Calling Recursive Functions and Chaining JSON Data for Evaluating Dr. Bijan Mazaheri's LACCTiC API

Tony DiRubbo
School of Information Studies, Syracuse University
IST 652: Scripting for Data Analysis
Hernando Hoyos
November 26th, 2024

Abstract

The sport of cross country running is unique as the terrain and conditions races occur on can be drastically different from one another. Bijan Mazaheri, a former PhD student at CalTech, created an algorithm to score and compare races taking place on different courses and conditions. Mazaheri offers an API to allow others to use the data from his algorithm. Three research questions were tested to explore and evaluate the ranking made by the algorithm. The 2023 NCAA Division I Cross Country Championships will be the race of focus for this analysis. La Salle NC State, Montana State, and Providence had the highest mean improvement when racing against their team predictions. The top individuals generally found themselves getting faster from year to year, with their fastest races not happening at the national championship. Range or consistency of performances did not appear to be a factor with how a runner placed at the championship. The source code for this analysis is included in a Jupyter Notebook meant to accompany this report, and all outputs for each research question are saved as .csv documents.

A Brief Explanation of Cross Country Scoring

In the sport of cross country (often abbreviated xc), multiple teams of seven runners race at the same time on a given course. The first five runners to finish for a team score based on their place, with the winning team having the lowest total score. For example, a team that scores 173 points, placing 1st, 2nd, 54th, 57th, 59th, loses to a team which scores 129 points, placing 3rd, 7th, 21st, 42nd, 56th, despite having two runners finish before the second team's first runner.

The LACCTiC Algorithm and API

With cross country races occurring on different courses which can greatly vary in terrain, weather conditions, or distance (often 6km [3.75 miles] to 10km [6.25 miles]), many coaches, fans, and media outlets have sought to find methods of comparing results from different races and courses to establish effective rankings and predictions for future races. Bijan Mazaheri, at the time a PhD student in Computing and Mathematical Sciences at the California Institute of Technology, is a former collegiate runner for NCAA Division III staple Williams College. Mazaheri wanted to try and use his computational and statistical coursework to develop an algorithm which could make accurate predictions. Mazaheri's result is LACCTiC, or Logarithmically Adjusted Cross Country Time Comparisons, a website which takes in all NCAA cross country races and converts performances to a predicted 5000m track time (a more consistent way to compare different performances). This created performance metric is declared as a TiC, Time Comparison, and according to the website "the primary component in your TiC score is how you perform relative to your peers in cross country races, and how your peers perform relative to others." Values such as TiCs and race significance will fluctuate throughout a given season (August - November of the calendar year). Rankings and race simulations are done through a Markov chain Monte Carlo (MCMC) approach which involves simulating the race thousands of times and reporting the most frequent outcomes and rankings. Mazaheri actively encourages students to conduct analysis on his website to test significance and offers an API to allow data to be imported instead of requiring web scrapping techniques.

Exploring the API: Cleaning the Data and Research Questions

Mazaheri's API does not include python or any other language packages, it simply is a collection of webpages and JSON documents which can be filtered by identification numbers (IDs). There are three main sources included in the API: runner pages - these pages show runner information and their results from each race they participated in. Race pages - these pages show results from a particular race. Team pages - these pages show roster information of any runner who has ever raced for a particular team. These three source types all have drastically different JSON structures due to the nature of what each source document is trying to collect. A method to read the JSON on a team source page would be incapable of reading the JSON of a runner's page. To reduce repetitiveness of reading in the data. Python functions will be created to read in each data source by ID number when needed. This will also allow for future reproduction of the code and future analysis. This evaluation will primarily focus on reading the race and runner source types, team pages will be ignored for this analysis because needed team members for race will be within a given dataset for that specific race. Three research questions will be tested to explore and evaluate the ranking of the algorithm. In a given race, which teams performed the best and worse based on their predicted place by

the LACCTiC algorithm? After reading an individual's source page, can it be seen if they have had significant improvement from year to year? Which individuals at the national championship were the most consistent racers, and which individuals had extreme (fast and lower or slow and higher) performance TiCs?

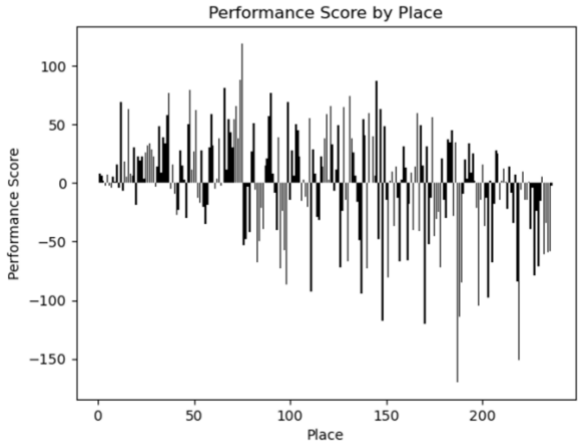
Main Race of Focus: The 2023 NCAA Cross Country Championships

The 2023 NCAA Division I Cross Country Championships, hosted by Virginia University, will be the race of focus due to a few factors. This meet is the final Division I championship race and will be the focal point of every team's end of season goals. There is no race beyond this to plan for, every competing team and individual's NCAA season will end at this meet. This race is also a recent national championship and will reflect modern changes Mazaheri made to the algorithm. The race data will be imported for analysis using one of the functions mentioned above and defined in the source code.

Research Question 1 (Race Source Based): Which teams performed the best and worst based on their predicted place by the LACCTiC algorithm.

The function written to read in the race source data was called to take 2023 NCAA XC Championship race ID and convert the associated page into structured data. A column was added which took the LACCTiC predicted place for an individual and found the difference between the actual place. For example: Habtom Samuel's *performance_score* of 6 means he performed 6 places better than expected. A negative *performance_score* means a runner performed worse than expected.

