1. Background and research (1-2 weeks)
    a. Sport Science staff will provide initial research sources (rather than specific research, where to find more info), data sets, and questions to interns
    b. Interns will build a roadmap for the rest of their project (including hypothesis, documentation style and modality, timelines, etc.)
    c. Interns will create a brief report (mini-literature review) (2-3 pages) on initial research sources found and their relation to answering the question
    d. Interns will receive feedback from Sports Science staff on viability of sources (we can provide different or additional sources for them to move on)
    e. First peer review/ performance review
2. Data analysis (3 weeks)
    a. Interns will then start to transform the dataset to start analysis as they see fit
    b. Bi-weekly check ins with Sports Science staff for guidance, Q&A, general housekeeping
    c. Interns will also have opportunities to gain exposure to sports science jobs (i.e. data entry, sports performance technology demos, meeting with other departmental staff members)
    d. Interns will create a logical data workflow with reproducible steps
    e. Each day of work (whatever schedule is set) will see at least 1 meaningful notebook commit to the team repository per Intern
    f. Second peer review/ performance review
3. Conclusion Presentation (1-2 weeks)
    a. Interns will create meaningful visualizations of the data
    b. Interns will present their findings and explain statistical significance
        i. Sampling methods are expected (if applicable)
        ii. Possible bias identification
            1. How do we limit these biases in the future?
        iii. Scalability
            1. What happens if we add additional variables?
            2. Can we use this for other sports? The whole athletic department?
        iv. CUSS
            1. Center
            2. Unusual features
            3. Shape
            4. Spread
            5. BE SPECIFIC!
    c. Interns will create a professional presentation and present to Sports Science Staff, their fellow interns, and 1 original stakeholder (i.e. AT/ S&C coach/ Sport Coach who presented question)
    d. Final peer/ performance review
    e. Clear and actionable set of principles

Introduction: Welcome to Sports Science!

Congratulations! Welcome to the Data Science Internship with Colorado Sports Science. You have been chosen because we believe you have the skills to work through complex problems, collaborate with other team members, and contribute meaningfully to the progress of Colorado Athletics.

If this is your first exposure to sports science, that's okay! This is a data science internship, not a sports science internship. However, there will be challenges to understand background, develop hypotheses, and communicate your findings to key stakeholders. These challenges will make you better problem solvers, better critical thinkers, and most importantly, better data scientists. One of the best skills you can develop working with data is being able to quickly grasp an understanding of the data, understand the questions being asked, and develop the tools necessary to analyze that data.

Sports science is multidisciplinary in nature; it utilizes multiple "departments" to optimize human performance in the realm of sport. Integrating concepts of strength and conditioning, sports nutrition, sports psychology, technical and tactical skills of sport, physiology, and biomechanics can push athletes, teams, and organizations to new levels. Our work is crucial to maintaining the health and performance of our athletes.

With sports science (and most other industries) comes *a lot* of data. You may remember us mentioning 88 million data points per year. We have excellent systems to collect that data, but as with all big data projects, we are always trying to find better ways to use that data. Your job as data scientists is to understand the research topics below, analyze the data, and effectively communicate your findings to our stakeholders.

Blake, our current lead of data science, will facilitate your internship experience. He will provide a roadmap, weekly check-ins, and overall support throughout your experience. He is your resource as you work through complex challenges, wrap your head around new sports science concepts, and communicate your data.

We are looking forward to working with you!

Colorado Sports Science Team

Research Topic #1 Part 1: Running Speeds in Football

Running speeds are one of the most prevalent variables pointed to by the literature when it comes to hamstring strain injury rates. Making sure athletes are achieving enough exposure to high-speed running is crucial to making sure they are prepared for games. However, too much sprinting can contribute to injury risk.

Typically, we see large changes in how often athletes reach their maximum velocity. During training camp, it is sometimes too often, whereas during spring training, it may not be often enough. The threshold we typically define for reaching “maximum velocity” is within 90% of their max. Given the nature of football (wearing pads and helmet), it is rare that athletes will achieve a true max during the season.

Here at CU, we track football players’ max velocities in a few different ways: 1) percentage of maximum velocity achieved during a session for a given athlete, 2) count of velocity efforts within 8 fenced bands, and 3) the athlete’s maximum velocity achieved.

