



THROWING MECHANICS · DIAGNOSTIC REFERENCE

Deficiency or *Adaptation*?

A body part by body part read on what to look for in a delivery: the anatomy and physics underneath it, the muscles doing the work and how they're working, the lifts that change it — and the cases where the thing you were about to "fix" is the reason he gets outs.

OUTLIER PERFORMANCE LAB · DRIVELINE · TREAD · BPC · WAKE FOREST PITCHING LAB · ASMI / ABBS · NSCA · PEER REVIEWED17 CHAIN LINKS

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How to read this sheet

Nine terms carry the whole document.

Front foot lands labs call it: foot contact / FC The frame where the stride foot first touches the mound. Most measurements get taken here because it's the last stable moment before everything explodes.	Peak layback labs call it: maximum external rotation / MER The frame where the forearm is turned back the farthest — palm facing roughly toward second base. This is the instant the elbow and shoulder take their biggest hit.	Release labs call it: ball release / BR The frame the ball leaves the fingers. The three frames — foot lands, peak layback, release — are the only ones worth freezing.
Elbow load labs call it: elbow varus torque The twisting force trying to pry the inside of the elbow open at peak layback. This is the number that tracks with UCL trouble. An average pitcher runs about 100 Nm — roughly the twist of hanging a 75 pound weight off the end of a one foot bar.	Size adjusted labs call it: normalized (%BW×H) The same load divided by the pitcher's body weight and height, so a 5'10"/170 and a 6'5"/240 can be compared fairly. Reported as a percentage — 6% or higher is the group researchers flag as high risk.	The sequence labs call it: kinematic sequence Hips turn, then chest, then arm, then hand — each one peaking later and faster than the one before. It's a whip, not a shove. When the order breaks, the arm pays.
Stress per mph labs call it: efficiency How much velocity he's getting for the load he's paying. This — not raw load — is the number that decides whether a pattern is a problem. High load with high output is expected. High load with low output is the red flag.	Arm level with the shoulders labs call it: 90° shoulder abduction Upper arm at a right angle to the torso, elbow at about shoulder height. Nearly every arm health finding in the research points back to being close to this at both foot landing and release.	Degrees, quickly for the angle numbers below 90° is a right angle (an "L"). 45° is halfway to that. 180° is a straight line. When you see "45 ± 9°," that means the average is 45° and most pitchers land between 36° and 54°.

Four gates before you change anything

Every source that actually publishes data lands in the same place: most things that look wrong are either downstream of a physical limit, or they are the price of something the pitcher is getting paid for. Run these in order.



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GATE 1 Can he physically get there? Check his range of motion and strength before you cue a position. Driveline's stated order is soft tissue → get the range back → get strong <i>in</i> that new range → then refine mechanics. Drilling a position an athlete has no range for just teaches him to fake it somewhere else. Classic example: a pitcher with low hip to shoulder separation is often tight because his hips are weak and his body is protecting itself — not because he doesn't know how to move.	GATE 2 What is it actually costing? A pattern is only a problem if it bills you in one of three currencies: velocity, command, or arm stress. If it bills none of the three, it's a signature, not a flaw. Get the number before the opinion — mph, how far he misses by, and size adjusted elbow load.	GATE 3 Cause or symptom? The far end of the chain pays for debts at the near end. A foot that lands open is usually a lead hip that can't rotate. A pushing arm is usually a chest that opened early. Fix the lowest link that's genuinely broken and film again before you touch anything above it.	GATE 4 Is the trade already good? In a study of 523 elite pitchers, the high load group was carrying 28% more elbow load for 1% more velocity. That's the bad trade. The reverse — a "flaw" that costs a tick and buys movement, deception, or health — is a good one. Price it, don't judge it.
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The numbers you're comparing against

These are population averages with real spread — use them to locate a pitcher, not to grade him. Where a number is abstract, the plain English equivalent is in the same cell.

REFERENCE VALUES, IN PLAIN ENGLISH				
WHAT IT IS	WHEN TO LOOK	NORMAL RANGE	WHY IT MATTERS	SOURCE
How far he strides stride length	The instant the front foot touches down	About 83% of his height , give or take 4%. A 6'0" pitcher strides roughly 5 feet – call it 57 to 63 inches.	The most reliable lower body velocity predictor there is. Every extra 1% of his height in stride is worth about 0.7 mph , and stride length alone explained roughly a quarter of why one pitcher throws harder than another. 39 high school and college pitchers	ASMI · SportRxiv
How bent his front knee is when he lands lead knee flexion at contact	The instant the front foot touches down	Bent about 45° – halfway between straight and an "L." Most pitchers land between 36° and 54°.	Here's the surprise: the angle at landing had no measurable effect on velocity . Stop coaching the landing angle. What matters is what the knee does <i>after</i> it lands.	ASMI · SportRxiv

WHAT IT IS	WHEN TO LOOK	NORMAL RANGE	WHY IT MATTERS	SOURCE
How fast the front knee straightens lead knee extension velocity	From foot landing to release	About 350 degrees per second – it should sweep through a right angle in about a quarter of a second. Under 242°/s reads as a soft front leg.	This is the real measure of the front leg block. Braking the hips is what makes the chest spin fast. A knee that keeps folding absorbs the energy instead of bouncing it up the chain.	Driveline
Where the throwing arm sits relative to the shoulders shoulder abduction	The instant the front foot touches down	Upper arm roughly level with the shoulders – a right angle to the torso $93 \pm 11^\circ$. Most land between 82° and 104° .	Drifting away from level in either direction cuts how much layback he can get, raises elbow load, and makes the shoulder joint less stable under load.	ASMI
Where the arm sits at release shoulder abduction at release	The instant the ball leaves the hand	Still about level with the shoulders $\sim 90^\circ$	More arm elevation at release is linked to less elbow load. This is one of the cleaner levers you can actually pull.	Fleisig
How bent the throwing elbow is when he lands elbow flexion at contact	The instant the front foot touches down	Bent to about a right angle $90 \pm 15^\circ$. Most land between 75° and 105° .	A more folded elbow at landing is linked to more elbow load — the layback event gets compressed into a shorter, sharper arc.	ASMI · Fleisig
How far the elbow sits behind the shoulder line shoulder horizontal abduction – the "scap load"	The instant the front foot touches down	ASMI says about 20° ; Driveline's own data averages closer to 40° , peaking near 57° . Under 5° means he's barely loading the shoulder blade at all.	Pulling the elbow behind the shoulder line stretches the chest and gives the arm runway to accelerate. Without it, the elbow has to supply the speed itself.	ASMI · Driveline
How turned back the forearm already is when he lands shoulder external rotation at contact	The instant the front foot touches down	Roughly halfway to full layback $\sim 45^\circ$	Arriving already turned over is linked to less elbow load. Arriving still packed means the layback happens as a violent snap instead of a long sweep.	ASMI · Fleisig
How much the hips outrun the shoulders hip-shoulder separation	The instant the front foot touches down	Hips open 40 to 50° more than the shoulders. Driveline calls 48° elite.	Treat this as a means, not a scoreboard. One study found no direct link to velocity at all . Another found that more separation at landing came with <i>more</i> elbow load. Chase it only when the chest genuinely isn't turning fast.	Driveline · Wake Forest

WHAT IT IS	WHEN TO LOOK	NORMAL RANGE	WHY IT MATTERS	SOURCE
How closed his chest still is when he lands trunk orientation at contact	The instant the front foot touches down	Chest still turned about 10° away from the plate	Staying stacked and closed at landing is linked to less elbow load. Flying open with the chest is one of the more expensive habits on this list.	Driveline · Fleisig
How far he leans away from his throwing arm lateral / contralateral trunk tilt	The instant the ball leaves the hand	Over the top guys lean about 34° ; sidearmers about 24° . Past 48° is a stress flag.	This is how a shorter pitcher manufactures a high release point — and it costs him. More sideways lean at release is linked to more elbow load.	Fleisig · Driveline
How far he bends forward over the front leg forward trunk tilt	The instant the ball leaves the hand	No clean target – measure his and track it	Of every <i>position</i> Driveline measured, this one tracked with velocity the most — it accounted for about 20% of the velocity difference between pitchers, and it's where extension toward the plate comes from. It also raises elbow load. Straight velocity for stress trade.	Driveline
Elbow load elbow varus torque	Right around peak layback	Driveline's sample averaged 101 Nm . Other sources report much lower figures, so compare like with like. Size adjusted, 6% or higher is the high risk group.	Cadaveric ligament failure is reported near 32 Nm, below what pitching produces, so the forearm muscles cover the difference on every pitch. That's why fatigue matters so much.	Driveline · Wake Forest
Pull trying to yank the arm out of the socket shoulder distraction force	Release and the arm slowing down	Over 225 pounds ^{>1000 N}	Roughly his own bodyweight pulling the arm bone away from the shoulder socket, every pitch. The back of the rotator cuff is what stops it — which is why deceleration training isn't optional.	Driveline · ASMI
Twist and forward shear on the shoulder shoulder internal rotation torque / anterior shear	Just before peak layback	About 50 foot pounds of twist ^{67 Nm} , plus about 70 lb of forward shear ^{310 N}	The front of the shoulder capsule is being pushed forward at the same moment the elbow is being pried open. This is the single most dangerous instant in the delivery.	Fleisig
The order things fire in kinematic sequence	Across the whole delivery	Hips → chest → arm → hand. The hand's internal rotation tops out near 7,000°/s – about 19 full turns per second, the fastest motion the human body produces.	Each segment should peak later <i>and</i> faster than the one before, then slow down to hand its speed forward. When the order breaks, the arm is generating what it should have been given.	ABBS · ASMI

- Red stripe — costs arm health ■ Amber stripe — costs velocity or command
- Slate stripe — commonly mislabeled: check before you touch it

Motor preference: why two clean deliveries look nothing alike

Before you call something a flaw, check whether it's a *preference*. The ActionTypes framework sorts athletes by how they naturally organize movement — and the profiles predict several of the exact things coaches most often try to standardize.