A trace plot of the *performance_score* by placement in the race can be used to get a good feel of how the predictions performed throughout each place. Figure 1 shows such a trace plot, created by a function



Throughout the placement there is a standard randomness of high and low *performance_scores*. As the axes approaches the end of the racers, there are more negative *performance_scores*, this makes sense as individual who do not do as well are going to get beat by individuals who perform better, and thus will be shifted to the end of the race.

The table can be "grouped by" or pivoted so that teams can be the emphasis from this race table. The smallest *performance_score*, average *performance_score*, median *performance_score*, and maximum *performance_score* for each time will be described by this pivot and displayed in Figure 2.

Figure 2 – Performance Scores by Team

team	Min	Median	Mean	Max
Air Force	-2	25	25.333333333333332	60
Alabama	-87	-53	-53	-19
Arkansas	-170	-7	-20.714286	58
BYU	-35	2	4.166666666666667	48
Boise State	32	32	32	32
Butler	-68	-6.5	-10.875	57
CBU	-73	-24	-27.4	12
Cal Poly	-12	-12	-12	-12
Charlotte	-3	-3	-3	-3
Cincinnati	10	10	10	10
Colorado	-81	-13	-19.444444	28
Duke	38	38	38	38
East Tenn. St.	19	19	19	19
Eastern Kentucky	-41	-32	-28.2	-14
Florida State	-98	1	-23.2	9
Furman	4	4	4	4
Georgetown	-24	8.5	14	74
Gonzaga	-93	3	-15.6	20
Harvard	-57	5	5	50
Illinois	-67	-67	-67	-67
Iona	-85	-14	-11.8	50
Iowa	43	43	43	43
Iowa State	-39	28	20.571428571428573	77
Kansas	-48	-48	-48	-48
Kent State	-18	-18	-18	-18
La Salle	13	39	39	65
Liberty	8	8	8	8
Loyola (Ill.)	2	8	8	14
Michigan	-16	23	16.428571428571427	60
Michigan State	-49	-49	-49	-49
Mid. Tenn. State	-105	-105	-105	-105
Montana State	-17	32	27	66
NC State	-9	29	28.4	62
Navy	23	23	23	23
New Mexico	-118	7.5	-16.333333	56
North Carolina	-71	1	-0.1428571	63
North Texas	15	15	15	15
Northeastern	-7	-7	-7	-7

Northern Arizona	-50	5	0.625	26
Notre Dame	-120	4	-3	79
Oklahoma State	-21	5	14.142857142857142	69
Ole Miss	81	81	81	81
Oregon	-29	-21.5	-21.5	-14
Portland	-53	9	3.2857142857142856	35
Princeton	-45	39	25	59
Providence	-15	27	27	69
Salt Lake	48	48	48	48
Santa Clara	-19	-19	-19	-19
Stanford	-73	-1	-0.6666667	88
Syracuse	-24	25.5	20.666666666666668	55
Tennessee	-72	-13	-10.6	77
Texas	-42	2	1.2857142857142858	45
Texas A&M	-67	-26	-26	15
Tulane	-6	11	11	28
UTEP	30	30	30	30
Villanova	-59	-6	-12	37
Virginia	-151	-37	-32.857143	38
Wake Forest	-94	40	19.714285714285715	51
Weber State	-14	-14	-14	-14
Wingate	87	87	87	87
Wisconsin	-114	-0.5	-5.6666667	119

Some individuals only have 1 runner, who qualified as an individual, which is why the min, max, median, and mean *performance_scores* all have the same value for a few observations. La Salle NC State, Montana State, and Providence had the highest mean *performance_scores*. Virginia, Eastern Kentucky, CBU, and Texas A&M were the teams with the three lowest *performance_scores*.

Research Question 2 (Runner Source Based): After reading an individual's source page, can we examine if they have had significant improvement from year to year

With most runners spending three to five years in the NCAA system, the goal is to get faster and have better performances as an individual progresses throughout their college career. The output created by calling an individual's race data from a created function can be grouped by year to see the fastest (lowest) TiCs per year, and where that race occurred. The race-id of that race is also included if the race which the TiC occurred wanted to be further analyzed, using the function developed from research question 1. Figure 3 shows the race progression for the first three finishers at the 2023 NCAA National Championship.

Figure 3: TiC Improvement by Top NCAA Runners

First Place Finisher Graham Blanks (Harvard)

date	modern_tic	race	race_id
2021	6.70872275	Coast-to-Coast Battle in Beantown	3037
2022	6.68948531	Cowboy Jamboree	4890
2023	6.67722422	Battle in Beantown	7260
2024	6.68736265	Ivy League Heptagonal Cross Country Championships	9563

2nd Place Finisher Habtom Samuel (New Mexico)

date	modern_tic	race	race_id
2023	6.678969274759291	2023 Mountain West Cross Country Championships	7135
2024	6.676649505031127	2024 Mountain West Cross Country Championships	9066

3rd Place Finisher Ky Robinson (Stanford)

