Grounding the Jump: An anthropometric basis for the vertical jump

How does sprint-time (s), thigh and calf circumference (cm), and tibial length (cm) relate with vertical jump performance in high-school male basketball athletes?

1.1 <u>Introduction:</u>

Ever since playing basketball as a child, I have been trying to reach higher and higher on the basketball hoop. I remember hooking the bottom of the basketball net and landing on the ground surrounded by my friends' wide eyes and gaping mouths. Next was the backboard, then the rim. Now, I've long lost the race in jumping the highest, but I've turned to science to understand how to reach new heights.

As trivial and immature as it may seem, jumping and slapping the backboard is a considerable physical task, with numerous variables contributing to vertical jump performance, including anthropometric, biomechanical and physiological factors (Sharma et al 1). I was particularly interested in physical characteristics (like leg length) rather than performance-related characteristics (like ankle angular velocity at take off) though some can be very closely related. My personal goal was to understand some of the physical markers of a strong jumper amongst my friends.

> ***"Wings"* – Macklemore & Ryan Lewis**
>
> *I hit that court*
> *and when I jumped*
> *I jumped*
> *I swear I got so high*
> *I touched the net*
> *Mom I touched the net*
> *This is the best day of my life*

Figure #1: Excerpt from a famous song about basketball culture ("Macklemore – Wings Lyrics")

Prior research on anthropometric factors included a wide range of variables. Research on young Indian national players found significant positive correlations between vertical jump and age, weight, height, midstylion-dactylion length (fingertip to base-of-palm), Trochanterion height (height from heel to hip), arm, thigh and calf girths, lower back and hamstring flexibility, and grip strength (Sharma et al 1). Though this investigation will not be measuring most of these variables, this work opens a glimpse into the complex physical factors behind jumping.

Of the group of mentioned variables, the positive relationship between vertical jump and weight might seen counter intuitive, but the subjects were all young national-level athletes that were not overweight. This should be similar in this study of high-school basketball performers, and thus will not be explored. To this point, other researchers found that body fat% had a significant negative relationship with vertical jump height (Abidin and Adam 39), as one would expect. Although body mass is not a good predictor of power production due to its lack of differentiation between fat and fat-free mass, peak power output per body mass have been show to correlate well with jump height in many sport modalities (Kons et al). This led me to suspect that physical features relating to leg musculature should correlate well with vertical jump performance.

Research on this topic was scarce. One study on Nigerian recreational basketball players concluded significant positive correlations between vertical jump and calf girth and foot size, while not with femoral or tibial length (Aiyebussi et al. 2853). Contrary to this, a research team in India found that humerus, hand, femur, tibia and foot lengths were a significant predictor of vertical jump performance (Saiyed et al.). Also, Sharma et al.'s work as mentioned before was also very helpful.

The aim of this investigation is to analyze the correlation of physical features with vertical jump height, specifically thigh and calf circumference, tibial length and half-court sprint time. Also, since both varsity and junior varsity players were used, this study lends itself well to investigating the role of these non-skill factors in selecting players at a high school level.

1.2 Method:

RQ: How does half-court sprint time (s), thigh and calf circumference (cm), and tibial length (cm) relate with maximum vertical jump height in high-school level male basketball athletes?

IV: Half-court sprint time (s), thigh and calf circumference (cm), and tibial length (cm)
DV: Jump height (reach height – standing reach) as measured by vertical jump recorder

Hypothesis: I predict that half-court sprint time and thigh circumference will correlate with maximum vertical jump negatively and positively, respectively, mainly because they both reflect lower-body power. I think that the other two variables (calf circumference and tibial length) will not correlate well with vertical jump.

1.3 Materials:

Tape measure	6 Plastic Cones	Stopwatch (on phone)	Computer
Long stick	Tape	Vertical jump test apparatus	

