



FINAL REPORT

LIFE JACKET AND RESCUE STUDY OF BOATERS WITH ADAPTIVE NEEDS

CONDUCTED BY

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LIFE JACKET AND RESCUE STUDY OF BOATERS WITH ADAPTIVE NEEDS

INTRODUCTION

The C. Thomas Clagett, Jr. Memorial Clinic & Regatta (The Clagett) has been a leader in offering competitive sailing opportunities for sailors with disabilities since 2003, and a significant number of these sailors went on to win medals in the 2008, 2012 and 2016 Paralympics. An integral part of The Clagett's mission involves safety. There were questions about the performance of life jackets if an adaptive sailor fell overboard. What would happen if the sailor ended up face-down in the water? Was there a preferred method to retrieve sailors into a safety boat? To address these and other questions, The Clagett was awarded a grant from the Bonnell Cove Foundation in 2015 to:

- Test and evaluate life jackets by adaptive boaters with a range of disabilities
- Identify desirable performance factors of life jackets
- Determine if existing life jackets meet the needs or are improvements needed, or is a new category of life jackets needed for adaptive boaters
- Share findings with manufacturers to improve design and performance
- Test and evaluate retrieval rescue equipment

As the sport of paddling has grown in popularity, the design of life jackets has evolved to provide more freedom in arm motion and comfort which is applicable to sailing and rowing. Inflatable life jackets are worn by some rowers, sailors, and powerboaters. With crossover use of life jackets in these water sports with adaptive boaters, The Clagett partnered with the American Canoe Association, USRowing, and US Sailing/US Powerboating to encompass these boaters in the study.

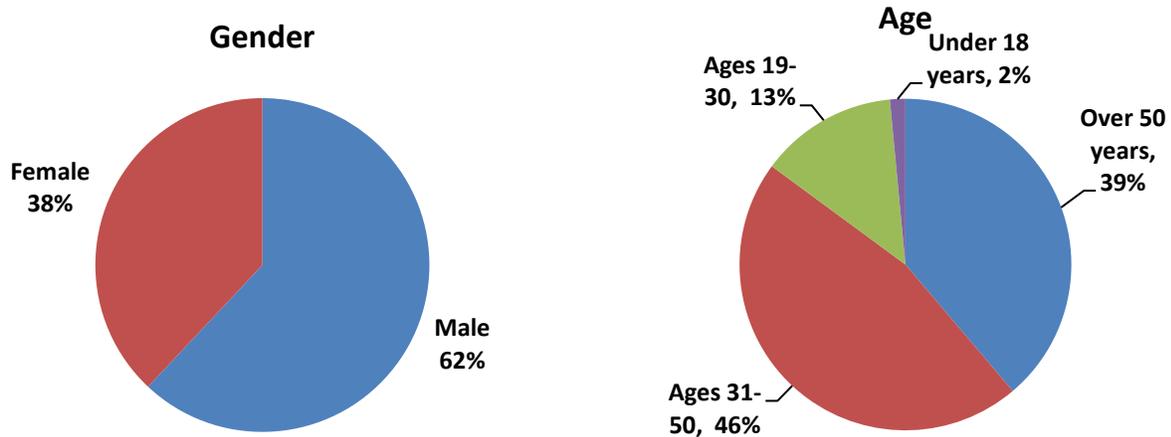
The study involved three phases. The first phase was an online survey monkey distributed to adaptive needs boaters within the four partnering organizations and completed at the end of 2015. The results from the survey helped to inform the second phase in 2016 that performed in-water testing of life jackets and rescue equipment at three venues. The third phase was sharing the findings and recommendations with the Life Jacket Manufacturers Association at its 2017 conference as well as interested parties at the 2018 US Sailing Leadership Forum.

The success of the in-water testing and demonstration was made possible through the outstanding commitment of these people and organizations and their contributions are greatly appreciated.

- The Clagett's partners for their invaluable assistance with the recruitment of participants in both the online survey and the in-water testing
- The testers who braved the waters and retrieval equipment; the volunteers who recorded data, took photographs and video tapes, and assisted in and on the water and on land
- The organizations that allowed use of their pools, on-water facilities and safety boats
- The manufacturers and contributors who donated life jackets for the study
- The Clagett Board members and administrative assistants who served as testers and volunteers

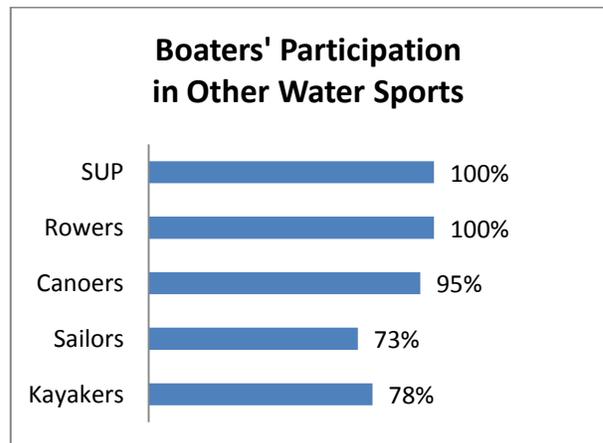
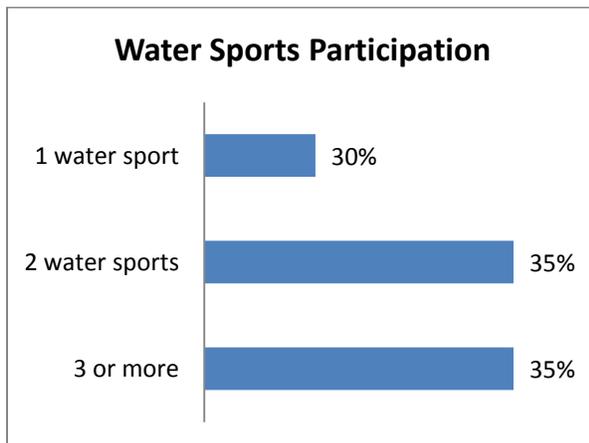
PHASE 1 – ONLINE SURVEY

Participants: Sixty-nine people participated in the survey with most of them located in the east coast, midwest, and west coast and with a couple responses from Canada, France and the UK. The participants' profiles included the following information:

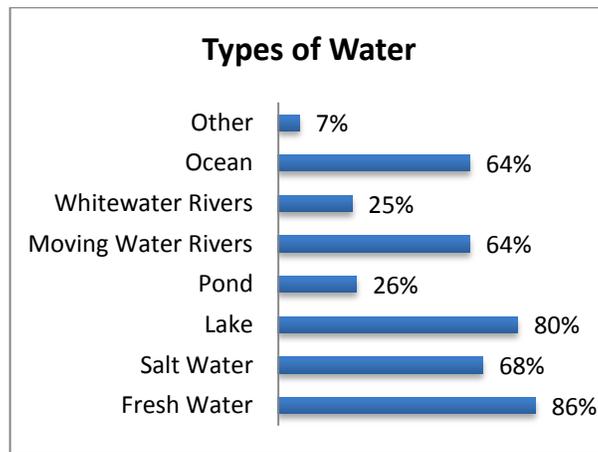


85% of the participants were over the age of 30. With regard to swimming ability, 93% could swim while 7% could not.

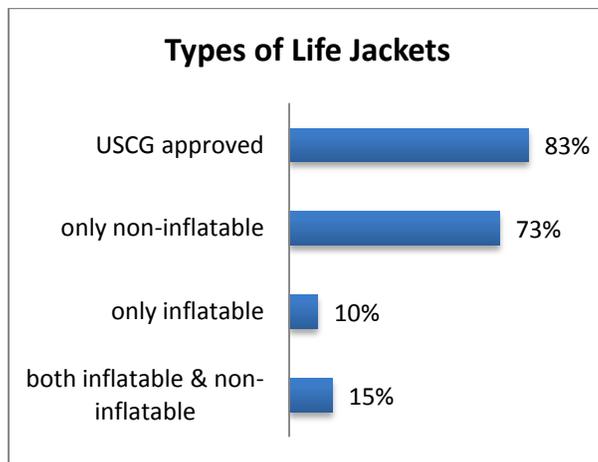
Water Sports Participation: The water sports identified in the survey were: kayaking (74%), swimming (48%), sailing (43%), canoeing (30%), stand up paddle boarding (SUP) (19%), and rowing (10%). 70% participated in more than one water sport, and in response to a question of whether they used a different life jacket for different water sports, 60% replied they did not. Below are graphs indicating participation in water sports.