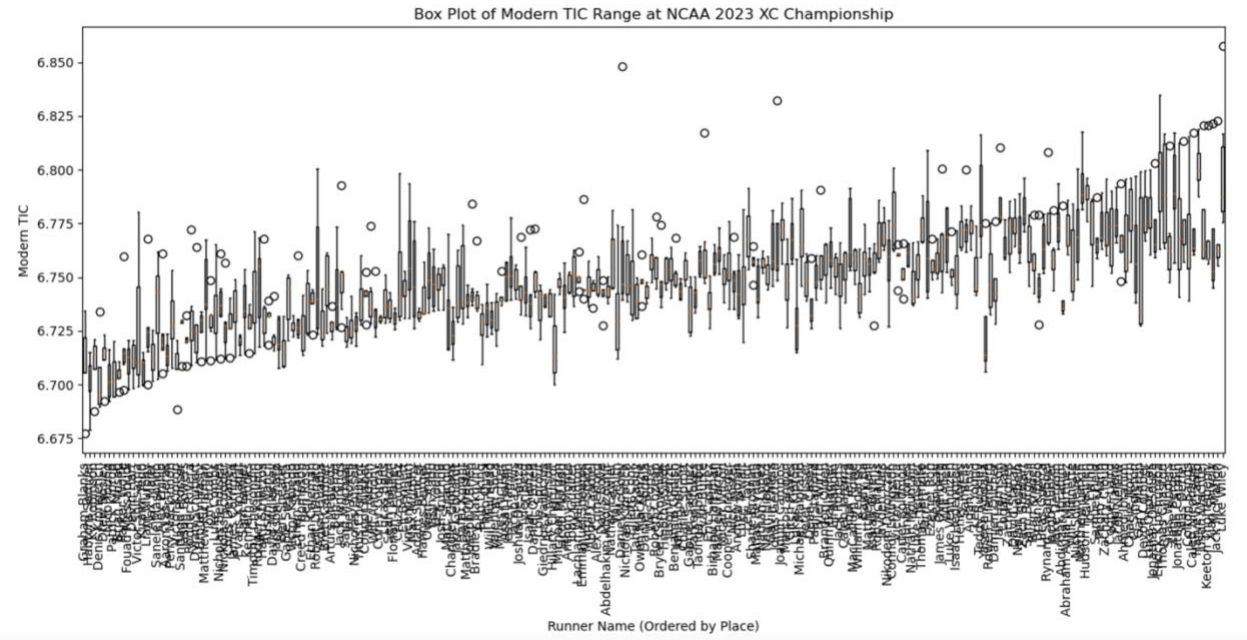
date	modern_tic	race	race_id
2021	6.705651772250759	Battle Born Collegiate Challenge	2146
2022	6.694649356065385	2022 Pac-12 Cross Country Championships	5671
2023	6.68764894	2023 Pac-12 Cross Country Championship	7154

Each of these top competitors follow a specific trend, while they do get faster every year. Their fastest race is not the national championship, as this race is usually a tactical affair where the competition goes out slower to have energy reserved for the last few kilometers of the race.

Research Question 3 (*Joining* Runner and Race Sources): Which individuals at the national championship were the most consistent racers, and which individuals had extreme (fast or slow) performance TiCs.

This final research question is the most complex as it requires joining the two different types of source documents together. A for loop was created to iterate through the ID for each runner in the race and a large data frame of all race performances for individuals from 2023 was created (step-by-step instructions included in the source code). This table was then joined with the original race table for the analysis.

The range of performances by individual, sorted by place, can be visually illustrated via the boxplot in Figure 4. For reference: Graham Blanks won the race and Luke Wiley finished last.



The range of TiCs does not appear to be significant with the individuals finishing place, as there are individuals with larger and smaller boxplots throughout the field. This joined table can be grouped by the individual and their best and worst and average TiC's as well as their TiC range as shown in Figure 5.

Figure 5: TiC Ranges for NCAA Competitors

runner_name	min_tic	median_tic	max_tic	tic_range	NCAA_Place	NCAA_tic
Corey Gorgas	6.72884976	6.730625652670508	6.7320701137592485	0.00322036	62	6.72884976
Adam Spencer	6.729662989205973	6.732602741302516	6.735698140465631	0.00603515	70	6.732602741302516
Giedrius Valinicius	6.73600412	6.741542304470381	6.742292538392311	0.00628842	96	6.741542304470381
Evans Kiplagat	6.713863915112963	6.721170469764332	6.723162253793965	0.00929834	33	6.713863915112963
Michael Morgan	6.742251897166516	6.746253355679435	6.751857755892617	0.00960586	99	6.742251897166516

Anthony Monte	6.74253811 1249968	6.75027010 70181494	6.75248793	0.00994982	101	6.74312445 9125133
Daniel Abdala	6.73770471 0207905	6.74410673 4487504	6.74769326	0.00998855	117	6.74769326
Florian LePallec	6.72580291	6.72940265 1183665	6.73586580 2105118	0.010062889 023178201	65	6.72940265 1183665
Victor Kibiego	6.72235903 0074301	6.72652400 3498404	6.73245215 8570489	0.010093128 496187376	44	6.72235903 0074301
Jona Bodirsky	6.73933013 2459458	6.74339402 1807408	6.74953664 4446017	0.010206511 986559086	124	6.74953664 4446017
Nathan Lopez	6.75212780 84614185	6.75667526 7717867	6.76241222 4942537	0.010284416 481118441	141	6.75553089 6122517
Hunter Jones	6.75478669	6.76144746 8847736	6.76592184 1595796	0.011135148 802225991	171	6.76592184 1595796
Abdelhakim Abouzouhir	6.73801129 6225018	6.74299035 1278875	6.75015679 0547235	0.012145494 322217232	109	6.74432327 5813226
Acer Iverson	6.73198639 2959061	6.73692506 0578807	6.74418336 1997813	0.012196969 038751782	97	6.74181527 5933458
Abdel Laadjel	6.73560394 2998587	6.74472220 3733022	6.74871422 0798309	0.01311028	106	6.74377857 1952865
Sean Maison	6.72918766 9848135	6.73618816 9809682	6.7427902	0.013602533 365815184	64	6.72923680 9437922
Said Mechaal	6.71761674 8519602	6.72307724 3363161	6.73150833 4292262	0.013891585 772659809	55	6.72702319 4044141
Birhanu Harriman	6.75126851 97333955	6.75615560 3066546	6.76532986	0.014061339 396234551	131	6.75126851 97333955
Brian Musau	6.69642548	6.70543847 6073404	6.71064164 3318921	0.01421616	8	6.69642548
Taonga Mbambo	6.75024064 3137691	6.75816352 1502879	6.76447984 2404745	0.014239199 267053415	128	6.75024064 3137691
Will Muirhead	6.72351084 1400881	6.73021198 1681421	6.73831564 5138784	0.014804803 737903605	85	6.73831564 5138784
Timothy Sindt	6.74408962 9359903	6.75351479	6.75913425 3959296	0.015044624 599393153	121	6.74839855 5478497