With this context, we want to understand:

1) How often are athletes reaching ≥90% maximum velocity throughout a training season?
2) Should we consider the number of sprinting efforts that athletes are completing?
3) Are relative efforts and bands more advantageous than the absolute bands provided below?
4) How does sprinting exposure (# of efforts, % max reached) relate to incidence of hamstring injuries?

Research Topic #1 Part 1 Data Sets

Catapult Session:

Contains all data collected from Catapult GPS technology. These GPS devices collect GPS data, accelerometer data, and inertial movement analysis data. The point of wearing these sensors is to quantify metrics of external load on the athletes.

Some metrics to pay attention to:

1) **Velocity bands (1-8):** these are all ranges of speeds that athletes had varying *duration, effort count, and distance.*
   a. Band 1: 0-5 mph
   b. Band 2: 5-8 mph
   c. Band 3: 8-10 mph
   d. Band 4: 10-12 mph
   e. Band 5: 12-14 mph
   f. Band 6: 14-16 mph
   g. Band 7: 16-18 mph
   h. Band 8: 18 mph +

2) **Days since last 90 effort:** this is the number of days since an athlete has reached 90% of their maximum velocity. This is often used in sports science, as achieving maximum velocities more regularly has been shown to protect against HSI.

3) **Days since Max Velocity:** this is the number of days since an athlete has reached their all-time maximum velocity. While most athletes may not always reach this regularly, it is an important metric to watch over time.

ACWR – Catapult:

Acute:Chronic Workload Ratio (ACWR) is a key indicator of appropriate training load in athletes. By comparing one's acute load to how much they have worked chronically, we can see if they are in an appropriate range. Generally, higher ACWR (>1.5) have been associated with increased risk of injury. A very low ACWR (<0.8) is associated with loss of fitness, under-training, and increased risk of injury.

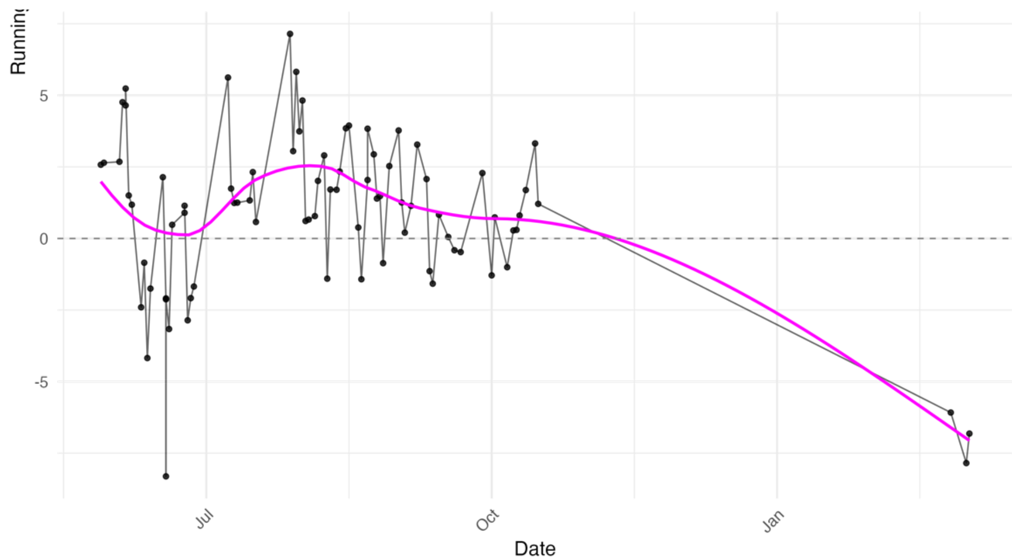
Incident:

Bread and butter. All injuries are categorized and logged. HSI will be deemed "Left Hamstring strain/tear, Right Hamstring strain/tear, Right biceps femoris stain, right hamstring tendon tear, etc." For data analysis, there is no functional difference between a strain and tear. If unsure which injuries qualify under hamstring, reach out to team leader.

