Biomechanics FOR Fly Casting

by

Mark Herron

As published on TheCuriousFlyCaster.com

(*https://thecuriousflycaster.com/*)

Table of contents

Biomechanics FOR Fly Casting..1
About the Series..1
Biomechanics FOR Fly Casting: Part 1..2
Introduction..2
The Context..2
What Use is Science?..4
Biomechanics FOR Fly Casting: Part 2..6
Biomechanical Principles and General Theory..6
Casting Principles and Biomechanics..8
Biomechanics FOR Fly Casting: Part 3..9
Meeting the Demands of Physics..9
Adding Biomechanics to the Analytical Mix..10
Casting Principles From General Theory..12
Proximal to Distal Throwing Sequence..13
Straight Lines Rule..13
Longer Cast Longer Stroke..16
Smooth Power Application..16
Biomechanics FOR Fly Casting: Part 4..18
Cast – Distance – Applied Biomechanics (The Short and the Long of It)..18
Rod Translation and Rotation..22
And Another Thing..24

Biomechanics FOR Fly Casting

About the Series

The Einstein Series[1] came out of my frustration with text book and online treatment of fly casting physics. However, once you get across the mechanics it becomes obvious that the journey toward enlightenment has only just begun. Physics tells you about what we need to achieve. It has little to say about what we need to do. Physics is long on Why and short on How.

The more I looked into and wrote about fly casting mechanics the more convinced I became that it pointed to efficiency as an "organising idea" for the understanding and performance of fly casting. In this context an organising idea is the hub of a metaphorical wheel from which radiate the spokes of different but related analytical pathways and knowledge sets. Biomechanics was the next logical spoke to follow because it takes us from the Why department to the How department.

There is a great deal of biomechanics literature out there in the analogue and digital spaces but not much of that is devoted specifically to fly casting. This Series is my next attempt at making a contribution to the fly casting body of knowledge by drawing on the scientific literature and relating stories from it that are accessible, practical, authentic and authoritative.

As before I needed some help with this work and I got exactly what I needed from the generous contributions of my two reviewers. For Vince Brandon it was a second go around as he was a member of the advisory group for the Einstein Series. John Waters also volunteered to help keep me on the straight and narrow. As a highly successful competition caster and instructor John has been a long time student and advocate of biomechanics as a vital source of knowledge to improve fly casting performance. As ever I thank them both for their assistance but assume sole responsibility for anything I've gotten wrong.

N.B.

1 https://thecuriousflycaster.com/physics-for-fly-casting/

for commercial gain. They were created as a free resource for those interested. For my fellow pilgrims, I hope you get some use and inspiration from the material.

Biomechanics FOR Fly Casting: Part 1

Introduction

Having made my way through the physics of fly casting it made sense to look at biomechanics and the sensory motor system as the next stops in the knowledge journey. Why? Because the mechanics (physics) of fly casting defines the most efficient outcomes of casting. It also enables us to measure them. The essential outcome is line speed achieved with an optimally efficient application of Force in the intended direction of the cast.

Knowing what we need to produce, however, is not the same as knowing how to produce it. Physics might explain why good casting technique works and even why bad technique is fugly, but it doesn't come up with many original ideas in the what to do and how to do it departments. Physics won't tell us what bodily movements to make in order to achieve optimally efficient application of Force. Neither will it tell us how to learn, revise, create, recreate and improvise those movements.

Secondly, it is the sensory motor system, not Newton's Laws of Motion, that we use to control those movements. It tells our bodies which bits to move, when, how much and how forcefully. The *sensory motor system* (SMS) is central to how we learn, remember, reproduce, refine and vary those movements. There is extensive scientific literature on biomechanics and the SMS. As with mechanics I want to extract the knowledge most useful to fly casters and explain it as accessibly as I can.

So, for me, there is a logical and compelling sequence to understanding this stuff and telling the story meaningfully. *Mechanics => Biomechanics => Sensory Motor Learning*. What organises and connects them all is the concept of efficiency. That is the conceptual framework for my research and the story I will try to tell.

The Context

What I write about fly casting is anchored in the context of fly fishing with a single handed rod. Most often that will involve a standard overhead cast. This is the context for most people who fly cast.

If you are a competition fly caster, accuracy or distance, you might well find some useful information and ideas here but I am not writing for you directly. One important implication (among others) of this approach is that I don't accept competition casting as the dominant model or sole arbiter of how fly casting ought to be performed.

To be clear, I'm not saying people who win casting competitions can't cast for fishing or that competing won't improve your casting or that we can't learn from what the best competition casters do. That would be silly. What I am saying is that competition casting is not the only source of fly casting knowledge. In this game no individual, organisation or pastime holds all the cards and has all the answers, including me of course.

When we fish or practice casting we throw lines of many different lengths. We might also intentionally throw lines of many different shapes and degrees of turnover. I won't be covering specialty casts directly. Some of the principles of "normal" single handed casts covered in what follows apply to specialty casts but I see those casts essentially in the improvised casting department.