Matthew Forrester	6.73146924	6.738379573191102	6.7465272439693384	0.015058003620648464	80	6.736506416154732
Noah Hibbard	6.744310787692703	6.753490917811547	6.759571715912866	0.01526093	142	6.7555847809972525
Kirami Yego	6.699673004583628	6.710174219040649	6.71514278	0.015469775369552075	13	6.6999603466831115
Nicholas Russell	6.718047847098761	6.727300212542684	6.733561602956721	0.015513755857959666	57	6.727300212542684
Charlie Sprott	6.7458735953831175	6.749915719784511	6.7614656843453504	0.015592088962232964	125	6.749915719784511
Arturs Medvedds	6.720890161537941	6.726976444243939	6.736505875285801	0.015615713747860305	52	6.724749486997741
Myles Richter	6.736933295322778	6.739056820412054	6.752907165078366	0.015973869755587344	87	6.739027475602313
Jacob Lewis	6.73990291	6.746927154819827	6.756008986778307	0.01610608	90	6.73990291
MacCallum Rowe	6.74673836	6.758573491183354	6.762933337322535	0.01619498	160	6.762933337322535
Parker Stokes	6.733512288910981	6.743100070378412	6.75013235	0.016620058172469143	127	6.75013235
Aaron Las-Heras	6.706709933908979	6.713347006453905	6.723591642075497	0.016881708166518017	18	6.706709933908979
Assaf Harari	6.739027530330598	6.750199619956795	6.75705287	0.01802534	88	6.739027530330598
Shane Brosnan	6.746390240797565	6.757245271339885	6.764569246839488	0.01817901	139	6.7552077412842815
Lachlan Wellington	6.74356051	6.750419366147240 5	6.761785130010931	0.018224620771380984	103	6.74356051
Logan Law	6.758575424572552	6.76028538	6.776996049215331	0.01842062	191	6.776996049215331
Alex Comerford	6.741154133929103	6.744050933743807	6.759652089847464	0.018497955918360454	107	6.744050933743807
Eli Nahom	6.742193479257098	6.754462032414128 5	6.760793416644335	0.01859994	156	6.760793416644335

Sean Kay	6.74936906 4194892	6.75653035	6.76805093 3913535	0.01868187	177	6.76805093 3913535
Taha Er-Raouy	6.73087597 2493378	6.73898187 0979618	6.74966939 7650429	0.018793425 157050514	115	6.74698757 1928039
Ezekiel Rop	6.74905552 3482036	6.75429286 01271415	6.76805088 0750823	0.018995357 268787316	176	6.76805088 0750823
Lex Young	6.73480377 88637525	6.74516990 3653639	6.75426843 1937051	0.01946465	74	6.73480377 88637525
Jayden Nats	6.76266298 6037666	6.76895279 60381435	6.78223855 3681159	0.019575567 643492775	166	6.76394841 6563812
Matthew Neill Hudson	6.74343533 6257392	6.75629770 8632497	6.76346770 9561272	0.020032373 303879858	163	6.76346770 9561272
Heikkinen	6.77622668 04484135	6.78731617 41771995	6.79639498 0731633	0.020168300 283219587	208	6.78612310 1935574
Wes Porter	6.74785606 7522642	6.75866385 2367929	6.76809908 0703687	0.02024301	118	6.74785606 7522642
Austin Vancil	6.71862335 5729129	6.73177811 36366515	6.73906875 8656647	0.020445402 927518508	39	6.71862335 5729129
Paul Stafford	6.73948317 9158066	6.74752883 4511685	6.76004322 1908877	0.02056004	152	6.76004322 1908877
Henry Myers	6.76289366 71540485	6.77176568 1257912	6.78350018 9174347	0.02060652	182	6.77176568 1257912
Aidan Ross	6.76252308 6027257	6.77345849 0254296	6.78337644 2656813	0.020853356 629555897	184	6.77282453 8224454
Murphy Smith	6.73657814 9921457	6.74372405	6.75743834 3620424	0.020860193 698966967	105	6.74372405
Ethan Coleman	6.72330482 4092769	6.73849002 5973287	6.74422995 8137824	0.020925134 045055138	48	6.72330482 4092769
Josh Truchon	6.73502364 9371845	6.75221950 0944274	6.75598965 8084353	0.020966008 712507644	75	6.73502364 9371845
Davis Bove	6.72750254 3646287	6.74338159	6.74858223 9186035	0.021079695 539747867	108	6.74421433 69966905
Matthew Farrell	6.75159289 5808918	6.76234266 20060885	6.77320333 1242475	0.021610435 433556674	132	6.75159289 5808918
Santiago Prosser	6.70868655 37724565	6.72962365 1415854	6.73030270 7005332	0.021616153 232875135	21	6.70868655 37724565