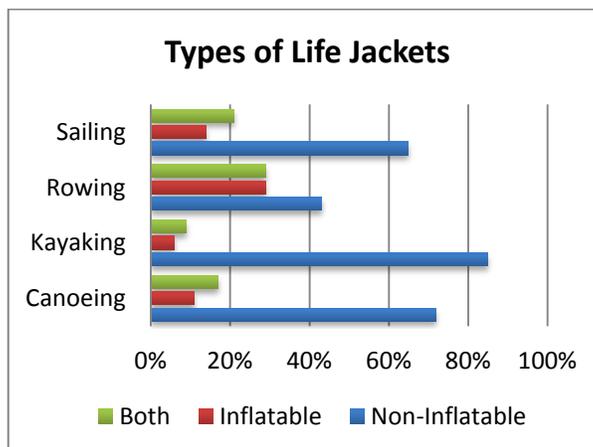
Types of Water: The survey also explored the types of water that boaters used for their water sports, whether it was fresh or salt water, rough or sheltered, which might affect the selection and performance of life jackets.



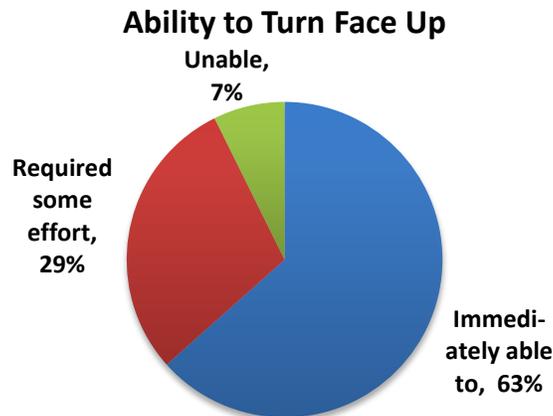
Types of Life Jackets: With regard to the types of life jackets, 90% of the responses identified their life jackets with the following results. Only five people used crotch straps.



If the data was broken down by water sports, the types of life jackets are depicted in the graph below where non-inflatable life jackets dominate in each water sport.



Falling in Water: With regard to the performance of life jackets when falling in the water, 64% reported they had fallen into the water. When asked if they turned face up, their responses are depicted below.



Reported Problems: Twenty-three or 1/3 of the responses reported problems with the fit and comfort of their life jacket. The most common complaint was ride ups on the neck by the jacket, sometimes accompanied by neck chafing or a choking sensation. The in-water testing of life jackets highlighted this as a common problem, most evident when crotch or thigh straps were not used. Other complaints to a lesser degree were the bulkiness of some jackets, fit problems for people with large stomachs or hips and women with large breasts, and being too restrictive when twisting. Straps and buckles were a problem with some who found straps difficult to reach or adjust, and buckles that were difficult to use or interfered with paddling. The in-water testing also confirmed that straps, buckles, and zippers were an issue with some testers and jackets.

Suggested Improvements: Twenty-six people had suggestions to improve their life jackets and most fell in the following categories with the highest number of suggestions listed first and then in descending order.

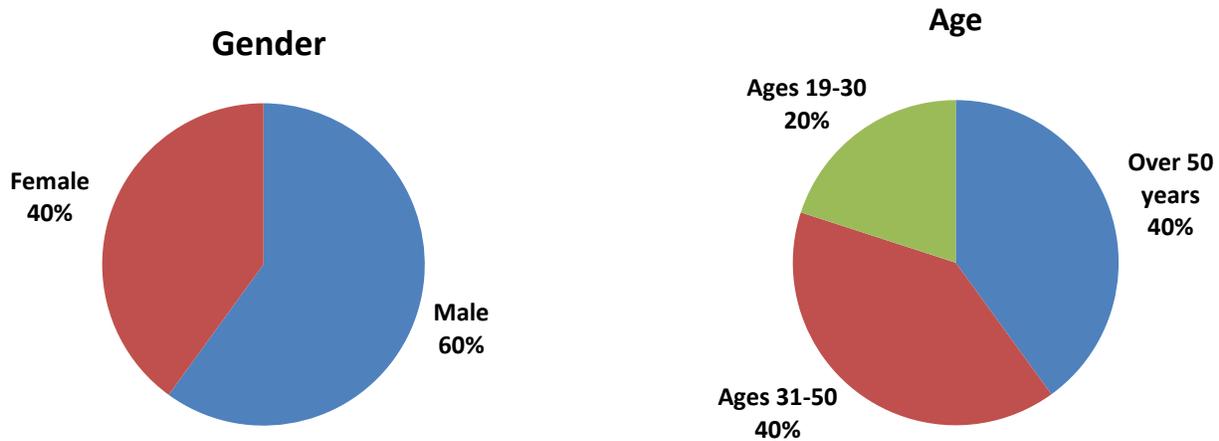
- Reduce ride up and increase comfort by making jackets more form fitting, especially for people with large torsos, breasts or hips. Be able to cinch the jacket below the stomach or rib cage.
- Reduce the bulk by making them flatter with a smaller profile
- Improve the straps and buckles by making the straps wider for an easier grab and make them adjustable from the front. Internalize the straps to prevent snagging. Make the buckles a bright color different from the color of the straps, and make them easier to fasten and unfasten for people with limited hand dexterity. Input from the in-water testing supported these suggestions and some testers recommended making each strap a different color to distinguish the straps from each other.
- Make the front of the jackets smooth to reduce snagging by internalizing the straps, harnesses, pockets for radios and timers.
- Provide a greater range of arm and torso twisting movement.
- Make the tabs larger on zippers to make them easier to grab and use.

PHASE 2 – IN-WATER TESTING OF LIFE JACKETS

Three in-water testing sessions were conducted in Newport, RI, Lake George, NY, and St. Petersburg, FL to evaluate a variety of life jackets and rescue retrieval methods. The first day of each session was done in the controlled environment of a pool followed by open water testing on the second day. The reason for this sequence was to ensure all the testers were comfortable in the water and to become familiar with the testing procedures before being exposed to unpredictable open water conditions. When selecting the venues, we wanted to perform the testing in salt water conditions at Newport and St. Petersburg and in fresh water at Lake George to determine any perceivable effect of water density on the life jacket performance.

A total of 196 life jacket tests were conducted with 104 in the pool and 92 in open water by 15 testers, 9 of which were male and 6 were female, and 13 were adaptive boaters and 2 were able-bodied. The range of disabilities was:

- Cerebral palsy
- Paraplegic T4/5
- Partial paraplegic T8
- MS/ Paraplegia T8
- Peripheral neuropathy
- Paresthesia, weak left side
- TBI, neuro muscular left side
- Born amputee all four limbs
- Bilateral above knee amputee
- Above knee left amputee
- Below knee right amputee
- Below elbow right amputee

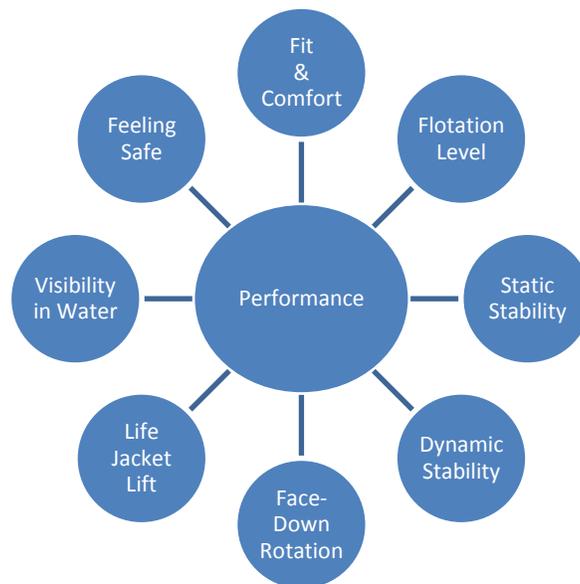


A variety of 29 life jackets were tested, including Type 1 Offshore, Type II Near-shore, Type III vest-type flotation aids, and inflatables. Two of the vests were CE 50 Newtons buoyancy aids, which conform to the European Standards' minimum buoyancy of 50 Newtons or 11.2 pounds, but do not meet the US Coast Guard's required minimum buoyancy of 15.5 pounds. Although these 50 Newtons vests are not US Coast Guard approved, there are popular with dinghy sailors in the US.

A testing protocol was used to guide the testers, safety swimmers and recorders through the process, and data inputs were recorded on tablets by recorders. In both the pool and open water testing, there was always a safety swimmer(s) in the water to assist as needed.

Life Jacket Performance Factors

The following eight performance factors were considered:



Fit & Comfort

This factor includes the ease of putting on a jacket, adjusting it for fit, and its comfort in the water.