Key Stakeholder: Kengo Sugimoto and Tessa Mendoza

Research Topic #1 Part 2: Running Imbalance in Football

Running imbalance is a metric collected by the Catapult Sports GPS Monitoring system. Catapult describes how this metric is collected. Essentially, it is a measure of percent load difference between left and right (calculated by an accelerometer). This metric is potentially important for a few reasons: 1) chronic alterations could be indicative of some kind of change in movement pattern, 2) it can be used as a metric of return to play from injury, and 3) it could be a marker we use to assess risk of injury. Below is an example plot of running imbalance we have used in the past. Essentially, we need to know what a relevant change is at the **team level,** and what is a relevant change at the **athlete (individual) level.**



Variation in % running imbalance can be indicative of a couple of things as well: 1) the athlete is randomly applying increased load to one side (usually most common) and 2) the athlete is compensating due to weakness or strength toward one side. Determining relevant variation, change, and chronic trends at the team and individual level will help inform utility of this metric moving forward.

Figure 1. Example of running imbalance trends over time. This athlete had an ACL reconstruction surgery. The steep drop-off indicates no data for that period (could not run), and then when resumed, a large difference compared to pre-injury levels.

With the running imbalance data, we want to understand:

1) What is the variation at the team level and at each individual athlete level?
2) What is a meaningful change? i.e. what red flags should go off when we see a week-to-week change in running imbalance?
3) Is running imbalance sensitive enough of a metric to use as a prognostic tool versus a rehab tool?

Research Topic #1 Part 2 Data Sets

External Catapult Data

This data contains catapult metrics from 2021-2025 for all players who have been on the CU Football roster. Running imbalance (%) is included in this data set. Negative values represent imbalance to the left, with positive values indicating imbalance to the right. The value given is the average for the entire practice/game, with each "effort" calculated as the imbalance for a given series of movements with a minimum of 8 steps. Catapult also collects running imbalance standard deviation, however, this metric is not currently useful, as it **sums** standard deviations instead of taking the SD from the entire activity. Below is a description of what the metric is supposed to be, and how you can recontextualize this for your variation analysis:

“Standard deviation of the Running Imbalance scores (%) from each running series. Generally low SD (<2) suggests consistent gait, free of injury or significant compensation. SD scores > 4 suggest the athlete is varying or compensating inconsistently” (Catapult Sports).

Furthermore, as this metric is relatively novel, there is question as to how to use it. Catapult Sports describes the use of it for:

Practical applications of Running Symmetry include:

- Rehabilitation - See changes over time as the athlete improves during the process of rehabilitation
- Return to Play - Use Running Symmetry as an objective return to play marker
- Athlete Screening- Use Running Symmetry on a weekly basis to identify changes in running mechanics

As impactful as it may be to say “x% running imbalance is bad” or “x% is good,” try to understand variation and patterns over time. This is why we have provided the example visualization to understand how someone’s “normal” running imbalance could suddenly take a turn.

Key Stakeholder: Kengo Sugimoto and Tessa Mendoza

Research Topic #2: Defining Thresholds in Women’s Sports

An unfortunate reality within Sports Science is the lack of research on female athletes. With this, there can be some misconceptions when it comes to what truly matters in assessing lower-body injury risk within the female athlete population. There are a few key tests that our performance staff use to help them tailor training and limit injury risk. Those are counter-movement jumps, single-leg counter-movement jumps, Nordic hamstring tests, groin tests, and hip tests. All these tests are designed to identify potential weak points in lower body strength that we can target during training. Weaknesses in lower body strength are associated with increased risk of injury, particularly overuse injuries (hamstring strains), or more intense injuries like ACL ruptures.

Women are at a 2-8-fold increased risk of ACL injury compared to men. While there are many factors contributing to this risk, changes in lower body strength may be one area to address to decrease this risk.

With our battery of strength testing, we want to understand:

1) What are meaningful thresholds for strength metrics as they relate to lower body injury risk?
    a. For example, one of our strength coaches uses 5 times body weight (kg) in Newtons for hamstring strength as a cutoff for injury risk. Is this supported by our data?
2) What trends in strength do we see across the women’s team sports?
    a. Soccer, lacrosse, volleyball, basketball.

Research Topic #2 Data Sets

Incident:

Bread and butter. All injuries are categorized and logged. HSI will be deemed “Left Hamstring strain/tear, Right Hamstring strain/tear, Right biceps femoris stain, right hamstring tendon tear, etc.” For data analysis, there is no functional difference between a strain and tear. If unsure which injuries qualify under hamstring, reach out to team leader.