Victor Neiva	6.74367567 1387599	6.76061250 3657642	6.76549543 5988193	0.021819764 600593317	169	6.76549543 5988193
David Slapak	6.76447962 8022215	6.77278741 7413385	6.78635878	0.021879150 900955047	193	6.77789147 1425465
Thomas Termote	6.76617192 7804859	6.77231880 93370075	6.78811594	0.021944012 774331334	174	6.76672082 2449153
Peter Visser	6.73893826 0984378	6.74817613 5887787	6.76091695 7432808	0.021978696 448429424	150	6.75897073 7191879
Joey Nokes	6.71920396 6109805	6.72453003 9148759	6.74146407 8076385	0.022260111 966580176	56	6.72707863 7115019
Eli Bennett	6.73078324 7713214	6.74272372 6371513	6.75305340 8050848	0.022270160 337633627	67	6.73078324 7713214
Lucas Bons	6.72884981 20905285	6.73678711 7925224	6.75113551 0885808	0.0222857	63	6.72884981 20905285
Micah Wilson	6.73835785 0041829	6.75082255 1453409	6.76066792 4035155	0.022310073 993326185	133	6.75202521 5625324
Benjamin Godish	6.74574745 7195495	6.74774543 3691714	6.76808196 9568821	0.022334512 373325843	123	6.74904906 61051075
Devin Hart	6.69819450 5720176	6.71110245 8907705	6.72081958 4382061	0.02262508	11	6.69819450 5720176
Kenneth Rooks	6.71448118 8901054	6.73063804 0862841	6.73721481 3214712	0.02273362	35	6.71448118 8901054
Fouad Messaoudi	6.69773827 0597389	6.71308028 4437356	6.72068934 12355795	0.022951070 638190352	10	6.69773827 0597389
Brodey Hasty	6.71077193 0393188	6.73029498 8960724	6.73406659 5985238	0.023294665 592050734	25	6.71077193 0393188
Jason Renze	6.74032651 0872346	6.75179496 8272179	6.76380164 2512186	0.02347513	122	6.74861545 7444349
Caleb Jarema	6.73835791 76733255	6.75870178 4632049	6.76187666 2794379	0.023518745 121053897	158	6.7613824
Nico Young	6.69253431 5558494	6.70120968 9217931	6.71620316 2368563	0.023668846 810068978	6	6.69253431 5558494
Jason Bowers	6.70874302 2832123	6.72038074 6250563	6.73245271 31914405	0.02370969	22	6.70874302 2832123
Ben Shearer	6.70815770 1926607	6.71568366	6.73190684 2376188	0.02374914	42	6.72057658 9847731
Alex Maier	6.70166626 48836585	6.71246940 2519012	6.72553388 0010556	0.023867615 126897945	15	6.70166626 48836585

Owen MacKenzie	6.736462237306616	6.748167839468719	6.76067733	0.024215089364163944	116	6.747204780121751
Hannes Burger	6.732933227961581	6.733484386631318	6.75718519	0.024251964487298494	71	6.732933227961581
Chandler Gibbens	6.711703994324523	6.722846850664236	6.736012331617371	0.024308337292848314	77	6.736012331617371
Jackson Sharp	6.707680181146049	6.719070219093099	6.731999397935319	0.024319216789270293	41	6.719070219093099
Valentin Soca	6.71807497	6.736576535689814	6.742413425822546	0.02433846	86	6.7387537419832615
Theo Quax	6.722548596712919	6.735775176127268	6.746939760623044	0.02439116	84	6.738315590371526
Connor Nisbet	6.728019924635786	6.742426172183069	6.75258706	0.024567133470664082	59	6.728019924635786
Eric Casarez	6.726024067442843	6.736748103615966	6.750835872587753	0.02481181	130	6.750835872587753
Zach Stewart	6.771250606482959	6.778628294963313	6.796119239121511	0.02486863	195	6.778628294963313
Luke Venhuizen	6.746458778929178	6.752945233427655	6.771394747401463	0.02493597	180	6.771394747401463
David Mullarkey	6.716101329303591	6.719346990164075	6.741183698875809	0.025082369572218433	40	6.718902654771333
Cole Sprout	6.720941175897141	6.741323862717011	6.746219719808717 5	0.025278543911576357	95	6.741323862717011
Abraham Avila-Martinez	6.760760017211444	6.76519771	6.786045123725108	0.02528511	204	6.7835613
Luke Henseler	6.740880561471308	6.755462792714283	6.766507812649977	0.02562725	173	6.766507812649977
Paul Talens	6.766159087243759	6.774456342111644	6.791850147555502	0.025691060311743286	214	6.791850147555502
Carter Solomon	6.739799628816594	6.751514667212237	6.765655372721591	0.02585574	170	6.765655372721591
Patrick Kiprop	6.69448985	6.701136294292072	6.720402869104106	0.025913022843566225	7	6.694539012067062

Pedro Marin	6.763202514045639	6.768137825935089	6.7893030422596965	0.02610053	211	6.7893030422596965
Toby Gualter	6.736557113453619	6.751282094911938	6.762822240768425	0.026265127314805348	102	6.743179016664997
Adisu Guadia	6.71800311	6.723805170126776	6.744881222616713	0.026878116195923063	50	6.723805170126776
Matias Reynaga	6.731381185236851 5	6.739885418819195	6.758467543921454	0.02708636	140	6.755477008344044
Gabriel Sanchez	6.722918731981043	6.734107022648639	6.750078167594585	0.027159435613541838	126	6.750078167594585
Brandon Olden	6.738208965466111	6.76063265	6.765748919199015	0.02753995	154	6.76063265
Creed Thompson	6.713988807001089	6.7230267	6.741549403897689	0.027560596896599954	46	6.7230267
Lucas Guerra	6.751917277755636	6.763082526121281	6.779574917543879	0.027657639788243316	199	6.779574917543879
Bob Liking	6.709679967750667	6.72965127	6.737438875242536	0.02775891	83	6.737438875242536
Chris Devaney	6.71268453	6.726627590544974	6.740608521601926	0.027924	31	6.71268453
Quinn Gallagher	6.744962947217179 5	6.758128449487271	6.773192143349462	0.028229196132282475	155	6.760739811714104
Samuel Field	6.758801904844816	6.765390158911298	6.787114715467723	0.028312810622907136	210	6.787114715467723
Nicholas Kiprotich	6.738688591178651	6.746064032672493	6.767021213043377	0.028332621864726626	113	6.746064032672493
Joaquin Campos	6.756069291432302	6.771952991055212	6.784750148804929	0.02868086	145	6.756069291432302
Yasin Sado	6.734332066412457	6.746883816450792	6.763102620917797	0.02877055	73	6.734418930346585
Rob McManus	6.757036115668624	6.763948363182551	6.785884657990691	0.02884854	165	6.763948363182551
Nathan Mountain	6.736937949953145	6.74046519	6.7660284412292775	0.029090491276132724	172	6.7660284412292775