Putting on a Life Jacket: Nine (60%) testers (5 males and 4 females), including an able-bodied one, reported problems with putting on 12 (41%) of the 29 life jackets for a total of 24 reported problems. 20 (83%) out of the 24 problems involved testers with some impairment of arms or hands. There were an additional three testers (1 male and 2 females) who reported problems with buckles and zippers. The most common problems cited were:

- The bulk of the front foam made it difficult to reach or engage and use the zipper
- Zippers on the side made it difficult to see, reach and use. This was especially evident with testers who had limited dexterity or one hand.
- Some buckles were hard to see, and a jacket with two types of buckles was confusing. On jackets with multiple straps, some thought there were too many buckles and figuring out which was which was confusing at times.
- Tie straps were difficult to tie, especially if being tensioned or with only one hand.

At the first testing venue, three testers tried putting on life jackets while in the pool. It was not easy and took too much time. Tightening for a good fit was particularly difficult, especially for a person with dexterity impairment. As a result, subsequent testing did not include this maneuver.

Adjustment for a Good Fit: The ability to adjust a life jacket for a good fit impacts its performance in the water and its susceptibility to ride-up as well as the comfort of the wearer. Of the 102 responses to the question of adjusting the straps for a good fit:

- 74% reported the straps were easy to adjust for a good fit.
- 12 testers (6 males and 6 females) reported difficulty with adjusting the straps for a good fit on 15 life jackets (6 males with 8 life jackets and 6 females with 10 life jackets).

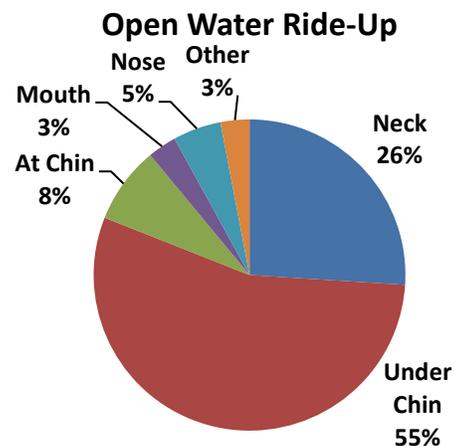
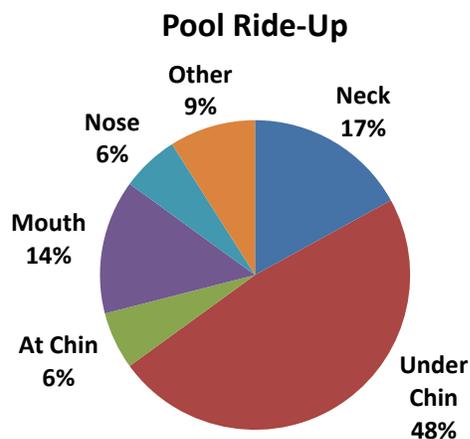
Adjustment To Keep Life Jacket in Place: Of the 99 responses to this question:

- 86% responses reported they were able to adjust the straps to keep the life jackets in place.
- 8 testers (4 males and 4 females) reported they were not able to adjust the straps to keep 12 life jackets in place (4 males with 5 life jackets and 4 females with 7 life jackets).

Problems with strap adjustment with highest number listed first included:

- Could not adjust on disabled side
- Limited arm movement made it difficult to tighten
- Needed two hands to adjust
- There were too many straps
- Side straps too far back to reach
- To tighten side straps had to pull backward instead of forward which limited tension
- Too much friction
- Bulkiness at front made it difficult to adjust
- Had to take life jacket off several times to make adjustment
- Only adjustment was in the back
- Shoulder straps were difficult to adjust or straps were not adjustable
- Difficult to tighten because buckle was not anchored
- Tying strap below waist was difficult

Life Jacket Ride-Ups: Ride-ups reduce the effective buoyancy of life jackets in the water, which in turn affects how high a person will float in the water. Contributing factors to ride-ups observed were: body shape (e.g. pear-shape), amount of activity in the water, and degree of secured fit. While ride-up is often measured as the gap above the shoulder to the life jacket, measurements were taken at the level of ride-up in relation to the head or neck. Some testers had excessive ride-up at the back of the head as shown in this image.



If a body had a pear-shape rather than a vee-shape (wider shoulders to waist), ride-up was most likely to occur.

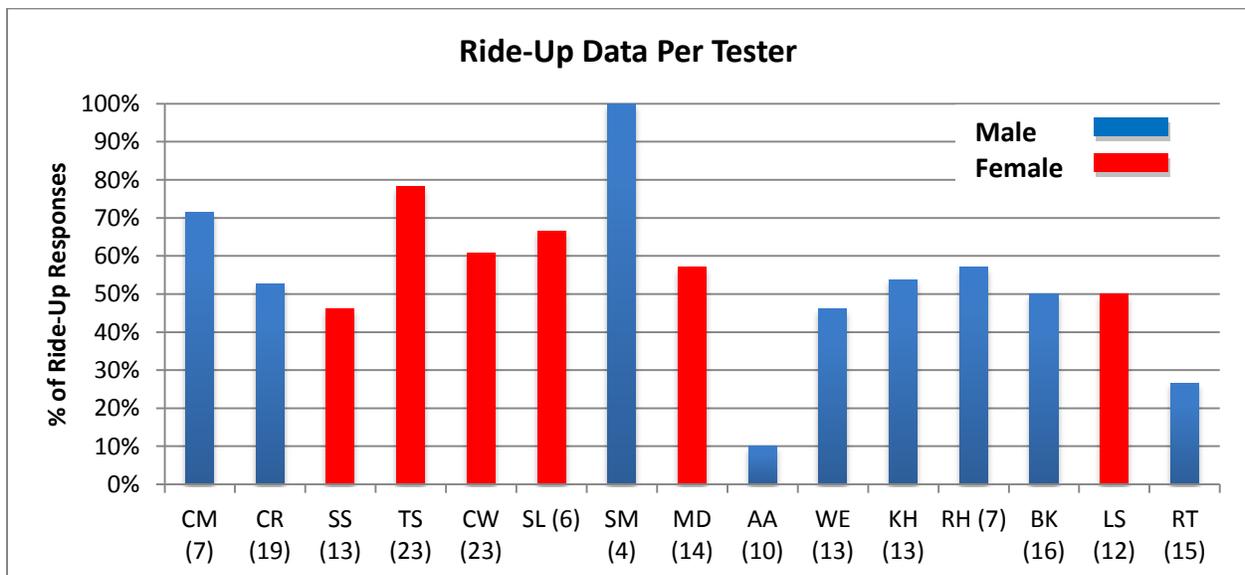
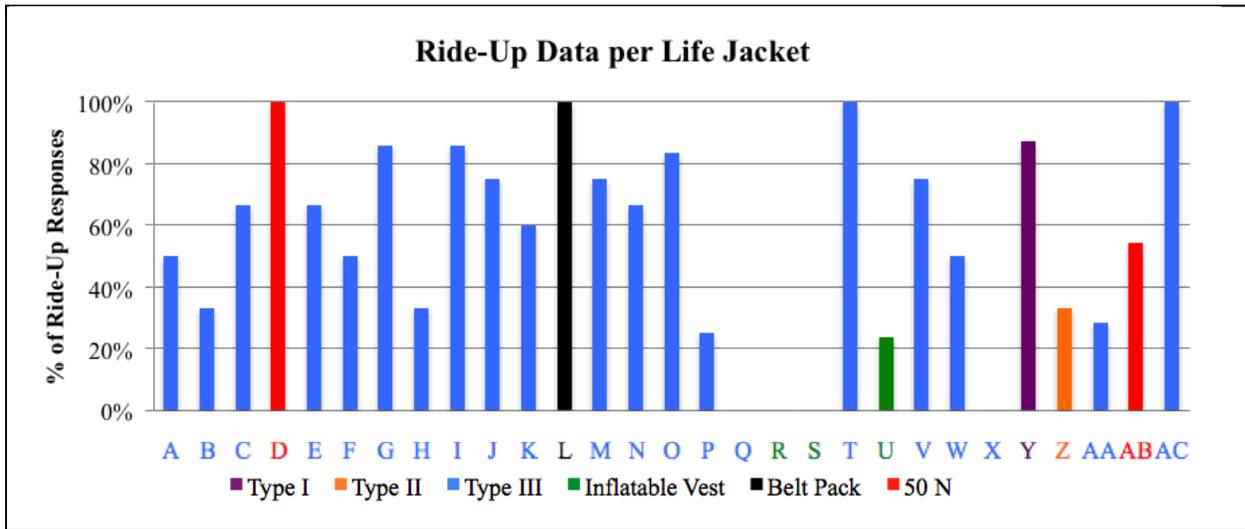
Testers also complained of a choking sensation when the front of the life jacket rose up their neck or under their chin or a smothering sensation when it rose to their nose. Life jackets with a high front instead of a scooped or vee neck were more likely to produce a choking sensation.

It is interesting to compare the 86% result for testers who reported they were able to secure their life jackets in place with the in-water ride-up results where only 28% to 58% had no ride-ups.