Getting back to the length variations, when needed , these will be conveniently divided into short, medium and long casts. You will know what lengths of your casting fall into those categories as I do for my casting but we will both understand the actual lengths won't be the same for everyone, no matter where they sit on the continuum of skill level . For some folks a 50' (15m) cast is long and for others it is barely medium.

In all cast lengths, we have to manage both power and finesse to reach the target efficiently. In short casts power is never a problem, except perhaps in trying to avoid using too much of it. Finesse is the main game. For medium casts finesse and power will be nicely balanced. In long casts the emphasis will shift slightly toward power or, more particularly, how we can increase line speed without destroying finesse. Of course we can all make casts of similar lengths with varying amounts of power (to say nothing of finesse!) and that is perfectly legitimate. However, the point is to offer a qualitative framework of general and subjective application rather than quantitative prescriptions for how everyone should define, say, a long cast.

What Use is Science?

If we take that question broadly then I hope the Einstein Series[2] has scored a few points for the home team. If we consider it more narrowly, with biomechanics as the science of human movement, then a more difficult problem arises. Throughout most of the history of our species we have managed to hunt, fish and express ourselves athletically and artistically in movement with little or no help from science.

In my country, for example, the first people populated Australia some 60,000 years ago and survived as hunter gatherers often in very challenging environments. I don't know for how much of that time they used woomeras (spear throwers) but they didn't have any need of Newtonian mechanics or biomechanical (kinematic) analysis of motion capture footage to sort out the design of their spears, woomeras or throwing techniques. Trial, error, intelligence and survival motivation did a pretty good job for them.

Traditional knowledge of fly casting has also been produced largely by experiential learning though in a comparatively short space of time. What value can science add to what we know already? During my research for this project I came across an article[3] by Bruce Elliot.

Concluding this article about biomechanics and tennis he wrote in part:

"*There is no question that players striving for more power, more control, or more variety in stroke production through trial and error are the primary determinants in changes to stroke mechanics. However, I have shown that biomechanics certainly plays a role in the process of change. General theory provides a base on which modifications can be made, and an understanding of individual stroke mechanics inevitably leads to improved performance.*"

There is a lot in that paragraph and still more in the whole article if you are up for it.

Here is my interpretation. Science is an add-on to the fruits of experiential learning which means:

- It is not a substitute for experiential learning, it is an aid.
- We should only discount and discard knowledge from shared experience

2 https://thecuriousflycaster.com/physics-for-fly-casting/
3 https://pmc.ncbi.nlm.nih.gov/articles/PMC2577481/

when and to the extent that it is proven wrong.

- General theory provides a foundation for understanding which can be modified as and when required.
- Understanding individual stroke mechanics can lead to improved performance.

These days it is alarmingly fashionable to try to marginalise and ridicule science as inferior to what "*normal*" people "*know*". My objective is to grasp how science fits with trial and error. My answer for the fly casting context is that science is a valuable accessory to experience which can significantly reduce the iterations of trial and error. It can also polish performance in ways that practice alone might not be able to achieve. Endless practice and field experience might (or might not) result in sound technique. We lack the survival motivation.

Traditional casting instruction/knowledge can also shortcut the trial and error process (what and how departments) to a considerable extent. Let's also remember that the why department can both test the veracity of received wisdom and supply insight beyond trial and error.

Of course there are practical and financial limits to scientific exploration of an individual's casting technique. For example, if an athlete has access to the facilities and expertise required to accurately measure and scientifically analyse what they are doing their performance might be significantly improved. This would be especially useful within elite competition. However, that's a pretty expensive "if" beyond the reach of me and most of my readers, even if it was of interest to them – another fair sized "if". Meantime, we get by with astute observation and video footage which tells no lies even if it doesn't reveal the whole truth. Oh, and speaking of truth in casting, a measuring tape is very good idea too.

In what follows I am going to try to remember that biomechanics is an add on, use general theory to generate and/or affirm general principles of casting and, to a necessarily limited extent, shed some light on individual (casting) stroke mechanics.

Science based insight might be useful to casters at all stages of proficiency though I expect it is at the upper levels and specifically, where the margin for error in technique grows slim, that it will be of greatest practical benefit and therefore more readily accepted.

Biomechanics FOR Fly Casting: Part 2

Biomechanical Principles and General Theory

Anatomy and Complexity

The anatomical parts of the human body which enable movement are surprisingly numerous, incredibly complex and wonderfully sophisticated in their design and interaction. We use a lot of those parts when casting and the longer we cast the more of them we use. Obviously, coordinating (timing and controlling) the activation of many parts is a bigger problem than when we are using far fewer parts.

In fly casting the net Force applied in the direction of the cast comes from sum of the force produced by the body parts we use. The amount of force we apply will vary greatly between say, a very short cast and a very long cast. In between short and long there is still plenty of room for variation. Moreover, we are usually striving for finesse as well as power.

Biomechanics is essentially about how force is applied internally. As fly casters it helps to understand how best to externalise that force, applying it ultimately via the rod and line to the fly. The internal application of force to perform fly casting should not be confused with or limited to power and strength as the sole enablers of net Force. Such an approach will be terribly limited and frankly, inadequate. It's just so much more subtle, elegant and complex than a simple application (and display) of muscle power.