Andrew Nolan	6.73087516 0917333	6.74222145 10037355	6.76075773 3098055	0.02988257	136	6.75326710 1759634
Ben Rosa	6.72313796 7898541	6.73897260 1980358	6.75307880 5815169	0.029940837 916627494	47	6.72313796 7898541
Will Allen Gable	6.75242645	6.76852939 0157736	6.78239633 95063025	0.02996989	179	6.76852939 0157736
Sieperda	6.72074387 3935772	6.74522594 8389735	6.75091490 8649668	0.030171034 713895928	43	6.72074387 3935772
Gitch Hayes	6.75617247 2284418	6.76729037 89528736	6.78653722 4448578	0.030364752 164159903	147	6.75795075
Jake Derouin	6.76332360 6902891	6.77290884 0995461	6.79372821 4631836	0.030404607 728944377	202	6.78141276 0675582
Will Anthony	6.72230634 6444077	6.73058964 9155771	6.75273459 5915777	0.030428249 471700752	61	6.72840729 8531121
Drew Bosley	6.69230490 0492223	6.71472347 69281035	6.72342038 6406087	0.031115485 913863594	5	6.69230490 0492223
Harvey Cramb	6.78766273 24566945	6.79981149 2099035	6.81879078 1606898	0.03112805	231	6.81879078 1606898
Daniel O'Brien	6.74088689 0634354	6.74804378 3455855	6.77239230 2625397	0.03150541	94	6.74088689 0634354
Leo Young	6.74184953 6078166	6.74475506 9138542	6.77367078 5570672	0.03182125	185	6.77367078 5570672
William Zegarski	6.73127046 5775721	6.74143236 6727744	6.76314710 9800883	0.03187664	161	6.76314710 9800883
Tyler Berg	6.73206483 3929166	6.74294037	6.76402339 6924666	0.03195856	92	6.74023104 6949287
Titus Cheruiyot	6.72796453	6.73751947 4907275	6.76002284 7961967	0.032058314 232296325	58	6.72796453
Victor Kiprop	6.68840441 0718396	6.70806574 8060044	6.72064757 43837935	0.032243163 665397034	20	6.70806574 8060044
Nolan Hosbein	6.75663925 1346436	6.76445941 0324499	6.78905008 4375505	0.03241083	194	6.77815470 0053733
Jacob McLeod	6.7244193	6.74095226 8770972	6.75689015 0140636	0.03247085	100	6.74263374
Bradley	6.73431483 1346376	6.73707814 1936339	6.76683621 0440284	0.03252138	82	6.73727436 10066275

Makuvire						
Baidy Ba	6.74214771 4204381	6.75779273	6.77478319 3878221	0.03263548	162	6.76320058 5846712
Devon Comber	6.76686438 3379618	6.77432663 3184596	6.79955564 5431222	0.03269126	220	6.79955564 5431222
Sam Burgess	6.74608303 3671224	6.76661498 8688589	6.77894391 7871088	0.03286088	196	6.77894391 7871088
Dean Casey	6.72609582 6233264	6.73219189 8132184	6.75897079 08395145	0.03287496	151	6.75897079 08395145
Robert Cozean	6.74468807 78119045	6.75658226 9275209	6.77802847 1781887	0.033340393 969982784	119	6.74791036 75343435
Zach Hughes	6.75228714 81035045	6.77472167 6796168	6.78563975 2715072	0.0333526	192	6.77736485 8879617
Nick Foster	6.73515399 2314688	6.74853105 32051175	6.76866791 3542373	0.03351392	135	6.75305120 6510242
Ky Robinson	6.68764894	6.71439414 8340329	6.72120120 09025415	0.033552264 066371684	3	6.68764894
Jake Gebhardt	6.72905088 19583135	6.73714776	6.76274529 1077466	0.033694409 119152446	78	6.73606727 8549819
Ian Harrison	6.77557661 7260098	6.77810690 7454693	6.81021851 7580009	0.0346419	190	6.77683791 6169255
Gavin Ehlers	6.74618487 1884291	6.75748843 7687931	6.78110786 9496193	0.034923	143	6.75569248 8212973
Zachary Cloud	6.76027684 7733631	6.76588892 0906454	6.79558391	0.03530706	212	6.78935513 77595545
Isaac Hedengren	6.73564582 0999015	6.74838728 5813399	6.77165969 1493372	0.036013870 494357114	181	6.77165969 1493372
Habtom Samuel	6.67896927 4759291	6.70753782 1803522	6.71505275 3966388	0.03608348	2	6.67896927 4759291
Joshua DeSouza	6.73274959 7308232	6.73995764 2635006	6.76888384 9709928	0.036134252 401695655	91	6.73995764 2635006
Matthew Larkin	6.78147039 3078926	6.78867123 7336233	6.81761180 8781755	0.03614142	207	6.78565304 4091422

James Corrigan	6.71290931 3902009	6.73363796 1158931	6.74905307 1397202	0.03614376	32	6.71290931 3902009
Ryan Kredell	6.74268816	6.7553561	6.77894397	0.03625581	197	6.77894397
Nathan Lawler	6.74464991 22320525	6.76613506 5579593	6.78115954 03238725	0.03650963	110	6.74464991 22320525
Jacob Hunter	6.74372482 0950437	6.75863977 0010257	6.78104544	0.03732062	201	6.78104544
Tom Brady	6.71122231 5287951	6.73233481 5701487	6.74874453 3554747	0.03752222	27	6.71122231 5287951
Brett Gardner	6.72408303	6.74464826 2416751	6.76162795 1688225	0.03754493	51	6.72408303
Levi Taylor	6.75364481 9808771	6.76784461	6.79135415 8843259	0.03770934	138	6.75364481 9808771
Abel Teffra	6.75328444 5946756	6.76186400 2883535	6.79127633 1839507	0.03799189	159	6.76186400 2883535
Bryce Cerkowniak	6.73627864 5215126	6.74663693 83983595	6.77431570 6611058	0.03803706	120	6.74807314 1409815
Jesse Hamlin	6.73962941 50011125	6.75058491	6.77771025 1199375	0.038080836 198262524	89	6.73962941 50011125
Cooper Laird	6.75203951 31755935	6.77328416 6234731	6.79023951 4339159	0.0382	213	6.79023951 4339159
Sam Ells	6.76193612	6.77218936 9184021	6.80022794 7514493	0.03829183	183	6.77218936 9184021
Ethan Strand	6.72179001 2192317	6.72666297 8901686	6.76013471 9178991	0.038344706 986674026	45	6.72269291 8974189
Isaiah Givens	6.72746461	6.75420931 6336468	6.76588894 41164565	0.03842434	164	6.76357457 1111608
Connor Livingston	6.76223029 9465641	6.77434283 3321271	6.80091199 5036446	0.0386817	168	6.76544208 2524441
Charlie North	6.75707487 5176657	6.77569705 2339488	6.79635651 4639705	0.039281639 463048634	217	6.79635651 4639705
Sam Lawler	6.71425675 4488432	6.73430315 7604633	6.75372907	0.03947232	34	6.71425675 4488432
Luke Ondracek	6.76051632 7149639	6.77597033	6.80001921 4969713	0.03950289	221	6.80001921 4969713
Owen Smith	6.73353879 0785374	6.74855670 89850065	6.77308867 5978458	0.039549885 193083334	72	6.73353879 0785374
Jack Roberts	6.72635507 4605204	6.74693772 2631066	6.76603887 7838759	0.0396838	157	6.76079347 0194278