- **Pool:** 72% ride-ups; 28% no ride-ups
- **Open Water :** 42% ride-ups; 58% no ride-ups

The lower ride-up percentage for the open water tests is likely due to testers cinching their jackets more tightly.

Only two life jackets had a Ride Up Prevention System (RUPS), or what is commonly known as crotch or thigh straps. The combined analysis of the pool and open water results indicate the high effectiveness of the RUPS where ride-ups were prevented in 92% of the tests with them. This supports the case that if all the life jackets had RUPS, ride-ups would have been greatly reduced, especially for pear-shaped bodies.

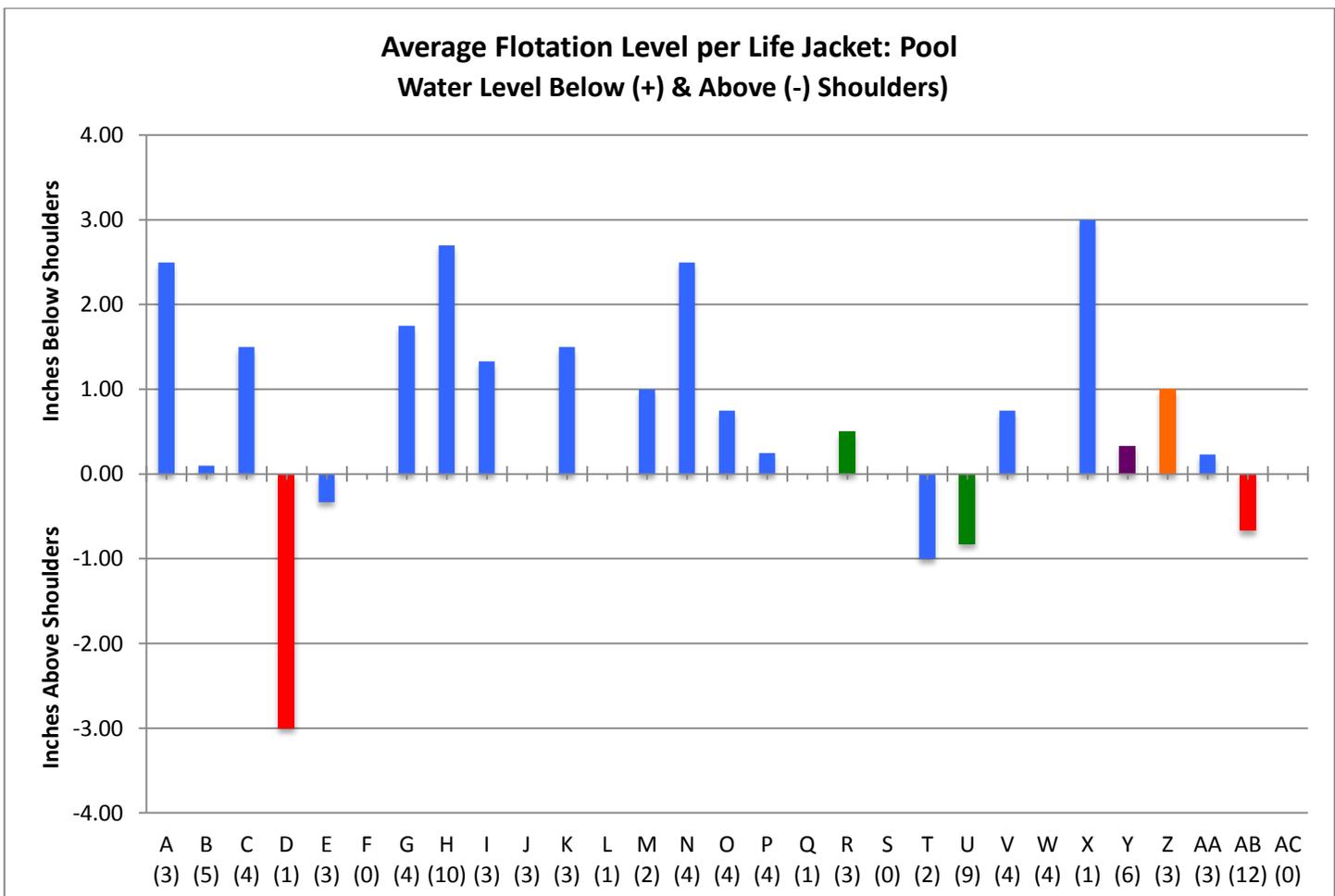


Comfort: The evaluation of life jacket comfort was conducted in the pool sessions with 77% of the 102 response reporting they were comfortable in the life jackets while 23% were not. Most of the discomfort was the result of ride-up symptoms (neck chafing, choking, uncomfortable pressure on the back of the neck or head) and the inability to assume a face-up or vertical position in the water.

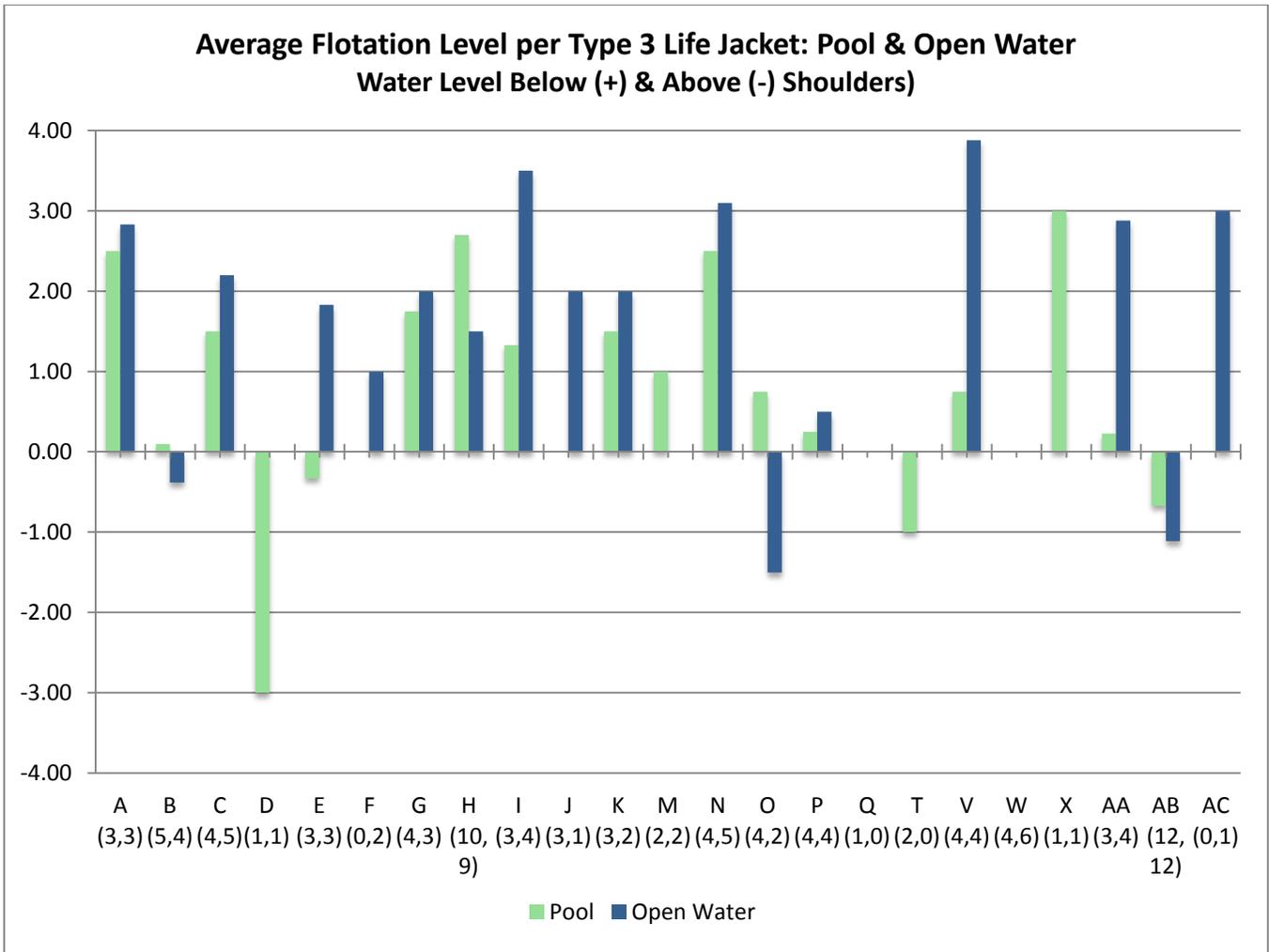
Flotation Level

Measurements were taken of water positions on the testers in both the pool and open water, using their shoulders as the datum reference. If the water level was below the shoulders, it was recorded as a positive number indicating the tester floated higher, and if the water level was higher than the shoulders, it was a negative number indicating a lower flotation. An undesirable condition of a water level at the chin was typically a minus 3 inches with just another 2 to 3 inches before impeding the nose airway.

