A Practical Guide to Rudderless Sailing

Rama Hoetzlein and Andy Hacket

Introduction

Why sail rudderless?

We believe that rudderless sailing allows the novice sailor to improve boat balance, sail trim and centerboard control much more directly. The rudder provides a guarantee for your point of sail whereas rudderless involves maintaining your point of sail by understanding and feeling all the forces on the boat. Aside from its help in managing rudder failures, we believe that rudderless gives the sailor a better intuitive sense for how to trim and balance a boat; which is valuable for performance sailing, sail trim and general good form.

A few motivations for this guide. First, we'd like to mention Joel Brand's e-book Rudderless Sailing from 2013 as an excellent review of rudderless sailing theory. We are also inspired by Harry Morton and Israel Smith's youtube video "29er No rudder sailing with Dave O'Connor" from 2012 which demonstrates two-handed rudderless on a small 29'er - with a spinnaker! Pretty amazing sailing, and still one of the few videos of rudderless with tacks and jibes. This isn't to say there aren't many great rudderless sailors. Yet we feel the lack of examples is because it is currently viewed as an extra skill rather than as a form. We hope to change that.

The primary reason for this *Practical Guide to Rudderless* is to provide a starting point for any club or novice sailor to learn rudderless as a way to intuitively feel the forces on the boat. While we briefly touch on theory, our focus is on a *practical* guide that helps you to understand what is happening when you're on the water. Of course nothing can replace actual sailing. So our intention is to give you an idea of what you're likely to experience, the tools you have to respond to it, and exercises to help you gradually improve.

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Document History

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I. Safety

We believe that rudderless sailing can be part of any dinghy sailing club and will improve the quality of sailing. Rudderless sailing has significant value to the intermediate sailor beyond just rudder emergencies. To advance this effort, we've created this set of *Guidelines for Safe Rudderless Sailing* which should help any club that wishes to introduce this practice.

Guidelines for Safe Rudderless Sailing

1) ***Sufficient Experience*** - A rudderless student should already be proficient with regular dinghy sailing. They should be comfortable with all points of sail, tacks and jibes as well as man over boards and capsize recovery. Hiking out and sailing close hauled to wind should be second nature.

2) ***Expect*** to have unplanned tacks and jibes when learning - A common issue with new rudderless sailors is to find oneself turning in place with unexpected tacks and jibs. *Expecting* this is key to learning safe rudderless. Once skills improve this becomes less of an issue.

3) ***Stay low*** at all times - Keeping ones' body low during all maneuvers will avoid unexpected boom swings. This is counter to the idea of sailing rudderless while standing, but we address this later and suggest that, while learning, weight shifts are done instead by *sliding* around the boat.

4) ***Clear space all around*** - When learning rudderless it is common to tack or jibe unexpectedly. It is necessary to have clear space all around. Do not practice near other boats or close to shore.

5) ***Balance your boat*** first - Before attempting rudderless your boat must be properly balanced so that you can lightly let go of the tiller and it will remain in place. This is achieved with centerboard, sail trim and weight balance.

6) ***Wind speed*** between 7 to 10 knots - We recommend initial teaching between 7 to 10 knots. As the wind decreases below 7 knots the amount of oscillation increases and makes handling more difficult and spinning in place more likely. As the wind increases beyond 10 knots the sails become difficult to control while also weight shifting.

7) ***Sail a straight*** course first - The key challenge of rudderless sailing is maintaining a proper course. While we cover COE/CLR theory, centerboard, weight shifting and turns in *theory*, every student should expect and plan to *practice* rudderless straight sailing first until there are no unexpected turns.

8) ***Multiple boats:*** S*tarboard tack, rudder off. Port tack, rudder on* - When multiple boats are sailing rudderless straight courses, we advise the starboard tack boats to sail rudder off. This enables the rudderless boats, with weakest maneuverability, to be the right-of-way boats (starboard). This last guideline is intended for teaching classes that involve multiple boats. This way rudderless boats on straight courses naturally fit into the starboard right of way rules.

It can often be difficult to tell *which* dinghy boats are currently rudderless when multiple are on the water. Only a good look at the stern will indicate it. Guideline #8 is there to help establish *when* you should be rudderless when learning as part of a class or group.

II. Motivation

There are many reasons to include rudderless sailing in a dingy club or sailing school. Primary among these is having a better intuition and feeling for the forces acting on the boat. For performance sailors racing is improved with faster maneuvers that require less boat handling. Finally, rudderless sailing is valuable during rudder emergencies but can also give a better sense of what to expect in other situations as well. We identify three major areas where rudderless sailing adds value.

1. Understanding Sailing Forces

Sailing rudderless requires that you master the controls of sail trim, weight balance and centerboard since there is no single control. This shift from relying on a rudder to relying on your complete knowledge of sailing forces will change how you view sailing.

The primary benefits are:

a. Better understanding of all forces on the boat
b. Better intuition for weight balance
c. Better boat handling overall

2. Performance Sailing

Performance sailing refers to sailing a boat with the most efficiency, and making best use of the wind, often for racing but also to make way (navigate to a point) or to gain experience. Rudderless sailing leads to several performance benefits, even when using the rudder:

a. Increased speed
b. More stability with better crew distribution
c. Faster and tighter turns

3. Emergencies

Rudderless sailing has an obvious advantage when one loses the rudder. Being able to dock without a rudder is also very valuable, for example when sailing single handed and you need to walk to the bow and step off with the bow painter. Not as obvious are the benefits to other failures such as a lost jib or main, in which having sailed rudderless gives you an intuitive sense of how the boat will handle differently:

a. Rudder failures
b. Docking without rudder
c. Other failures

III. Balance

A balanced boat means the wind, water and weight forces are adjusted to allow the boat to maintain a heading.

The balancing of a boat becomes even more important when attempting to sail rudderless. It should be mentioned that rudderless sailing is aimed to teach and train the intermediate as well as the experienced sailor to focus on balancing the boat and to minimize the need for the rudder. The boat will sail faster and its components will be under less stress. This becomes very important on large boats in high winds. In order to achieve balance, the following actions are advisable when preparing to sail rudderless:

Preparing for Rudderless

1) Pull up the centerboard about 70% and further adjust as needed while sailing. This help to eliminate the built in weather helm that is designed into most boats. It still gives the boat some hydrodynamic lift but lessens the tendency of the boat to want to turn windward by itself.

2) On some boats it is advisable to reef the mainsail in order to move the overall COE forward and so closer to the CLR. This also helps to reduce the built in weather helm caused by the large main sail area compared to the jib. With a reduced main, sail adjustments will be less forceful making it easier to turn delicately.

