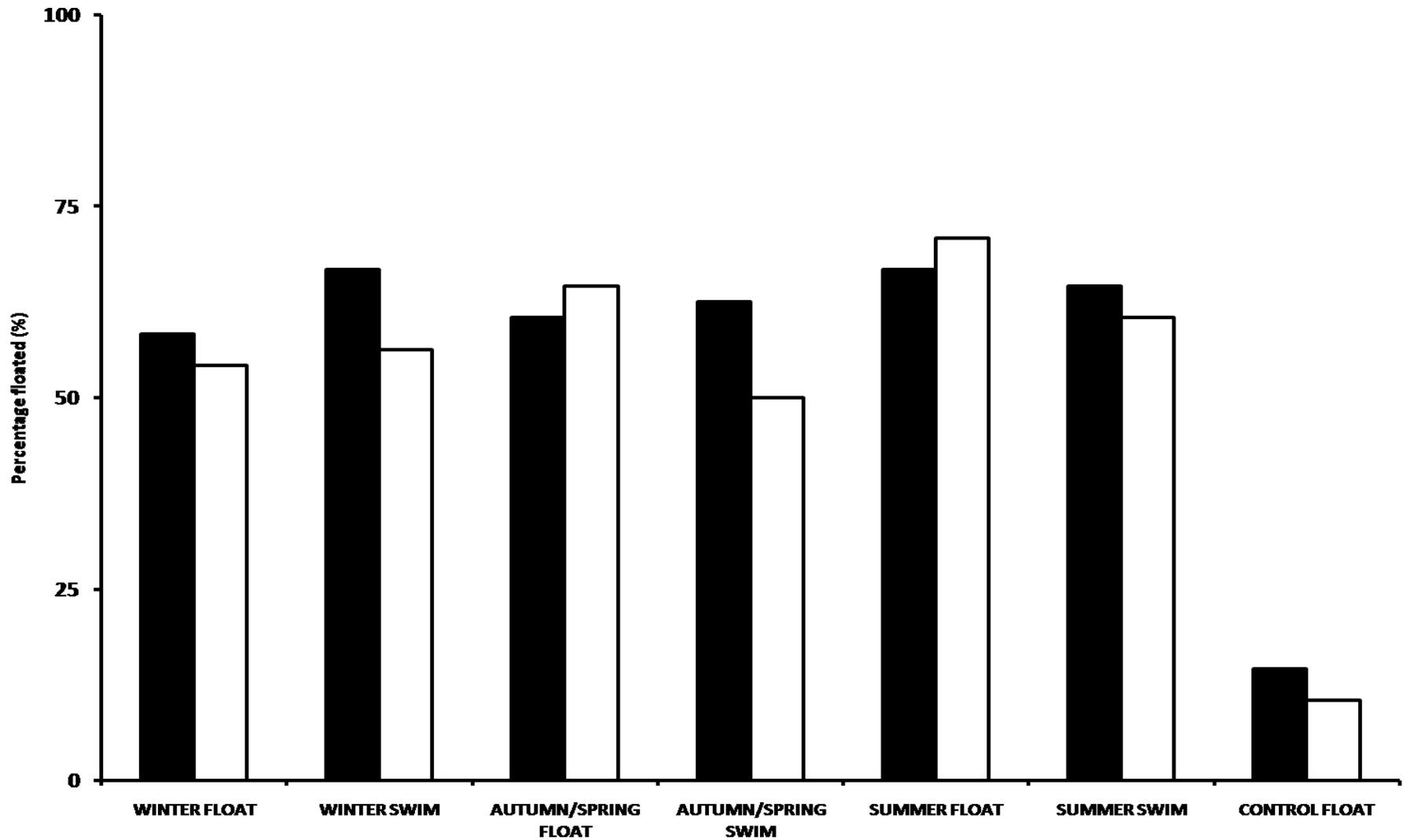


Figure 6. Percentage of occasions the participants' airway remained clear of the water in each condition just following the first buoyancy measurement (black bars) and just prior to the second buoyancy measurement (white bars) in all participants ($n=24$).