In the graph below, the average flotation measurements of each life jacket are depicted for the pool tests. On the scale at the bottom of the graph, the numbers in the parenthesis under the letters indicate the number of tests. The blue depicting the Type III life jackets with a buoyancy of 15.5 lbs. or more indicate the average flotation level of the testers floated with the water level below their shoulders, except for two jackets. The red bars of the two 50 Newtons (11.2 lbs.) jackets with a lower buoyancy than the Type IIIs show the testers floating with the water level above their shoulders with one at the chin position. The two inflatable jackets (green bars) averaged out just below and above the shoulders as a result of these jackets floating the testers face-up on their backs.

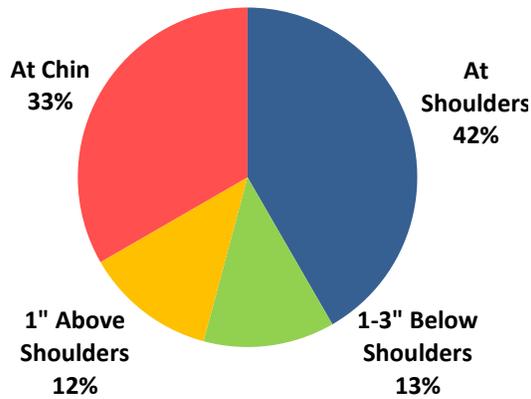


In the graph below, the average flotation measurements of each Type III life jacket are compared from the pool and open water tests. Of the life jackets which were tested in both the pool and open water, 62% of the life jackets floated higher in open water while 33% floated lower and only one jacket's flotation average remained unchanged. There may be several factors involved in the difference such as the degree of ride-up, the fit of the jackets, the differences in water densities, and the accuracy of the open water measurements where testers were bobbing up and down in the waves. Generally, testers seemed to tighten their jackets more tightly for the open water conditions, which would have reduced ride-up and resulted in more effective use of the jackets' buoyancy to float a tester higher. Salt water is denser than pool water and a tester theoretically would float higher in salt water, but the difference might be difficult to measure precisely. In comparing the flotation levels measured in the fresh waters of Lake George to the salt open waters, the numbers didn't support the expected density differences. However, there were fewer Lake George tests compared to the salt water ones.

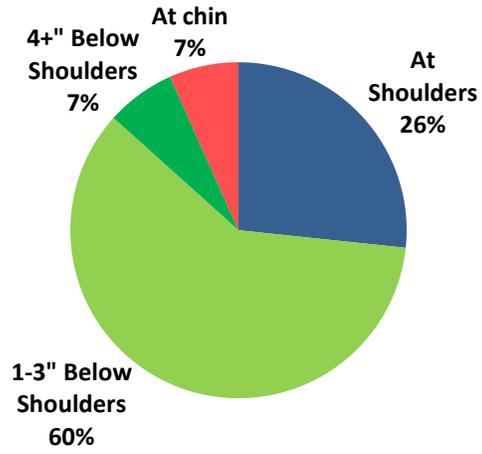


When the results of both the pool and open water are combined, the combined totals indicate the 50 Newtons (11.2 pounds) buoyancy life jackets floated lower than any of the other non-inflatable jackets with a higher buoyancy and 35% of the tests recorded the water at chin level. Below is a comparison depicting the water levels of an 11.2 lbs. jacket to a 15.5 lbs. jacket, which is the required minimum buoyancy for US Coast Guard approval of a buoyancy aid.

11.2 lbs. (50 Newtons) Life Jacket



15.5 lbs. (69 Newtons) Life Jacket



The vertical measurement from the water surface to the lowest point where a person’s airway may be impeded is commonly referred to as freeboard. This condition is accentuated in wave conditions where a person is heaving up and down. The images below show the same person in open water wave conditions wearing an 11.2 lbs. (50 Newtons) jacket and a 15.5 lbs. (69 Newtons) one. As he bobs down in the 11.2 lbs. one, the water covers his nose, and if his reserve buoyancy is low, his nose will be covered for a longer period of time.

11.2 lbs. (50 Newtons) Life Jacket



15.5 lbs. (69 Newtons) Life Jacket



Another factor that appears to influence the flotation level is the ratio of body fat to muscle mass (and bone density). Fat has a lower density than muscle and will float in water while higher density muscle will sink. People with low body fat and high muscle mass will float lower. While we were able to calculate the body mass index (BMI) for most of the testers, this does not provide an accurate measurement of the fat mass and muscle mass indexes. One of the testers floated at the lowest level in seven out of eight life jacket tests when compared to the other testers. He appeared to be quite muscular, but bone density may have been another factor.

25.8 BMI Tester in 11.2 lbs. Jacket

29.6 BMI Tester in 11.2 lbs. Jacket



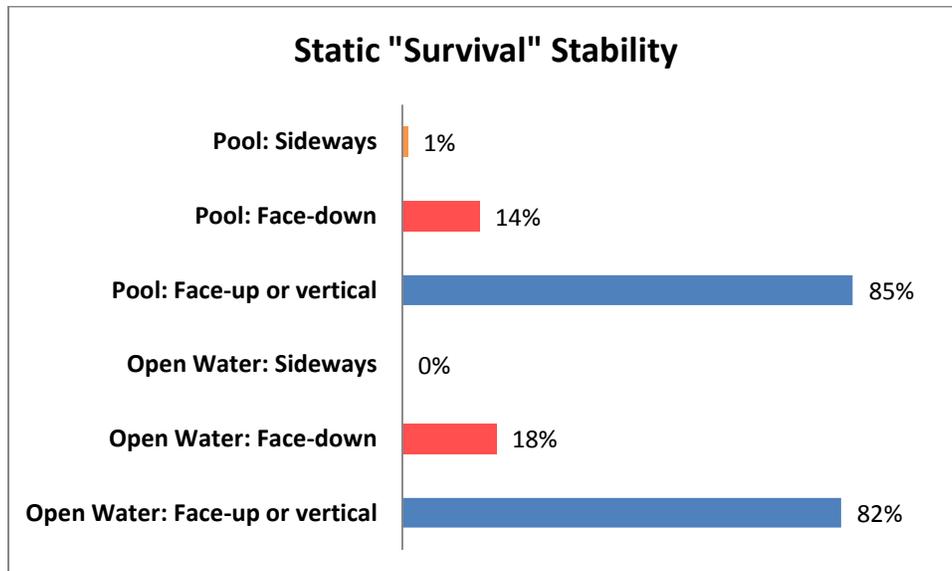
Shoulders are below water.



Shoulders are above water.

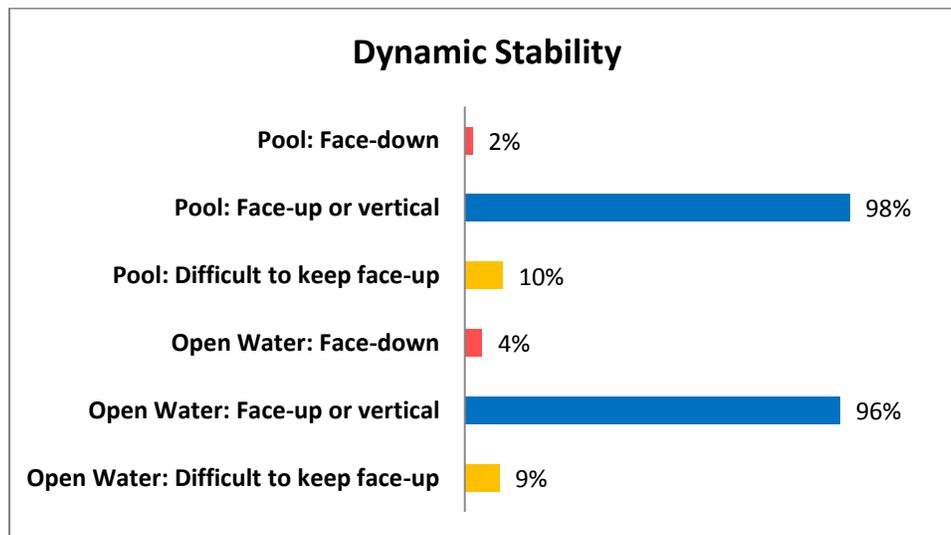
Static Stability

This is sometimes referred to as the “survival” position where the tester assumes a vertical position in the water with arms at side and no movement of arms and legs to simulate unconsciousness or an inability to hold that position. In both pool and open water tests, more than 80% remained in a vertical position or rotated onto their back. All testers with non-hybrid inflatables floated on their back. The face-down results involved 17 identified Type III vest-type jackets and increased slightly in the open water conditions. Some reported the tilt of their head determined the rotation direction. For life jackets with more than 6 tests, the 11.2 lbs. one had the highest face-down percentage with 33%. A couple testers tilted to one side with one tester ending up face-down and another time sideways in the water.