Figure #2: Experiment setup

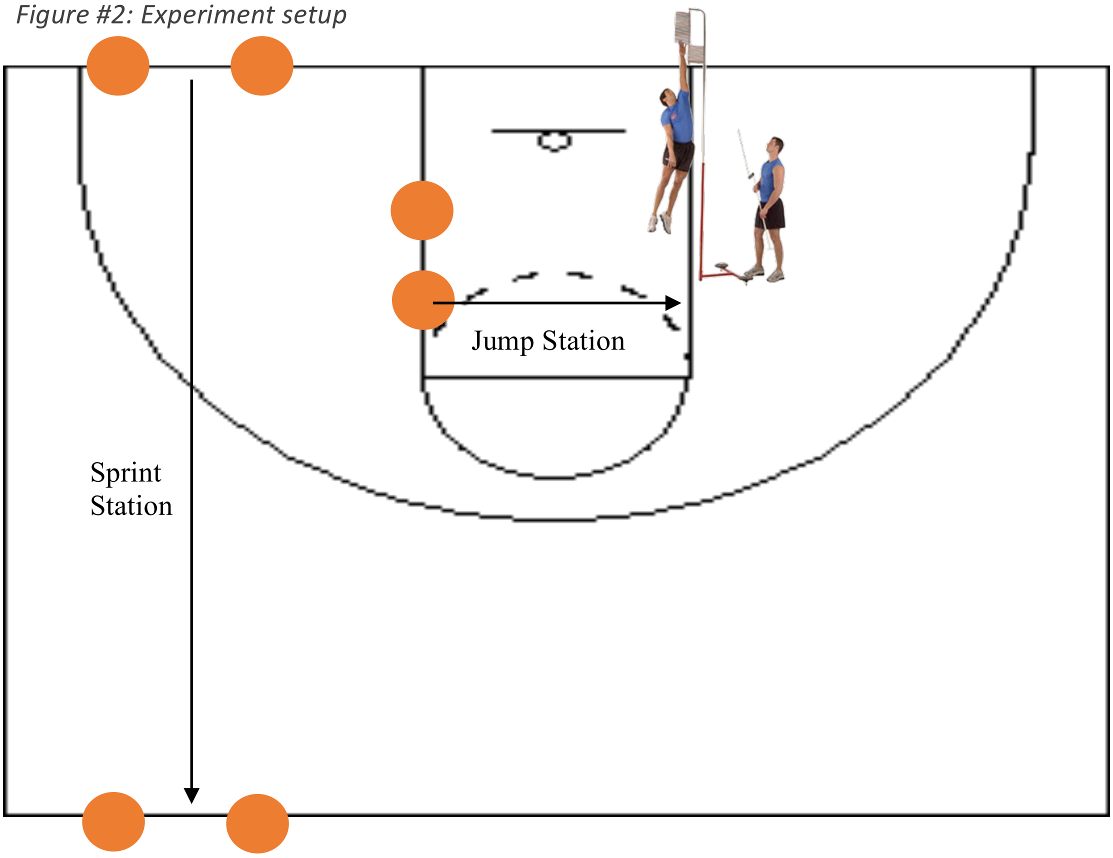


Table #1: List of controlled and confounding variables

Controlled Variable	Why	How
Environment and equipment	The wide range of environmental factors could affect the experimental results considerably, with things like court friction, court bounce, temperature, and many more. These inconsistencies could've covered differences in athletic performance and diminished the actual results.	To minimize these differences, I used the same gym and equipment for all trials. Varsity and JV teams were conducted separately, but the gym helped maintained a stable temperature year-round.
Subject's accessories	What subjects wear can significantly impact their vertical jump performance, especially since this is a multi-joint movement. Most importantly, subjects should not be athletically limited by their clothing.	Only subjects who wore athletic outfits were tested, mainly loose or stretchy shorts and athletic shoes. Also, no subject should have any significantly performance-boosting accessory.
Procedure	The procedure is strictly designed to minimize experiment time and maximize subject recovery between tests. If the procedure varied for each subject, their different levels of fatigue at different stages of the experiment may interfere with the data.	All trials used the same procedure, including order, duration, and pace of each stage in the procedure.
Expertise with basketball	The amount of time that subjects have played basketball will directly affect their fluency with jumping as a movement. Fluency and expertise has shown to improve the neuromuscular efficiency and will thus be another factor contributing to the maximum jump height (McErlain-Naylor et al. 7).	All the subjects were from two highest level high-school basketball teams (varsity and junior varsity 1) out of 4 teams. Being selected for these teams at this relatively athletic school was enough of an inclusion criterion for this.
Confounding variable	**Why**	
Level of fatigue prior to experimentation	Firstly, this is a metric that is highly subjective and is hard to monitor precisely at a high-school level. Also, the experiments were conducted during/after practice to ensure subjects were fully warmed up. This added another level of uncertainty to the amount of fatigue they felt.	
Jump technique	The original intent of this experiment was to determine the correlation between physical measurements and *maximal* vertical jump, and so it was designed to allow for the subjects to use their own most comfortable way to jump. Upon reflection, this seems to be a confounding factor because of its effects on vertical jump performance (McErlain-Naylor et al. 9).	