3) The centerboard, mainsail and jib should be adjusted - with body weight more forward than usual - and balanced overall so that one can lightly let go of the rudder and it will remain in the same direction.

When the boat maintains a course without touching the rudder you are ready to raise the rudder and attempt sailing a straight course. Before attempting your first rudderless in section IV (Straight Course) we will briefly review the major controls during rudderless.

Major Controls for Rudderless

The controls available while sailing rudderless determine options for turning.
The primary controls are:

1) Sail trim - Jib & Main
2) Weight shifting - Heeling angle
3) Centerboard position

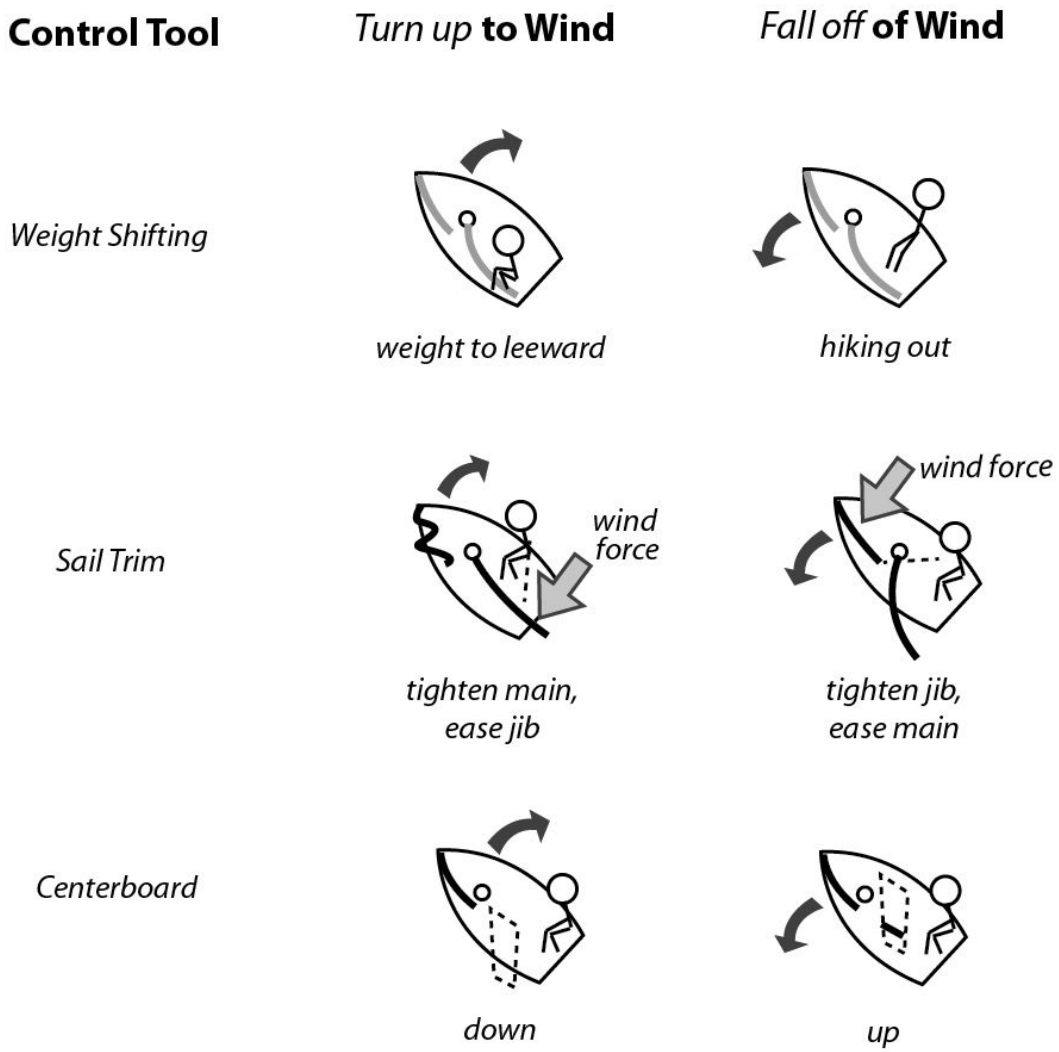


Figure 3.1. Major controls available to change direction of the boat without a rudder. Details of each control will be discussed later.

Sail controls
The effect of the sails on the direction of the boat is probably easiest explained by looking at the extremes:

- With only a jib, the boat will turn to lee ward (away from the wind) because the COE is positioned very forward of the CLR.
- With only a main, the boat will turn to windward (toward the wind) because the COE is positioned very far back of the CLR.

Centerboard
The centerboard is adjusted up to have a balanced boat by moving the CLR aft. A raised centerboard decrease the weather helm, or can be lowered to increase weather helm when tacking. While the centerboard is usually adjusted in specific situations (see sections on tack and gybe) the sail trim and weight shifting are used constantly to maneuver.

Weight Shifting
Shifting weight on the boat has a strong influence on the direction the boat wants to take. When weight is changed it causes heeling, which puts the boat into a state where one side is out of the water compared to the other side. This in turn causes the boat to rotate.

These main controls are visualized in Figure 3.1, while more details of each are found in the following chapters.

IV. Straight Sailing

Once the boat is well balanced - with the centerboard set, the sails adjusted, and weight distributed - then a very light touch on the tiller can keep one sailing straight. At this point you're *ready* for rudderless. *Now you bring up the rudder!*

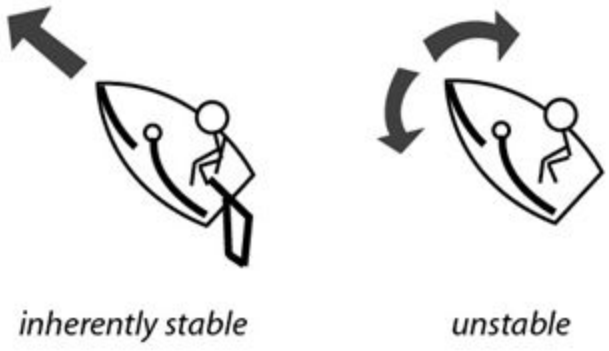


Figure 4.1. Inherent stability of a rudder versus instability of rudderless.

The first challenge, and for some time, will be to sail a straight course. Like sailing for the first time you can only learn rudderless through practice. The difference is that learning to sail with a rudder is *inherently stable*, whereas learning to sail rudderless is *unstable*. See *Figure 4.1*. The rudder is inherently stable because it provides a guarantee (mostly) that the boat will go in that direction. Without a rudder the boat is unstable. This does not mean there aren't rules or tools at your disposal to change or alter direction, it just means you no longer have one *single* control for altering and setting course.