THE FOUR AXES, AND WHAT EACH ONE PREDICTS ON THE MOUND			
THE AXIS	ONE TYPE	THE OTHER TYPE	WHAT IT CHANGES IN HIS DELIVERY
How he loads the ground terrestrial / aerial	Ground loader — weight sits toward his heels, slow low leg lift, back knee bends right away, can pause at the top without losing anything, drives from the hips, lands heel first. His lower body starts the movement and the upper body follows.	Springer — weight sits toward the balls of his feet, fast high leg lift with no pause, back leg barely bends, shoulders start the movement. He rebounds off the ground rather than pushing off it.	Leg lift height and tempo, how deep he sits into the back leg, whether "get more load in the back leg" helps him or wrecks him, and whether a controlled fall forward is a fault or the whole engine.
How much he twists associated / dissociated	One piece turner — smaller chest rotation, closes his hips more to make up for having less twist available.	Spiral turner — bigger gap between hips and shoulders, less hip closing needed.	Directly predicts his natural separation number. A one piece turner chasing a spiral turner's separation is chasing range he isn't built to organize.
Which side of his body he lives on anterior / posterior chain	Front side — quads, hip flexors, chest. He pushes.	Back side — glutes, hamstrings, lats. He pulls.	Which cues land ("claw the rubber back toward second" is a back side cue), and which lifts he actually expresses power in.
Which way his hand naturally turns pronator / supinator	Palm down bias at release.	Palm up bias at release.	Arm slot and release point get treated as expressions of preference rather than choices — and it predicts which second pitch will come easy (changeup and sinker vs. slider and sweeper).

Use this honestly. Motor preference is a coaching framework, not settled science — nothing like the evidence behind elbow load or stride length. Use it as a *reason to ask a question*: when a pitcher fights a change that should obviously help him, preference is a plausible explanation for why. Don't use it as a diagnosis, and don't let it override a measured arm health flag. The framework's own core claim is the useful part: coaching a guy against how he's built is where avoidable oblique strains and arm injuries come from.

The chain, ground up

Each link opens with the anatomy — which muscles are working, whether they're shortening, lengthening, or holding, what to test, and what to load. Then the diagnostic rows: what you see on film, why it happens, what changes it, and the case for leaving it alone.

Shortening = the muscle is producing the movement. **Lengthening** = it's braking a movement while being stretched (this is where most injuries happen). **Holding** = it's not moving, just keeping a position stable.

LINK 01 · DRIVE SIDE

Back foot & ankle

The only thing touching the ground while his body is speeding up. Everything the delivery gets, it gets here first — and force is only half of it. **How long he can keep applying that force is the other half.**

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Calf (soleus and gastrocnemius) — lengthening as the shin travels forward over the foot, then shortening to push. The deep calf does most of it because the knee is bent. Deep arch muscle (tibialis posterior) — holding. This is the muscle that stops the arch collapsing. Outside of the shin (peroneals) — holding, keeps the big toe side of the foot pressed down. Front of the shin (tibialis anterior) — lengthening, controls how fast the shin travels. Small foot muscles hold the arch up under load.	• Knee to wall ankle test, both sides — you want 4 to 5 inches • Single leg heel raises to failure (calf endurance) • Does the arch flatten when he stands on one leg? • Big toe extension range — he needs it to finish the push	• Heavy calf raises, straight leg and bent knee, 3–4 seconds lowering • Seated calf raise, heavy, 8–12 reps • Tibialis raises for the front of the shin • Short foot and toe splay work for the small foot muscles • Heavy sled marches and lateral sled drags — long ground contact, force going sideways and forward • Ankle mobility work <i>before</i> the loading, not instead of it

SEE	WHY	FIX	OR LEAVE IT
Heel pops off the rubber early; the foot rolls in and the arch collapses; he's off the rubber well before the front foot lands.	He can only push the ground while the foot is still loaded. Coming off early cuts the <i>time</i> he has to apply force, so even the same push produces less speed. Think of it as a shorter runway, not a weaker engine. Usually a stiff ankle or a calf that can't hold a stretched position under load.	Get the ankle range back, then load it: heavy slow lowering calf work and split squat holds. Banded lateral drives and skater bounds to teach sideways force. Cue him sideways, not upward — Tread's version is "claw or pull the rubber back toward second," which gets the glutes and hamstrings involved instead of the quads.	Coming off the rubber early raises his tempo, and tempo steals timing from hitters. It's also just how a springer type athlete is built. If the velocity and command are there, a longer drive phase buys you nothing you can measure.
SEE	WHY	FIX	OR LEAVE IT
No toe drag at all, or a drag line that hooks toward his arm side instead of running toward the plate.	The drag line is a <i>readout</i> of when his hips turned, not a cause of anything. A hooked drag means the hips opened before the front foot landed and dragged the foot around with them.	Don't drill the drag. Go upstream to back hip rotation and hip timing (links 03–04). The drag line fixes itself when the hips wait.	Guys with a lot of back hip range naturally hook the drag while still holding their separation. If the separation number at landing is fine, the line on the mound is cosmetic.

LINK 02 · DRIVE SIDE

Back knee

The knee decides which **direction** his push points. A knee that straightens early sends him up. A knee that stays bent while the hip drives sends him out toward the plate.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Quads (front of the thigh) — lengthening into the load, shortening out of it. Relying too heavily on these is the fault, not the muscle itself. Hamstrings (back of the thigh) — working alongside the glutes to extend the hip while the knee stays bent. This pairing is what points him at the plate instead of at the sky. Big inner thigh muscle (adductor magnus) — a major and undercredited hip extender in the drive. Main butt muscle (gluteus maximus) is the primary engine.	• Rear foot elevated split squat — depth and control • Single leg broad jump: distance versus height tells you which way he pushes • Lateral bound distance, back leg versus front leg • Can he hinge at the hip and load the hamstring without using his low back?	• Trap bar deadlift and Romanian deadlift — build the hinge before the push • Rear foot elevated split squat, heavy • Skater bounds and lateral bounds for sideways springiness • Lateral sled drag and band resisted lateral drives • Step back roll ins, rocker drill, step back windups — set up the drill so the pattern happens on its own instead of cueing it

SEE	WHY	FIX	OR LEAVE IT
He rises up at the top of leg lift; there's a visible float or jump; the back knee straightens before his hips have moved toward the plate.	Quad driven knee extension sends him <i>up</i>. Force that goes up doesn't become ball speed — it becomes hang time. Tread names this as the most common lower half fault: it turns a rotational athlete into a linear pusher.	Reverse the pattern with drill setups rather than cues: step back roll ins, step back windups, a properly run rocker drill. In the weight room: hinge strength, lateral sled drives, skater bounds. Tread's own check — if he can hit the low 80s in warmups feeling like his lower half is throwing the ball, the timing is right.	A controlled rise then drop raises his release point and steepens the angle the ball comes in on. If his identity is a downhill sinker or a curveball he lives on, that rise is buying him pitch shape. Judge it on ball flight, not on the silhouette.
Back knee caves inward at peak load; the hip drops on that side; the stride ends up short or closed because of it.	The side hip muscles aren't holding. Once the pelvis tips, the chest has to counter lean and the arm inherits the correction. In high school pitchers, better balance and pelvic control standing on the back leg came with less load on the shoulder $r = .30$.	Banded hip abduction, Copenhagen planks, lateral lunge with a reach, single leg balance work when he's tired. Then retest: the average pitcher's pelvis wobbles about 6° during a single leg lift test.	Rarely. This is the version of a lower half fault that shows up on the shoulder's bill, not just the radar gun.