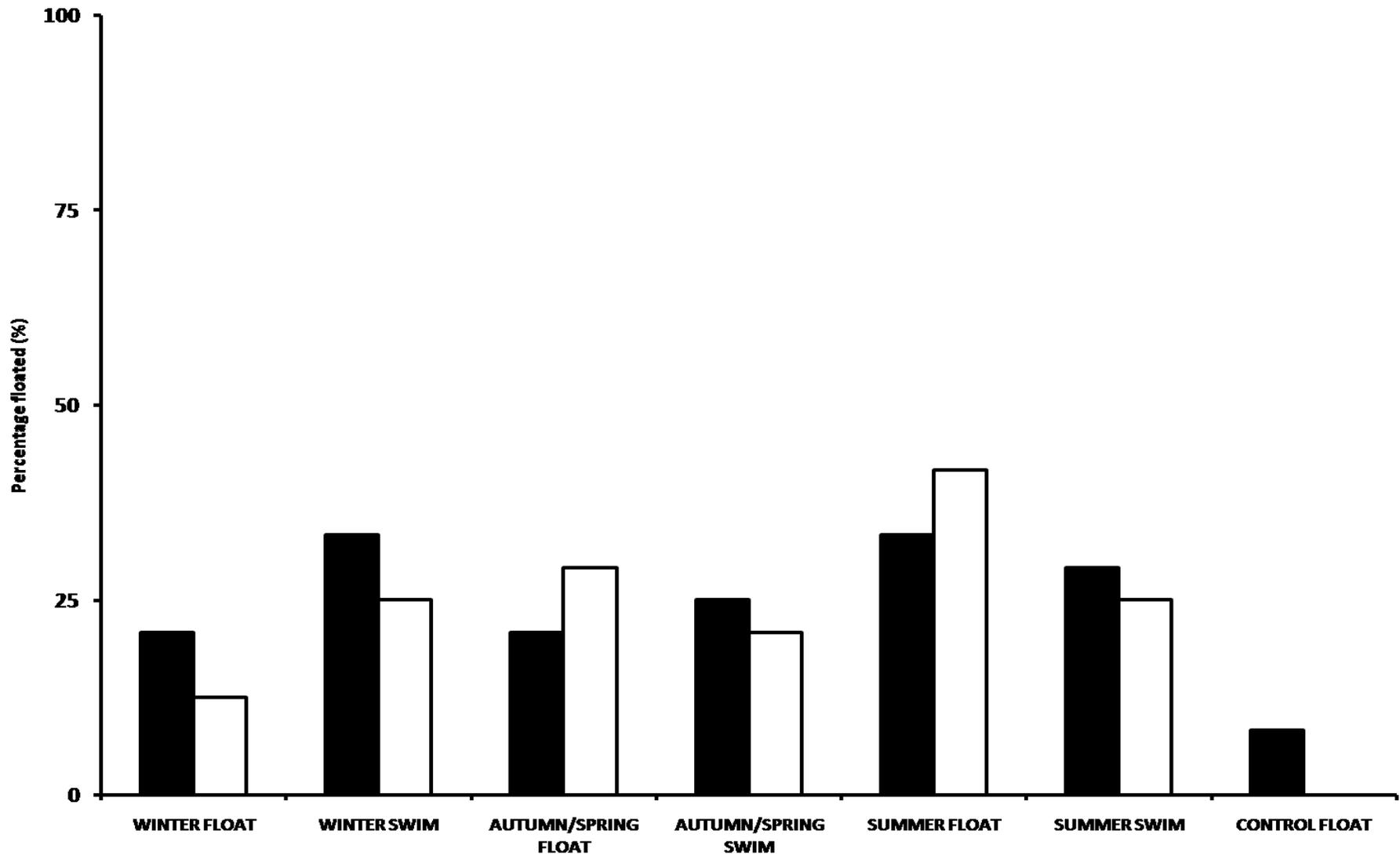


Figure 7. Percentage of occasions the participants' airway remained clear of the water in each condition just following the first buoyancy measurement (black bars) and just prior to the second buoyancy measurement (white bars) in males ($n=12$).