Joe Ewing Cooper	6.74597946 0785965	6.77685188 2919714	6.78643636 8522178	0.04045691	209	6.78643636 8522178
Schroeder	6.73544974 2738633	6.75240335	6.77618398 2719689	0.040734239 981055964	134	6.75240335
Marco Langon	6.72686196 0149477	6.74844106 7450083	6.76783082 49888595	0.04096886	146	6.75623074 2757943
Hillary Cheruiyot	6.70024426 9045752	6.71328736 9799259	6.74225184 26144125	0.04200757	98	6.74225184 26144125
Rowen Ellenberg	6.73279642 8265871	6.74686436 5361114	6.77525563 1099501	0.0424592	188	6.77525563 1099501
Rynard Swanepoel	6.76509861 8283392	6.77296318 8092158	6.80822768 6523688	0.04312907	200	6.77989024 1864331
Lukas Kiprop	6.71515268 47737815	6.72765125 2722947	6.75843400 9514514	0.04328132	148	6.75843400 9514514
Jonathan DeSouza	6.75946380 2809213	6.76527999	6.80325789 0600175	0.043794087 790962166	222	6.80325789 0600175
Denis Kipngetich	6.68995088 8243598	6.69541057 2982698	6.73385990 1512137	0.043909013 268538466	4	6.68995088 8243598
Nickolas Scudder	6.7120662	6.72748360 4885727	6.75651580 8437342	0.04444961	30	6.7120662
Will Minnette	6.73955043	6.74945376 7160025	6.78408465 6665932	0.04453423	205	6.78408465 6665932
Michael Maiorano	6.74592826 52803525	6.76514094 4649314	6.79062920 2410727	0.04470094	149	6.75848773 8186398
Joe Hudson	6.72824129 1618469	6.7360835	6.77370059 6628739	0.04545931	60	6.72824129 1618469
Perry Mackinnon	6.70767046 8587204	6.72763742 3619392	6.75320664 0793431	0.04553617	19	6.70767046 8587204
Jacob Nenow	6.74817420 6320673	6.76791320 8210682	6.79376911 6501676	0.04559491	215	6.79376911 6501676
Tyler Wirth	6.74488547 2042058	6.75682790 7907996	6.79051303 37891775	0.04562756	153	6.76031119 0249923

Haftu Knight	6.728288371511352	6.739250404217932	6.774122928549183	0.04583456	79	6.736341748431848
Isaac Alonzo Emmanuel	6.72608551	6.738019456353264	6.772339081317211	0.046253573344241516	93	6.740449727523619
Sgouros	6.739868551281361	6.743890704056502	6.786156007290175	0.046287456008813344	104	6.743669519302715
Joseph O'Brien	6.737000147014418	6.739502781692334	6.783981590874635	0.04698144	81	6.737000147014418
Ben Perrin	6.726001011336651	6.737233154560988	6.773267105637315	0.04726609	53	6.72652446
Damien Dilcher	6.728231408373128	6.742676828039046	6.776099824505633	0.04786842	189	6.776099824505633
Ahmed Ibrahim	6.747544937675441	6.755830949541405	6.795942945396642	0.048398007721201175	216	6.795942945396642
Nicholas Bendtsen	6.712066142228526	6.737024214621149	6.761066795252176	0.049000653023649754	29	6.712066142228526
Nikodem Dworczak	6.727283386131923	6.75987594	6.776582410521705	0.049299024389782176	167	6.764375428840272
Max Murphy	6.726355019888664	6.745693293032314	6.775972383228677	0.049617363340012766	69	6.731721
Haftu Strintzos	6.71806458	6.729269170232249	6.767916876987272	0.0498523	38	6.71806458
Abdirizak Ibrahim	6.733001535053056	6.735202667691266	6.783142400235071	0.05014087	203	6.783142400235071
Rodgers Kiplimo	6.717673233335411	6.755381445872198	6.76846472	0.05079149	37	6.717673233335411
Brian Kiptoo	6.727743610303634	6.744677077164198	6.779101770843835	0.05135816	198	6.779101770843835
Nick Soldevere	6.748923964918504	6.768900696591217	6.800315125204091	0.05139116	206	6.784816880407033