LINK 03 · DRIVE SIDE

Back hip

To rotate around a loaded leg he needs the hip to turn **inward** on that side. To hold his counter rotation while he strides he needs it to turn **outward** and hold. Missing either one and the hips open early, because they have nowhere else to go.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Main butt muscle (gluteus maximus) — the primary engine for extending and rotating the hip; shortening through the drive. Side of the hip (gluteus medius and minimus) — holding, keeps the pelvis level. Measured at 20 to 40%+ of a max effort through acceleration and deceleration, and it tracks with how well the shoulder blade is controlled. Deep hip rotators (piriformis and friends) — holding the ball of the hip centered in the socket while the pelvis turns on it. Inner thigh (adductors) — lengthening as the stride opens, then shortening to help extend the hip.	- Hip rotation both directions, both sides — flag a 5°+ difference in inward rotation - Total rotation per hip (inward + outward), not just inward - Hip airplane — can he control rotation over a loaded leg? - Copenhagen plank hold time for the inner thigh	90/90 hip switches, then loaded; hip rotation stretches held under tension - Banded hip airplane; banded hip abduction (Driveline's named side hip prescription) - Wall press dead bug and bear crawl — hip rotation plus front side core - Copenhagen plank; adductor slides - Single leg Romanian deadlift; hip thrust; cable hip rotations - Step back med ball shotput to reload the back hip

SEE	WHY	FIX	OR LEAVE IT
He loses the hinge and sits back in the bucket; his belt buckle points at the plate before the front foot lands; the separation number comes in low.	Without back hip range, the pelvis can't turn <i>around</i> the leg — so it turns the whole leg instead. That spends the separation window before the chest has anything to separate from. Less stretch across the side abs and the lat, less snap back.	Get the rotation back, then load it. Driveline's published case paired hip rotation work (wall press dead bug, bear crawl, banded hip abduction) with step back med ball shotput and lateral lunge with reach.	Early hips are only a problem if the chest goes with them. Some pitchers open the hips early and generate all their separation through the mid back instead. Measure the separation, not the hip timing by itself.
His back hip turns inward about 5° less than his front hip does.	A 5° difference in inward hip rotation predicted back and abdominal injuries across 258 professional player seasons — not shoulder or elbow, but core. Tight hips also raise the load on the shoulder, because the rotation has to come from somewhere.	Restore it, then load it. Mobility alone slides back within a week. Range he can't control is range he won't use. Track total rotation per hip.	No. This is one of the few screen findings with a direct published injury link.

LINK 04 · BASE OF THE CHAIN

Hips & pelvis

First segment to peak in the sequence. Its job is to peak **early and get out of the way** so the chest can be accelerated against it.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Back side butt muscle — shortening to extend and rotate; this is what drives hip turning speed. Side abs, working diagonally (internal oblique on the throwing side, external oblique on the glove side) — shortening to turn the hips underneath a chest that's staying put. Deep corset muscle and diaphragm (transverse abdominis) — holding, creating pressure in the trunk. Without it the diagonal sling has nothing to pull against. Deep low back and spine stabilizers (quadratus lumborum, multifidus) — holding, side to side and in rotation.	• When his hips peak, as a share of the delivery — earlier is better • Seated trunk rotation test (isolates hips from chest) • Pallof press hold quality — can he resist rotation before he produces it? • Rotational med ball throw speed, both directions	• Pallof press and half kneeling antirotation holds • Landmine rotations; cable chops and lifts • Rotational and shotput med ball throws — 3 to 6 reps, full rest • Hip thrusts and glute bridges for the back side extender • Step back and rocker patterns to move hip initiation earlier

SEE	WHY	FIX	OR LEAVE IT
His hips peak late in the delivery; hips and chest turn together as one block.	The direction trends that way, but be honest about its strength: this parameter did not separate the high and low torque groups significantly in the 523 pitcher study, so it is weaker evidence than the arm positions. The mechanical story is still clean. A late hip turn means nothing gets handed off, so the arm supplies its own speed and the elbow absorbs the difference.	Start the rotation from the ground earlier: step back and rocker patterns, med ball throws timed off the front foot. Back hip range (link 03) is usually the prerequisite.	Rarely — this is one of the cleaner arm health levers in the research.

SEE	WHY	FIX	OR LEAVE IT
Low hip to shoulder separation on the report, and someone has already declared it the reason he throws 84.	Two findings complicate the usual story. One study found no link at all between separation and fastball velocity at any point in the delivery. A Wake Forest study of 298 pitchers found that more separation at landing came with <i>more</i> elbow load. Separation is a way of loading the chest, not a scoreboard. And a one piece turner is simply built to run less of it.	Chase it only when his chest genuinely isn't turning fast. Then treat the input — back hip rotation, mid back rotation, front side core — not the number itself.	Very often, yes. If he throws hard with modest separation, he's finding his rotation speed somewhere else. Adding separation to a pitcher who doesn't need it can raise his arm bill for nothing.

LINK 05 · LEAD SIDE Front hip

After the foot lands, the front hip stops being a leg and becomes an **axle**. All that speed he built moving forward has to become spin around that point — which only works if the point stays put.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Front side butt muscle — lengthening on landing, then holding to be the axle. This is a braking muscle here, not a pushing one. Side of the front hip — holding; this is the reason the hip doesn't drift forward. Inner thigh — lengthening to decelerate the stride, then stabilizing. Hamstrings — lengthening to control the hip as his chest tips forward over the leg. Deep rotators — supply the inward turn his body rotates over.	• Front hip inward rotation, seated and lying face down • Single leg Romanian deadlift — control and depth • Drop and stick landing quality • Split squat hold time at depth	• Split squat holds at depth, 20 to 45 seconds • Single leg Romanian deadlift; Romanian deadlift with a two second pause at the bottom • Lateral lunge with reach; Copenhagen plank • Hurdle hops with a stuck landing; box drop and hold • Band resisted inward hip rotation; pigeon to half kneeling for range • Half kneeling med ball scoop toss — rotation over a stable front leg

SEE	WHY	FIX	OR LEAVE IT
The front hip keeps sliding toward the plate after the foot lands, instead of parking and letting the body rotate around it.	Driveline defines a good block as the hip staying basically in place from landing to release while the body turns around it. If the hip drifts, his speed stays linear and never becomes chest rotation.	Front leg braking strength first — split squat holds, single leg Romanian deadlifts, hurdle hop stick landings, box drop and hold. Then measure again how fast the knee straightens.	Sliding forward buys extension — releasing the ball closer to the plate makes the pitch play faster than the gun says and flattens the angle. Some pitchers ride out six plus inches of extension on purpose. The bill shows up in elbow load; check it before you decide.

SEE	WHY	FIX	OR LEAVE IT
Limited inward rotation in the front hip on the screen; the front side stalls; his chest turns but the front leg doesn't roll over with it.	To rotate over a hip, that hip has to turn inward. When it can't, the low back tries to supply the rotation instead — and the low back only has about 13° of rotation in total . That's exactly why this shows up as oblique and low back strains. It also forces the chest to turn early, which rushes the arm.	Get the front hip inward rotation back (90/90 work, pigeon to half kneeling), then get strong in it — Romanian deadlift with a two second pause, half kneeling med ball scoop toss.	No. This is the single most common upstream cause of a fault that ends up getting coached at the foot or the arm.

LINK 06 · LEAD SIDE Front knee

The block is a **collision**. Stopping the hips is what makes the chest spin fast — same reason a car stops and the passenger keeps going. A soft knee absorbs the collision instead of bouncing it back up the chain.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Quads — all three jobs in one landing: lengthening on impact, holding at the transition, then shortening to snap the knee straight. How fast that last part happens is the output you measure. Hamstrings — working alongside to protect the knee and control the hip while the quad straightens it. Their ability to brake while lengthening is what makes a violent block survivable. Calf — helps control the knee at the far end of extension.	- How fast the front knee straightens from landing to release — target ~350°/s, flag under 242°/s - Drop jump: how fast he leaves the ground after landing - Nordic hamstring curl — where does he break? - Box drop and stick — does he hold, or does he sink?	- Box drops with a stuck landing; drop jumps; landings from height - Nordic hamstring curls and reverse Nordics (lengthening focused) - Heavy split squat holds at his actual landing angle - Band resisted knee lockouts - Run it in blocks: braking work first, then holding work, then explosive work

SEE	WHY	FIX	OR LEAVE IT
The knee keeps bending through release; he sinks and then pushes. Knee straightening speed under about 242°/s .	Driveline's target is around 350°/s , and they want <i>continuous</i> straightening after the foot lands — not sink then push. Fair warning: a fast straightening knee is also linked to more elbow load. A good block genuinely does raise the arm bill, and buys velocity for it.	Landing and braking capacity first: box drops with a stick, landings from height, band resisted lockouts. Then drills that punish a soft front side.	A softer block is a legitimate low stress strategy for a pitcher whose value is command and movement rather than velocity. It's also the right call for someone whose low back or knee won't tolerate a violent stop.