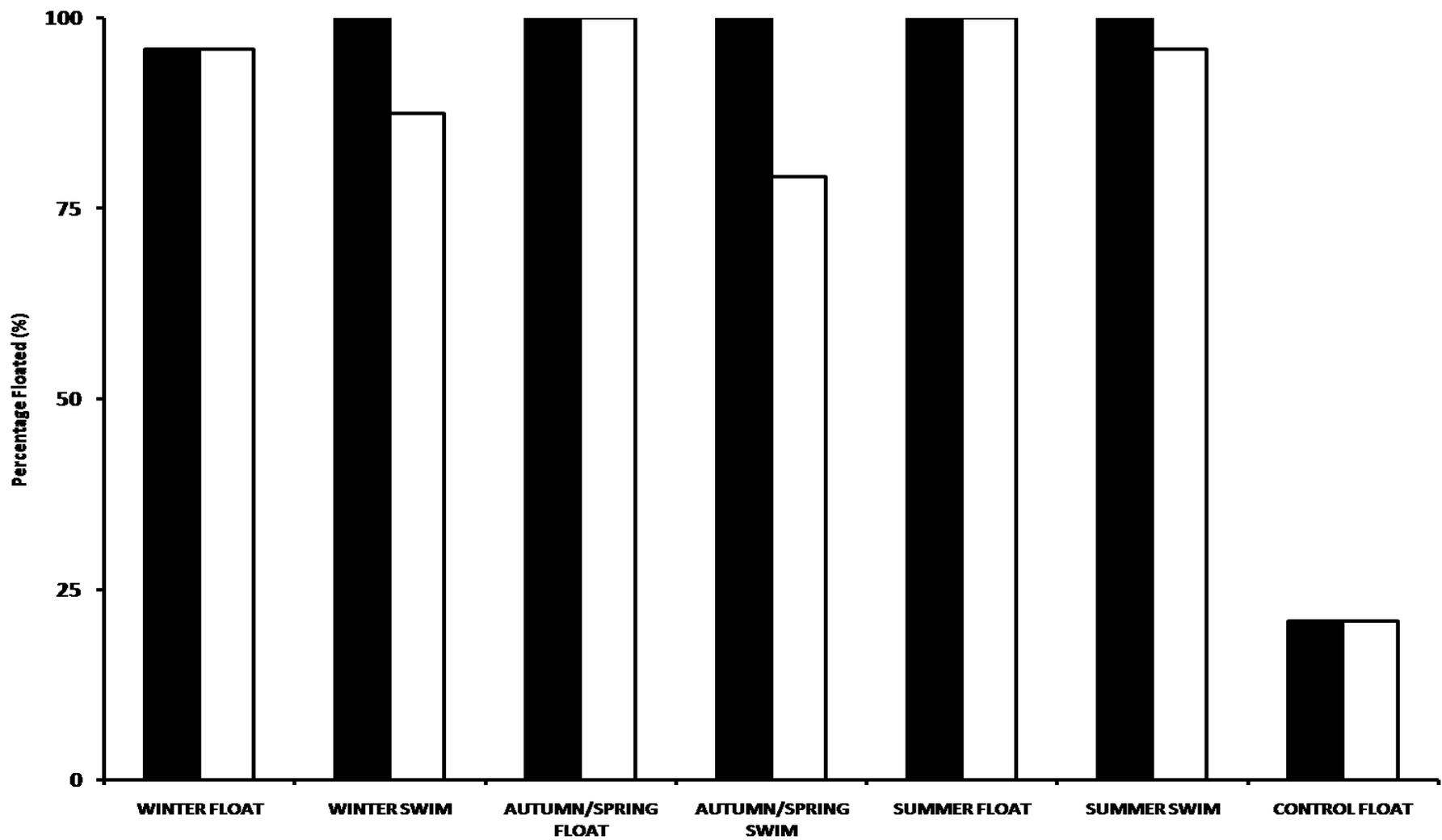


Figure 8. Percentage of occasions the participants' airway remained clear of the water in each condition just following the first buoyancy measurement (black bars) and just prior to the second buoyancy measurement (white bars) in females ($n=12$).

DISCUSSION

Study one examined the extent to which buoyancy was provided by air trapped between clothing layers on immersion and whether staying still (floating) enabled more air to remain trapped between clothing layers in the early minutes of immersion. The data suggest that a significant amount of buoyancy, over and above that seen when unclothed (Control), was present on initial immersion; the null hypothesis (a.) is therefore rejected. Indeed, up to 45 N of buoyancy (similar to that provided by an entry level buoyancy aid) was apparent in the winter clothing assembly; this clothing assembly providing the greatest amount of buoyancy in the present tests. As the clothing layers were reduced the amount of inherent buoyancy was also significantly reduced to 25 N and 7 N for autumn/spring and summer respectively; the null hypothesis (b.) is again rejected. However, buoyancy was reduced to a similar value irrespective of whether the participants swam or floated after the first buoyancy measurement; null hypothesis (c.) is therefore accepted. During the second buoyancy measurement clothing provided 5 to 14 N more buoyancy than that seen in the Control condition, with the winter clothing assembly again providing the most buoyancy at this time.