Dynamic Stability

The tester uses arms and legs to stay in the vertical position. As expected, the results indicate an improvement over static stability with a more than 10% increase in holding a vertical or face-up position and a corresponding decrease in a face-down position. Again, only Type III vest-type jackets emerge in the face-down results, but with a total of 4 instead of 17. If life jackets with more than 6 tests were considered, the 11.2 lbs. one had the only face-down result (4%).



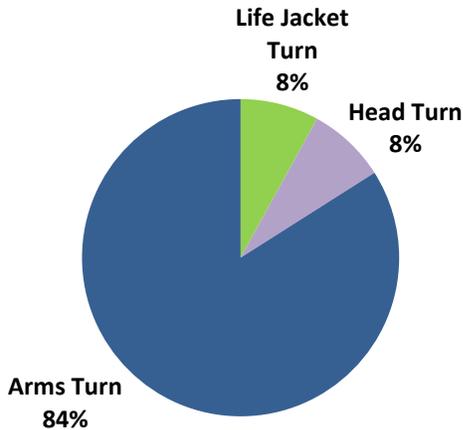
Face-Down Rotation (Turning) Ability

In this test, the tester assumes a face-down position to determine if the life jacket will automatically rotate the person face up. If not, the next step is to determine how much effort it takes to rotate into a face-up position. This was done by first turning the head to see whether it would result in a successful rotation. If that did not work, then arms would be used. With some testers, turning their head or using their arms would also result in rotation of their torso. All of which would change the relationship of the tester's center of gravity and center of buoyancy combined with the propelling force of arms and legs. In almost all cases a positive righting moment from face-down to face-up resulted. However, in the open water tests 6% percent were unable to turn face-up and this involved two testers, one able-bodied male and one female with a weak left side, and five Type III inherently buoyant life jackets.

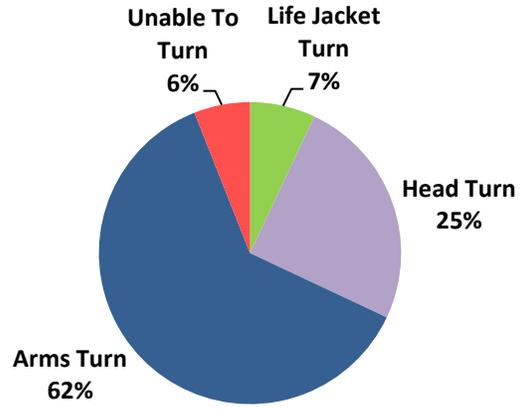
As expected, the Type I Offshore life jackets turned testers face-up without assistance albeit slowly in a couple of instances. The inflatables with almost all of its buoyancy on the front side turned testers face-up quickly with or without head movement. There were several cases where testers were unable to get into the face-down position because they could not overcome the frontal buoyancy of the inflatables. One tester brought his personal inflatable to the open water session that did not deploy when he entered the water. Its deployment activation status indicated it was functioning, which brought into question the reliability of the type of activator it used.

Comparison of the pool and open water tests (below) indicate hardly any difference in the percentage of life jackets self-turning while head turns increased significantly with a corresponding decrease with arms turns in the open water tests.

Pool Rotation from Face-Down



Open Water Rotation from Face-Down



Life Jacket Lift

This is one of the popular rescue methods for quickly retrieving a person in the water into a boat with a low freeboard and frequently used by safety or rescue boats. It involves one or two people grabbing the shoulder straps of a life jacket, doing a “1-2-3 bounce and lift” over the side into the boat. The design of the shoulder straps affects the success of this method. Elastic straps will stretch making it more difficult to heave the person out of the water while non-stretch straps won’t. Another problem may involve the fit. If the jacket is too loose, it may pull off during the lift, and there was one instance where this occurred.



Stretch of elastic straps makes a lift difficult.

Visibility in the Water

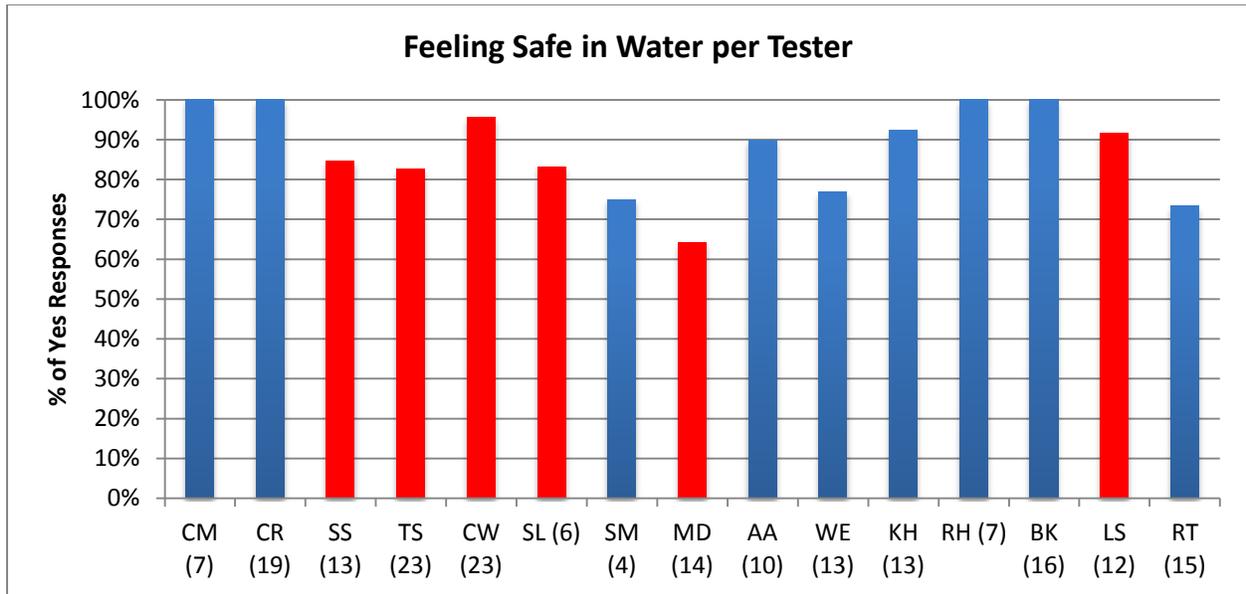
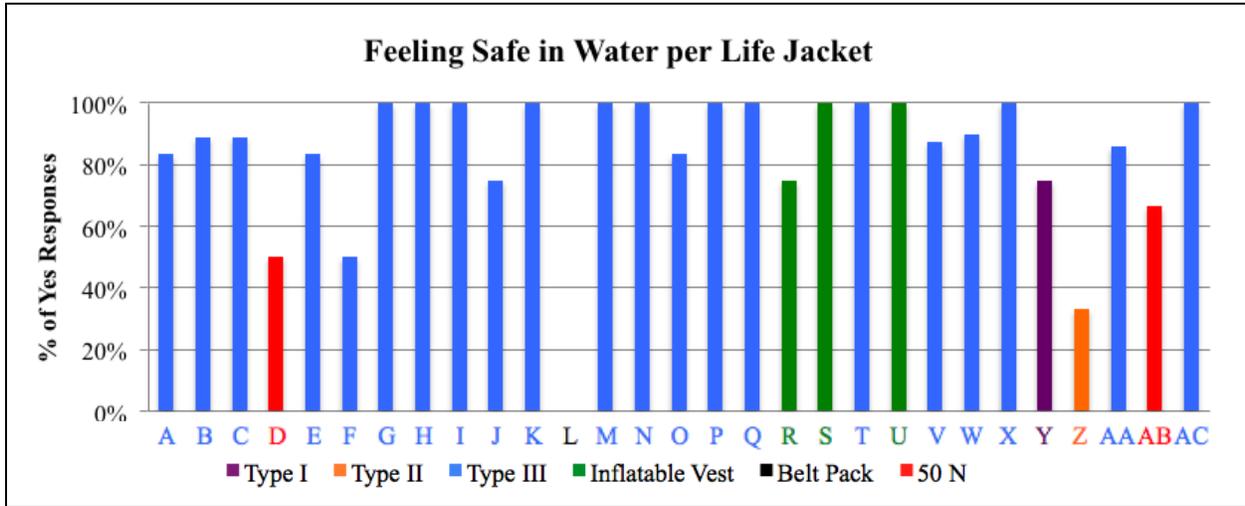
Visibility is important for boaters and rescuers to be able to see a person in the water. There have been fatal accidents where powerboat operators ran over a person because they did not see them. Visibility is greatly limited, especially in waves, if a life jacket is fully immersed beneath the water or the shoulder straps and jacket top above the water are a dark or black color. To reduce this problem, life jackets should have brightly colored straps and tops with reflective strips and have sufficient buoyancy to float a person high in the water.