SEE He lands with what looks like too much (or too little) knee bend, and someone wants to standardize it.	WHY The knee angle <i>at the moment he lands</i> showed no effect on velocity . The normal range is wide — anywhere from 36° to 54° of bend is ordinary. What predicts velocity is what happens between landing and release, not the frame you froze.	FIX Stop coaching the landing angle. Measure how fast the knee straightens instead.	OR LEAVE IT Yes — one of the most coached, least supported cues in the delivery.
SEE The knee snaps into full lockout, violently, right at release.	WHY That's what a maximal block looks like. Very fast knee straightening, very fast chest rotation, and real load through the hamstring, the knee tendon, and the low back.	FIX Nothing mechanical. Build the tissue that has to survive it — Nordics, heavy lengthening hamstring work, back side strength — and keep an eye on the low back.	OR LEAVE IT Leave it. The best blockers in the game do exactly this. Softening it to make the delivery look calmer is a direct subtraction from his velocity.

LINK 07 · LEAD SIDE Front foot & landing

Where and how the front foot lands sets his stride length, how much his hips are allowed to turn, and where the ball comes out — all at once. It's also the position most often **blamed for something that isn't its fault**.

MUSCLES & WHAT THEY'RE DOING Front of the shin — lengthening, controlling the foot from heel contact down to the forefoot. Calf — lengthening to absorb the hit, then holding so the leg becomes a rigid post for the block. Outside shin and deep arch muscle — holding. These decide whether the foot becomes a stable base or a collapsing one. Side hip muscles — holding. Landing control actually starts above the foot, not at it.	TEST IT - Stride length as a share of his height (normal is about 83%) - Where the foot lands relative to a line to the plate - Ankle range — usually the thing capping stride length - Inner thigh length and braking strength - Single leg landing control off a box	LOAD IT - Landing progressions — two feet, then one foot, then sideways - Heavy calf and shin work for absorption capacity - Adductor slides and Copenhagens so a longer stride is tolerable - Broad jumps and lateral bounds for forward power - Tape or a marker on the mound as the constraint — let him find it instead of telling him
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SEE Stride noticeably short — under about 78% of his height.	WHY Stride length is the best supported lower body velocity predictor there is: every extra 1% of his height is worth about 0.7 mph, and it explained roughly a quarter of the velocity difference between pitchers in a study of 39 high school and college arms. Normal is about 83% of height. A short stride also raises his release point and shortens his extension toward the plate.	FIX Find the actual limiter before you add distance — back leg power, ankle range, inner thigh length, or fear of landing. Then use a tape marker so he organizes into it himself.	OR LEAVE IT A short stride raises the release point and steepens the angle the ball comes in on — genuinely useful if he lives on a downhill sinker or a big curveball, and it shortens the time his arm spends under load. But if he lives at the top of the zone with a four seam, the short stride is costing him.
SEE Lands closed — foot planted well across the line to the plate. Crossfire.	WHY A closed landing restricts how much his hips can turn, so the chest has to rotate over a partly locked pelvis. That raises the demand on the low back and side abs, and it can shorten his effective stride.	FIX Only if it's costing him. Address back hip range and stride direction with a lane constraint on the mound.	OR LEAVE IT Crossfire is deception. It changes where the hitter expects the ball to appear, and it's a real weapon for a lefty against lefties or for anyone throwing from a lower slot. If separation, health, and command all hold, this is an identity, not a fault.
SEE Front foot flies open at landing; the toe points toward the on deck circle.	WHY Usually not a foot problem at all. He's turning the foot early to buy rotation his front hip can't give him. It lets the hips leak open early and drains the separation window.	FIX Restore front hip inward rotation first (link 05), then film again. If the foot still opens once the hip has range, <i>then</i> constrain the landing.	OR LEAVE IT An open landing with intact separation and a firm block is just a rotational preference. Check the separation number before you touch it.
SEE Heel first, stiff, audible landing with no roll onto the forefoot.	WHY No absorption at the ankle sends the impact spike straight up the chain into the low back, and forces the knee to do the entire job of the block by itself.	FIX Ankle range plus calf braking strength; teach heel to forefoot landing with landing progressions.	OR LEAVE IT Heel first landing is normal for a ground loader type, and some hard throwing blockers land nearly flat on purpose. If the ankle range is normal and the low back is quiet, it's a strategy.

LINK 08 · TRUNK

Low back & front side core

The low back has roughly **13° of rotation available, total**. It's a transmitter, not a generator. Every degree of rotation the hips and

mid back fail to supply gets demanded here — and it can't pay.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Side abs, working diagonally (obliques) — stretched at peak separation, then shortening hard through the turn. They hit peak activity right when his chest is turning fastest, alongside the glutes. Front abs (rectus abdominis) — shortening to tip him forward over the front leg at release. Deep corset muscle and diaphragm — holding, creating pressure. This is the platform the diagonal sling pulls against. Long back muscles and deep spine stabilizers — lengthening and holding. They pay for whatever the hips and mid back don't supply. This is where oblique and low back strains come from.	- Do his ribs flare and his pelvis tip forward, at rest and in the delivery? - Single leg lift test on the back leg — average pelvis wobble is about 6° - Side plank hold time, both sides - Can he exhale all the way out and keep his ribs down under load?	- Wall press dead bug with a full exhale; 90/90 breathing - Bear crawl and bear position holds - Ab wheel rollouts, side planks, Pallof presses - Suitcase carries and offset load carries - Half kneeling med ball scoop toss; landmine rotation Order matters: pressure and antirotation work <i>before</i> rotational power work

SEE	WHY	FIX	OR LEAVE IT
Ribs flared up, pelvis tipped forward, big visible arch in the low back through the delivery — the "arch and layback" look.	Flared ribs disconnect the rib cage from the pelvis, so the side abs never actually get stretched — the separation you see on film doesn't turn into stored energy. It also stacks an arched low back on top of a rotating low back, which is the exact combination that produces oblique and back injuries.	Front side core work with a full exhale to get the rib cage back over the pelvis, then loading that resists arching, then rotational loading. Don't start with rotational med ball work.	Some of the biggest layback in the sport is just spine and rib flexibility in a guy who tolerates it. If it's painless, the separation is real, and the arm bill is normal, it's a signature.
His pelvis wobbles front to back during a single leg lift test on the back leg.	In 54 high school pitchers, better pelvic control on the back leg came with less load on the shoulder . Average wobble was about 6°. The link was weaker than in college and pro athletes, so treat it as a direction, not a diagnosis.	Balance and pelvic control work standing on the back leg — that's the specific recommendation the authors made.	Worth knowing: it showed <i>no</i> relationship with elbow load or with how hard he pushes the ground. Don't sell it as an elbow intervention.

LINK 09 · TRUNK

Mid back & rib cage

The mid back supplies most of the rotation his chest actually has. Driveline's framing: mid back rotation is what lets the hips open

while the chest stays back. Stiff here, and his separation has to be manufactured at the shoulder or the low back instead.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Small spine rotators (rotatores, multifidus) — segment by segment rotation. Small muscles, big consequences. Big back muscle under the armpit (latissimus dorsi) — it runs from the low back all the way to the upper arm bone, so it is the literal mechanical link between trunk and arm. Stretched at peak layback, shortening through acceleration. Ribs under the armpit muscle (serratus anterior) — anchors the shoulder blade to the rib cage. Working at over 40% of a max effort through acceleration and deceleration. Rib muscles and diaphragm — rib mobility <i>is</i> mid back mobility. A locked rib cage can't rotate no matter what the spine can do.	- Seated mid back rotation, both directions - Rotation on all fours or side lying with the pelvis locked down - How far he leans away from his arm at release (flag past 48°) - How far he tips forward over his front leg at release - Rib position on a full exhale — mobility screens lie when the ribs are flared	- Side lying windmill with a full exhale (Driveline's named drill) - Open books; thread the needle; all fours rotation - Landmine rotation; cable chops and lifts - Rotational med ball throws to load the new range at speed - Lat and chest soft tissue work first if the restriction is tissue, not joint

SEE	WHY	FIX	OR LEAVE IT
Chest and hips turn as one unit; measured mid back rotation is limited.	Without mid back rotation, the chest starts turning the instant the hips do. The arm gets dragged instead of whipped, and the elbow absorbs the acceleration the chest failed to deliver.	Mobilize, then load the new range with rotational med ball work so it sticks under speed. Mobility without loading is gone inside a week.	Stiff chested throwers who generate velocity through a violent block and fast arm speed absolutely exist — and a one piece turner is built that way. If the mph is there and the arm bill is normal, you're solving a picture, not a problem.
SEE	WHY	FIX	OR LEAVE IT
Heavy sideways lean away from the throwing arm at release — the "spine tilt" high slot. Flag past about 48° .	More sideways lean at release comes with more elbow load. Typical is about 34° for over the top guys and 24° for sidearmers. The lean is how a shorter pitcher manufactures a high release point.	Reduce it only if the arm bill is high <i>and</i> he isn't getting paid for the release height. Usually the real fix is a better block, so he doesn't have to lean to clear his front side.	This is how a 6'0" pitcher gets a 6'4" release point and the ride that comes with it. If his four seam plays at the top of the zone <i>because</i> of that lean, taking it away removes the pitch.

