University of Vermont (UVM) Field Hockey Force Plate Jump Analysis,

An Undergraduate Mathematics Thesis Proposal

Abstract

This project will draw upon a data set produced by over one thousand jumps by UVM women's field hockey players jumping for the Hawkin Dynamics force plate countermovement jump (FPCMJ) test. The FPCMJ test is a fitness assessment that measures many characteristics of jumping, which can be used to indicate left, right, and net leg strength. Since field hockey sticks are right-handed only[4], we hypothesize that there is an association between hand dominance and leg strength asymmetry. The purpose of this project is to describe leg strength asymmetry in UVM D1 field hockey players and identify associated characteristics.

Description

One goal of this thesis is to identify the relationship between bilateral asymmetry and jump height, which will require assessing the FPCMJ variables encompassing left and right differences, as well as jump height. Since field hockey is a sport with only right-handed sticks[4], variables accounting for leftness versus rightness will be examined in deeper detail to investigate the hypothesis that hand-dominance is correlated with asymmetry. This thesis will test for associations between numerous variables measured by the FPCMJ, across the averages of all two hundred and ninety-six jump sets. Therefore this thesis project seeks to use the averages of each set of approximately three jumps to compile a new data set to test for associations between aspects measured by the FPCMJ test. The new data set will also sort through points to eliminate outliers created by points that encompass single-leg jumps via injuries, or jumps with

hands swinging, which do not comply with the standardized warm up. The overarching goal of this thesis is to look for connections between the multiple qualitative variables during the unweighting, brakling, propulsive, flight, and landing phases of the FPCMJ, as analyzed in [9]. Such variables include ten different measurements of force: at minimum displacement, during braking, peak during braking, propulsive, peak propulsive, left versus right during braking, left versus right propulsive, peak landing, and left versus right landing. More of these variables include different measurements of velocity: during braking, propulsive, during takeoff, and peak velocity. Furthermore variables include impulses: net braking, net propulsive, left versus right braking index, left versus right propulsive, left versus right landing index, relative braking, relative propulsive, and impulse ratio. Lastly, uncategorized variables include: jump height, jump momentum, countermovement depth, braking rate of force development (RFD), stiffness, unweighting phase, braking phase, propulsive phrase, time to takeoff, relative propulsive power, peak propulsive power, relative strength index (RSI), and modified RSI (mRSI). Previous works that discuss prior FPCMJ studies will be elaborated upon to contextualize trends associated with optimal jumps and jump height, in conjunction with sources on bilateral asymmetry for further understanding of the general implications of jumping (a)symmetry. Symmetry is an aspect that can be looked at independently for deeper evaluation. In relation to the previous works, [2] and [8] take a closer look at asymmetry in jumps. Since [2]'s statistical analyses yielded p-values that provide evidence that asymmetry above 10% decreases jump height by around 3.5 inches and [8]'s statistical analyses yielded p-values that suggest females have less lower-limb asymmetry than males, I predict that higher symmetry, which means the same thing as lower asymmetry, will be associated with higher jump height in the data set. However, this population is fully female which may yield different findings than the previously mentioned, unisex, works.

Previous Work

Previous works conducted and described experiments and statistical analyses. In [1], subjects were surveyed for anthropometric and demographic data, completed a standardized warm-up, and performed three CMJs. The data for the three jumps were exported using a personal computer Bioware program, analyzed using MATLAB, and the vertical GRF (ground reaction force) data were summed together. Associations were drawn between eighteen variables with jump height, RSI, and jump time. The CMJ GRF was studied as a function of time, divided into the phases of unloading, eccentric, and concentric In [2], subjects underwent a full body scan that calculated lean and fat mass, performed three CMJs with standardized test directions, including one foot on each plate, and rested in between jumps. The Leonardo Mechanograph was used for jumping, and the associated program calculated peak force and peak power. Peak force asymmetry and peak power asymmetry were calculated using the equation: Asymmetry = ([Right limb-Left limb)/½(Right limb + Left limb])x100% and statistical conclusions were drawn from numerous regression models. In [3], subjects performed jumps with hands on their hips. The data were divided into above average, average, and below average groups, categorized as single or double-peaked, and tested for jump metric association with using chi-squared and independent t-tests. In [5], subjects completed a standardized, ten minute warm up and performed three jumps on the Quattro Jump for which the QuattroJump computer program recorded values and computed averages. After splitting these data into LOW and HIGH-scoring groups, force, velocity, position, and RFD were studied as functions of time. In [6], subjects completed a standardized, ten minute warm up and performed three jumps on the Quattro Jump for which the highest jump was used for analysis by PASW software modeling. After splitting these data into LOW and HIGH-scoring groups, force, velocity, displacement, and RFD were studied as