Let's stop there for a moment because we are on the edge of a precipice that plunges into a deep abyss of detail. That is somewhere you probably don't want to go and I want to avoid trying to take you. What follows then will simultaneously risk too much and too little simplification, but hey, I can only do my best not to fall off the high wire in either direction. There is, however, an upside to all this. At the very least the complexity signals that it is understandable why we can't always land the fly where we want to and why we can't all do it as beautifully as Joan Wulff.

Understanding Muscle Types and Functions

Larger muscle groups are for power. Typical examples include your quads, glutes and biceps. Smaller muscle groups are for finer movements such as by your hands or fingers. Makes sense then that you run with your legs and draw with your hands.

Smaller muscles notably include stabilising muscles. The power muscles enable us to move the skeleton via the joints. The stabilisers add finesse by helping to control the joint movement. They also help protect the joints from injury.

We need to maintain our balance while we cast, not just to avoid falling in the water but to promote efficiency by keeping our movements on track rather than on multiple tracks that change as we wobble about. For this task core stabilisers are going to be important. Weights shifts caused by movement of the upper body require compensatory relaxation and bracing from the lower body.

Summing up. We have larger muscles for power, smaller muscles for finesse and stabilisers for control, balance and joint injury prevention.

Lastly, I can't in conscience finish this description of muscle function without giving you at least a sniff of the beauty and complexity of even the simplest controlled movement which lie beyond my wilfully simplified account. When we lift an arm out to the side or in front of us it is not just the muscles of that arm and shoulder which produce the movement. A whole range of other muscles facilitate and compensate for that movement, maintaining balance and posture. All this will happen without any conscious awareness of the sweeping extensions and contractions of muscles other than those of the arm we decided to move.

Without these coordinated and unconscious activities the voluntary and intended movement would not be feasible even if it were possible at all. For those who might be interested find a copy of "*Deane Juhan's 2003 book Job's Body*"[4] and read pages 114-115 where he talks about what happens when we lift our right arm out to the side and up to the horizontal.

Proximal and Distal

If you have a quick look around your body you will notice that the bigger muscles are closer to its centre. Technically, they are closer to the axial skeleton – your skull and spine. As you move further away from the centre, out along your limbs, the bone and muscle structures become smaller. The nearer bits are proximal and further away bits are distal. So, now we know that in technical terms the

4 Juan Dean, Job's Body, 120 Station Hill Road, Barrytown, New York, USA, Station Hill Press, 2003 ISBN: 9781581770995

musculoskeletal structures are organised from bigger to smaller and proximally to distally. Oddly enough, it makes biomechanical and fly casting sense to use them in the way they are organised and the purposes for which they were made.

Casting Principles and Biomechanics

Human beings have been in the business and habit of throwing things for a very long time, maybe 2 million years. That seems to be about when we acquired the three anatomical variations from other primates which permit high speed throwing. Only humans can throw fast and accurately. The kicker lies in our ability to store and release elastic energy during the throwing action, known commonly as “cocking” the arm. An early version of rod loading? Just kidding folks. Forget I mentioned it.

Fast forward to the 21st century and now we have the technology of motion capture which allows us to minutely (kinematically) analyse what goes on when we throw things; javelins, baseballs and cricket balls as well as fly lines with a bendy lever. There are significant similarities between **all** these throwing actions. Of course, the bendy lever we use to propel fly lines introduces some important variations for fly casting but basically what we do and how we do it are neither entirely original nor unique.

Mo-cap[5] of fly casting enables us to see how casters, with varying skill levels perform the task. In particular it shows us what elite casters do differently; what they do more or less of compared with not-so-elite casters. What interests me about the results of kinematic analysis is not the fine detail but the bigger picture – the general points and how they fit with traditional knowledge gained through trial and error, passed on by competent instructors.

No two casters, including elite casters, move in exactly the same way. The finer points of individual style might interest some people but they don’t do much for me or the audience I am writing for. In what follows then I will stick to the salients points of similarity.

5 Motion capture

Biomechanics FOR Fly Casting: Part 3

Meeting the Demands of Physics

As detailed in the *Physic FOR Fly Casting series* (*The Einstein Series*)[6] mechanical casting efficiency demands body movements which:

1. Optimise the net Force applied in the intended direction of the cast, in other words its target bearing (and the line trajectory needed to reach the target). (This applies to all casts, whether the target is in front or behind the caster, to back casts as much as to forward casts.)

2. Generate line speed sufficient to overcome gravity and air resistance so that we reach our target. In others words, so we achieve the range to target. Range and bearing mark the exact position of your casting target which is especially important for the delivery. (Yes, we also need trajectory but for present purposes it would be an unnecessary complication to do more than note it as a variable.)

3. Enable and compensate for the use of a bendy lever to achieve 1. and 2.

Using a lever which extends our casting arm is advantageous because it amplifies the speed of the rod hand. Speed is distance over time. During a casting stroke the rod tip, which tows the line, moves further than the rod hand. More distance over much the same time means more speed. This is basically good.