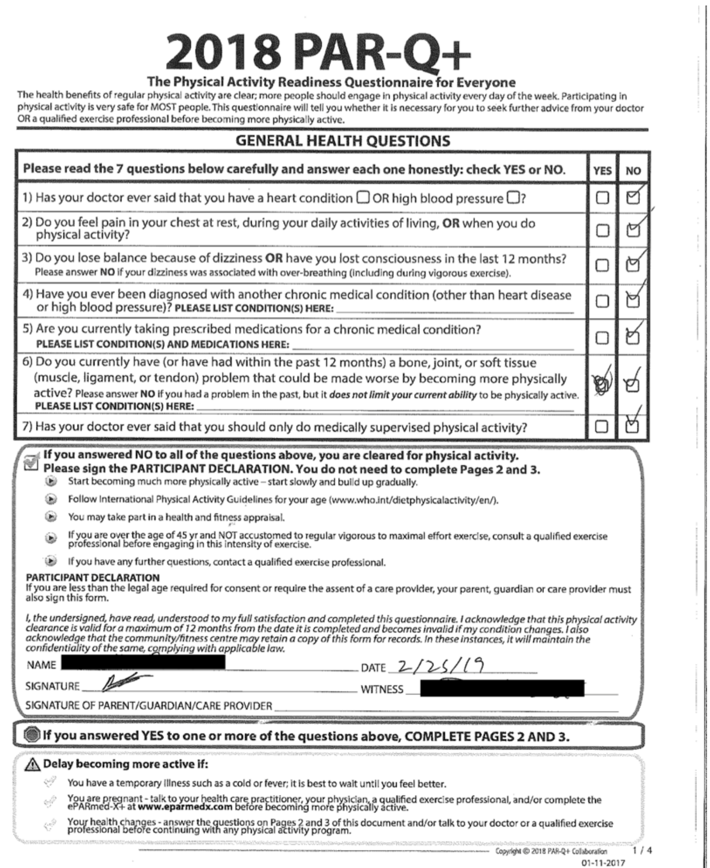
Body characteristics	Similar to the reasons for jump technique, physical characteristics like bodyweight, height, wingspan and many others were not measured because they did not align with the purpose of this investigation of relating vertical jump performance to anthropomorphic features. However, these variable still relate significantly to vertical jump, and should've been measured.

1.4 <u>Procedure</u>

1. Inclusion criteria: currently enrolled in my high school, with >3 years' experience with school-team basketball, counting both middle and high school.
2. The area of experiment was set up as shown in Figure #2.
3. All subjects were required to be warmed-up and in appropriate athletic outfits, specifically athletic shorts and shoes so that their performance was optimized.
4. First was the maximum sprint time test. The subjects started at a spot marked with cones on the baseline of a basketball court, and prepared to sprint till half-court.
5. Then the left thigh and calf circumferences were measured. This was measured while standing up, legs straight, with no additional leg contractions other than that for standing up, with the measuring tape skin-tight, and at half way along the femur and tibia. This time was designed to give the subjects recovery time from sprinting.
6. After that, the length from the calcaneus bone to the proximal head of the tibia on the same leg was measured. This was the tibial length. The measuring tape should be skin-tight while measuring.
7. Lastly, the vertical jump test was performed. Using the tape ruler hanging from the apparatus, the maximum reach height for subjects was measured before jumping, and adjustments to the apparatus were made accordingly. Pacing, counting steps, or measuring distance were all permitted within a 3m space. The maximum vertical was recorded.

1.5 <u>Ethical Considerations</u>

Although there were no significant sites of danger in this experiment, all subjects filled out the PAR-Q survey (See Figure #3) to ensure their physical readiness for the fitness testing. 1 subject was removed from the sample due to persisting knee joint pain.



2018 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☑
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☑
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☑
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☑
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☑
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☑	☑
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☑

If you answered NO to all of the questions above, you are cleared for physical activity. Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION

If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness centre may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME [redacted] DATE 2/25/19

SIGNATURE ______ WITNESS [redacted]

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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Figure #3: PAR-Q Document for 1 of 12 subjects

2.1 Raw Data

Table #2: Collected data of all dependant variables of 12 subjects

Subject #	Left thigh circumference ± 1 (cm)	Left calf circumference ± 1 (cm)	Maximum half-court sprint time ± 0.05 (s)*	Tibial length ± 1 (cm)	Total vertical jump ± 1(cm)**
JV					
1	49	35	2.85	49	78
2	49	35	2.95	45	83
3	52	36	3.00	43	63
4	42	40	3.10	41	58
5	47	35	2.95	46	85
6	49	35	2.80	43	65
7	51	36	2.85	45	74
V					
8	45	32	2.70	40	77
9	50	34	2.70	40	88
10	42	33	2.70	44	92
11	57	37	2.70	45	83
12	55	41	2.70	47	69

*Uncertainty widened to account for both recorder and subject reaction time

**Converted from inches to centimeters through multiplying by 2.54cm/inch

2.2 Processed Data:

Table #3: Processed data for thigh and calf circumference

	Average thigh circumference (cm)	STDEV	CV	Average calf circumference (cm)	STDEV	CV
JV	48.37	3.25	0.07	35.93	1.88	0.05
V	49.80	6.38	0.13	35.40	3.65	0.10

Table #4: Processed data for sprint time, tibia length and maximum vertical

	Average half-court sprint time (cm)	STDEV	CV	Average tibia length (cm)	STDEV	CV	Average maximum vertical jump (cm)	STDEV	CV
JV	2.92	0.11	0.04	44.50	2.57	0.06	72.35	10.32	0.14
V	2.70	0.02	0.01	43.20	3.11	0.07	81.62	9.01	0.11

** V – Varsity, JV – Junior Varsity, STDEV – Standard Deviation, CV – Coefficient of Variation.*

Table #5: T-test values comparing Varsity and Junior Varsity data

Unpaired, Two-ended T-test between JV and V	p-values
Calf Circumference	0.777
Thigh Circumference	0.663

Sprint Speed	0.001
Tibial Length	0.467
Vertical Jump	0.131

2.3 Sample Calculations:

All sample calculations will be performed with Varsity measurements for maximum vertical leap.