Elliott Cook Thomas	6.72988821	6.746227107336135	6.781452939809888	0.05156473	114	6.746227107336135
Chaston	6.7637543940405065	6.7885937314817495	6.816882255139262	0.05312786	224	6.810264718268947
Luke Combs	6.711841165080245	6.735155132583206	6.765300139791594	0.05345897	28	6.711841165080245
Dylan Schubert	6.710321398882556	6.724070246792448	6.76390754	0.05358614	24	6.710321398882556
Matt Strangio	6.716253932079995	6.735737771293039	6.770189038685893	0.05393511	76	6.735737771293039
Alex Phillip	6.705408936681861	6.718595133259564	6.7610375733967665	0.055628636714905255	17	6.705408936681861
Matthew Richtman	6.711053430652385 5	6.737419300459989	6.767320004875348	0.05626657	26	6.711053430652385 5
Silas Derfel	6.756959464526298 5	6.774297300768091	6.813318168807905	0.0563587	228	6.813318168807905
Timothy Chesondin	6.714761647083288 5	6.744919703155047	6.771232803266568	0.05647116	36	6.714761647083288 5
Caleb Niednagel	6.760724092567797	6.763362992331681	6.817374818102534	0.05665073	230	6.817374818102534
Teddy Buckley	6.759229927747127 5	6.774305014656011	6.816400559730749	0.057170631983621156	186	6.774305014656011
Graham Blanks	6.677224218628782 5	6.7169465	6.734465326194505	0.05724111	1	6.677224218628782 5
James Overberg	6.743100158430767	6.762011462301929	6.800345516500728 5	0.05724536	178	6.768210462483295
CJ Singleton	6.738356022304087	6.756261297002712 5	6.797183088724381	0.058827066420294116	218	6.797183088724381
Sanele Masondo	6.702745161350184	6.743100227059862	6.762013037859534	0.059267876509349726	16	6.702745161350184
Zane Bergen	6.756684963297708	6.789056605332211 4	6.817309149154849	0.06062419	226	6.811538139556991 05

Luke Tewalt	6.720009624631844	6.751551526083801	6.781414012533127	0.06140439	137	6.75342901
Justin Wachtel	6.758686260170075	6.763210757675974	6.820709227059992	0.062022966889917264	232	6.820709227059992
Wil Smith	6.7120084	6.7295571733247055	6.774315616739587	0.06230722	111	6.745085243426472
Parker Wolfe	6.697338886912805	6.714598288401294 5	6.759795910352382	0.06245702	9	6.697338886912805
Vincent Mauri	6.731059171540457	6.754070983567177 5	6.793693513681279	0.06263434	68	6.731059171540457
Silas Winders	6.747741079814111	6.762383699047244	6.811028955432198	0.06328788	225	6.811028955432198
Rodger Rivera	6.708912298078109	6.72541191	6.772339193512849	0.0634269	23	6.708912298078109
Keeton Thornsberry	6.756083316228429 5	6.75860094	6.820759711904905 5	0.0646764	233	6.820759711904905
Jack Jennings	6.726856957182377	6.752078452850274	6.79266594	0.06580898	54	6.726856957182377
Jack McMahon	6.755550149254586	6.76242185	6.822825436327448	0.06727529	235	6.822825436327448
Liam Murphy	6.700131115038983	6.724732394510182	6.768002921581376	0.06787181	14	6.700131115038983
Cruz Gomez	6.730176013426407	6.740965767287141 5	6.798269452029986	0.06809344	66	6.730176013426407
Jarrett Kirk	6.740281881899608	6.758760547778064	6.80905286	0.06877098	175	6.767306272445333 4
Yaseen Abdalla	6.706185170248306	6.713954040518421	6.7752028	0.06901763	187	6.7752028
Evan Burke	6.747314505694191	6.750798878331983	6.817374952659578	0.07006045	129	6.750565352749051
Jonathan Carmin	6.740959648110917	6.768074190626924	6.812504829924792	0.07154518	227	6.812504829924792
Enock Kipchumba	6.762967777183848	6.803976213968657 5	6.834602612033091	0.07163483	223	6.803976213968657 5
Gary Martin	6.72770829	6.733610621405575	6.799349516901137	0.07164122	219	6.799349516901137

Xian Shively	6.74525025 5502142	6.75299939 7577433	6.82131437 2996928	0.07606412	234	6.82131437 2996928
Colton Sands	6.73902709 4909103	6.75914897	6.81539925 5997676	0.07637216	229	6.81539925 5997676
Robert DiDonato	6.72363839 74044625	6.74014816 0871547	6.80052108 98602675	0.07688269	49	6.72363839 74044625
Victor Shitsama	6.6993341	6.71052842 48424555	6.78017398	0.08083988	12	6.6993341
Luke Wiley	6.77541244 8426014	6.78780096 2403985	6.85744944 2263459	0.08203699	236	6.85744944 2263459
Jonas Gertsen	6.74871607 5246226	6.75528555 87089615	6.83243499 0202055	0.08371891	144	6.75580018 3829098
Daniel McGoey	6.73966183 8499978	6.74678604 6983846	6.84812779	0.108465952 93581185	112	6.74579221 8695716

Corey Gorgas, Adam Spencer, Giedrius Valincius, Evans Kiplagat, Michael Morgan, Anthony Monte, Daniel Abdala all had TiC ranges less than 0.01, this is only 3% of the competition. Daniel McGoey was the only individual who had a TiC range greater than 0.1. These individuals all placed throughout the entire spread of finishers, continuing to support the trend that consistency is not a significant factor when predicting an individual's placement at this championship meet.

Accompanying Source Code and Output Creation

The source code for this analysis is included in a Jupyter Notebook titled *SourceCode.ipynb*. All outputs for each research question are included in .csv format, and images for each graph are also included in .png format. Since the reason for creating the functions was for replicability, a document titled *BonusAnalysis.py* is included to evaluate the performance for the 2024 NCAA Cross Country Championships held on November 23rd, 2024.

References:

Bijan Mazaheri - bijanmazaheri.com - lacctic.com

flotrack.org/articles/11480196-ncaa-cross-country-championship-2023-results-graham-blanks-wins-title

Markov Chains: From Theory to Implementation and Experimentation" by D. P. Kroese, T. Taimre, and Z. I. Botev

Stanton, J. M. (2017). *Reasoning with data: An introduction to traditional and Bayesian statistics using R*. Guilford Publications.