VALD Performance:

VALD is a company that supplies various sports performance testing equipment. For testing, we primarily reference the NordBord™, an eccentric hamstring strength testing machine. We are interested in hamstring max force (both total and unilateral), hamstring average percentage imbalance, and strength relative to normative data. Furthermore, VALD Performance contains the ForceFrame™, a device that measures glute strength and groin strength. Essentially, it is 2 tests; one where you are squeezing like you have an exercise ball in between your legs, and one where you are trying to spread your legs outward against a resistance.

For NordBord™ and ForceFrame™, we tend to use max force left, max force right, max bilateral force, and average imbalance (%). **Abduction is glute strength**; **adduction is groin strength.**

Performance Normative Data:

VALD release normative data for each sport by position, similar height, weight, and age. This normative data is how athletes “stack up to the bell curve.”

VALD Normative Datasets

Normative data sets from VALD are released every calendar year. They take all tests from athletes across skill levels, positions, ages, sizes, etc., and release standards. This is one of the easiest ways to reference how an athlete’s strength is compared relative to similar athletes.

Key Stakeholders: Skylar Rubalcaba and Frances Stephenson

Research Topic #3: Soft Tissue Watch Dashboard Validation

Hamstring injuries in American football are the key preventative lower-body injury our team is working to address. Using input from athletic trainers, strength staff, and performance staff, we have assigned athletes into 4 hamstring risk categories: high, medium, low, and routine. Using these assignments, can your team determine how accurate our categorization methods were? If our accuracy was low, can your team find a stronger variable(s) in determining hamstring risk?

When we attempt to look at hamstring strain injury (HSI) risk, we must consider multiple factors. Strength of the hamstring muscle, history of injury, imbalances between left and right, hydration, etc., all affect the potential risk of HSI. We currently place athletes on the “soft tissue watch list” in low, medium, and high priority based on various risk factors ***we believe*** to be significant, and in some capacity, have been shown in the research to be significant.

For context, there has been research to support that many of these metrics contribute to HSI risk. Previous ACL or HSI is typically the strongest predictor of future injury. Positional normative data difference (%) describes how their hamstring strength is relative to other athletes of the same position, across the NCAA. Average imbalance describes the difference in force (%) between the two legs. Make sure you have read:

> *Wing, Chris MSc[1]; Bishop, Chris MSc[2]. Hamstring Strain Injuries: Incidence, Mechanisms, Risk Factors, and Training Recommendations. Strength and Conditioning Journal 42(3):p 40-57, June 2020. | DOI: 10.1519/SSC.0000000000000538*

Previous ACL/HSI?	Positional Norm % Difference	Average Imbalance (%)	Trend	Test Date
	-47	31	Neutral	12/19/24
Left Hamstring strain/tear	-13	53	Down	03/17/25
Right Hamstring strain/tear	-15	12	Down	04/09/25
Left Hamstring strain/tear	-11	7	Up	04/07/25
Left Hamstring strain/tear	-14	3	Up	04/07/25
Left Hamstring strain/tear	-27	10	Neutral	03/17/25
	6	24	Neutral	01/09/25
Left Hamstring strain/tear	-2	22	Down	04/14/25
	-7	30	Neutral	07/15/24
	-19	12	Neutral	12/20/24
Left Hamstring strain/tear	-3	7	Neutral	02/19/25
Left Hamstring strain/tear	-33	3	Down	04/04/25
Left Hamstring strain/tear	-8	0	Up	04/12/25
Left Hamstring strain/tear	8	17	Neutral	03/17/25
Left Hamstring tendon injury	-16	9	Up	03/18/25
	-30	6	Neutral	01/09/25
Left Hamstring strain/tear	-22	18	Down	04/14/25
Left Hamstring strain/tear	-25	3	Down	02/24/25
Right Hamstring strain/tear	-15	10	Up	02/12/25
Right Hamstring strain/tear	18	2	Neutral	01/31/25

Figure 2. Example of high-risk individuals for soft tissue watch dashboard.

We are looking to understand:

1) Does simply being deemed as **high** risk on the soft tissue watch list predict HSI incidence?
2) If so, how do the **components** of the watch list **predict** subsequent HSI injury risk?
3) If the components of the watch list are predictive of HSI, can we establish better thresholds as being flagged?

Research Topic #3 Data Sets

Incident:

Bread and butter. All injuries are categorized and logged. HSI will be deemed "Left Hamstring strain/tear, Right Hamstring strain/tear, Right biceps femoris stain, right hamstring tendon tear, etc." For data analysis, there is no functional difference between a strain and tear. If unsure which injuries qualify under hamstring, reach out to team leader.