Average maximum vertical leap (cm)
= (Sum of all values) / (total # of data points)
= (76.64 + 88.1 + 91.64 + 82.64 + 69.1) / 5
= 81.62 cm

Standard Deviation for vertical leap (cm)
= Excel function: =STDEV{whole data set}
= 9.01 cm

Coefficient of Variation
= Standard Deviation of Values / Average Value
= 9.01 / 81.62

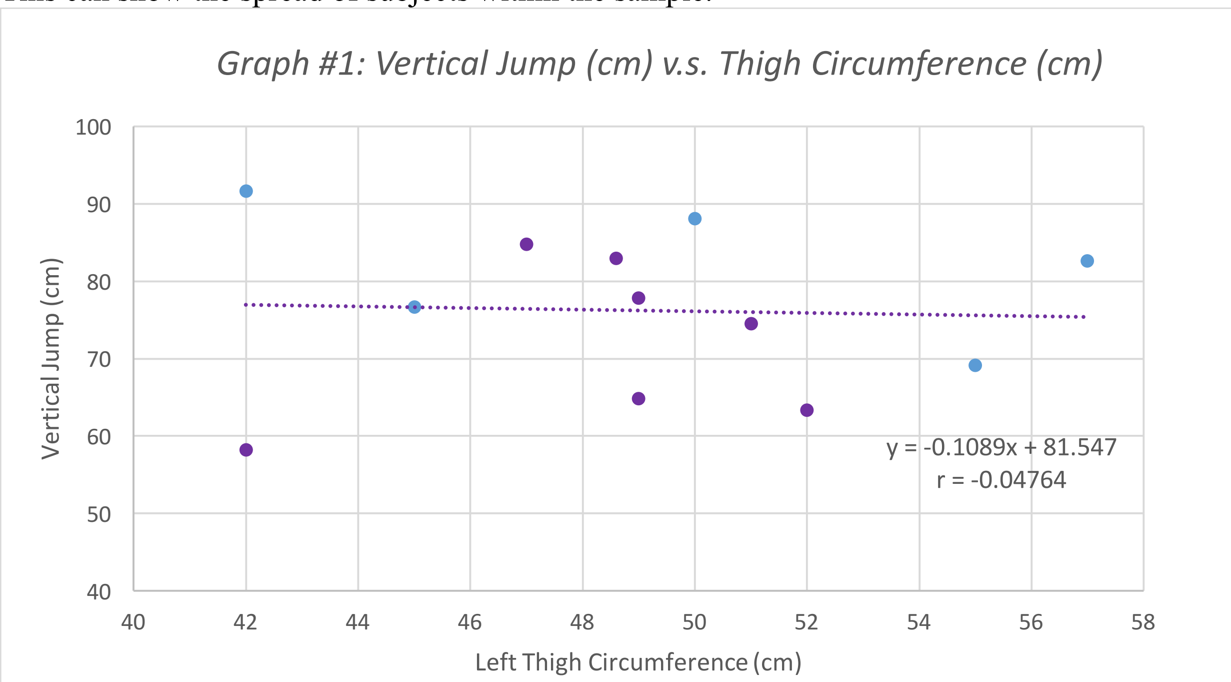
T-test Values
= See Equation #1 below and use Excel function:
= TTEST ([JV data], [Varsity Data], 2, 3)
= 0.131