Your first goal in rudderless is to regain a straight course. How this is accomplished is through the tools of main & jib trim and with weight shifting, which are discussed in detail in the following sections. Here we will focus on describing the goal of rudderless and its challenges. The unstable nature of rudderless is why practical safety includes the notion that you should *expect* and *plan* for accidental tacks and jibes when learning. The boat *will* turn unexpectedly and you will be unable to stop its rotation at first. This is often a surprise when one first sails rudderless as the boat may seem to turn in circles without reason or control.

The initial goal of rudderless sailing is to regain control. The key to this is understanding, intuitively, how it is that you are losing control. The two basic scenarios are light wind and heavy wind.

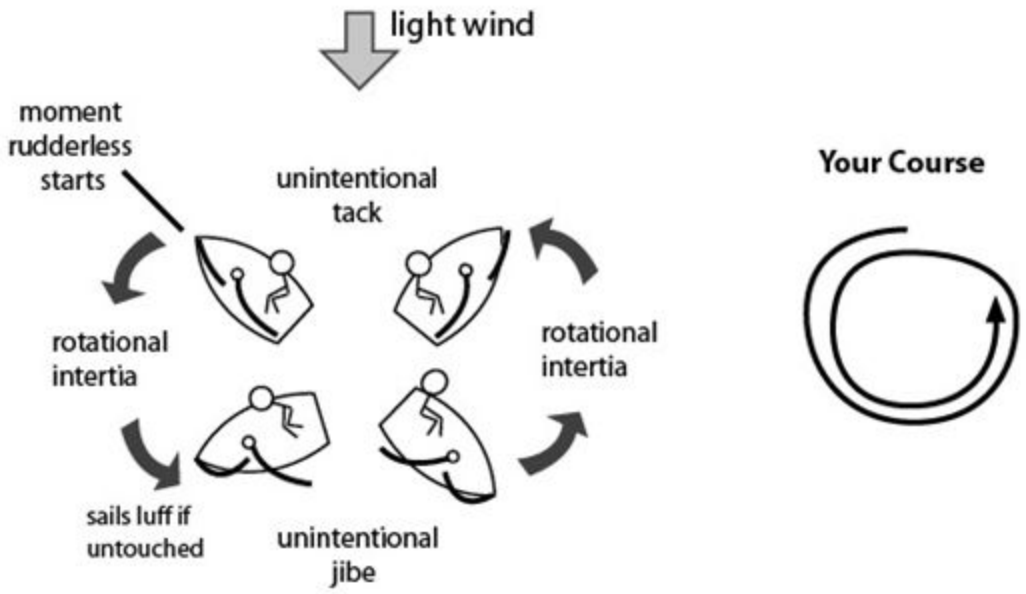


Figure 4.2. Unintentional circles in light wind

In light wind it is very easy for the boat to continue through any rotational inertia. See *Figure 4.2*. If weight balance or other circumstances begin a counter-clockwise turn to leeward (on a starboard tack), then the natural weather helm will be insufficient to prevent an accidental jibe. You will then continue through the jibe, and also through a tack, unless you do *something* to stop rotating. Your course is an unintentional circle. The goal with rudderless in light wind is to stop your rotational inertia.

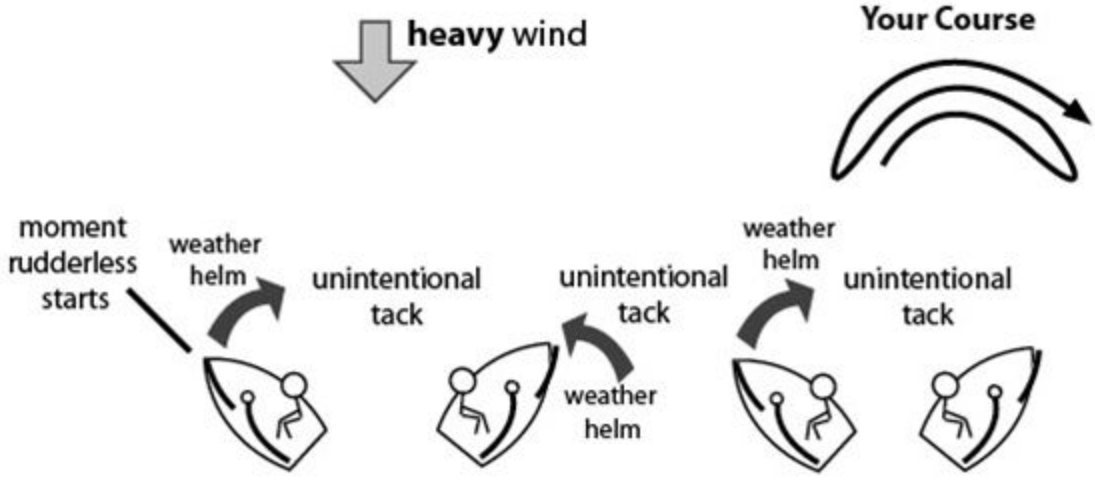


Figure 4.3. Unintentional tacking in heavy wind

In heavier wind, most dinghies will have strong weather helm to wind, regardless of how much you've pulled up the centerboard. See *Figure 4.3.* The boat may begin to fall off to leeward but then it will be unnatural for it to jibe without some real effort on your part (see later sections on how to jibe). Weather helm will cause the boat to head up, and with enough momentum, it will continue through a tack and then do the same thing on the opposite side. Falling off and then rounding up to tack again. The goal with rudderless in heavy wind is to prevent continual tacking.

The first challenge in rudderless sailing is to maintain control of the boat. Allow yourself to learn from accidental turns and take the time to analyze why they happened; don't fool yourself into thinking you've accomplished a turn until it is intentional and controlled.