SEE	WHY	FIX	OR LEAVE IT
He finishes upright — very little forward bend over the front leg.	Of every position Driveline measured, forward tilt at release tracked with velocity the most — roughly 20% of the velocity difference between pitchers — and it's where extension toward the plate comes from. It also raises elbow load, so it's an explicit velocity for stress trade. And you can't tip forward over a leg that's collapsing, so this is frequently a front knee problem in a chest costume.	Fix the block first (link 06), then hinge and hamstring strength so he can get over the front side without losing his head line to the target.	Finishing upright protects the arm and often the command. For a pitcher whose margin comes from location rather than velocity, staying tall is a defensible choice.

LINK 10 · ARM

Shoulder blade

The platform the arm bone moves on. Where the shoulder blade sits decides how much real layback is available and how long the arm's runway is.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Ribs under the armpit muscle (serratus anterior) — pulls the blade forward and rotates it upward; keeps it flat on the rib cage. Working at over 40% of a max effort through acceleration and deceleration. The single most important shoulder blade muscle for a thrower. Mid back between the blades (lower and middle trapezius) — rotate the blade up and pull it back; holding through cocking, then braking through the finish. Between the blades, deeper (rhomboids) — pull the blade back; braking hard during deceleration. Small chest muscle under the pec (pectoralis minor) — pulls the blade forward and tips it down. Chronically short in throwers, and usually the thing blocking real retraction. Neck to blade muscles (upper trap, levator) — often overrecruited as a substitute for the two muscles above.	- How far the elbow sits behind the shoulder line at landing (flag under 5–10°) - Does the blade rotate upward smoothly as he raises his arm? Any winging on a wall slide? - Small chest muscle length — lying face up, does the shoulder sit off the table? - Prone Y and T strength endurance - Side hip strength — it tracks with shoulder blade control	- Wall slides and bear position reaches; serratus punches - Prone Y / T / W raises; low trap raises; face pulls - Landmine press (upward rotation under load) - Release the small chest muscle before you try to strengthen anything - Pivot pickoff (Driveline's primary drill) and scap retraction throws, cueing the elbow back, not up - Thrower's Ten as the year round base — the evidence supports blade stability, range of motion, cuff strength and endurance gains

SEE	WHY	FIX	OR LEAVE IT
Barely any shoulder blade load — the elbow sits at or under 5° behind the shoulder line at landing, or visibly in front of it.	Pulling the blade back stretches the chest and gives the arm room to travel. Driveline's own pitchers average about 40° at landing with a peak near 57°; ASMI puts it around 20°. Below the floor, the arm has no runway and the elbow supplies the speed instead.	Driveline's stated prescription: pivot pickoff first, scap retraction throws second, with the cue pointing the elbow <i>backward</i> . Back it up with mid back and serratus work.	Short, compact arm actions with minimal blade load are a real deception strategy — less time for the hitter to see the ball. If he throws hard with a compact action, adding load may just add elbow stress.
SEE	WHY	FIX	OR LEAVE IT
The shoulder blade wings off the rib cage, or doesn't rotate upward as the arm goes up.	If the blade doesn't rotate up, the shoulder joint itself has to make up the difference — which pinches the space under the shoulder and cuts how much real layback he can get. Research shows a poorly positioned blade at cocking directly raises the load on the elbow.	Serratus work (wall slides, bear position reaches) and mid back trap work; mid back mobility upstream, since a rounded upper back physically prevents the blade from rotating up. Add side hip work too — the link between hip control and blade control is published.	No — this one shows up on both the shoulder's bill and the elbow's.
SEE	WHY	FIX	OR LEAVE IT
The "inverted W" — both elbows above the shoulder line at landing.	The shape itself has never been shown to be an independent injury risk. A clinical review looking at this directly found that early trunk rotation correlated with injury requiring surgery while the inverted W did not . What is in the data: the arm being roughly level with the shoulders at landing, and the timing of peak layback relative to when the chest turns. Randy Johnson carried an enormous blade load with his elbows <i>below</i> the shoulder line — the load and the shape are separate things.	Don't chase the silhouette. Chase arm level with the shoulders and arm timing. Driveline's example of a real problem was an arm at 103° at landing climbing to 135° — that's the elbow climbing, which is a different finding than an inverted W.	Frequently. If his arm is roughly level at landing and on time when the chest turns, the shape of the arm path is his.
SEE	WHY	FIX	OR LEAVE IT
Both shoulder blades stay locked together — the glove side freezes in place instead of separating from the throwing side.	Driveline's position: blocking with the glove and a firm front side kills shoulder rotation speed — the biggest single contributor to a 90+ fastball — and pulls the neck off the target line. Elite arms show the two shoulder blades clearly disconnecting from each other.	Coach the glove arm to keep moving and decelerate, not to hold a position. See link 15.	Never worth adding on purpose — but know that "firm front side" is still taught widely enough that you may be undoing someone else's cue.

LINK 11 · ARM

Shoulder joint

The arm rotates here at nearly **19 full turns per second** — the fastest motion the human body produces. Then over **225 pounds** of pull tries to yank the arm bone out of the socket while it slows down. Every pitch.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
COCKING → Back of the rotator cuff (infraspinatus, teres minor) peaks, shortening to turn the arm back. At the same instant the front of the rotator cuff (subscapularis) is <i>lengthening</i> to brake that turn and protect the front of the joint. The chest, lat, and front shoulder stretch under load — this is the rubber band that pays for acceleration. ACCELERATION → Front of the cuff, chest, lat, and the muscle beside the lat (teres major) all shorten to whip the arm forward. Serratus and triceps heavily involved. Pros show noticeably more activation here than amateurs. DECELERATION → Teres minor hits its peak while <i>lengthening</i>, fighting the arm bone being pulled forward and inward — higher than the muscle next to it, which is exactly why soreness after outings shows up at that spot and not the other. Back shoulder, rhomboids, traps all braking.	• Is the arm level with the shoulders at landing and at release? • Rotation both ways, and total rotation, comparing throwing side to the other side • Peak layback — is it real, or is he faking it by bending the elbow forward? • Prone horizontal abduction and external rotation strength • Sort out whether tightness is capsule, soft tissue, or just how the bone is shaped — before you treat it	• External and internal rotation at 90°, band and cable • Slow lowering external rotation for the back of the cuff • Prone horizontal abduction; prone external rotation at 90° • Rhythmic stabilization and bottoms up kettlebell carries for reflexive stability • Reverse throw plyo work for braking capacity • Soft tissue first when he's tissue limited: chest, small chest muscle, upper trap, lat, long head of the triceps (Tread's list) • Thrower's Ten as the year round base

SEE	WHY	FIX	OR LEAVE IT
The elbow climbs — arm well above level at landing and rising further into cocking. Driveline's real example: 103° at landing climbing to 135°.	Drifting away from level cuts how much layback he can get, raises elbow load, and makes the joint less stable. Here's the nuance that matters: arm elevation <i>at landing</i> is linked to more load, while arm elevation <i>at release</i> is linked to less. The goal isn't "high" or "low" — it's level at both frames.	Pivot pickoff and scap retraction throws, cued "elbow back," not "elbow down." Driveline pairs these specifically for the climbing arm plus low blade load profile.	Only if his elbow load and his stress per mph are both fine. Arm elevation is one of the more reliably fixable things on the report.