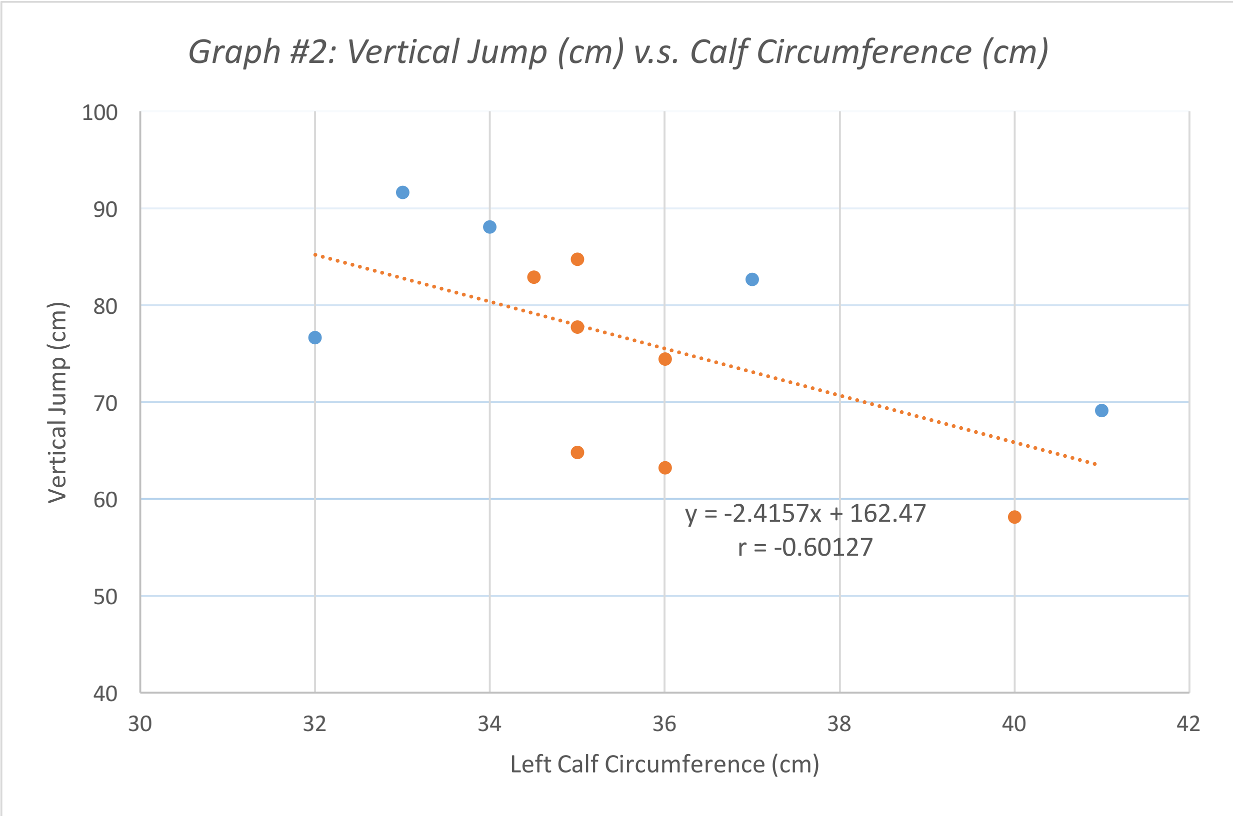
Equation #1:

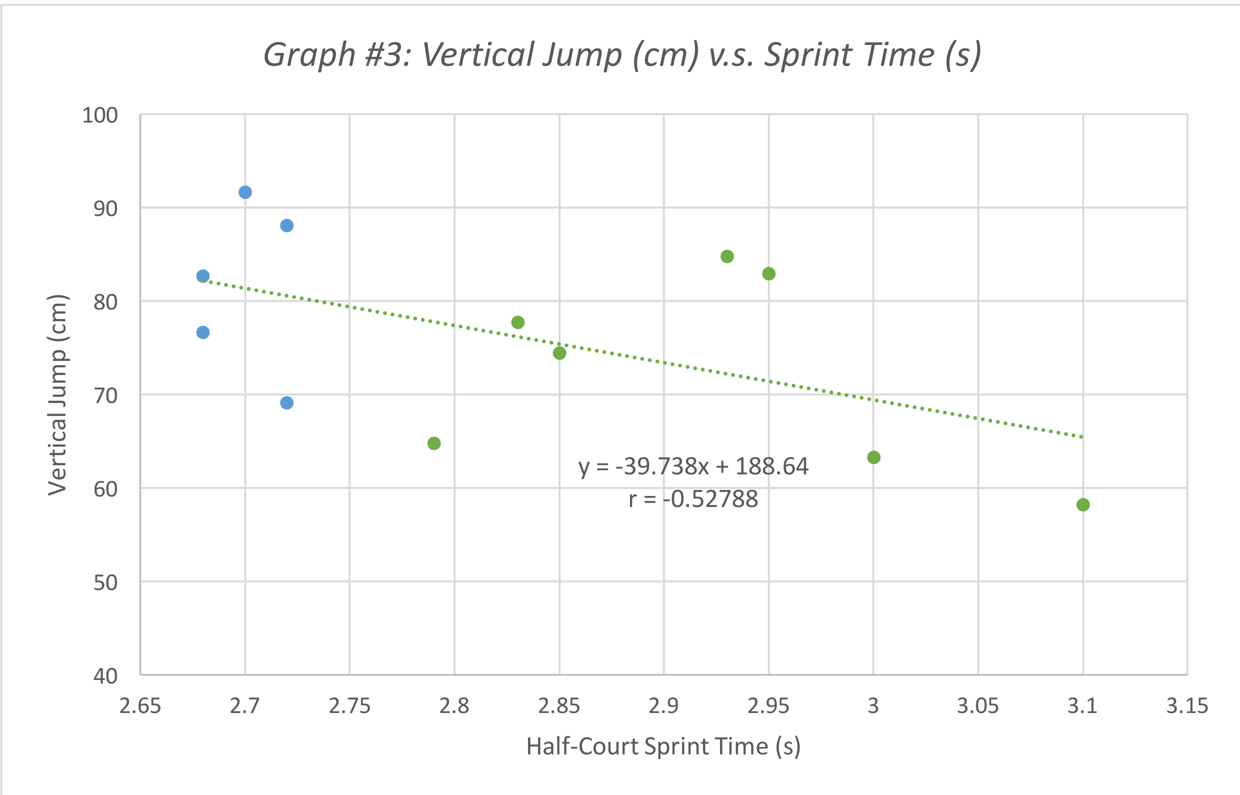
$$t = \frac{(x_1 - x_2)}{\sqrt{\frac{(S_1)^2}{n_1} + \frac{(S_2)^2}{n_2}}}$$