The bendiness of the lever also does useful things. It causes delays in acceleration and deceleration, respectively before the rod bends and then again as it unbends. Thus it softens both the stops and the starts. Lastly, this flexibility effectively changes the length of the lever, shortening and then lengthening it again during the stroke. These features are both the good and the bad news. The softer stops and starts are easier on the body. Length changes make the whole shebang harder to control as we try to keep everything travelling as straight as possible and our loops aerodynamically clean.

6 https://thecuriousflycaster.com/physics-for-fly-casting/

Adding Biomechanics to the Analytical Mix

I like *Bruce Richards' six step model*[7] for casting instruction because it demonstrates how in practice we can connect mechanics and biomechanics. As he puts it "*The six steps analyse the cause of the problem from top to bottom, then produce the cure of the problem from bottom to top.*" The six steps are *line*, *rod*, *body then body*, *rod*, *line*. We look at the line to see what the rod is doing to see what the caster is doing to the rod. Correcting the body, we change what the rod is doing and therefore what the line is doing. Mechanics is concerned with what the rod and line are doing to each other. Biomechanics looks at what we are doing to make the rod do what it does to the line.

The Basic Casting Stroke

For much of our casting, short to medium length and maybe more, all we need is the basic or foundation casting stroke. This largely involves a proximal to distal movement sequence of the upper arm, forearm and hand using the shoulder, elbow and wrist joints. There is little if any weight transfer or rotation of the torso. So ideally the upper arm sets the line of the vertical plane. The elbow being a hinge joint, the forearm will follow the leader and if we don't rotate the hand (further inwards or outwards) then it too will stay on track. Job done.

Accuracy casters and many anglers utilise the basic stroke because it is simple, repeatable and minimises tracking error. You face the forward target, keep your eyes on it and move in line with that target.

The basic stroke also allows for some translation of the rod together with the more apparent rotation of the rod. As a foundation stroke, it can be extended by some leaning of the upper body backwards and forwards. Leaning back for the back cast and forward for the forward cast will also involve weight transfer which adds momentum. Additionally it can be extended on the forward cast by a fuller extension of the arm into a thrusting finish.

Getting a Grip

The grip you choose will have significant biomechanical implications but I won't be providing a separate analysis for all the possible grips. So instead of that here is a

7 https://www.sexyloops.com/articles/thesixsteps.shtml

general rundown. There are three standard grips and, roughly in order of commonality, they are thumb on top, V grip, and index finger on top. They each affect the range of movement a hand can make at the wrist during a cast. This is because they effect how the hand is oriented during the cast.

The range of possible hand movements is conveniently extensive for a species that makes tools and likes throwing things. Hold your hand out as though about to shake hands and follow along:

- We can bend the hand inwards and outwards using the wrist joint (flexion and extension).
- We can make the hand curve slightly down and slightly up at the wrist joint (ulna and radial deviation.)
- We can rotate the hand (and wrist) inwards until the palm is facing down and outwards until the palm is facing up (pronation and supination).
- We can variously combine all the above movements.

The thumb on top grip puts the hand in a vertical position as though shaking hands or hammering a nail. Strength clue. The V grip rotates the palm slightly inwards (pronation) as for inserting a key into a lock. Finger on top further pronates the hand and extends the index finger along the rod grip.

I'm not going to do the pros and cons because in the end it's a personal choice. My personal choice is sometimes the thumb on top – heavier outfits and close in shots. Sometimes it's the V grip especially when going long. It is the closest of the three to a natural throwing action and allows a good range of movement. Hint, hint. Never really got on with the finger on top grip but can see its usefulness for shorter casts.

One last thing about grips. We seem to be conditioned to exert greater grip pressure when trying to achieve greater casting force and/or control – the grip of death syndrome. As with casting force, grip force is a case of just enough. The rod is unlikely to fly out of your hand because you weren't holding it securely i.e. too little grip force. Too much grip force restricts movement and can lead to overuse injuries like tennis elbow.

Casting Principles From General Theory

Here is where we try to bring together the casting knowledge given to us by mechanics, biomechanics and traditional trial and error experience. The big picture for fly casting technique is that we need both repeatability and adaptability.

Repeatability gives us consistency in achieving the required range and bearing to target.

Adaptability enables us to adjust our casting smoothly to different conditions and different gear combinations and to improvise casts to a fish that isn't in a text book position.

Forced to make a choice between the two I'll take adaptability every time because if you have the technique to adapt well and quickly then it is pretty likely that you have already achieved and surpassed repeatability.

These two abilities are what we recognise almost instinctively when watching great casters at work. The work of the master appears effortless because their technique is sustained and solid in all departments. The novice struggles because their technique is unsustainable and weak in many departments.

Elite golfers are better at getting out of trouble just as much as whacking the ball longer and/or closer to the pin. Their overall mastery of technique enables better performance in every aspect of the game. So it is in many sports, including fly casting whether for fish or in competitions. If you are fishing, improvisation and adaption to changing conditions are even more important. One cast might be very short, the next quite long. One cast goes straight out in front, the next is off to the side. Some fish tolerate repeated presentations and innumerable false casts much better than others. Like many anglers it is the hard fish I most want to catch, the ones that demand excellent casting and tolerate few mistakes – in casting or otherwise.