Wet hair and black jackets decrease visibility.

Feeling Safe

This takes into account the overall performance of the life jacket in the water regarding comfort (freedom of movement, amount of ride-up, no chafing, choking or smothering), how high the jacket floated the testers, the ability to stay upright or face-up, ease of turning from face-down, and a general feeling of being safe. The graphs below indicate the results per life jacket and tester.



PHASE 2 – IN-WATER TESTING OF RESCUE RETRIEVAL METHODS

Several retrieval methods were tested in both the pool and open water that included life jacket lift, sit-in net, parbuckle rescue net, and backboard. These methods required little if any involvement of a person assisting with his or her retrieval in order to address the issue of person that may be incapable of helping with their rescue. Boat ladders were not included in the study because they require a person able to climb a ladder and in rough wave conditions the use of ladders may be hazardous.

Life Jacket Lift: This method, which was described earlier in this report, was tested 22 times in the pool and 47 times in the open water by a total of 13 testers. It is the quickest retrieval method, but is best used with low freeboard boats. The weight of the person to the strength of the person doing the lifting is another factor. The weight of the heaviest tester was 235 pounds and it required two men to do the lifting. Generally, anyone weighing over 150 pounds will need two lifters. As mentioned earlier, the life jacket fit was another consideration. Too loose, and there was a risk of it slipping off during the lift. Also tested was the orientation of a tester to the side of the rescue boat: facing the boat or back to the boat. The backside to the boat works best with a low freeboard RIB where the lifter can lift the person vertically, keeping the spine of the person being lifted in column. With this orientation, the ratio of the weight of the person to the strength and size of the lifter is critically important. If successful, the retrieved person ends up sitting on the top of the tube and only needs to swing his or her legs into the cockpit. If the person in the water cannot be lifted keeping the spine in column, then facing the side of the rescue boat is the best and safest alternative. Most lifts were done with testers facing the boat and the side of the pool. In a couple cases, responses indicated discomfort with the pressure of a jacket on the body and of the crotch straps. Another problem was a jacket snagging on the boat's rail or handle bars.



Sit-In Net: This net was tested 20 times in the pool and twice in the open water involving a total of 10 testers. Four of the 10 testers rated this method as the best one. The net is deployed by throwing a bag containing a floating polypropylene line that is used by the person in the water to pull the net toward him or her. The person gets into the net in a sitting position and is hoisted up over the side of the rescue boat usually by two people. This method is more comfortable than the life jacket lift because there is no ride-up pressure from the life jacket, but again the ratio of the person's weight to the strength of the lifters is a determining factor in its success. If the rescue boat has a davit or boom, it makes this method more successful for both the person and the rescuers. Figuring how to get into the net was confusing for one tester, and another tester found it difficult to pull on the polypropylene line with only one hand.



Parbuckle Rescue Net: This was tested 11 times in the open water by 8 testers, but not in the pool because of the shape of its edge. The net is deployed over the side with one edge attached to the boat. The tester is floated into the submerged net head first and then parbuckled (rolled) up over the side of the boat. The soft tube of a RIB has a positive effect on the comfort level of this method. Some testers ended up face-down on top of the tube. If they have upper body mobility, this is not a problem because they can easily get into an upright position. But for anyone with inadequate mobility, they will need assistance. The other cautionary is to be aware of the possibility of the remaining portion of an amputated limb slipping through one of the openings in the net which could result in an injury as the person is parbuckled into the boat. Check to make sure this has not occurred before starting the retrieval. There were positive comments recorded from four testers such as “very successful; best system – quick; comfortable; very effective into a RIB.”



Backboard: The backboard was tested 4 times in the pool and 5 times in the open water by a total of 7 testers. Three of the testers reported this method worked best for them because they did not have to do anything. However, positioning and strapping a person on the board could take considerable time, especially in the open water wave conditions. The length of the straps was also a problem with one tester when they didn't fit over the bulk of his life jacket. Subsequent to the testing, we learned the use of backboards is no longer recommended as they have been found to heighten the risk of damage to the spine.



PHASE 3 – LIFE JACKET PERFORMANCE IMPROVEMENTS AND AWARENESS

Life Jacket Manufacturers

This phase involved sharing the findings of the life jacket study with manufacturers and encouraging them to improve the performance of life jackets for boaters with adaptive needs. Initially, there was also the possibility the study results might recommend the need to develop and test an adaptive prototype life jacket.

A presentation of The Clagett's life jacket study was given at the 2017 Life Jacket Association Conference, which was attended by manufacturers and representatives of the US Coast Guard, the National Association of State Boating Law Administrators (NASBLA), National Safe Boating Council (NSBC), Water Sports Industry Association, American Canoe Association, and the Underwriters Laboratories (UL). There was strong interest in the study because it seemed that this was the first time data had been collected on life jacket performance involving adaptive boaters. The face-down rotation of the adaptive testers was of particular interest with some of the attendees. After the presentation there was a discussion with several manufacturers and the Director, UL Standards-Canada who also chairs the UL Standards Technical Panel 1123 that has been developing Canada-US standards for life jackets. There was agreement that more data needed to be collected on life jacket performance with adaptive boaters to determine its effect on existing standards or the need to develop separate life jacket standards for adaptive boaters. Two data collection approaches were considered. One would be the inclusion of two adaptive testers in future life jacket certification testing by UL or to conduct another and larger grant-funded study led by the Life Jacket Association in cooperation with UL. The latter approach was the preferred one, but would be dependent on the Association getting approved as a non-profit organization.

Public Awareness and Education

During the study it became apparent there was a need for increased awareness and education concerning life jacket performance, not only for adaptive boaters but for their instructors, coaches, course providers and event organizers. This resulted in a presentation of the study at US Sailing's 2018 Leadership Forum which included a life jacket demonstration in a pool by six able-bodied people with a mix of body shapes. Five life jackets were Type III inherently buoyant ones, one with RUPS (crotch straps) and two were 11.2 lbs. (50 Newtons Level) jackets. The sixth was an inflatable life jacket with RUPS. After swimming a short distance, the demonstrators performed the maneuvers of static and dynamic stability, and face-down rotation.

There were eye-opening moments for both the demonstrators and audience where both the people wearing the 11.2 lbs. jackets floated lower and turned face-down in the static stability test. A pear-shaped demonstrator with no RUPS had considerable ride-up problems while another pear-shaped person with RUPS had little or none ride-up. The reaction to the pool demonstration highlighted its effectiveness to increase the message of awareness and education of life jacket performance.



Face-down rotation: three have rotated, one is starting to rotate, and two did not rotate.

SUMMARY OF CONCLUSIONS

Key Takeaways:

- ▶ Further study of life jacket performance with both adaptive needs and able-bodied people is needed to collect more performance data to inform users, manufacturers, and the standards.
- ▶ Many existing life jackets were suitable for the adaptive testers, but improvements could be made to make them safer and more wearable.
 - ☑ Ride-up of life jackets was a significant factor in comfort and performance of the life jackets and needs to be addressed..
 - ☑ The use of RUPS (crotch or thigh straps) was effective in reducing or eliminating ride-up and more awareness of their benefits should be increased and included as an option.
 - ☑ Improvements are needed with regard to buckles, straps and their adjustment. The direction of pull in tightening a strap affects its adjustment: pulling forward is easier and more effective than pulling backward.
 - ☑ Side zippers were more difficult to engage and zip, especially for people with limited dexterity or without a hand.
 - ☑ The visibility of life jackets could be improved by more brightly colored tops and shoulder straps, and reflective strips.
- ▶ The importance of the selection of life jacket and proper fit to enhance life jacket performance and comfort needs to be emphasized.
 - ☑ Body shapes (pear-shape, vee-shape, short torsos) had a noticeable effect on ride-up and more consideration of this should be taken into account in the design of life jackets and their fit adjustments.
- ▶ Life jackets were found to be noticeably difficult to put on and adjust for a good fit while in the water. Therefore they should only be considered as a reliable life saving device if they are worn at all times while on the water.
- ▶ The amount of a life jacket's buoyancy affects the wearer's flotation level in the water, but the wearer's muscle mass and fat mass indexes seem to be a factor as well and more study is needed.
 - ☑ The flotation performance and rotation ability of the 11.2 lbs. (50 Newtons Level) jackets, which meets European standards, were noticeably inferior to the US Coast Guard required minimum 15.5 lbs. buoyancy jackets and those with higher buoyancies.
 - ☑ The amount of flotation on the front and back of a life jacket affects whether a person floats face-down, vertical or face-up. More flotation on the front resists face-down, but makes it bulky and may negatively impact freedom of movement or difficulty with using a zipper on the front.
 - ☑ Inflatable life jackets were very effective in keeping the testers' face-up in the water and turning them from a face-down position to face-up. If a person were unconscious or too weak, the survival rate would be improved with an inflatable compared to a Type III inherently buoyant jacket. However, it is critically important to routinely inspect the inflator and CO₂ cylinder and test for inflation leaks to minimize the risk of malfunction.