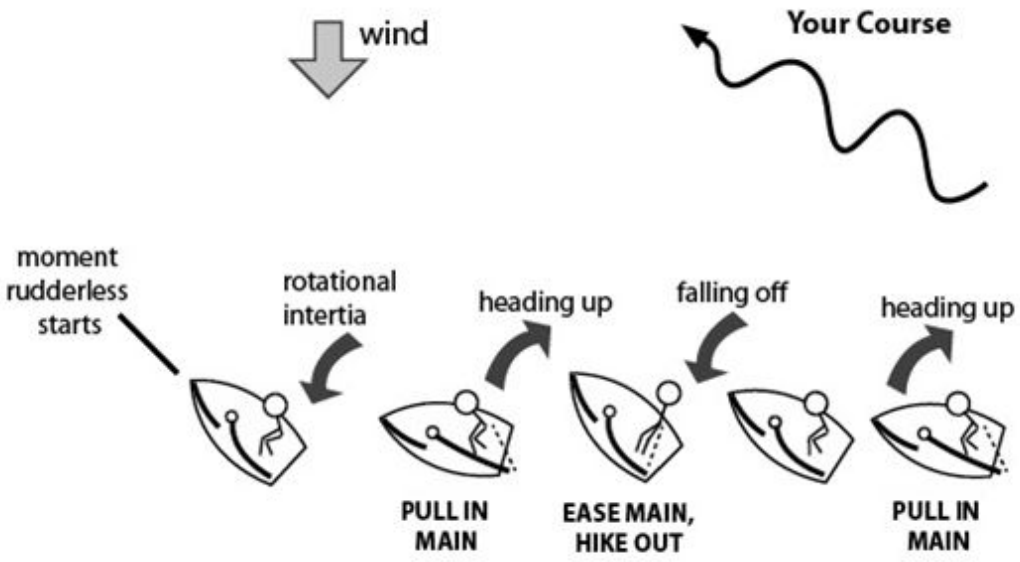


Figure 4.4. Semi-controlled oscillation around a straight course

Although we haven't covered rudderless sail trim yet let's imagine for a moment that you can properly adjust the sails to regain control. See *Figure 4.4.* If the boat veers to leeward, you adjust to make it head up (by pulling in the main). If the boat turns too far to wind you adjust to fall off (by easing the main and hiking out). If you prevent an accidental tack then you will find yourself rotating and falling off again. You then adjust too much and are turning up again. The end result is that you find yourself *oscillating* the boat around a straight course.

Oscillating around your intended course, without an accidental tack or jibe, is the first milestone. At this point you are not turning uncontrollably in light or heavy wind. You are closer to controlling the boat along a straight course but your corrections are still overcompensating, which leads to oscillation.

Thus another way to describe straight rudderless sailing is to *anticipate* the rotation of the boat and *gradually* make adjustments so that you converge on a straight course.

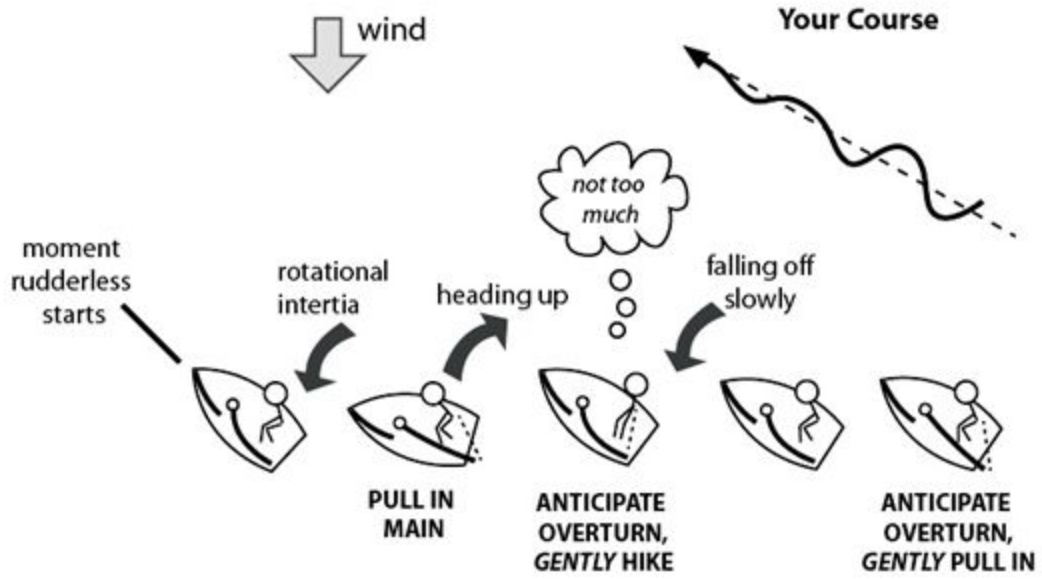


Figure 4.5. Anticipating oscillation to arrive at a straight course

Finally you arrive at a straight course by anticipating over-rotation around your point of sail, *Figure 4.5.* By making smaller and smaller adjustments you can bring the boat towards a stable point of sail. The wind, waves, centerboard, sail trim and weight distribution are all factors in this delicate balance since you no longer have the guarantee of the rudder (and thus perhaps more freedom?). This makes a perfectly straight course nearly impossible. As mentioned rudderless sailing is unstable but it's not without reason. Therefore, like balancing a pencil on your finger, you continually and gently adjust your trim and balance in order to find a straight course.

In the next two sections we will cover the tools for *how* you control the boat: main & jib sail trim and weight shifting. You should then return here and see if you can maintain a straight course in practice. After that we will cover *intentional* turning with rudderless tacks and jibes.

V. Sail Trim

The primary tool for controlling your direction while rudderless is sail trim. As described in the theory section, adjustment of the main and jib determine the Center of Effort (COE) which is the location of the total aerodynamic force on the boat. In keeping with our goal for a practical guide we first give an intuitive understanding of how sail trim changes boat direction and then follow up at the end with a bit of theory about why.

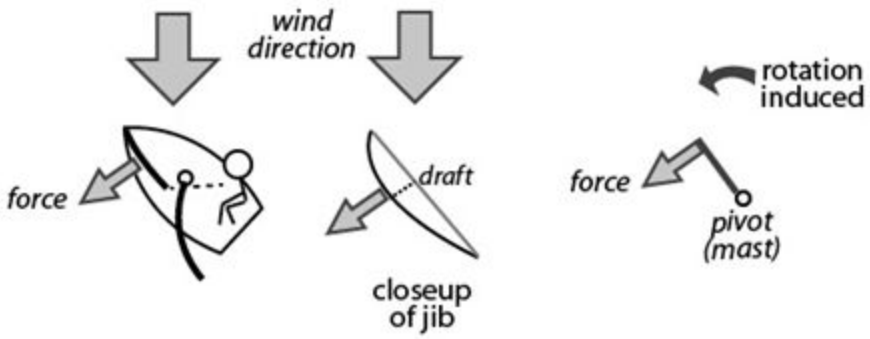


Figure 5.1. Wind on the jib causes a force perpendicular to the sail draft which acts as a pivot around the mast as leads to rotation.

Consider a boat in which the mast acts like a pivot in *Figure 5.1*. If you sheet in the jib, then the jib will be catching the wind and generate a lot of force to leeward at the bow of the boat. Overall since the mast is a pivot point (for simplicity) the strong force from your jib will cause the boat to rotate away from the wind. Notice that direction of force is not the direction of the wind but is perpendicular to the draft of the sail. If you release the jib then the same amount of wind moves past but generates little force on the boat. This rotational effect is usually not noticed when sailing with a tiller since the rudder prevents rotation and instead turns this additional force into increased speed. When rudderless, however, we make use of this rotational force to control the boat.