A grasp of general principles is a sound foundation for developing the ability to adjust our movements at will. It is a different path than rote learning to perform somewhat robotic overhead or other casts at a limited range of distances.

Proximal to Distal Throwing Sequence

We are anatomically designed to throw things using a proximal to distal sequence. As we have seen big muscles are for power and smaller ones are for finesse. The sensory motor system, as much as the muscles, bones and connective tissues, is laid out on this basis.

As we will see this design principle holds up for short casts, through medium casts and on to long casts. It holds up for side casts as much as overhead casts, for hauls as well as strokes. You get the picture. It is fundamental.

By understanding, accepting and consciously incorporating this anatomical and biomechanical reality we can optimise our casting technique. It is as useful in avoiding and curing movement errors as it is in increasing performance – achieving range and bearing to target.

Straight Lines Rule

As previously explored in depth (*in The Einstein Series*)[8], to optimise the net Force applied in the intended direction of the cast we need to stay straight. Staying straight means not making errors in either the vertical or the horizontal plane when casting forward or back.

The vertical plane is what we would see if looking down from above the caster – the drone or birds eye view. Rod movement away from a straight line in this plane is usually called a tracking error. Using a basic casting stroke reduces the risk of tracking errors. We can make controlled variations in the amount of force applied and the distance over which it is applied (stroke length) and all with comparatively less risk of movement away from the line to the target.

The issue of force application brings us to the horizontal plane in which we also need to stay as straight as possible. This is what we observe from side on to the caster and watching the path of the rod tip. It's the tricky bit. In order to maintain a straight line (rod tip) path in the horizontal plane while using a bendy lever (that changes length) we have to make complex adjustments. These adjustments are more complex, in fact, than throwing just about anything else I can think of including spears using spear throwers. Let's unpack the complexity but without

8 https://thecuriousflycaster.com/physics-for-fly-casting/276-2/

forgetting that we manage all this stuff mostly without needing to think about it at all. Two million years of evolution has made us pretty handy at throwing things – even with a bendy lever.

Let's consider a forward cast using the basic casting stroke. As we accelerate the rod it starts to bend and shorten. (The translation phase is relatively short so in the basic stroke most of the rod bending and all of the unbending happens during the rotation phase.) The rod will also want to rise above the horizontal plane as it moves toward the perpendicular and dip away again after passing through the 90deg point. That is, unless we do something about it the rod tip will describe an arc instead of a straight line. Our options are either to make the rod bend more or to change/curve the path of our rod hand to compensate. The third option is a combination of both.

You see a problem here, right? We cast to many different distances requiring different amounts of force. More acceleration during rotation will produce more rod bend. Less acceleration means less bend and more of a problem in keeping the rod tip tracking along a straight line and not rising above it. The tip of a straight rod or one bent to a particular length from our casting hand will travel upwards and then downwards in an arc instead of a straight line unless we do something about it. Too much or too little hand path curvature at the wrong time will spoil the party.

To adjust for the net effect of rod bend and the naturally curved path of the tip we have to progressively and accurately change the pace and track of our rod hand. No great problem really. We have a sensory motor system which can monitor and control the force being applied. That takes care of pace. The pivoting of the upper arm in the shoulder joint (the proximal section of the arm) will start the process of curving the rod hand path. The extension of the forearm carries it on, both increasing the speed of the hand movement and the length of its arc. The wrist action finishes it off. The alternative adjustment is to keep increasing the rod acceleration so that it bends more. But this tactic has it limits. Rods can only bend so much. Also, at some point we have to stop accelerating and start decelerating at which time the rod will start lengthening again.

In practice and ideally we use a variable combination of rod bend under acceleration and curved hand path to achieve the desired rod length and loop shape of any given cast. In my opinion the skill of a caster is fundamentally defined by their ability to adaptively control their movements thereby using rod bend and hand path combinations pretty much at will.

Let's assume we choose to make a hard stop. As we decelerate the rod, it will unbend. This also needs to be managed, largely by timing. To keep the loop fairly narrow we don't want the rod to dip too far below the horizontal before (or for a while after) the loop is formed but the rod still has to get out of the way of the line as it begins to overtake the rod tip. As the rod unbends it will lengthen but by the time we make the hard stop the rod should be well past the perpendicular so we don't have to adjust the rod hand path as much, if at all. Stopping at the right point will take care of the tip path, and thus the loop shape. So we stop below the perpendicular by not too far towards the horizontal.

We achieve all this by using a proximal to distal movement sequence of the upper arm, forearm and hand. It isn't necessary to finish one part completely before the next part of the sequence begins. That would ruin the flow of the movement. The job is rather to perform the sequence in its proper order while maintaining flow. Flow comes from some overlap between the movements of the body parts included in the sequence. We don't get to start the wrist action before the upper arm has done its thing just because Mark said some overlap was permitted. Rather we start the forearm extension before the upper arm movement is completed and likewise the hand moves at the wrist before the forearm has done all of its work.

After all that, here is the biomechanical take away. I truly hope it was worth the wait.