Despite the increased buoyancy with clothing layers, the participants were only able to lie still with their airway clear of the water on half of the occasions. Those participants who were initially able to float were still able to do so even if they had swum for two minutes. This, in part, can be attributed to gender. There were clear differences in measured buoyancy and freeboard between males and females, confirming that physical characteristics, such as percentage body fat (Table 1), play a role in determining the ability to remain afloat. However, the ability to float is determined by a number of factors in addition to body composition, including the volume of air in the lungs (Pendergast, di Prampero Craig, Wilson & Rennie., 1977) and the salinity of water in which the immersion takes place.

In addition to these factors, the number of clothing layers and type of clothing worn plays a significant role in determining buoyancy in the initial minutes of immersion when swim performance is most susceptible to cold shock (Tipton et al, 1999). The permeability of the surface clothing layer, which was waterproof in the present tests, appears to be the main determinant of the amount of buoyancy provided and the rate at which it dissipates. Our data suggest that when the waterproof layer was not worn, the initial buoyancy was reduced to ~7 N, a value that we primarily attribute to the running trainers which include air pockets and foam pads (Figures 2 & 6). However, even this minor addition to buoyancy enabled the female participants to 'float freely' on approximately 95 percent of occasions; this percentage fell to ~25 % when the trainers were removed in the Control condition (Figure 8).

It is possible that during an actual accidental immersion more buoyancy would be retained in clothing similar to that tested than was measured in the present tests. This is because the measurement of buoyancy by underwater weighing may, itself, have reduced buoyancy due to hydrostatic compression of the clothing. Whilst this will occur on any immersion, experimental or accidental, it is unlikely that an immersion victim would be held underwater for a period of 20 s necessary in the present experiments to determine underwater weight in a valid and reproducible way. Despite the extended period of submersion the buoyancy data showed a significant relationship with the freeboard data. During an accidental immersion it is possible that the victim's head would be forced below the level of the water. In such a situation air trapped in the hood of the clothing would assist the victim in returning to the surface of the water and help keep their airway clear of the water.

It is concluded that a significant amount of air is trapped by clothing on immersion in water and the volume of this air is primarily dependent on the permeability of the surface clothing layer. This buoyancy is reduced over the initial minutes of immersion irrespective of whether an individual swims or floats, but for up to at least three minutes, buoyancy remains higher than that seen without clothing. Therefore, the wearing of clothing may assist buoyancy in certain real life scenarios where accidental immersion occurs. In combination with observations from the cold immersion literature (Golden et al., 1986), which suggest that cold shock can cause swim failure during the initial minutes of immersion, our data continue to support a policy of 'float first' for the initial minutes of accidental immersion in to cold water.

It should be noted that the above data apply to adult participants. However, a sizeable proportion of those persons accidentally immersed in cold water each year are children and adolescents (RoSPA U.K drowning statistics 2000-2003). Therefore, Study 2 was conducted to examine the extent to which the buoyancy provided by clothing enabled children and adolescents to float, and how swimming compared to floating affected this buoyancy.

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STUDY 2. AN ASSESSMENT OF THE BUOYANCY PROVIDED BY WINTER CLOTHING IN CHILDREN AND ADOLESCENTS

Participants

Prior to acceptance to the study each participant completed a health history questionnaire to ensure they were fit and healthy to complete the procedures. Twenty nine participants (16 male and 13 female) volunteered for the study and each provided written informed consent to participate in the experiment. The mean (SD) participant characteristics are displayed in Table 2.

Table 2. Mean (SD) participant characteristics for the children and adolescents completing the swimming pool studies.

	Age (years)	Height (m)	Mass (kg)	Skinfold (mm)	Body Fat (%)
Overall (N=29)	12 (3)	1.53 (0.2)	48.7 (15.8)	36.9 (19.4)	20.9 (6.4)
Males (N=16)	13 (3)	1.55 (0.2)	51.6 (17.2)	33.1 (17.0)	18.1 (5.3)
Females (N=13)	12 (2)	1.51 (0.1)	45.1 (14.0)	41.6 (21.7)	24.3 (6.2)

Experiment Design

Each participant visited a local swimming pool on one occasion where they completed two immersions into warm water (29.5°C). Both immersions took place in a winter clothing assembly similar to the one pictured in Figure 2. Freeboard was measured subjectively and quantitatively at the start and end of each immersion. The two experimental conditions comprised one 'float only' (rest) condition and one condition where freeboard measurement was followed by up to 25 metres of sub-maximal breast stroke swimming, the tests ended with a further freeboard measurement.