VALD Performance:

VALD is a company that supplies various sports performance testing equipment. For testing, we primarily reference the NordBord™, an eccentric hamstring strength testing machine. We are interested in hamstring max force (both total and unilateral), hamstring average percentage imbalance, and strength relative to normative data.

Performance Normative Data:

VALD release normative data for each sport by position, similar height, weight, and age. This normative data is how athletes "stack up to the bell curve."

Soft Tissue Risk Status:

Divided into high, medium, and low. Combines 4 factors: previous ACL/HSI injury, positional normative data % difference, average % strength imbalance between legs, and trend (if they are getting stronger or weaker). These categories are then subjectively interpreted, and athletes are categorized.

Strength Testing Data:

A Hamstring: Quad ratio is a measure of how strong an athlete's hamstring is compared to their quadricep strength. Both of these numbers are taken from VALD weightroom strength tests. This is a valuable number in understanding how these two bodily systems interact with each other, specifically in determining lower body injury risk.

Wellness:

The University has a vested interest in how athletes perceive how their training programs, schoolwork, practice, and competitions affect their mental, physical, and emotional wellbeing. Therefore, the athletic department collects data related to how athletes are feeling, how they slept, where they are sore, and how they are doing overall. This data is collected and stored in Teamworks AMS, where scores are converted to fit the same scale and present a standardized score for coaches, support staff, and athletic trainers to interpret.

Key Stakeholders: Anthony Pass, Kengo Sugimoto, and Tessa Mendoza

Research Topic #4: Reactive Strength Index

Reactive strength index (RSI) (refer to article for more context; don't worry about how it is measured by Output) is a measure of how effectively an athlete can utilize the stretch-shortening cycle (SSC) during explosive movements. The SSC is essentially the ability of the elastic components of the muscle to store energy and release it to produce explosive movements.

One way to think about this is thinking of the difference between a running jump and a jump from holding a squat. When you are running into a jump, the elastic components of the calf muscle and the leg act to transfer energy and propel you upward. When you jump from holding a squat, you simply push yourself upwards with no transfer of elastic energy. One uses a rubber band; the other is more like a throw.

RSI is calculated from the ratio of jump height to ground contact time. In the case of a drop jump, athletes will step off a box (18 inches above the force plates), land and then immediately try to jump. Changes in RSI across days and weeks can be indicative of neuromuscular readiness, as RSI will decrease with fatigue. Here is a link to a drop-jump example. Feel free to go to the weight room with Blake if you want to see the force plates and visualize this.

RSI levels that are higher indicate better explosive training and neuromuscular readiness. Comparing athlete to athlete will give an idea of how explosively trained they are. Comparing RSI within an athlete will give a better idea of neuromuscular changes (days to weeks) and explosive training effects (months to years).

Keep in mind, any intra-athlete changes in RSI throughout the season (week-to-week) will almost certainly be the results of either 1) fatigue (lower RSI due to neuromuscular fatigue) or 2) measurement variability.

We want to understand how RSI fluctuates with Men's Basketball:

1) Are changes in RSI related to team game performance?
2) Are changes in RSI related to individual statistic game performance?
3) Is the previous week's load related to RSI?
4) What is each athlete's variation in RSI? What is a meaningful change in RSI for the team, and for the athletes?

You **should** also read, "The Use of Contact Time and the Reactive Strength Index to Optimize Fast Stretch-Shortening Cycle Training" (in the intern folder) to add more context. It isn't necessary to understand the full concept of RSI for the data analysis, but if it helps for your understanding, please read beyond the information provided.

Question 4 Data Sets:

VALD – ForceDecks

Force plates are the platforms we use to transduce changes in force overtime with various types of jumps. RSI is calculated during a drop jump test, using their calculated jump height and the time they were in contact with the plates while initiating the jump. In addition to using RSI, you can use Jump Height (flight time, inches) to see how that may change.

MBB – Statistic Tracking

General game statistics for basketball players. Contains minutes, points, rebounds, assists, steals, plus/minus. Feel free to pull additional data from public domains. This data can be used to look at individual (shooting percentage, points, etc.) and team performance (wins and losses) across the season in relation to RSI (marker of fatigue).

Kinexon Session

This is the tracking wearable that basketball uses for all practices and games. Contains measurements of components of player load.

Key Stakeholder: Tessa Mendoza