We optimise the cumulative application of force to the rod by our body when and only if, we make the relevant movements in the proper order and with the flow that evolution has created – just for us.

Throwing a fly line with a bendy lever does make the throwing action much harder to do well because of the adjustments we have to make. They demand exacting control of the power applied throughout the proximal to distal flow but hey, isn't that what any experienced and competent fielder would say about a return throw? The benefits are why we accept the challenge and most of us can meet it. Evolution has made us damn good at controlling our throwing movements.

Longer Cast Longer Stroke

One of the famous *Five Essentials of Fly Casting*[9] is that stroke length needs to vary with the amount of line being carried. The reason given is that the rod bends more when the mass of the line being accelerated increases. And, in a general sense that's true (enough).

It is equally true that the same amount of line can be cast quite efficiently with strokes of different lengths, provided we make the necessary adjustments. Of course there are limits. Way too short and way too long a stroke will mess things up. Why is that so? Because the rate of acceleration affects rod bend and too much or too little bend will make it harder to manage the path of the rod tip. Our ingrained managerial competence and expectations will be thrown out of whack and that interrupts the flow of our movements. Co-ordination fails.

Likewise we can cast a fixed amount of line easily with the same stroke length but with less, more or far more power applied.

Overpowering, using more power than we need to complete turnover, is very easy to do.

Underpowering, however, is actually much harder to do, intentionally in a controlled way.

What I'm getting at here is that varying the stroke length with line length is not just about rod bend. It has to do with Work, which is multiple of the force applied to something by the distance that something is moved. We use the rod to put kinetic energy into the fly line. That is, we do Work on the rod and we can vary both the amount of force and the distance over which it is applied. This brings us to the next principle.

Smooth Power Application

I think smoothness of power application deserves far more prominence and more detailed attention than it has generally received. It's true that we want to be smooth because it helps maintain the control needed to keep the tip as straight as we can – in both the vertical and horizontal planes. It is also true that it helps us to avoid the demons of a tailing loop. For my $0.02AUD, however, it means a whole lot more

9 https://www.flyfishersinternational.org/Portals/0/Documents/Casting/The%20Loop/2009.SUMMER.LOOP.PDF

than that. We'll get to that directly. First though, let's recap the mechanics of Work and how they relate to smooth casting.

Work is about how power (force) is applied.

How much force we apply over what distance determines how smoothly or roughly we apply power. Smooth power application is what we need to optimise loop shape and net Force in the direction of the cast.

In short, smooth power application equals more net Force applied by the rod to the fly line in a straight(er) line. Lumpy power promotes tracking errors in the vertical plane and in the horizontal plane it causes dips and rises of the rod tip away from a straight line path.

What are the biomechanical implications of the task so defined? Easy question. We follow the proximal to distal sequence with a nice flow. We use the bigger muscles for power when it is needed – say at the beginning of the stroke to get things moving. We use smaller muscles for finesse, to complete the movement and stay on track despite the increasing speed of our movements.

How do we move smoothly? More difficult question. Smoothness is a demonstration of controlled and progressive power application and the very opposite of jerky, instant, maximum power application. It's co-ordinated movement. Remember, even power lifters need to stay smooth, both to perform the task and to avoid injury.

Fly casters aren't power athletes demonstrating strength. We are more like dancers trying to demonstrate grace. Graceful movement comes from fluid economy of effort. It looks elegant and effortless because nothing is being overpowered. It is no co-incidence that Joan Wulff and Christopher Rownes were both professional dancers before they became renowned and distinguished fly casters.

Controlled power is easier to produce and maintain when less effort is required from the muscles providing the power. We start the stroke with the bigger muscles and we go easy knowing we have more than enough power in reserve. As the sequence progresses the movements speed up. However, as the musculoskeletal structures get smaller we can get away with a bit more effort because we have finer control over them. That's because the parts we use for finer motor skill have more sensory motor connections controlling them. Again, we can do it that way because that's how we are built for the job.

In a sense then, smoothness is both a cause and an effect of mechanical and biomechanical casting efficiency. Honestly, I have thought about it a lot and still can't decide which is the chicken and which the egg – smoothness or advanced technique. So I'll put it this way. Whether you are a fly fisher or tournament caster, trust me, effective technique is built on efficiency and smoothness is essential to efficiency.

Biomechanics FOR Fly Casting: Part 4

Cast – Distance – Applied Biomechanics (The Short and the Long of It)

Fly fishing involves casts of greatly varied lengths, from the leader only to a few feet of fly line and the leader, to way out as far as we can make it sail. In between very short and very long there is plenty of space. Each of us will have marked out that space in our heads. We will know, at least roughly, where short gives way to medium, medium to long and so on out to the maximum distance we can cast. It isn't a matter of quantitative prescription by me but rather of qualitative experience by you.

- A short cast is about finesse. Power isn't a problem except for not using too much of it.
- A medium cast will be a nice balance of power and finesse.
- A long cast will begin to test seriously the strength of our technique. It will be about increasing power (a bit) without losing finesse.
- A very long cast will be right at the limits of technique and getting it to fully extend won't be entirely predictable. Finesse of the delivery landing will be the least of our worries. However, finesse in the sense of staying smooth remains critical – always.