Similarly, if you sheet in the main, then the main sail will generate a lot of force to leeward near the stern of the boat. Since the mast is the pivot the strong force on the main will cause the boat to pivot toward the wind. Thus you can quickly head up to wind sheeting in the main and releasing the jib.

We experimented a lot for this guide on the best practices for rudderless sail trim on a dinghy. Our finding was that it is very easy, on many types of dinghies, to overcompensate with the main and cause an accidental tack. Turning away from the wind is difficult. This led to two different approaches or *styles* to rudderless sail trim: one for heavy and one for light wind.

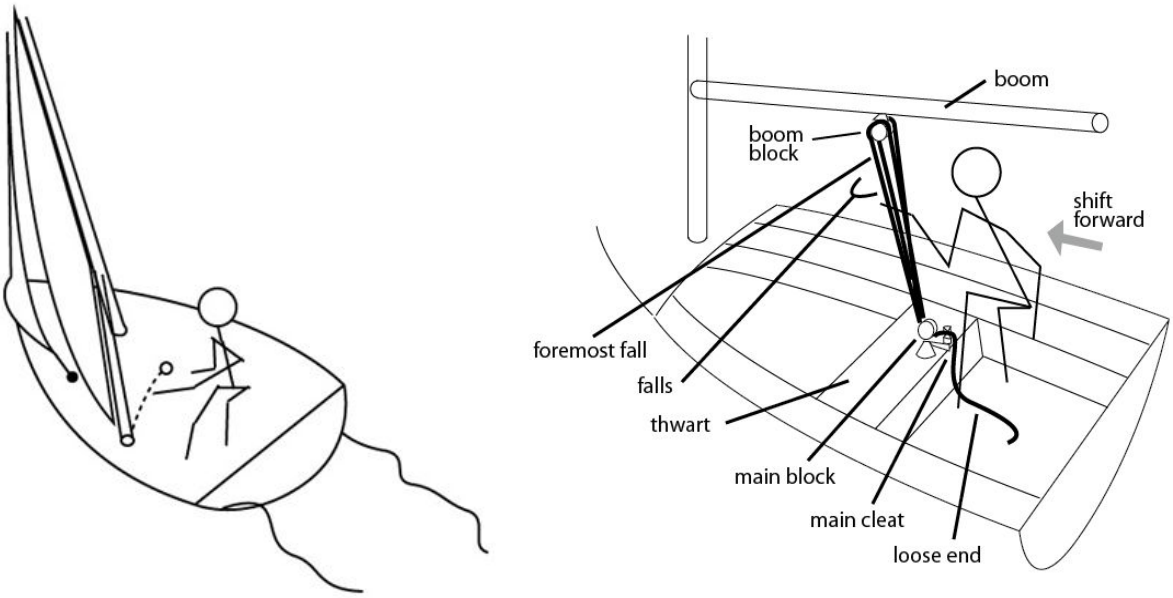


Figure 5.2. Rudderless sailing with the main sheet in heavier wind. The right image shows body position and handling for rudderless.

Sail Trim - Heavy Winds

In heavier wind, over 7 knots, you do not need to worry as much about accidental jibes. You can sheet the jib in quite far and just set it there while you sail rudderless entirely by controlling main trim. The best place to handle the main sheet for rudderless is using the mainsheet *fall* [1], which has less mechanical advantage but allows you to adjust more quickly, see *Figure 5.2b*. You can use the entire fall - grabbing all four runs as you would slow sailing - or you may find that using the *foremost fall* [2], the one of the four runs which is most forward, will still allow you to maintain your weight position and balance when leaning back or hiking out.

[1] *fall* - The rope of a block and tackle system. Multiple runs of the mainsheet line through the boom and main blocks give mechanical advantage. In a hoist system the handled rope end is called the tackle.

[2] *foremost fall (or forefall)* - The forward most fall line in a single block system (set of runs).

[3] *foreward fall* - On large ships, with a two crane hoist for boats, refers to the forward line of the hoist for dropping the boat into the sea from the ship. e.g. “I cut the forward fall, and our boat dropped to the sea.”

Figure 5.3. Rudderless sailing with the jib and main sheets in lighter wind.

Sail Trim - Light Winds

In lighter winds, you will need all the jib can offer in order to turn away from the wind. When turning away from the wind (to avoid a tack) you need to sheet in the jib as tightly and flat as possible. Setting it at a fixed point will not work here. Instead the sailor can use one hand to hold the main sheet above the block and the other hand to pull on the currently active jib sheet. We experimented with a second crew person handling the jib sheets but the problem you will find is that the dance between the jib and main sheets requires *precise* timing. In light winds you will pull the main while easing the jib, then be easing the main while pulling in the jib, back and forth in rhythm with the wind and waves. Your left and right arm are alternating in and out exactly in concert. This needs to be carefully timed otherwise rotational inertia will take over and cause an unplanned turn.

More Details: Sail Trim in Theory

We have simplified to above discussion to try and convey a *feeling* for sail trim. While sailing it is easiest to think of the mast as a pivot and the jib and main sail as levers that turn the boat around this pivot. The underlying theory is a bit more complex but explains more.

The mast is not actually a pivot but is a simplification for the Center of Lateral Resistant (CLR), the sum of below waterline or hydrodynamic forces acting on the boat. Factors that affect the CLR include the hull shape, the centerboard position, weight distribution and wave action. The CLR defines the hull balance point.

The COE, on the other hand, is the point that combines the sum of aerodynamic forces. The jib and main sail area, their draft, and angle to the wind all contribute to the COE. When the jib is sheeted in, the COE is moved forward. When the main is sheeted in, the COE is move aft.

The boat will turn away from the wind when the COE is forward of the CLR, and will pivot toward the wind when the COE is aft of the CLR. You are causing the COE to move when you adjust sail trim and causing the CLR to move when you adjust the centerboard or weight distribution.

Several aspects are better explained by COE/CLR theory than by our discussion above. First, in heavy wind the sail area plays a much bigger role. The main sail, even sheeted off, produces so much force that the COE is very far aft. This explains why it is difficult to turn and stay downwind while rudderless. Somewhat related, when there are large waves the CLR is also moved very far aft at the moment the wave strikes the bow. This explains why it can be difficult to turn through a tack while rudderless in larger waves.

VI. Weight Shifting

Aside from sail trim your other main control during rudderless sailing is weight shifting. Moving your weight around will change the forces on the boat, causing rotation.