SEE Not much layback — or "fake layback," where it looks like 180° from the side but turns out to be a forced elbow bend rather than the arm actually turning back.	WHY More real layback is linked to less elbow load, not more. Longer arc to reverse the arm means a lower peak force for the same job. Fake layback gets the look without the arc — so he pays the load and doesn't collect the velocity. Tread's root causes: balls heavier than 1 lb, standing too close on plyo wall work, overcuing strikes, an upper half that flies open, guarding after an injury, and tightness in the chest, small chest muscle, upper trap, lat, and long head of the triceps.	FIX Release the tissue first — that's Tread's explicit order — then throw. Long toss to reteach a rotational finish. Cap the ball weights: be selective above 1 lb for high school and college, and avoid 2 lb entirely for youth. Do not drill the position. Layback is an outcome, not an action.	OR LEAVE IT Genuinely limited layback in a guy who tolerates it is a viable, lower stress build. It's also very often a <i>protective response after an injury</i> — the nervous system limiting range around tissue it doesn't trust yet. Forcing range on that athlete is how you get the next injury.
SEE His throwing shoulder turns inward noticeably less than his other shoulder.	WHY The whole body reorganizes around it — this pattern has been linked to changes in how the chest compensates and even to changes in knee mechanics during the pitch. The shoulder isn't the only thing that adjusts.	FIX Figure out <i>why</i> before you stretch anything — capsule, soft tissue, or the shape of the arm bone itself. Track total rotation side to side, not just inward rotation. Then add cuff strength through whatever range you got back.	OR LEAVE IT Some loss on the throwing side is normal adaptation, including bone shape you cannot and should not try to stretch out. Only the soft tissue portion is a target.
SEE The arm arrives at landing still packed and facing down — not turned back at all yet.	WHY Arriving already partly turned over is linked to less elbow load. Arriving packed means the layback happens as a violent snap instead of a long sweep.	FIX This is arm timing, not shoulder flexibility. Move the arm path earlier relative to the lower half — it usually resolves once the hips stop being late.	OR LEAVE IT A genuinely late arm can be deceptive — the hitter picks the ball up later. Weigh it against the elbow load number, which is where it shows up.

LINK 12 · ARM Elbow

At peak layback the elbow takes a large twisting force. Reported values vary widely by study and method, from around 30 Nm up to Driveline's sample average of 101 Nm. What holds across all of them: **cadaveric testing puts ligament failure near 32 Nm**,

below what pitching produces, so the forearm muscles are covering the difference on every single pitch. Fatigue isn't an abstraction.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
The meat on the inside of the forearm (flexor pronator mass) — holding and braking against the elbow being pried open at peak layback. This is the tissue standing between the load and the ligament. Back of the upper arm (triceps) — shortening to straighten the elbow through acceleration. Relying too heavily on this is the "pushing" pattern. Front of the upper arm (biceps, brachialis) — lengthening to brake the elbow after release. A common late outing soreness spot.	• Elbow bend at landing (normal is about a right angle, 75–105°) • Size adjusted elbow load — 6% or higher is the high risk group — and stress per mph • Grip strength fresh versus late in an outing • Forearm palm down strength and endurance	• Dumbbell wrist curls and palm down rotations; hammer rotations • Heavy grip work — towel hangs, plate pinches, thick grip carries • Slow lowering biceps work for braking capacity • Rice bucket or high rep endurance work late in the week • Thrower's Ten forearm block • Understand what this is: armor. It raises how long he can hold up. It does not lower the load itself.

SEE	WHY	FIX	OR LEAVE IT
Elbow noticeably more bent than a right angle when the front foot lands.	A more folded elbow at landing is linked to more elbow load — the layback event compresses into a shorter, sharper arc. A markerless camera study found four things together — how much layback he gets, elbow bend at peak load, elbow bend at release, and when peak elbow bend happens — predicted about 60% of the elbow load.	Shoulder blade retraction so the elbow travels back instead of folding; arm timing work. Forearm strength as armor, not as a mechanics fix.	Short arm actions run a more folded elbow by design and are a legitimate deception and repeatability strategy — especially out of the bullpen. Price the load and decide.
The elbow snaps straight very fast; a triceps driven push finish; the ball cuts and finishes flat.	Faster elbow straightening is linked to more elbow load. Pushing means the chest failed to deliver rotation, so the arm is extending its way to the plate instead of being carried there.	Work Tread's seven causes in order: cap the ball weights; back him off the plyo wall and rotate the back shoulder <i>through</i> the target line (tape a target so it forces rotation); stop overcuing strikes; keep the upper half closed at landing; respect guarding after an injury; release the chest, lat and triceps; and stop chasing fake layback. Long toss is the fastest reteach — pushing visibly loses distance, so the feedback is instant.	If the cut <i>is</i> the pitch — an actual cutter he lives on — you're looking at his weapon, not his flaw. Confirm on ball flight data before you take it away.

SEE	WHY	FIX	OR LEAVE IT
High size adjusted elbow load, or poor stress per mph. The high risk cut used in the research is 6% or higher.	The Wake Forest study of 298 pitchers found the high risk group was spinning the chest fast without the positions to spend it through — less forward tilt at release and a lower arm at cocking. For reference: about 100 Nm of elbow load and over 225 lb of shoulder pull is typical. Driveline reports lefties carry lower loads and better efficiency (16.1 versus 13.2 mph per unit of stress).	Pull several small levers instead of making one big change. Wake Forest's own conclusion was that <i>small improvements across the whole delivery</i> beat any single mechanical fix — their best prediction model only explained about 10% of the variance, so there is no formula. The published levers: • Arm more level with the shoulders at release • More real layback • Chest more stacked and closed at landing • Arm more turned over at landing • Hips peak earlier • Less sideways lean at release • More forward tilt at release	Load scales with velocity — a high 90s arm <i>should</i> read high. Stress per mph is the number that matters. Consider the counterexample: Dominican preprofessional pitchers carried 7.5% size adjusted load with <i>slower</i> hands than US pitchers at 5.9%. High load with low output is the actual red flag.
A "safe" throwing program built on reduced effort — 60%, 70%, 80% intent days.	What he feels and what his elbow takes are not the same thing. Throwing at 75–80% effort still produced 80 to 95% of full effort elbow load. High school pitchers told to throw at 50% still produced 86% of their velocity and 75% of their max elbow load. Perceived effort drops a lot faster than actual effort does.	Manage his workload by throw count and total accumulated load, not by asking for a percentage. "Take something off" is a feeling, not a recovery plan.	Reduced effort still has a place for skill and command work. Just stop counting it as rest.

LINK 13 · ARM Forearm & wrist

The last place he has real control over how the ball spins — and the muscle group standing between the elbow load and the

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Palm down turners (pronator teres, pronator quadratus) — shortening through release. The bigger one also doubles as an elbow protector. Palm up turners (supinator, biceps) — lengthening to control how fast the palm turns down. The balance between these two sets the spin axis. Wrist flexors (inside forearm) — snap the wrist into release, plus they support the inside of the elbow. Wrist extensors (outside forearm) — lengthening to control the wrist; the counterbalance. Thumb side forearm (brachioradialis) — bends the elbow and neutralizes rotation.	• How far his wrist can tilt toward the thumb — this gates any arm slot change • Palm up and palm down range and strength • Wrist flexion and extension strength, both sides • Grip endurance when he's tired	• Wrist roller, both directions • Hammer rotations palm up and palm down; hammer tilts side to side • Band palm down rotations at speed, for quickness not just strength • Plate pinches and towel hangs for grip • Wrist mobility work before attempting a slot change, not after it fails

SEE	WHY	FIX	OR LEAVE IT
Limited wrist tilt toward the thumb — and someone has suggested dropping his arm slot.	Driveline's analysis of the league wide move to lower slots is explicit: dropping the slot changes where the fingers sit on the ball at release, and it takes wrist tilt toward the thumb to keep the spin working through that new position. Without the wrist range, the slot change subtracts the pitch instead of reshaping it.	Build the wrist range and forearm strength first — or don't lower the slot. This is a prerequisite check, not an afterthought.	Not everyone should go low. Their stated profile for a good candidate: lots of wrist tilt available, the ability to generate very high active spin, a natural slot that doesn't need a dramatic overhaul, and a willingness to trade a tick of velocity.
He turns the hand over early, cuts the fastball, or gets under it at release.	How the hand is turning at release sets the spin axis, which sets the angle the ball comes in on — so it moves both the shape <i>and</i> the location, not just the break. And which way the hand naturally wants to turn is treated as a built in preference, not a technique choice.	Tread's cutting fix is environmental, not verbal: move him farther from the plyo wall, tape a target that forces the back shoulder to rotate <i>through</i> the target line, and let the arm find its own slot. Pair it with grip and seam work on a ball flight unit.	Cut is a pitch. A natural cutting action is where a lot of cutters and sweepers come from. Take it to pitch design before you take it to the fix list.

SEE	WHY	FIX	OR LEAVE IT
Weak or quickly fatiguing forearm; grip strength drops late in outings.	Those muscles are the main active protection against the elbow being pried open. When they fatigue, the ligament takes a bigger share of a load that's already near its limit. This is why late inning and late season mechanics changes matter more than they look.	Direct forearm and wrist work plus honest workload management. It raises how long he can hold up; it does not lower the load.	No.