I was going to break distance into 5 categories and give a biomechanical analysis for each category beginning with very short and ending with very long. However, when I started writing this up it turned into a detailed description, getting ever longer, more detailed and thus ever more like instructions on how to make the casts. As the range of movement extended so did the written description. Detailed casting instructions are not my objective. There is no shortage of instructions out there and watching a video clip would probably be lot more useful. So let's turn it around and avoid a lot of the detail by starting with the bigger picture.

As we cast longer we need to make longer casting strokes. Sooner or later the basic casting stroke will have run its race, even with leans at the start and a thrust extension at the finish. Put another way, adding ever more power to a limited range of movement will eventually become counterproductive. You know, the bendy lever problem again.

At this point, we have to extend the stroke by progressively recruiting more and more proximal parts of the body. The stance will be opened up by the stepping the casting side leg backwards. The torso and hips can then begin to rotate without us losing our balance and falling over. Weight will be shifted between the front and back legs providing some linear movement of the upper body and some momentum, eventually, to the line.

~~Meanwhile, the elbow will have moved away from the side of body (abducted). The upper arm and forearm will now form something close to a right angle with the upper arm being in line with the shoulder. Freeze frame right there and what do we see? Dang, looks a lot like someone about to throw a ball in from the outfield or a spear into a fish. We've been here before I think.~~

[***Edit***] Five years further on I'm not inclined to recommend abducting the elbow as we rotate the torso but rather to keep it more tucked in until quite late in the torso rotation. This will reduce strain on the shoulder in general and the rotator cuff in particular. (Yep, personal experience.) I now prefer to wait until the torso has turned far enough to permit arm extension, particularly forearm extension, in straighter lines which aids tracking. Right angles turned out to be wrong angles for me.

On then to the 5 categories.

Very Short

Little or no fly line outside the tip. It will most likely be a wrist flick with a tiny bit of forearm. Still needs to be smooth. Still possible to form a nice loop. No haul. It's a very distal thing.

Short

At least one rod length of line and perhaps several outside the tip now. Maybe a little bit of upper arm movement but it's mostly done by forearm extension and a gentle straightening of the hand. No real need to haul but a short one is acceptable if you must or you want a short stroke and slightly more zippy turnover. It's still a bit constrained and distal but it's starting to feel a bit more like a "real cast".

Medium

This is where we can start to move more expansively and with rhythm – back cast to forward cast and repeat as necessary. Using a basic stroke the upper arm is fully mobilised and the proximal to distal sequence of the arm is complete. The stroke is extended far enough to comfortably manage the carry. Hauls can be added routinely to share the workload. We aren't straining and we aren't feeling constrained.

I find this range extremely helpful for refining technique whether that be correct tracking, smooth power application, full finish, variations to haul timing, length and speed, line release timing and so on. Time and again I come back here to get the feel of how effortless a good cast is to make and how good it feels to make one. Then I try to keep that sweet feeling as I progressively extend the carry and the cast. Keep the flow and finesse, add just enough power to increase the distance.

Long

Around this point it will become necessary to start using some torso (shoulder) rotation and eventually that will start to involve weight transfer. Hauls will become pretty much essential. The biomechanical point is to observe that the proximal part of the casting sequence now includes an axial movement of the whole upper body and possibly the hips as well. The largest muscles and bones we have are becoming involved. As it gets more complicated it gets harder to maintain control, especially if we use too much power too soon. As ever the trick is to follow the sequence and the flow – that is, to stay smooth.

Very Long

This is where it gets much harder to do well. Technique is at or very close to its limit.

If it hadn't already, the sequence will now recruit our leg muscles. The vast expansion of the proximal recruitment has about reached its practical limit.

You may want to fully extend the forearm into the back cast, finishing with a straight arm. If so, you will have to rotate your torso/shoulders through a full ninety degrees. That's because the elbow is a hinge joint (not a ball joint) so your forearm can only move (flex and extend) in the line of your upper arm. Failure to rotate far enough or premature forearm extension will see the fly line fired partly sideways instead of straight behind you. Bingo, tracking error.

As you move into the forward cast you reverse the weight transfer and the rotation of the upper body. The rod is translated but not significantly rotated while this part of the sequence is executed. In fact rod rotation by extension of the forearm and then hand will be largely delayed until the upper body is again facing the target and weight is transferred almost entirely to the front foot. After rotation is complete you can further extend the movement with a thrusting action, as though pushing into the bend of the rod to prolong it. This is will help increase Work done and to narrow the loop.

The greater the extent of our movements the less the margin for error in sequence timing, in flow and in effort. That's the bad news. The good news is that fly lines don't weigh much and we can throw them a surprisingly long way with the application of surprisingly little net Force provided we stay smooth and move in the correct order of the sequence.

The total range of movement and the body parts involved both change a lot but the sequence stays the same from the very short to the very long cast. Proximal to distal, ok?