Experiment Procedure

The timing of all data points (i.e. initial freeboard measurement, 2nd freeboard measurement) was matched to those noted in the first condition (winter clothing assembly and swimming). Each test lasted approximately 2 minutes. The participant dressed in their winter clothing assembly and approached the poolside. The experimental procedure was explained and the participant lowered themselves on to the second step of the entry steps and held on to the hand rail. Following a count down the participant fell backwards into the water with their arms outstretched and to the side of their body. Following water entry, they lay still in the water whilst an objective (see measurements section) and subjective assessment (experimenter observation) was made of their freeboard. Depending upon the experimental condition, the participant then either swam a maximum of 25 metres (swim condition), or remained still paddling as little as possible to remain afloat (rest condition). If the participant was unable to swim 25 metres they stopped, lay on their back and freeboard was measured before exiting the pool. The total distance covered was recorded. The test ended following the second freeboard measurement.

The participant then undressed to their bathing costume, dried themselves with a towel and re-dressed in dry clothes in preparation for the second (floating) condition. The duration of floating (rest condition) was matched to the duration taken to complete the swim in the swim

condition (~1.5 minutes). The difference in freeboard measurements before and after the rest condition compared to the swim condition was used to indicate the extent of any buoyancy retained in the clothing. Body composition was also measured (see below) either before or following the immersion tests.

The winter clothing assembly corresponded to that used in the laboratory tests (Study 1) and was based on the insulation required to keep an average individual warm in winter conditions. The participants were asked to bring two sets of their own clothing to ensure a good fit of the garments. The experimenters provided the waterproof jacket sized to fit. The winter clothing assembly comprised the following:

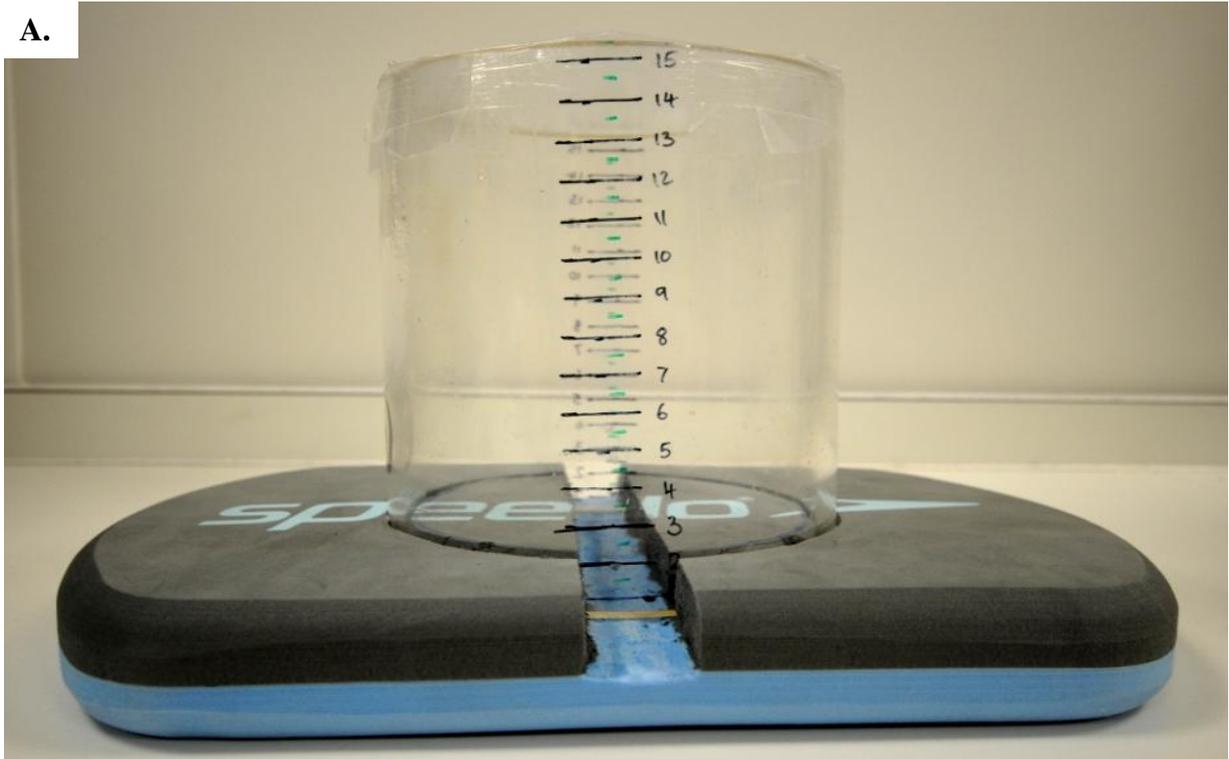
- 1) Trainers/leisure shoes, jeans, a t-shirt and a jumper (non woollen) both tucked into the waistband of the trousers and a waterproof jacket.