LINK 14 · LAST SEGMENT Hand & fingers

Everything upstream exists to deliver this. How high he releases, how far off to the side, how far out toward the plate, and how the ball is spinning — those four things are what the hitter actually swings at.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Finger flexors (running from the forearm into the fingers) — the last thing to touch the ball. Finger pressure at release sets how efficiently the ball spins. Small hand muscles (lumbricals, interossei) — fine control of where the fingers sit on the seams. Thumb muscles — thumb pressure quietly sets the ball's axis on most grips. Finger extensors — lengthening to time the release. A rushed pattern here is one source of inconsistent spin.	- Spin efficiency on each pitch, on a ball flight unit - Release height, side, and extension — how consistent are they? - Grip strength and finger endurance - Hand size versus his grip choice — a real constraint, not a preference	- Grip trainers, towel hangs, thick bar carries - Finger extension bands to balance out all that gripping - Ball spin drills and seam orientation work with immediate feedback - This is the one link where measurement beats coaching eyes by the widest margin

SEE	WHY	FIX	OR LEAVE IT
Low spin efficiency on a pitch that's supposed to ride or sweep; inconsistent finger pressure at release.	Spin efficiency is a release geometry problem, not an effort problem. The same delivery with different finger pressure produces a materially different pitch.	Ball flight driven pitch design — grips, seam orientation, seam shifted wake work.	A spin inefficient "dead" fastball is a bad four seam and a promising cutter or slider. Change the label before you change the athlete.
SEE	WHY	FIX	OR LEAVE IT
Release point that moves around pitch to pitch.	Some of that is on purpose. Driveline's command work found that variability in the arm near peak layback and in how the hand turns at release actually <i>came with better command</i> — elite arms adjust late to fix what happened earlier.	Chase consistency at foot landing , not at release. Their model is a funnel: varied entries converging on a consistent firing position at foot landing, then diverging again through late adjustments.	Yes — late adjustability is a skill. Drilling it out in pursuit of a "repeatable release" removes the mechanism that saves a pitch that started wrong.

LINK 15 · OFF THE CHAIN

Glove arm

The most overcoached limb in pitching. Two of the oldest cues in the sport — "equal and opposite" and "firm front side" — are both actively argued against by the labs, and there's published data on what the glove arm should do instead.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Back of the glove shoulder and between the blades (posterior deltoid, rhomboids, mid trap) — shortening to open the glove arm out during cocking, then braking. An extended, opened out glove arm at peak layback is what the data supports. Glove side lat and serratus — control the shoulder blade disconnection that lets the throwing shoulder accelerate. Glove side side abs — link the front arm to chest rotation. This is where a glove "pull" either helps him turn or turns into linear drag.	- How bent the glove elbow is at peak layback (more bent = worse, per the data) - How far the glove arm is opened out at peak layback - How consistent the glove shoulder is at foot landing, pitch to pitch - Does his head stay on line through release?	- Prone horizontal abduction and face pulls — on the glove side too, not just the throwing side - Band resisted glove arm braking patterns - Rotational med ball throws that finish with the glove side <i>rotating</i>, not stopping - Fix the back leg first — glove pulling is very often compensation for missing back leg power

SEE	WHY	FIX	OR LEAVE IT
Glove yanks hard to the glove side; the head gets pulled off the target line with it.	Pulling the glove often overcompensates for weak back leg drive, and it makes the chest move <i>forward in a line</i> instead of rotating. Driveline's case against glove blocking: it kills shoulder rotation speed — the biggest single contributor to a 90+ fastball — and drags the neck off line, which hurts consistency.	Fix the back leg first (links 02–03). Then teach the glove side shoulder blade to <i>disconnect</i> from the throwing side blade and let the glove decelerate over the front hip instead of stopping cold.	Some pullers throw hard and command it. If shoulder rotation speed is high and the head stays on line, the glove is doing its job in an unfamiliar looking way.
Dead, passive glove arm; glove elbow tucked in tight and heavily bent at peak layback.	Published data: a more bent glove elbow comes with more force on the throwing elbow, more force on the front of the throwing shoulder, and slower hips . The reverse is also true — a more opened out glove arm at peak layback comes with faster chest rotation and a faster arm. An unused glove arm literally restricts how much the chest can turn.	Target a straighter, more opened out glove arm at peak layback — then let it decelerate. Not "equal and opposite," which contradicts the whole principle that each segment slows down <i>before</i> the next one speeds up.	No — this is the rare glove arm finding with real consequences on the throwing arm.

SEE	WHY	FIX	OR LEAVE IT
Glove shoulder height and chest lean vary pitch to pitch at the moment the foot lands.	Driveline's command analysis found that consistency in the glove shoulder and chest lean at foot landing tracked with how far he misses by . Foot landing is the firing point — the last stable frame before everything spins.	Build repeatability into the foot landing frame specifically, not the finish.	Weigh it against velocity: their framing is that velocity buys margin for error on command. A high velocity arm can carry average command; a soft tossing arm needs elite command. Spend your training time on whichever one he's short on.

LINK 16 · OFF THE CHAIN **Head, neck & eyes**

The head is the reference point the whole delivery is aimed from. It's almost never the cause of anything — but it's a very good indicator.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
Deep front of neck muscles — holding; they keep the head on line against the rotational forces. Sides of the neck (sternocleidomastoid, scalenes) — lengthening to control head rotation; overrecruited when the deep ones are weak. Top of the shoulder into the neck (upper trap, levator) — often substituting for shoulder blade muscles, which is what drags the neck into the delivery.	- Chin tuck hold time (deep neck endurance) - Head position at foot landing versus at release, on video - When he actually finds the target, relative to leg lift - Neck rotation range, both directions	- Chin tuck and deep neck holds - Neck isometrics in every direction, or harness / Iron Neck work - Calm the upper trap down by strengthening serratus and mid back instead - Target acquisition timing drills

SEE	WHY	FIX	OR LEAVE IT
Head whips violently off line at release or in the follow through.	Usually just the cost of slowing down a fast rotating chest — hard throwers' heads move. But when it happens <i>early</i> , the usual cause is glove blocking pulling the neck around, which wrecks his visual reference.	Fix the glove arm (link 15), not the head. Cueing a still head in a high velocity delivery adds tension without changing the cause.	A violent head finish <i>after</i> release does nothing. Distinguish "head moves while he's accelerating" from "head moves after the ball is gone" — the second one is free.
SEE	WHY	FIX	OR LEAVE IT
He finds the glove late — eyes get to the target well after the front foot has started down.	The aiming solution is built during the stride. Finding the target late compresses the window in which he can still steer the delivery toward it.	Target acquisition timing drills; often resolves once his head stops getting yanked by the glove.	Some deliberately "blind" deliveries — head down or turned late — are deception. If he commands it, it works.

LINK 17 · THE WHOLE THING Timing & the sequence

Not a body part — the relationship between all of them. Hips, then chest, then arm, then hand, each peaking **later and faster** than the one before, each slowing down to hand its speed forward. This is the whip, and it's where most "arm problems" actually live.

MUSCLES & WHAT THEY'RE DOING	TEST IT	LOAD IT
The whole chain alternates between producing and braking. The glutes fire, the side abs fire, the lat fires, the cuff fires — but every one of them is also <i>stopping</i> the segment behind it. A pitcher who can produce but can't absorb will show a broken sequence no matter how strong he is. That's why braking and holding work matters more for a thrower than raw pushing strength: the sequence is limited by his weakest brake, not his strongest engine.	• The order and timing of peak speeds on the report • Med ball throw speed versus vertical jump — production versus transfer • Drop jump quality (how well he absorbs and returns) • Variability at foot landing versus at release — they should <i>not</i> be the same	• Set up drills so the pattern happens on its own: step back roll ins, rocker drill, plyo wall work, tempo drills • Cue outward ("drive through the ground," "throw through the catcher's glove"), not inward ("load your back leg") • Train braking and holding, not just pushing • Med ball throws in the actual sequence — low reps, full rest

SEE	WHY	FIX	OR LEAVE IT
Sequence out of order — chest peaks before hips, or the arm peaks before the chest.	The whip only works if each segment slows down before the next one speeds up. Out of order means the arm is generating its own speed — which is exactly the profile that reads as high elbow load with unremarkable velocity.	Change the environment instead of adding cues. Driveline's stance is that weighted implements act as their own pitching coach, and that outward focused cues beat body part cues for full body movements.	Rarely — sequence order is one of the few things close to a genuine universal.
SEE	WHY	FIX	OR LEAVE IT
The delivery doesn't look identical pitch to pitch, and the plan is to make it repeatable.	Research found that skilled pitching is not less variability — it's better organized variability. The chest and hips settle down before the foot lands; the shoulder doesn't settle down until peak layback. The base stays very repeatable while the arm carries the adjustments. Higher velocity pitchers were <i>better coordinated</i> at release, not more frozen.	Train it in the right places: repeatability from the ground through foot landing, adjustability in the arm. Perfect repeatability isn't achievable and isn't the goal.	Yes — variability in the arm is a feature. It's the mechanism by which he saves a pitch that started wrong.