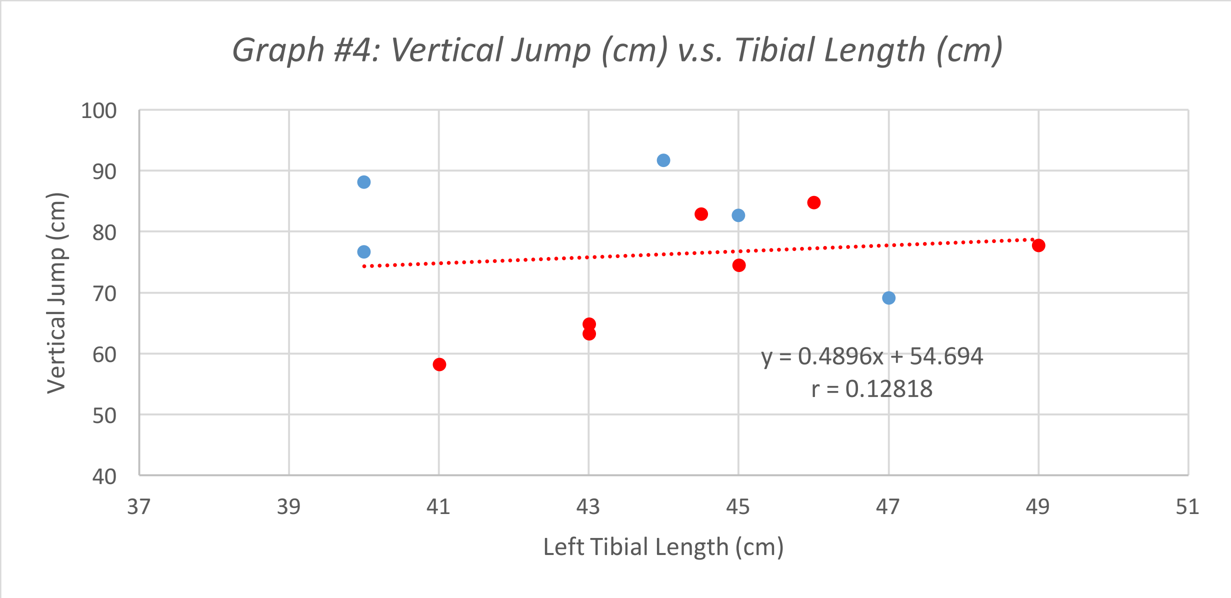
2.4 Graphical Analysis

While averages are useful to generalize certain groups of subjects and show cumulative differences, graphs can show trends and correlations by including every single subject.
On each graph is the r value for that graphs' regression model, calculated from the square root of R^2 values given by Microsoft Excel ("Correlation"). his value measures the "strength and direction of a linear relationship", where correlations beyond 0.5 or -0.5 are worth discussing (Rumsey).
Also, all blue data points represent varsity subjects, while the not-blue dots are JV subjects.
This can show the spread of subjects within the sample.




Graph #2: Vertical Jump (cm) v.s. Calf Circumference (cm)
Vertical Jump (cm)
100
90
80
70
60
50
40
30
32
34
36
38
40
42
Left Calf Circumference (cm)
y = -2.4157x + 162.47
r = -0.60127


Graph #3: Vertical Jump (cm) v.s. Sprint Time (s)
Vertical Jump (cm)
100
90
80
70
60
50
40
2.65
2.7
2.75
2.8
2.85
2.9
2.95
3
3.05
3.1
3.15
Half-Court Sprint Time (s)
y = -39.738x + 188.64
r = -0.52788



Qualitative Observations:

1. Varsity subjects were quite significantly fatigued before the tests began
2. There were slightly more single-leg jumpers than double-leg jumpers, with all subjects jumping off of their left leg.
3. The majority of subjects were very familiar with the vertical jump movement
4. General effort and exertion was high across the group
5. V subjects performed the tests with their teammates watching and talking next to them, while the JV ones did not.
6. Through careful observations, no subject had significantly different left and right leg musculatures.

3.1 Analysis and Conclusion

The aim of this exploration was to investigate how physical features can be an indicator of or correlate with vertical jump performance. According to the data, sprint time and calf circumference had a relatively significant correlation with vertical jump, with an R-value of approximately -0.6 and -0.53 respectively (See graphs #2 and #3). Vertical jump performances' correlation with sprint-time makes sense – even if a maximal sprint is not a power test, a shorter sprint time most likely reflects a stronger, more explosive lower body musculature that can translate into achieving higher vertical jumps; however, the calf circumference negative correlation may seem counter-intuitive. The other two variables, thigh circumference and tibial length, correlated very poorly, with R-values of a mere 0.05 and 0.13 respectively (see graphs #1 and #4).