Applying all this doesn't mean reciting or consciously thinking about the exact order of the body parts in the movement sequence for every cast. What it means is practising to habitualise[10] (groove) leading the stroke with the proximal bits and following with the distal bits. As we will see later on (*Fly Casting and Sensory Motor Learning*)[11] slow motion exercises, pantomimes and even just mental rehearsal of the movements will help entrench the correct order, effort and flow of the movement until most of it becomes unconscious. On the water then, we can see

10 Accustom or internalise

11 https://thecuriousflycaster.com/fly-casting-and-sensory-motor-learning/

the target and take the shot. The cast just happens.

Rod Translation and Rotation

If we are making a short cast with a short, basic casting stroke there will be a limited amount of rod translation. For medium casts the translation phase will become more distinct and as we get into long casts with body rotation so rod translation will become far more pronounced and important. It is commonly accepted that to make seriously long casts we must learn to delay rotation of the rod and execution of the haul.

By now it will be obvious that this is in keeping with the proximal to distal sequence. Rod rotation is performed by the smaller structures of the forearm and hand. Translation is performed by the larger more proximal structures – whatever those might be according to the extent of recruitment as discussed above.

The Haul

In the *Einstein Series*[12] hauling got a number of mentions and was examined in more detail here . Hauls share the Work done on the fly line between the rod hand and the line hand. That means in a hauled cast we can use less Force applied to the rod and thus a shorter stroke than we would in a non-hauled cast. We achieve the same line speed and distance in both casts. The hauled cast means less effort from the rod hand and that improves control and therefore accuracy.

Hauling accelerates the line in the direction of the cast if we do it before loop formation and it promotes loop propagation if we do it after loop formation. If you haul at least partly after loop formation then you are now pulling back on the rod leg instead of forward on the “fly leg”. This will enhance loop propagation velocity but diminish loop travel velocity. You will get zippier turnover but a tad less distance.

Hauling can also give us tighter loops because the stroke length can be reduced and rod flex (bend) and “counterflex” (bend the other way) will also be reduced. Tighter loops mean less opposition from drag.

Lastly, haul timing and completion affects when we release the line for shooting purposes. Obviously you don’t release before the haul is finished and you can play

12 https://thecuriousflycaster.com/physics-for-fly-casting/

around with release timing but for maximum distance you will want a clean release about when the rod straightens.

From a biomechanical perspective, hauls of varying lengths are similarly made with a proximal to distal sequence. You might do more Work on the line with a longer haul but against that you can produce harder, faster hauls using just forearm and hand movements. Different casters make different choices for different casts. I do and I encourage you to do the same. I find it easier to stay smooth when the tempo of the hauls matches the cast movements and since I very rarely go to maximum distance when fishing I reserve the right to improvise the combinations and vary the haul length and speed.

Just a couple of years ago some guys in a Swedish lab made a very detailed and informative biomechanical study of elite fly casters casting with various lines and rods of differing stiffness and weight ratings. The results for the Trout Distance casts using a 5wt SA MED[13] line and three different 9' rods are particularly interesting. You can read the whole article in the Annals of Applied Sport Science, vol. 5, no. 2, pp. 61-72, Summer 2017. The PDF is available with the link below[14].

Their focus was on co-ordination of haul and rod contributions to line speed but of course they captured and analysed both using a 3D motion analysis system. For our purposes their conclusion is affirming as well as informative.

"*Among elite casters, single-handed fly casting with double haul is coordinated in an order of events whereby the peak speed occurs first for the translation of the rod, then for the rotation of the rod and finally for the line haul.*"

The succession of peak speeds speaks to each building on the Work of the previous stage, progressively accelerating the fly line. It implicitly confirms the mechanical effects of the proximal to distal sequence for both rod and line hands. Less obviously, it affirms the flow and integration of the body movements, including the overlaps between activation of the body parts.

And just because I can't resist, checkout the range of rods used for the Trout Distance casts – from stiff competition rods to a bit of a noodle they weren't too familiar with. The mean difference between the length of the casts? About 3 metres

13 Scientific Anglers 5 wt Mastery Expert Distance Weight Forward
14 https://aassjournal.com/article-1-499-en.pdf

with most casts being 30 metres or more. *Technique is what matters*, *not the gear*.

And Another Thing

I have tried to give you general principles combining biomechanics and traditional casting knowledge, linking both back to physics and the mechanical requirements for efficient fly casting. General principles apply generally and that means across the range of single handed casts. Equally, it implies the possibility of exceptions. What is optimal or ideal for one person or one situation will not be exactly the same for different people and situations.

People come in different shapes, sizes, physical prowess and functionality. A tall, fit, young, muscular athlete may well have different ranges of movement, strength and learning/skill acquisition capabilities to a short, unfit and ageing non athlete. Sensible expectations and adaptions need to be adopted.

The purpose of the cast and the order of the casters priorities will similarly vary and these variations will both affect and be affected by biomechanics. If, for example, delicate presentation is paramount the biomechanics of your cast will change and change further with the range to target. As the range increases the caster might have to choose between movements which promote finesse and movements better suited to power. Contrastingly, if there is no fish in sight and the purpose is simply maximum distance then finesse is unlikely to be a big deal. In both cases, however, the general principles apply equally albeit differently. Efficiency is the link. If it is a missing link, general principles will always be a good place to look.