Measurements

Quantitative and qualitative measurements of the practical significance of any inherent buoyancy (freeboard) were made on two occasions during each test. The quantitative measurement was made using a parallax measuring device (Figure 9), deployed by the safety swimmer who was in the water throughout all tests. The freeboard measuring device was a perspex cylinder mounted on a swim float, with gradations marked at 0.5cm intervals on opposite sides. The zero baseline was set at the water level. The researcher measured the height of the lowest part of the mouth above the waterline.

As in Study 1, for the subjective assessment the experimenter assigned a fixed value of 1 to participants whose airway remained clear of the water without paddling, 0.5 if the airway remained clear of the water with minimal paddling and zero if the participant's airway dropped consistently below the level of the water. Following completion of both conditions, and where the participant was required to paddle to maintain their airway in the float condition, the participant was asked in which condition (swim compared to paddling to float) they exerted greatest effort.

A.



B.

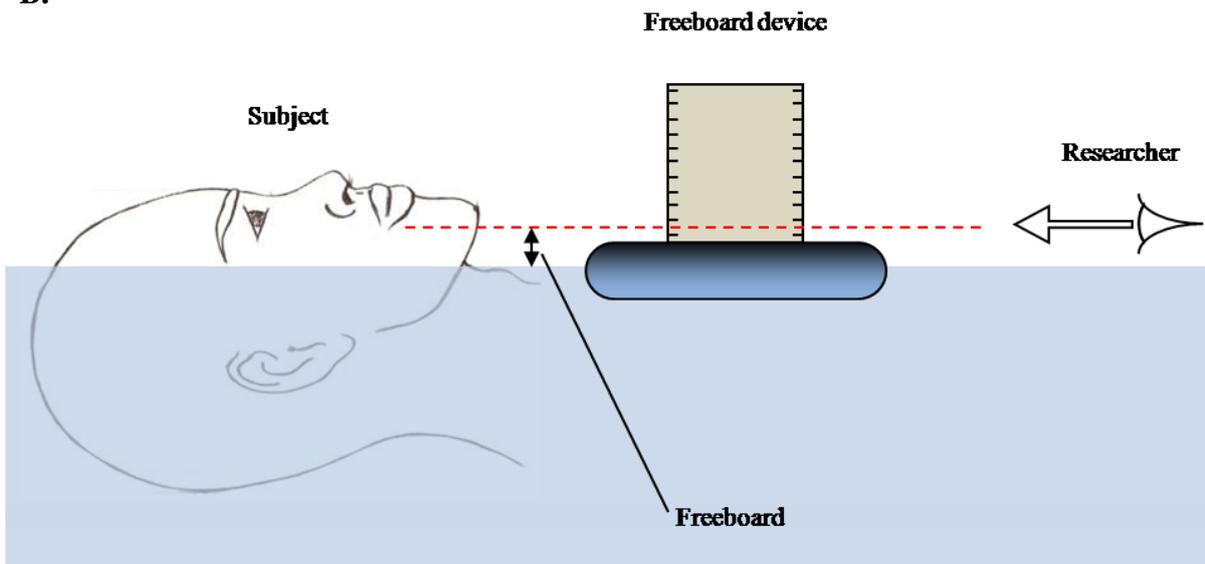


Figure 9. The parallax freeboard measurement device (panel A) and diagram depicting the use of the device to generate the freeboard measurement (panel B).

Participants completed a restricted anthropometric profile of skinfold thickness at four different sites (bicep, tricep, subscapular, iliac crest). Measures were taken, in duplicate, by an accredited anthropometrist. These data were used to calculate body composition (body fat percentage) and a sum of four skinfolds according to the formula of Brook (1971).

DATA ANALYSES

Means (SD) for the objective freeboard data were calculated for the measurements generated before and after resting or swimming. Data were then compared using an analysis of variance

(ANOVA) with repeated measures for change in freeboard both as a consequence of swimming compared to resting and between genders.