Also, the comparisons between the JV and varsity statistics generally do not show many strong differences. One implication of this is that perhaps the selection of varsity and JV basketball players at this high-school is not solely based on raw athleticism but also other factors like skill, leadership, and game intelligence. The relative importance of athleticism in athletic screening (even at a high-school level) may also vary between sports, with team sports like football or basketball depending much less on physiology than track & field or cross country.

Sprint speed was the only variable that was significantly different between the two groups, where the varsity team was significantly faster than the JV team (p=0.001). The significance of this variable was slightly surprising, since data from high-school students was not expected to show such a strong significant difference. Thus, this information can illuminate certain elements of the team-selecting process for high school level athletes, where perhaps at some level, consciously or unconsciously, the faster athletes are selected. The NFL and NBA both uses sprint tests for recruiting athletes (Wood, "Combine"), and so does this school. One such reason could be that sprinting is a movement pattern extremely fundamental to almost all sports, and even if its not directly used for competition (cycling, swimming, rowing, combat sports), its still a very common way to cross-train and exercise cardiorespiratory fitness. Thus, proficiency in the maximal sprint not only shows the athlete's speed (mainly driven by leg turnover rate), but potentially also their general athletic experience, as strong sprinters will likely have significant skill transfer from other sports. Both implications are beneficial for an athlete, which may explain why the significantly faster players were selected for varsity.

Another interesting thing is that although sprint time was significantly different between JV and V groups, vertical jump was not (p=0.131). This could have many implications:

1. If both tests produced accurate and valid results, this would mean that varsity players are significantly faster than JV players, while not necessarily higher jumpers. But jumping is arguably a skill that is more central to basketball than running, yet there is no significant different there. This may reflect the reality of high-school level sports, where competition and stakes aren't high enough for the relatively minute details (jump height and sprint time) to matter very much. Or, perhaps tryouts only screen for a certain "threshold" of vertical jump performance, and since all these players were already far above average – the aggregate average was almost two STDEVs above the study-average of 22.2 inches (Patterson and Peterson 33). Therefore, these players' vertical jump may be good enough so that the specifics do not matter.
2. Although the maximal sprint is not a power test, the fact that the performance displayed in the sprint did not translate into a similar performance in the vertical jump test reveals issues of the vertical jump test's validity and specificity. The level of coordination and skill required in the vertical jump test can reduce its effectiveness as a test for muscular power. This notion is supported by research conducted by McErlain-Naylor et al., claiming that "technique [influences] the extent to which maximal muscle capabilities can be utilized during the jump." (McErlain-Naylor et al. 9). This is also partially supported by research that reported the stork balance test as a strong predictor of vertical jump (Davis et al 1), showing that perhaps power is not the only fitness component being utilized in jumping.

The negative correlation between calf circumference and vertical jump (r=-0.60) could be related to the marginal strength gains from increasing muscle mass. As muscle mass increases, the ability for the body to produce power is improved, especially if it is type II muscle fibers which are gained (Beardsley). However, there are diminishing returns for gaining more muscle, because muscle is also very dense, and it adds mass to the body which it needs to push. At a certain point, gaining more muscle may provide less gains in strength than gains in mass, which would actually decrease vertical jump performance. This is especially the case with the gastrocnemius which is predominantly type I muscle (Beardsley).

Given this, it's possible the negative linear correlation between calf circumference and vertical jump shown in this experiment only holds for this particular range of calf measurements. Too small, calves do not carry the amount of muscle required to generate strong power and strength. One would suspect the full correlation between calf circumference and vertical jump to be quadratic, where as you gain muscle mass on your calves you'll increase your power output, but once you get past a certain point, the extra muscle mass will 1) likely to be type I and/or 2) offer very little muscular power that cannot cover the very weight it adds to your body. This may explain why previous researchers found positive correlations between vertical jump and calf girth while this investigation found a negative one (Sharma et al. 1). Further research can investigate this specific "magical point" where optimum strength is achieved, and it can begin with observational studies of high-jumping athletes like Olympic high-jumpers or NBA basketball players. This point will probably depend on other physiological factors like body fat %, height, genetics, gender etc. This research can help athletes optimize their vertical jump, a movement that is essential in sports like basketball, volleyball, American football, handball, and many more.

In this experiment, calf circumference had a much stronger correlation with vertical jump performance than thigh circumference did (R-value of -0.6 and -0.04 respectively), likely attributable to how most subjects used the single-leg jump technique. This is because during a single-leg take-off the leg is "near full extension and [is] in a poor position to develop further propulsive forces", while this is not the case in a double-leg jump (Vint and Hinrichs 354). This may mean that the quadriceps and hamstrings (which mainly serve to flex and extend the knee joint) cannot contribute majorly to the single-leg jump – the predominant selection of jump choice in this experiment. By the same token, this means that the main contributors to the single-leg jump are the gastrocnemius, soleus, and gluteal muscles that facilitate plantar-flexion and hip extension for take-off. This notion is supported by EMG data of volleyball players that showed higher activity in the gastrocnemius in single-leg jump than did double-legged jumps (Soest et al.). The biomechanical position of a single-leg jump likely explains why calf circumference correlated better with the vertical jump than thigh circumference did. On the flip side, research showed that in a double-leg jump, there is significantly greater angular velocities at the hip and knee than a single-leg jump (Soest et al.), an indicator of higher contribution of the quadriceps and hip flexors to the movement. This means that if all subjects in this experiment used the double-leg jump technique, it would be expected that thigh circumference would correlate stronger with vertical jump performance than calf circumference.