SEE	WHY	FIX	OR LEAVE IT
A hard thrower whose mechanics score poorly on efficiency.	Driveline's own finding from 182 captures: harder throwers looked <i>less</i> efficient than slower ones despite the higher velocity. The harder you throw, the messier the mechanics tend to score. Efficiency and output aren't the same axis.	Judge on stress per mph, not on efficiency by itself.	Frequently. "Inefficient" at 96 is a completely different problem than "inefficient" at 84 — and only one of them is worth risking.

The programming layer

Which lift, for which quality, at which point in the year. Throwing lives at the very fast, very light end of the spectrum — which is exactly why you can't only train there.

HEAVY AND SLOW TO LIGHT AND FAST, MAPPED TO THE DELIVERY			
ZONE	HOW HEAVY, HOW MANY	LIFTS	WHAT IT BUYS THE DELIVERY
Pure strength max strength	85–100% of the most he could lift once 1–5 reps · 3–5 sets · 3–5 min rest	Trap bar deadlift, squat, rear foot elevated split squat, weighted chin up, heavy hip thrust	Raises the ceiling everything else is a percentage of. Most underbuilt pitchers belong here, not in the med ball room.
Heavy but fast strength speed	55–80% of his max 3–5 reps, moved with intent	Trap bar jump, clean pull or hang clean, heavy med ball shotput, sled push	Back leg force against a real load — the ground phase of the delivery.
Light and fast speed strength	30–55% of his max 3–6 reps · full rest	Jump squat, rotational and scoop med ball throws, band resisted rotation	Hip and chest rotation speed. This is the closest thing in the weight room to the delivery itself.
Bodyweight, maximum speed max velocity	Bodyweight or lighter low volume · every rep high quality	Bounds, skaters, depth jumps, plyo ball work, long toss, weighted and underweight balls	How fast he can produce force — the block, the arm, and the whip.
Braking eccentric / absorption	Heavy on the lowering, or very slow tempo	Nordics, reverse Nordics, box drops with a stick, landings from height, slow lowering cuff work	The front leg block and the arm's deceleration. The most commonly skipped zone, and the one that shows up as injury.

Train all three phases, because throwing uses all three

Every lift has a lowering phase, a turnaround, and a lifting phase — and the delivery uses all three in different places. Program them as emphasis blocks: braking first, then holding, then explosive, with load climbing and volume dropping across the blocks.

Map it: the **front leg block is braking into holding**. The **back leg is explosive**. The **arm's deceleration is pure braking**. A pitcher who only trains the lifting phase has trained a third of his delivery.

Build it in the right order across the year

Off season: build tissue and restore range → build pure strength → convert it to speed and throwing intent. **In season:** cut the volume hard, keep the intensity — two full body sessions a week is enough to hold what he built.

The common mistake is running a velocity block on a guy who never built the strength to express it. The other one is running a strength block in season and wondering why his arm feels slow.

Arm care is a separate ledger

The Thrower's Ten has consistent evidence behind it: better shoulder blade stability, more range of motion, stronger and more durable rotator cuff, and better on field performance. Run it year round — high reps, light load, plus real slow lowering work for the back of the cuff.

Understand what it is: **armor, not mechanics**. It raises how much he can tolerate. It does not lower the load his delivery produces — only the mechanical levers in the elbow section do that.

Med ball: the transfer tool

Rotational and scoop throws are the closest thing in the gym to the sequence itself. The drop step side toss and the scoop side toss are the two highest value variations. Program them like sprints: **3 to 6 reps, full rest, quality over volume**.

Put them *after* the front side core is competent. Med ball on top of a flared rib cage and an uncontrolled low back is exactly how oblique strains happen.

Train the athlete you have

A back side, ground loading athlete will express power in hinges, sled work, and lateral drives. A front side, springy athlete will express it in squats, jumps, and reactive work. Both belong in the program — but the ratio should follow the athlete.

If a lift never clicks for someone who is otherwise strong and coachable, that's information about how he's built, not a character flaw.

Weighted balls, with the guardrails on

Driveline's position is that heavier and lighter balls are effective teachers — "their own pitching coach." Tread's guardrail is the other half: be very selective above 1 lb for high school and college, and avoid 2 lb entirely for youth, because at heavy weights the athlete tenses up protectively and produces the exact triceps driven pushing pattern you're trying to remove.

Both are true. Use them as teaching tools, not as a velocity program.

The adaptation ledger

Seven situations where the compensation is the answer. If a pattern fits one of these, the right move is usually to build capacity around it rather than remove it.

CASE 01

It's downstream of a physical limit

The compensation is his best available solution given the range and strength he has right now. Take it away without removing the limit and he just finds a worse one — usually further down the chain, usually in the arm. Fix the limit and the compensation dissolves on its own.

CASE 02

It's how he's built, not a fault

Leg lift height, back leg depth, separation, arm slot, and which way his hand turns all track with how he naturally organizes movement. Coaching a pitcher across his own wiring is the mechanism the framework blames for avoidable oblique strains and arm injuries — and it's the most common reason a "correct" change never sticks.

CASE 03

It buys pitch shape

Dropping the arm slot cost pitchers about **0.15 mph** on average — and gained about **18 rpm** on the four seam, flattened the angle it comes in on, and cut elbow load about **4%**. A "flaw" that trades a tick for deception and health is a good trade. Price it in results, not mph.

CASE 04

It buys deception

Crossfire landings, quick tempo, short arm actions, late target acquisition, unusual release windows. None of these show up on a biomechanics report as an asset, and every one of them shows up in the hitter's swing decisions. A delivery that looks clean and is easy to pick up is worse than one that isn't.

CASE 05

It buys command

Velocity buys margin for error on command; below average velocity demands elite command. If a compensation is what makes him repeatable at foot landing, it's paying for the thing that keeps him employed. Training time is finite — know which axis you're spending on.

CASE 06

The stress per mph is already fine

Load scales with velocity, so a big number on a hard thrower is expected. Efficiency is the real diagnostic. The published bad trade is **28% more load for 1% more velocity**. The published worst profile is high load with low output — Dominican preprofessionals at **7.5%** size adjusted load with slower hands than US pitchers at **5.9%**.

CASE 07

He isn't the guy in the study

Arm slot data splits by level. Pros with lower slots showed lower elbow and shoulder load. High schoolers with lower slots showed higher elbow load. Same change, opposite bill. Don't transplant a big leaguer's compensation onto a sixteen year old and expect the same invoice.

The physics you're actually arguing with

Six ideas that explain most of what a report is telling you. No math required.

Force times time builds the delivery

How hard he pushes × how long he pushes =
how fast he's moving

$$J = F \cdot \Delta t = \Delta p$$

Speed comes from force applied *over time* against the ground. This is why coming off the rubber early and pushing straight up both cost velocity: one shortens the time, the other points the force the wrong way.

Stop the bottom, the top speeds up

Braking the hips against a firm front leg
makes the chest spin faster

conservation of angular momentum

Same reason a car stops and the passenger keeps going. That's why how fast the front knee straightens predicts how fast the chest turns — and why a soft front side eats the energy instead of bouncing it up.

Twist is force times how far out it acts

The same arm speed costs more when the
arm is in a worse position

$$\tau = F \times r$$

This is why *position* matters more than effort at the elbow. An arm off level, too much sideways lean, and a folded elbow at landing all lengthen or misalign the lever — so the same arm speed writes a bigger check.

Longer runway, lower peak

Slow the arm down over a longer arc and the
peak force drops

$$\text{average force} = \text{momentum change} \div \text{time}$$

This is exactly why more real layback comes with *less* elbow load. Fake layback shortens the arc while keeping the look — so he pays the peak force and doesn't collect the velocity.

The chain is a handoff, not a pile on

Hips → chest → arm → hand, each one
slowing down to pass it forward

proximal to distal sequencing

Every segment has to slow down to hand its speed to the next one. That's why "equal and opposite" fails as a cue, and why a broken sequence shows up as elbow load: the arm is generating what it should have been handed.

The hand is where you get paid

Release height + release side + extension +
spin axis = what the hitter sees

approach angle

Everything upstream exists to serve four numbers at the hand. A mechanical "flaw" that improves any of them isn't a flaw — it's pitch design that happened by accident.

Sources

Coaching sources are cited for their published frameworks and thresholds; peer reviewed work is cited for the numbers.

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- The Contribution of Lower Body Kinematics to Pitching and Hitting Performance (OpenBiomechanics Project)

The reference numbers are population averages with real spread — use them to locate a pitcher, not to grade him. Where a coaching source and a research finding disagree, both are shown rather than reconciled. The motor preference material is a coaching framework and is labeled as such.