- ▶ More awareness and education is needed to inform both adaptive and able-bodied boaters about the importance of model selection, fit, RUPS, and maintenance.
 - ☑ “Try before you buy” – in the water. It is difficult to predict how a particular life jacket design will work on people of different physical shapes and abilities. The only sure way to know is to try the life jacket in the water.
- ▶ It is recommended that all future testing protocols for life jacket certification should include adaptive needs people along with able-bodied people. The recommended adaptive categories are:
 - ☑ At least one (1) above the elbow amputation
 - ☑ One side of the body affected by paralysis (e.g., stroke, TBI, etc.)
 - ☑ Paralysis at or above T6 vertebrate

Additionally, it is recommended that the certification protocol include testing of the amount of effort to rotate from face-down to face-up.

Respectfully submitted by
Timothea S. Larr

APPENDIX A – LIFE JACKETS

The following are life jackets that were tested in the study, many of which were donated.

- A – Astral Camino (15.5 lbs. buoyancy, SM/MD)
- B – Astral Norge (17.4 lbs. buoyancy, LG/XL)
- C – Astral Linda (16 lbs. buoyancy, SM/MD)
- D – Baltic Dinghy Pro (13.5 lbs./50 Newtons Level)
- E – Kokatat Aries (16.5 lbs. buoyancy, MD/LG)
- F – Kokatat Bahai (16.5 lbs. buoyancy, SM/MD)
- G – MTI APF (16.75 lbs. buoyancy, Universal)
- H – MTI Atlas (24 lbs. buoyancy, XS/SM & 26.31 lbs. buoyancy, MD/LG)
- I – MTI Cascade (15.5 lbs. buoyancy, SM/MD)
- J – MTI Destiny (16.5 lbs. buoyancy, LG/XL)
- K – MTI PFDiva (16.5 lbs. buoyancy, SM/MD)
- L – MTI Fluid Belt Pack (26.13 lbs. buoyancy, Adult universal)
- M – MTI Mona Lisa (17.0 lbs. buoyancy, MD/LG)
- N – MTI Reflex (16.38 lbs. buoyancy, XS/SM)
- O – MTI Trident (15.69 lbs. buoyancy, LG/XL)
- P – MTI Vibe (15.5 lbs. buoyancy, LG/XL)
- Q – NRS Ninja (16.5 lbs. buoyancy, LG/XL)
- R – Mustang Hybrid Inflatable (22.5 lbs. buoyancy, Adult universal)
- S – Revere Inflatable (35 lbs. buoyancy, Adult universal)
- T – Salus Ungava (15.5 lbs. buoyancy)
- U – Spinlock Deckvest LITE Inflatable (38 lbs. buoyancy)
- V – Stohlquist Betsea (16.63 lbs. buoyancy, SM/MD)
- W – Stohlquist Drifter (16.63 lbs. buoyancy, LG/XL)
- X – Stohlquist Rocker (16.5 lbs. buoyancy)
- Y – Kent Type I (32 lbs. buoyancy, Adult universal)
- Z – Kent Type II (15.5 lbs. buoyancy, Adult universal)
- AA – West Marine Medalist (17 lbs. buoyancy, M/L)
- AB – Zhik (11.2 lbs./50 Newtons Level, SM & LG)
- AC – West Marine Runabout (15.5 lbs. buoyancy, Adult universal)

APPENDIX B – TESTERS

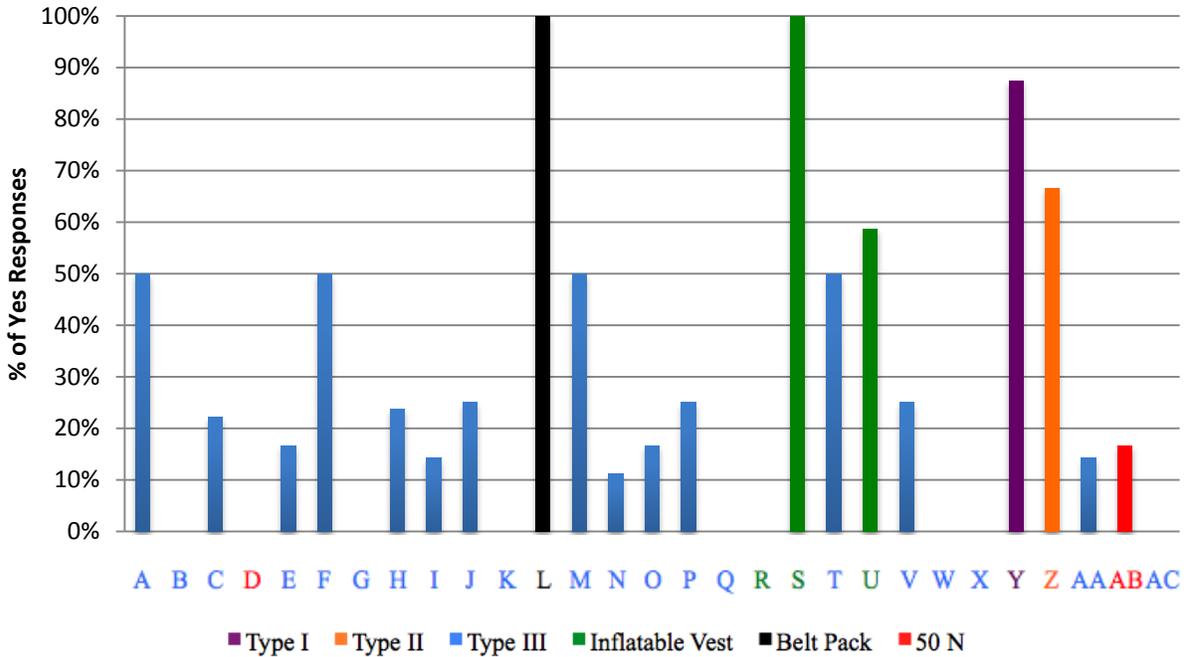
BMI – Body Mass Index

SBMI – Smart Body Mass Index

- AA male; 19-30yrs.; able-bodied; 5'11" & 165 lbs.; SBMI 35/70, BMI 23.0 (normal range); sail, ski;
- MD female; 22 yrs.; cerebral palsy & epilepsy, weak left side; 5'1" & 109 lbs.; SBMI 35/70, BMI 20.6 (normal range); sail
- WE male; over 50 yrs; AK, left amputee; sail
- KH male; 24 yrs; TBI, neuro muscular left side; 5'11" & 185 lbs.; SBMI 40/70, BMI 25.8 (overweight range); kayak, SUP, sailing, swim
- RH male; over 50 yrs; BK, right amputee; 5'11" & 235 lbs.; SBMI 46/70, BMI 32.8 (obese range); canoe, kayak, SUP, rowing, sailing
- BK male; 31-50 yrs; bilateral AK amputee; (6'0") & 155 lbs.; SBMI 32/70, BMI 21.0 (normal range); kayak, sail, swim
- SL female; over 50 yrs; peripheral neuropathy, feet & fingers; kayak, sail
- CM male; 31-50 years; cerebral palsy
- SM male; over 50 yrs; paresthesia, weak left side; sail, swim
- CR male; 31-50 yrs.; able-bodied; 5'11" & 170 lbs.; SBMI 36/70, BMI 23.7 (normal range); sail
- LS female; over 50 yrs; MS/paraplegia T8 level; 5'9" & 140 lbs.; SBMI 32/70, BMI 20.7 (normal range); kayak, rowing, swim
- SS female; 50 yrs; paraplegic T4/5; 5'8" & 117 lbs.; SBMI 21/70, BMI 17.8 (underweight range); sail, sea kayak, scuba diving, open-water swim
- TS female; 31-50 yrs.; born amputee all four limbs; canoe, kayak, sail, swim
- RT male; over 50 yrs; below elbow (BE), right amputee; 5'8" & 195 lbs.; SBMI 42/70, BMI 29.6 (overweight range); sailing, scuba diving
- CW female; 31-50 yrs.; partial paraplegic T8 & below; 5'3" & 145 lbs.; SBMI 39/70, BMI 25.7 (overweight range); kayak, sail, swim

APPENDIX C – ADDITIONAL GRAPHS

Did the PFD make it difficult to move in the water?



Did the PFD make it difficult to move in the water?