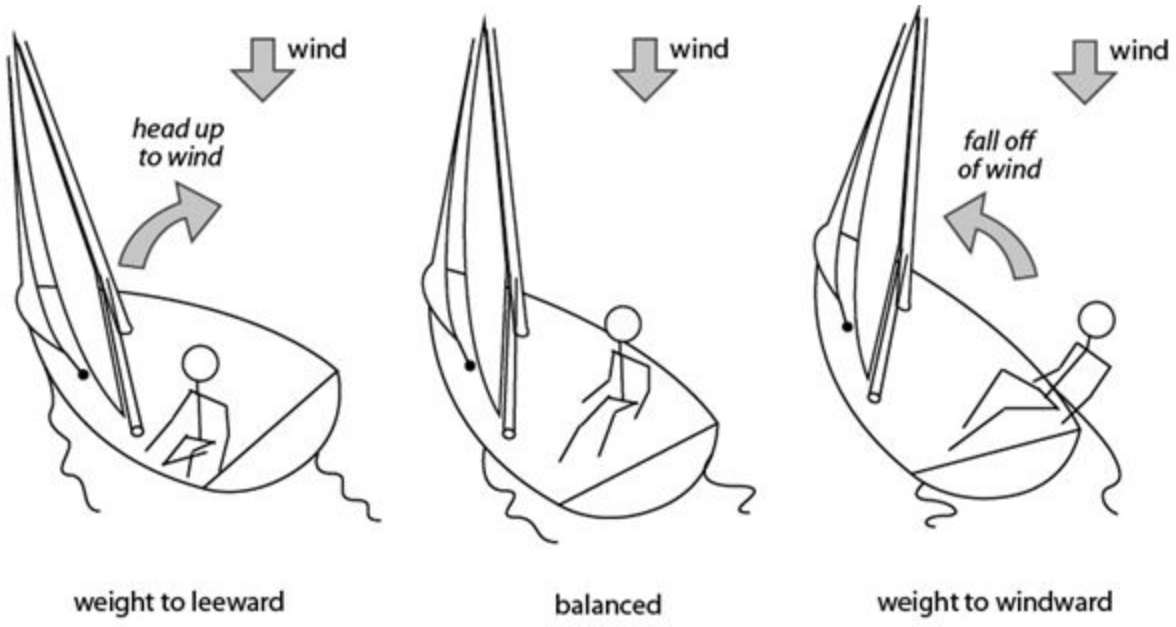


Figure 6.1. Weight shift to leeward causes the boat to head up while a weight shift to windward turns away from the wind.

Hiking your body weight out to windward will cause the boat to turn to leeward (*Figure 6.1*). Why? When you hike out you place more downward weight on the windward side, thus causing that side to press into the water while the leeward side lifts more out of the water. The boat's buoyancy is no longer evenly distributed, and the difference between the windward (deeper) and leeward (less deep) buoyancy causes the boat to turn to leeward. Shifting your weight to leeward will cause the boat to head up to wind. Weight shifts can be dramatic when you need to tack or gibe or they can be subtle as you try to maintain a straight course.

You can also try sailing a straight course primarily with your body weight. As soon as you lift out the rudder, begin adjusting your weight immediately - be observant even as you pull up the rudder. If you can stay on the same tack, you should be able to shift your weight to adjust your course and prevent a turn.

There are at least two styles of rudderless sailing. One approach is to use your body as the primary control for balance and orientation. This approach may include standing, shift weight at the knees, and walk along the boat as needed - and can be impressive to watch. Your body is the primary control. Another style is to control the boat mostly with sail trim, while moving your body much less. This type of rudderless sailor will stay in one place and handle the sheets delicately; controlling direction almost entirely by sail. Both are elegant ways to sail. While all controls will be needed, the style of sailor you are depends on whether you begin to favor sail trim or weight shifting.

Regarding Standing

We feel the best way to sail rudderless is by sitting or kneeling. In his guide to rudderless Joel Brand suggests the ideal way to sail rudderless is by standing. However, we think there are more benefits to sitting. These include better safety during boom swings, better safety from an accidental overboard, better handling in waves, and more focus placed on sailing. Especially if you are just starting to sail rudderless the safety benefits outweigh other considerations. When you find yourself in the first uncontrolled tack or jibe, or even circles, it is good to know that even if you do nothing else but keep your head down you should be fairly safe. Then you can regain your composure and find the right moment to straighten your course either by sail trim or weight. If you are kneeling you can control weight distribution by leaning, or if sitting you can slide around as needed.

Two Person Sailing

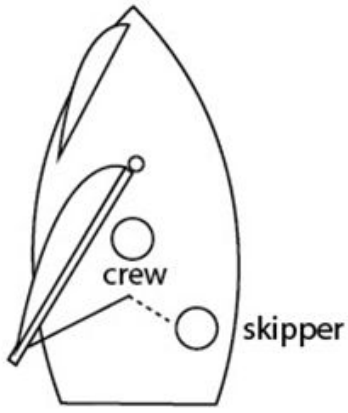


Figure 6.2. Body positions when sailing with two people on a rudderless boat. The skipper stays aft and rebalances on port or starboard while the crew remains stationary amidships.

Learning to sail rudderless is a challenge. Since balance is such a factor attempting to sail rudderless with a second person can be difficult. Yet there are benefits to having another person on board. You can learn together, talk about what happened during moments of rest, and manage emergencies and docking more easily.

Having a second person is ok when learning so long as that person is placed amidships. See *Figure 6.2.* Your crew person can sit amidships on the *thwart* [2], if there is one, otherwise they can sit on the centerboard frame. In stronger wind you may need their ballast next to you. The key is to have your crew remain in place so that they do not affect your own port and starboard weight shifts. In lighter wind we don't suggest your crew person handle the jib. In this case it's best to have all sheets (main, port & starboard jib) held by the active skipper. However, your crew person can handle the jib sheets under the right conditions. You really need good communication for this to work. The timing of easing in and out must be precise. We recommend that you become familiar with the jib sheet in rudderless yourself first before handing off that part of the job.

[2] *thwart* - Cross bracing which adds hull strength, holds the mainsheet block, and serves as a center seating position for a neutral balanced crew person. Also see *Figure 5.1*.

VII. Tacking

The techniques for tacking may initially seem counterintuitive to intermediate sailors. People get used to using the rudder and rely on it as the major boat control for executing a tack through the wind. Experienced dinghy racers avoid using the rudder during tacks because it slows down the boat.