functions of time. In [8], subjects attended two jumping sessions with three jumps each: one using arm swing and one not. ForceDecks dual platform hardware was used and its software was used to compute variables, of many being types of forces and power. Statistical analyses also analyzed distinctions between left and right, male and female, and arms and no arms.In [9], subjects completed a standardized warm up and jumped on Hawkin Dynamics dual force plates. The data were divided into unimodal and bimodal categories and force was expressed as a function of time, beginning at body weight and then low force, minimum velocity, force at low position, 2nd peak force, maximum velocity, and ending at takeoff. The data were classified into three groups: above average, average, and below average. Statistical analyses involved chi-square testing. In [10], subjects were involved in a cross-sectional study with blocking for CMJs of larger depths, shorter depths, and self-preferred depths. Another blocking randomly divided the subjects into as fast as possible velocity when jumping and self-selected velocity when jumping. Force and displacement were studied as functions of time for both the fast and self-selected velocities. The CMJ platform was Dinascan/IBV and these data were calculated using Microsoft Excel. In [11], two Kistler force plates were used to gather information about the left and right sides. Subjects did a shuttle run as a warm up before completing six jumps. The highest three jumps were used for calculations within Microsoft Excel. A t-test analyzed the difference between left and right leg stiffnesses for countermovement and takeoff phases.

Significance

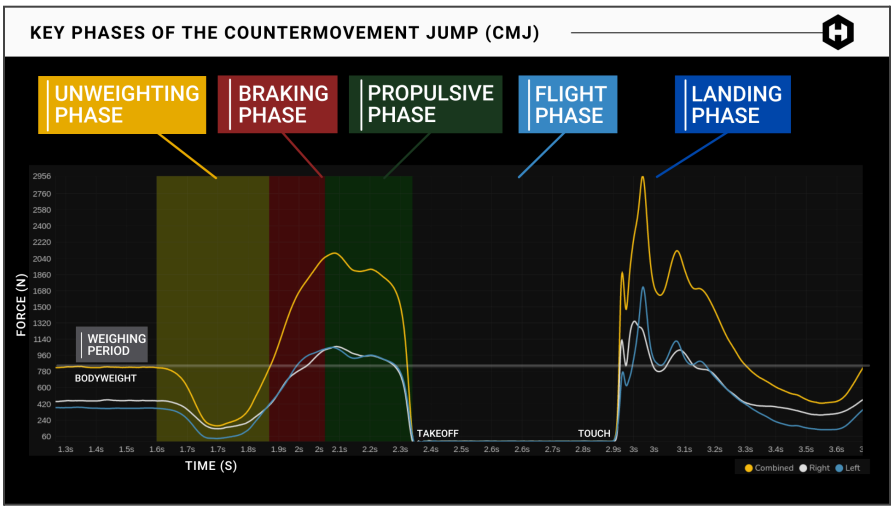
The aim of this project is to learn more about the UVM field hockey team's FPCMJs with pertinence to a broader female, athletic context and relevance to the sports performance industry. The Hawkin Dynamics FPCMJ test is one used by programs from all around the country. Having