To establish the practical significance of any inherent buoyancy, the freeboard data were converted to a percentage by dividing the total generated by the freeboard observations (a value of 0, 0.5 or 1) by the four occasions the participants were asked to remain still in the water for freeboard measurement. These percentages were calculated for all the data and separately for males and females. In order to gain an estimation of the physical effort required to swim the 25 metres in comparison with floating, each participant was asked to rate their required effort on a scale of 1 *low intensity exercise/easy* to 10 *maximal effort exercise/hard*. These data were statistically examined for differences using a paired samples t-test.

The alpha level for all statistical tests was set at 0.05, $P < 0.05$ indicates a statistically significant result.

RESULTS

Swim Performance

The average (SD) distance swum by the participants was 24 (4) metres and was similar in males (23 [5.3] m) and females (25 [0.0] m). The time taken to complete this distance averaged 84 [14] seconds and was again similar between males (84 [15] s) and females (84 [12] s). The duration of the float condition was matched to the duration of the swim condition. The participants perceived that the effort required to swim was significantly more (6 [2]) out of 10) than that required to float (3 [2] out of 10) for a similar period of time ($P=0.001$).

Freeboard

Irrespective of clothing condition, experiment condition and gender the participants floated (i.e. the airway remained clear of the water) on 94 [21] % of occasions just following entry to the water and 77 [30] % of occasions at the end of the experiment ($n=29$). Males floated on 92 [27] % of occasions just after entering the water and 75 [32] % of occasions at the end of the experiment ($n=16$). Females floated on 96 [13] % of occasions just after entering the water and 79 [29] % of occasions at the end of the experiment ($n=13$).

When freeboard was directly quantified the airway remained clear of the water on initial immersion by an average (SD) of 5.5 (3.0) cm ($n=29$); a distance that was similar in males (5.5 [3.4] cm) and females (5.4 [2.7] cm). The airway became significantly closer to the water over time ($P=0.001$) but this distance was not influenced by whether the participant swam or remained still (floated $P=0.992$). There was no difference in the decrease in the freeboard measurement between males and females ($P=0.849$). The measured freeboard data are displayed in Figure 10 for all participants and males and females separately, before and after each experimental condition.