Rudderless tacking is possible when the weight and sails are shifted at the correct time. Here are the major steps to go through to execute a rudderless tack:

a. Let the jib out (as needed)
b. Slowly pull in the mainsheet, maintaining momentum
c. Move your body weight towards the center
d. Let boat tack through wind
e. Place your weight in the center
f. After the turn is made, backwind the jib to help fall off. Then right it and sheet in.
g. Use mainsail sheet to set desired course
h. Adjust your position in the boat as needed to apply heeling

You may not need to blow the jib, but it is likely you will have to let it out significantly (step a) in heavier wind in order to make the turn. Backwinding the jib (step f) is optional but you cannot tack into it as that would prevent your turn. As when tacking with a rudder you need to maintain speed to turn and can turn on top of a wave. In light wind the main will be sufficient to turn.

It can be useful to lower the centerboard (move CLR forward) in order to increase the weather helm prior to a tack; especially in strong winds. Also in strong winds you can add some roll

tacking technique by leaving the jib cleated and hiking out on the windward side so that the jib backwinds earlier. When pulling in the mainsheet you can do that more as a yanking which will move the apparent wind aft and accelerate the turn.

The above steps describe an eight step process which may be necessary in heavy wind. It shows you three variables you can use to make the tack work (jib, main, and weight). When you start out it is advisable to focus on the handling of the jib and the main sail while keeping your weight in the center part of the boat. It is easier to learn when changing less variables at once because you will be able to see the direct consequence (boat handling) of the sail trim changes (CE changes).

Tack with Main Only

The most important adjustment is the mainsail. In light wind it is often possible to tack with only the mainsail and without letting the jib go or weight shifts. When one uses only the main sail the instructions for tacking can be simplified to:

a. Pull in main sheet
b. Let boat tack through wind
c. Change the jib
d. Use mainsail to set the desired course

The main thing in the beginning is to be very aware of the instructions you execute and to observe how the boat reacts to each of them. As mentioned earlier you will be learning from both successful and unsuccessful attempts. Sometime the analysis of an unsuccessful tack is the stronger teaching moment, so keep going.

VIII. Jibes

Jibing is a different challenge from tacking. With a rudder one has delicate control over the tiller and can control the exact moment of a jibe. When sailing rudderless the only way to jibe is to create strong lee helm using the controls mentioned in order to make the turn. Due to the inherent design of many boats, it can be a challenge to induce this rotation.

Change the centerboard to be 80% up (reduce weather helm) and let the main out completely to produce a lee helm that will turn the boat down wind. Experiment with the centerboard position and your ability to fall off with weight shifting before you attempt a jibe.

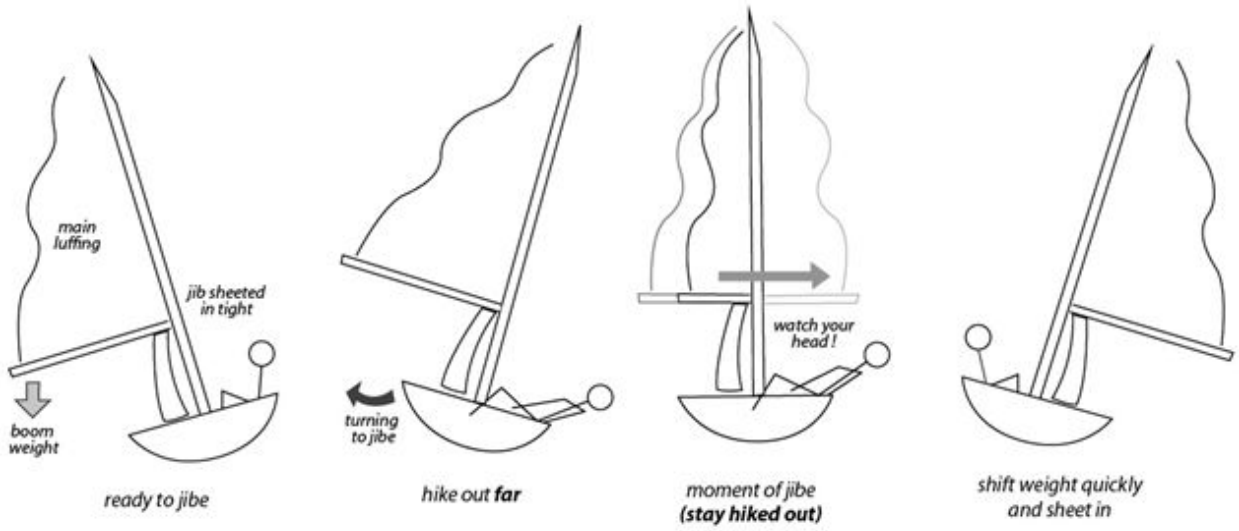
The major steps to undertake a rudderless jibe are:

a. Sheet in the jib tightly
b. Let the mainsheet out completely
c. Allow the boat turn towards a run
d. Hike out to help complete the turn
e. Bring the main across at exactly the moment of jibe - not too early!
f. Position yourself on the opposite side quickly
g. Change the jib
h. Use mainsail sheet and jib to set desired course
i. Reset the centerboard as desired

In the beginning it is advised to focus less on controls, and more on observing the boat balance and moment of the jibe.

Be careful with the handling of the main as you need to conduct a controlled change once you hit the jibe point (jib falters as you turn into running -> hitting the jibe point). If you change the main too early the boat will start to turn toward windward due to the COE being moved aft and so prevent you from completing your jibe.

Heavy Wind



8.1a 8.1b 8.1c 8.1d

Figure 8.1. Jibing in heavy wind

In heavier wind the main must be luffing to turn downwind and the boom will be out over the water. If the main is sheeted in even a little it will likely prevent you from turning downwind. Since the main is all the way out the *weight* of the main sail and boom introduce a new above-water, downward force which will *turn* the boat to windward [1]. This additional force from the boom weight further prevents you from turning downwind.

In heavier wind, to overcome the weather helm you must put your body weight *very far* out and *stay there* until the exact moment of the jibe *(8.1b)*. You cannot pull in the mainsheet as you might with a normal jibe as this will cause the boat to turn upwind, preventing your jibe. Instead leave the main out, turn using your weight *(8.1b, 8.1c)*, and watch your head! Then quickly re-center *(8.1d)* and regain balance on the opposite tack.

[1] Note the weight of the boom over water is neither a CLR force, it is not hydraulic below the water line, and nor is it a COE force, it is not an aerodynamic force above water. It is literally a weight force.

IX. Theory - COE/CLR

While we have intentionally focused on practice above, here we discuss the physics of rudderless sailing in a bit more detail from a theory perspective. It should be said that this write up assumes that the student sailor has gained a general understanding of the physics of a sailboat and is familiar with sail trim as well as the concepts of weather helm and lee helm.

Wind and water produce forces on the boat above and below the waterline. The wind creates aerodynamic forces at the sails and the portion of the boat that is above water. The aerodynamic forces get the boat moving while the hydrodynamic forces are a reaction to the movement of the boat through the water.