more information about the stages of the CMJ, specifically about bilateral symmetry, can provide further insight for athletes and athletics performance coaches such that they can adjust their strength training and weight lifting training programs to athletes based on such symmetry, or lack thereof. Further research can be done based on this project's results that seeks a correlation between bilateral symmetry and athletic success relative to a sport. Furthermore, studies can be done that compare the different trends among different sports teams since different sports teams utilize different regions of the body in different ways. This possibility for further research relates to the studies in the previous work section that involve a wide range of sports, including male Division 1 soccer players[1], male and female Division 1 athletes[2], male and female Division 1 athletes for hockey[3], lacrosse, soccer, basketball, et cetera, female youth gymnasts[5], teenage rugby players[6], male and female Division 1 basketball players at the University of Oklahoma[8], male and female Division 1 athletes for hockey, lacrosse, soccer, basketball, track and field, skiing, et cetera[10], and male and female basketball players for the Lower Silesia University League[11]. [9] was the only research that I encountered that analyzed or discussed the sport of field hockey for CMJ research, so this thesis project will contribute many new developments to the realm of field hockey athletic performance.

Methodology

For the countermovement jump test, student-athletes stand on an assessment plate after following a specific warm-up given by the test administrator–who are often UVM strength and conditioning staff–where "the warm-up consisted of 10 bodyweight squats, five drop squats, 10 reverse lunges with overhead reach, five practice jumps with arms akimbo and with increasing intensity with each jump"[9]. While on the plate, the student-athlete is asked to put their hands

on their hips, hold still, and then jump as high as they can while keeping their hands on their hips. Furthermore, in my experience with this test, once every team member jumps, everyone will jump again, and then a third time. The results of this test yield hundreds of measures that fall into the unweighting, braking, propulsive, flight, and landing phases of the FPCMJ, as described by Hawkin Dynamics Metric Database [7] and as seen in the following table that has been included for the benefit of the reader.



The actual force plate that provides the force plate countermovement jump test data points is a product of Hawkin Dynamics, and measures numerous accounts of information. Amongst a long process that involved getting a new advisor for my thesis project and switching research projects midway through the Spring 2024 Semester, I was able to get in contact with Marc Hickok, UVM Assistant Director of Athletics and UVM Director of Athletic Performance. Marc Hickok is also the second author for one of the main references that will later be included in the actual write up for the thesis in addition to sections of this thesis proposal. He also has copious tracking information on numbers involving UVM student-athlete performance. My team's strength and conditioning coach, who works under Marc Hickok, was kind enough to send me thirty nine measures of data for over one thousand jumps in an Excel Sheet on behalf of Marc Hickok, her boss. (Note: these data were de-identified for the purpose of protecting the

privacy of the student-athletes and remain anonymous. Furthermore, consent and release forms were signed by the student-athletes granting permission to use their anonymous data for research purposes.) This process for obtaining the FPCMJ data is very relevant to my personal life as I have a lot of respect for the importance that these professionals have within the UVM athletic department, and I look forward to continuing to see connections build between the spaces of UVM athletics and my educational experiences at UVM–including this thesis project.

Timeline

In the Fall 2024 Semester I will be completing three credits of mathematical research, referred to as MATH 4996 in the UVM Schedule of Courses, to fulfill one-half of my undergraduate thesis work for the Patrick Leahy Honors College requirements. These credits will consist of individual instruction from Associate Professor Abigail Crocker from the UVM Department of Mathematics and Statistics. This individualized instruction will parallel her UVM Statistical Computing & Data Analysis class, STAT 3010, focusing on learning the R-studio program and how to program the student-athlete FPCMJ data as inputs. In the Spring 2025 Semester I will also be completing three credits of MATH 4996 mathematical research to fulfill the second half of my undergraduate thesis work for the Patrick Leahy Honors College requirements. These credits will consist of a statistical report on the work from the Fall 2024 Semester as well as a corresponding thesis write-up, with Associate Professor Abigail Crocker as well as another Professor in the UVM Department of Mathematics and Statistics, Professor Jun Yu. My committee thus far consists of Associate Professor Abigail Crocker, serving as chair, and Professor Jun Yu, serving as a member. Until then, I will continue to dissect the listed references

through close reading and literary analysis to further propel my comprehension of the FPCMJ as a whole.