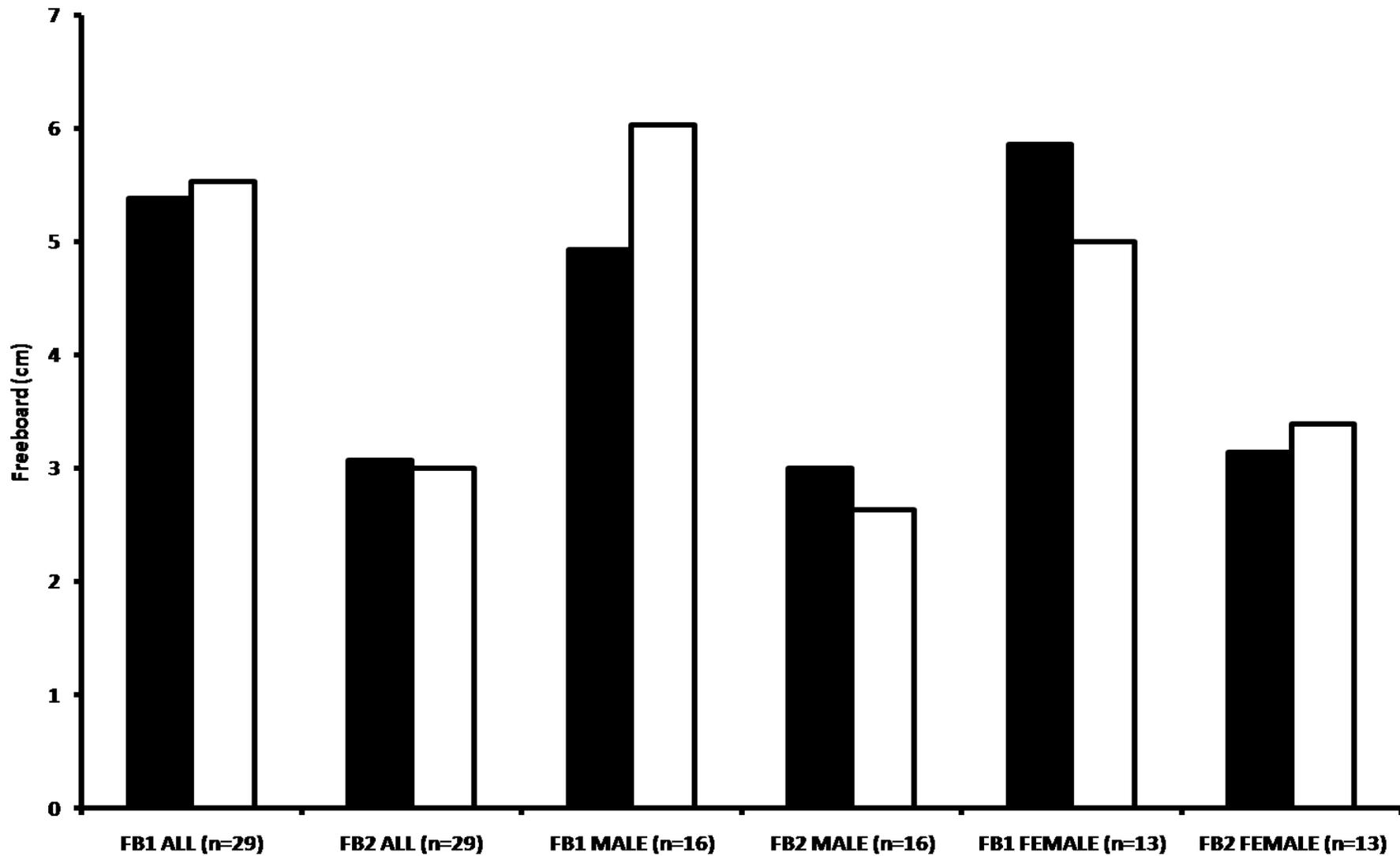


Figure 10. Measured freeboard in the winter clothing swim (black bars) and winter clothing float conditions (white bars) just after entering the water (FB1) and at the end of the experiment (FB2) in all participants ($n=29$), males ($n=16$) and females ($n=13$).

DISCUSSION

The data suggest that children with an average age of 12 years of age, and wearing typical winter clothing, are able to float on entry to water and keep their airway clear of the water with only minimal paddling. The ability to float is relatively unaffected by a short period of swimming in comparison with remaining still; which suggests that any inherent buoyancy created by trapped air between clothing layers diminishes by a small amount with time, irrespective of body movement. These data agree with the observations made on adults in Study 1. However, the results obtained from children and adults were not identical. From the tests conducted, the vast majority of children were able to float irrespective of gender; this finding corresponded with that seen in adult females, with a smaller percentage of adult males being able to float without exercise. The differences in the responses seen between children and adult males may be due to the methodological issues discussed in Study 1; this will be established by further experimentation. Alternatively, it could be due to: a. The similarities and differences in the anthropometric characteristics of children and adult females and males, and b. That the amount of air trapped in the clothing assembly of children is relatively greater in relation to body mass due to the higher surface area to mass ratio of children. This combined with buoyant footwear (i.e. running trainers) may have been sufficient to enable flotation.

The average estimated body fat percentage of boys undertaking the current studies was about four percent higher than that of the men (Tables 1 & 2), this is similar to the difference seen in anthropometric studies (Guo et al., 1998). Using the data of Barlett et al (1991), based on US citizens, it is possible to calculate the ratio of fat mass to fat free mass for children and adults of corresponding age to those in the present study; these data are presented in Table 3. Given the buoyancy characteristics of human fat and fat-free tissue, the higher this ratio, the more likely an individual should be able to float.

Table 3. Fat mass, fat free mass of adults and children (based on Barlett et al, 1991)

Group	Fat Mass (kg)	Fat Free Mass (kg)	Ratio
Boys 11-13 years	10.2	35.1	0.29
Men 19-22 years	15.6	64.6	0.24
Girls 11-13 years	9.7	32.7	0.30
Women 19-22 years	16.1	45.6	0.35

It can be seen from Table 3 that men in the age range of those participating in Study 1 have the lowest ratio of fat mass to fat free mass; this helps to explain the relative difficulty this group have floating.

It is concluded that children and adult women are better able to float than adult men, and that this is likely to aid them on accidental immersion to water. The effort required to swim even a short distance in warm water is significantly increased by wearing clothing; the fatigue associated with clothed swimming is likely to be exacerbated in cold water (Tipton et al, 1999). In children and adults a policy of 'float first' represents sensible behavioural advice should accidental immersion in cold water occur.

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