The center board and rudder (if used) as well as the hull react to the sideward shift and forward movement of the boat caused by the wind.

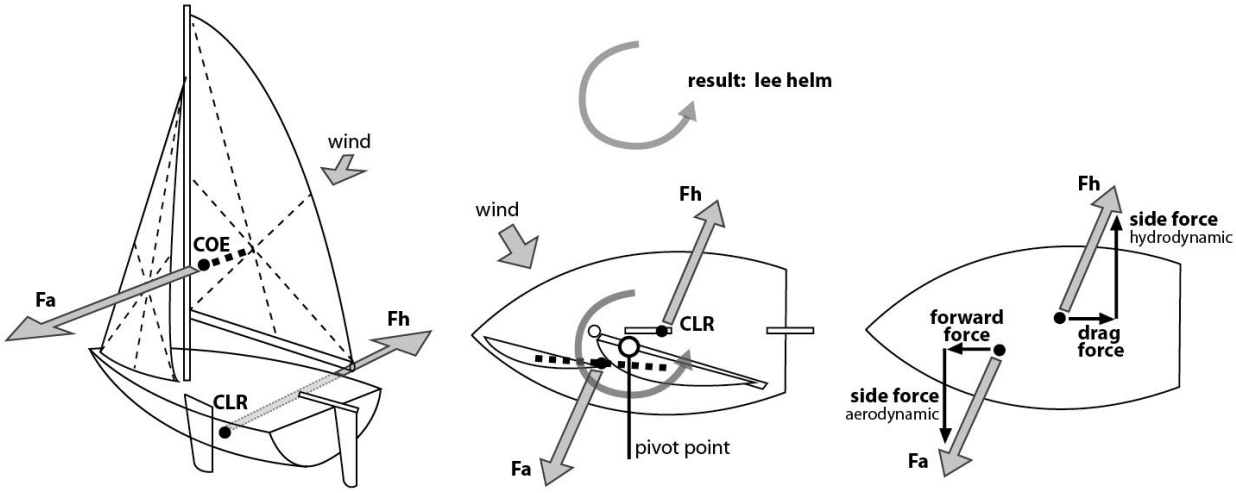


Figure 9.1. Theory of sailing forces.

COE is the center of effort, the point where combined aerodynamic forces are exerted (Fa). CLR is the center of lateral resistance, the point where combined hydrodynamic forces underwater (Fh) balance out the sail forces. In the above picture, the COE is forward of the CLR, resulting in a leeward turn around the pivot point.

Aerodynamic Forces

Let us remember from our other literature that the apparent wind as it flows over the two sides of a well trimmed sail creates a lift force that is broken into two components (vectors). One vector, the forward force, points to the bow of the boat; the other vector, the side force, points either starboard or port. The point on the sails (main and jib) that are center of the wind power

are called Center of Effort (COE). The combined COE resulting from both the mainsail and jib COE's is the main side force on a boat above the waterline.

The vector component of that force pointing to starboard or port pushes the boat seideward away from the wind. The other vector component pushes the boat forward.

Hydrodynamic Forces

The fact that the boat is moving forward due the wind creates a waterflow around the parts of the boat below the waterline. This waterflow is the cause of the hydrodynamic forces that influence the movement of the boat below the waterline. It should be reminded that the hydrodynamic forces are much larger than the wind forces meaning that the area of impact (rudder, centerboard, hull) can be much smaller than the areas of impact above the waterline (sails). The reason for this is the much larger density of water compared to that or air.

The point of lift force on the centerboard/rudder pointing windward is called the Center of Lateral Resistance (CLR). This lift force points windward and backward. The windward vector component works to keep the boat moving in the forward direction as much as possible and reduces the leeway angle. The vector pointing to stern is also called drag, slowing the boats forward movement.

Both combined hydrodynamic forces (side and draft force), being a reaction to the wind forces have to be equal and so cancel out the combined wind force and so let the boat move forward at a constant speed without any acceleration. Of course a change of the aerodynamic forces will cause a positive or negative acceleration of the boat until both aerodynamic and hydrodynamic forces are equal and the boat moves at a constant speed again.

Two examples to observe the impact of the hydrodynamic lift are:

1) If you minimize the hydrodynamic forces by for example slow sailing into a berth or a slot you will notice a stronger sideward drift to leeward. This should be included in the planning when approaching the dock.

2) Another way to experience the the stronger sideshift (a large increase in leeway angle) is to pull up the centerboard completely while reaching.

Weather Helm

In the vast majority of sail boats the position of the COE and the CLR to each other are such that the COE is set to be behind the CLR, which creates a weather helm, meaning that with well trimmed sails and if no rudder is used the boat will tend to turn to windward. This is meant to be a safety feature for the event that the crew loses control over the rudder (broken, stuck, etc.) or the whole boat for some reason.

As mentioned in the chapters above this weather helm needs to be adjusted down to minimize that self correcting effect in order to have the boat in a more balanced state. Also without the rudder you lose the hydrodynamic lift created there which puts the overall CLR further forward. The main adjustments to move the CLR backward are to pull up (rotating up) the centerboard and on some boats it is advised to reef the mainsail in addition. The balanced state is then the starting point for sail and heeling manipulation to make the boat sail a defined point of sail or undergo a maneuver.

Impact from Weight Positioning

The portion of the hull below the waterline creates hydrodynamic forces. When heeling due to wind forces and/or positioning your weight, one side of the hull is exposed to more water which creates buoyancy power. This pushes the bow of the boat to the side that is out of the water.

In a boat heeling due to side wind pushes the boat windward. In order to keep the boat straight you need to either reduce the heel of the boat of reduce the weather helm by adjusting the sail trim (let out the mainsail).

Closing Comments

It is advised to start with adjusting one component at a time and to observe the changes in boat direction. Once more experienced one will naturally start to combine the sail trim and heel changes at the same time. A good practice would be to sail with jib only and use your weight position to control the heeling. The jib will tend to turn the boat to leeward. The healing will serve to counterbalance the leeward movement. Then you can add the mainsail, etc.

Further Reading

Since this manual is meant to be a practical guide, further reading about the physics of sailboats is available in many publications. Some recommendations for further reading are:

Stuart H. Walker, “A Manual of Sail Trim”, ISBN 0-393-03296-5. Chapter 1. July, 1985.
Especially detailed discussions on the theory and finer points of sail trim

Joel Brand, “Rudderless Sailing”, ISBN 9780557903139. March 4, 2013.
General discussion of rudderless sailing theory

Steve Colgate, “On Sailing”, ISBN 0-393-02903-4. January 1991.
Overview of sailing theory and practice suitable for all levels