Further research can be conducted with similar and more anthropometric features and their correlations with double and single-leg jumping. Amongst the basketball player community here, it is a common conception that players with "thicker" legs tend to perform better at double-leg jumping, while those with "skinnier" legs tend perform better in a single-leg jump. By looking at large populations and drawing correlations, along with electromyography data, the physiological explanation for this apparent phenomena may be explained or refuted. This research can then assist athletes with realizing their best potential in either single-legged or double-legged jumping according to their current anthropometry. For example, preliminary research on experienced volleyball players has shown higher levels of EMG activation in the gastrocnemius in one-legged jumps than in double-legged jumps, hinting that if an athlete has a strong calf musculature (either genetically or trained) they may perform marginally better in a one-legged jump (Soest et al.).

If calf activation really is greater than thigh activation in the single-leg jump, then *relative* tibial length (length of the tibia as a percentage of the entire leg) may have been a stronger variable to test than tibial length. Tibial length can measure how *proportionally* long someone's tibia is, and thus how long their calf muscles are. Longer muscle means potentially more muscle, which could improve vertical jump performance. Future research can be conducted on this as well. Also, an extension to this is figuring out the optimal proportion of relative tibial length in different sport modules. For example, one would expect higher average relative tibial lengths in marathon runners than ordinary people.

All in all, the purpose of this experiment was to investigate the relationship between anthropometric factors and athletes' performance, an effort to reduce performance to its fundamental components of forces and levers in the body. This investigation shows that while some correlations exist for vertical jump, anthropometry does not tell the whole story. Anthropometry matters most in individual, elite-level, less skill-related sport modules, where small differences in physiology matter much more than skill differences per se. Some examples include cycling, marathon running, high jump, powerlifting and many other similar sports. From the opposite perspective, when the top-level athletes in a particular sport all have very similar body types, leanness, muscularity, height etc., it indicates a "natural selection" process within the sport that eliminates the athletes with a "sub-optimal body type", indirectly revealing the importance of anthropometry. Further research on the relationships between anthropometry and physical performance can thus dramatically assist athletic screening.

3.2 <u>Evaluation:</u>

Strengths:

A. <u>Study design:</u>
The study design of this experiment was specifically made to save time and effort for the subjects participating. By catching players during/immediately after practice ensured their warmness and safety; and the sequencing of measurements allowed for recovery between the sprint and the vertical jump test. Also, achieving a high vertical jump is something that is in itself motivating for many basketball players, which reduced the effect that a lack of intrinsic motivation would usually have in a typical study with high-school students.

B. <u>Subject selection</u>
The subjects' selection not only revealed a wide range of data points, but also allowed for the comparison between JV and Varsity basketball levels. Plus, all subjects were male, which eliminated genetic difference in vertical jump performance due to inherent muscle mass and body fat differences (Abidin and Adam 39). This selection of subjects can then shed light on the nature of high school level team-selection.

Limitations	**Improvement**
<u>Fatigue level was not held constant across the study's subjects.</u> Fatigue strongly reduces athletic performance and could've impaired the experimental data.	Instead of being done after/during practices, this experiment should be conducted from a resting fatigue level, like right after school. Then, as long as all subjects go through the same warm up, then the baseline fatigue levels would be controlled for. This also makes the experiment less rushed, and

	leaves more room for more trials and/or more accurate measurements.
Lack of trials/repetition. Usually experiments conduct more than 3-5 trials to ensure the data's brevity. In this case, due to time and subject constraints, only 12 subjects were used and each one only got 1 trial for many of the tests.	Realistically, it would not be practical to do 15-minute elaborate tests with multiple trials for each subject. However, the only things that need multiple trials are the vertical jump test and the sprint test, each of which don't take very long. Furthermore, it could've been interesting to do a pre-, during, and post-season comparison for every player and use paired t-test to determine whether changes in leg measurements, for example, was correlated with their changes in vertical jump after a 3-month season.
The jumping technique of these jumps was not held constant across the jumpers. There were significantly more single-legged than two-legged jumpers, and this variation in technique may have allowed for uncertainties because of its effects on vertical jump performance (McErlain-Naylor et al. 9).	Vertical jump technique plays a large role in performance. By limiting the jumping technique to a certain step width, step count, windup time etc., this can eliminate areas of uncertainty in subjects' power generation. At the same time, this shouldn't be a very significant limitation (like forcing all athletes to use one-legged jump), or else it might reverse its role and limit the performance of subjects unfairly.

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