References

[1] Barker, L. A. et al. (2018). Relationships Between Countermovement Jump Ground Reaction Forces and Jump Height, Reactive Strength Index, and Jump Time. *Journal of Strength and Conditioning Research*, *32*(1), 248-254. Ovid. Retrieved 2024, from https://oce-ovid-com.ezproxy.uvm.edu/article/00124278-201801000-00032/HTML

[2] Bell, D. R. et al. (2014). Lean Mass Asymmetry Influences Force and Power Asymmetry During Jumping in Collegiate Athletes. *Journal of Strength and Conditioning Research*, *28*(4), 884-891. Ovid. Retrieved 2024, from https://oce-ovid-com.ezproxy.uvm.edu/article/00124278-201404000-00002/HTML

[3] Cohen, J. A. et al. (2020). Is There An Optimal Vertical Ground Reaction Force Profile for Maximizing Jump Height In A Countermovement Jump?. *Medicine & Science in Sports & Exercise*, *52*(7S), 261-262. Ovid. Retrieved 2024, from https://oce-ovid-com.ezproxy.uvm.edu/article/00005768-202007001-00779?relatedarticle=y

[4] Field hockey rules keep IU player from using dominant hand. (2015, October 13). UWIRE Text, 1. https://link-gale-oh.orc.scoolaid.net/apps/doc/A432313604/AONE?u=nysl_ce_ccs&sid=bookmark-AONE&xid=3d30c6b4

[5] Floría, P. & Harrison, A. J. (2013). Ground Reaction Force Differences in the Countermovement Jump in Girls With Different Levels of Performance. *Research Quarterly for Exercise and Sport*, *84*(3), 329-335. Taylor & Francis Online. Retrieved 2024, from https://www-tandfonline-com.ezproxy.uvm.edu/doi/full/10.1080/02701367.2013.813896

[6] Floría, P. et al. (2016). Kinetic and Kinematic Analysis for Assessing the Differences in Countermovement Jump Performance in Rugby Players. *Journal of Strength and Conditioning Research*, *30*(9), 2533-2539. Ovid. Retrieved 2024, from https://oce-ovid-com.ezproxy.uvm.edu/article/00124278-201609000-00022/HTML

[7] *Hawkin Metric Database*. (n.d.). Hawkin Dynamics. Retrieved 2024, from https://www.hawkindynamics.com/hawkin-metric-database

[8] Heishman, A. et al. (2019). Countermovement Jump Inter-Limb Asymmetries in Collegiate Basketball Players. *Sports (Basel)*, *7*(5), 103. PubMed Central. Retrieved 2024, from https://www-ncbi-nlm-nih-gov.ezproxy.uvm.edu/pmc/articles/PMC6572434/

[9] McHugh, M. P. et al. (2020). Is there a biomechanically efficient vertical ground reaction force profile for countermovement jumps? *Translational Sports Medicine*, 138-146. EBSCOhost. Retrieved 2024, from https://web-p-ebscohost-com.ezproxy.uvm.edu/ehost/pdfviewer/pdfviewer?vid=0&sid=20ea3974-a26f-4b73-8255-80c29b0d607e%40redis

[10] Pérez-Castilla, A. et al. (2021). Vertical jump performance is affected by the velocity and depth of the countermovement. *Sports Biomechanics*, *20*(8), 1015-1030. EBSCOhost. Retrieved 2024, from https://web-p-ebscohost-com.ezproxy.uvm.edu/ehost/pdfviewer/pdfviewer?vid=0&sid=81a3818d-bd84-4c32-94d5-b45d3e1fdd99%40redis

[11] Struzik, A., & Zawadzki, J. (2013). Leg stiffness during phases of countermovement and take-off in vertical jump. *Acta of Bioengineering and Biomechanics*, *15*(2), 113-118. EBSCOhost. Retrieved 2024, from

https://web-p-ebscohost-com.ezproxy.uvm.edu/ehost/pdfviewer/pdfviewer?vid=0&sid=2e18d04e-8925-443f-b9fe-8d278a5f33e7%40redis