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# Examination of Hamstring Flexibility and Maximal Sprint Speed

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# Examination of Hamstring Flexibility and Maximal Sprint Speed

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Exercise Science: Pre-Physical Therapy

**Honors Research Project**

Submitted to

*The Honors College*

# Abstract

## Purpose

Maximal sprinting ability is a highly sought after trait in athletes. Many studies have been performed in an effort to determine the factors of sprinting ability, such as the vertical jump, squatting ability, and others. However, very limited research has been performed on the relationship between flexibility and maximal sprinting speed. The vast majority of research done involving hamstring flexibility and performance involves the acute effects of stretching on performance, or the relationship between flexibility and injury prevention. The purpose of this study is to determine the relationship between hamstring flexibility and maximal sprinting speed.

## Methods

This study involved 65 participants, all of whom were 18-24-year-old men from the University of Akron football team. The participants underwent testing in the 40-Yard Dash (maximal sprint speed), the Sit-and-Reach (hamstring flexibility), the vertical jump, and a body composition analysis. Linear regression analysis was performed between each test and the flexibility measurements.

## Results

There was a significant no correlation relationship between the 40-Yard dash and the Sit-and-Reach ($p < 0.001$, $R^2 = 0.111$).

## Conclusion

This study found that there is no relationship between maximal sprint speed and hamstring flexibility.

## Introduction

Stretching is a standard component of practically all athletic and exercise related events. Everyone from youth football teams to Olympic athletes begin their movement with some sort of choreographed routine designed to increase their range of motion and prepare their bodies for activity. Flexibility is a component of performance and fitness that is well regarded and valued. Professionals in the exercise science field and the strength and conditioning field promote stretching to their clientele.

In the world of athletics today, there are a few specific traits that coaches and recruiters try to identify and develop in their athletes. These include strength, power, toughness, intelligence, and coordination. However, one of the most critical variables desired in athletes is speed. Talent evaluators identify and prioritize sprinting ability. For example, research has shown that football players that get drafted into the National Football League who perform better in maximal sprint tests (40-yard dash) than players who go undrafted (Sierer et al., 2008).

As a result of the lack of research surrounding the relationship between hamstring flexibility and maximal sprint speed, as well as the large societal demand to develop mechanisms and exercises to increase sprinting ability, this study was designed. This study focuses on the correlation between hamstring flexibility and maximal sprint speed in Division I-FBS football players at the University of Akron. This study is correlational, and as such it is not designed to diagnose a causal relationship. The benefit to society would be to either affirm the performance benefits of flexibility or dispel them.

Many varying hypotheses of how lower-body flexibility affects sprint speed exist among a variety of populations. From the lowest level of sporting events it is purported from youth coaches that the easiest way to become faster is to increase flexibility. However, certain strength and conditioning experts have observed that it is usually the least flexible individuals who turn in the fastest sprinting times. One of the few studies performed on this subject, found no correlation between hamstring flexibility and 100-meter sprint times in high school track and field athletes (Skaggs et al., 2015). Additionally, as a result of the length-tension relationship of a muscle, it does not seem that the capacity for a muscle to stretch passed a certain point would be advantageous for force production, and ultimately maximal sprint speed.

This study is operating under the hypothesis that there will be no relationship between maximal sprint speed (as measured by the 40-Yard Dash) and hamstring flexibility (as measured by the Sit-and-Reach).

## Literature Review

As mentioned briefly in the introduction, the research on this subject matter is extremely limited. The databases searched through included the University of Akron's Search-A-Roo, Google Scholar, SPORTDiscus, and The Journal of Strength and Conditioning Research.  Search terms utilized in the databases included, "sprint speed and flexibility," "maximal sprint speed and hamstring flexibility," "flexibility and force production," and "sprint speed and performance."

Extensive research has been done regarding flexibility, but the clear majority of that research has been done relating stretching and flexibility to injury prevention. The relationship between flexibility and sprint speed is often perpetuated by novices and professionals alike, but has been largely neglected in the research. Furthermore, the limited amount of research that has been done relating sprint performance and flexibility mostly focuses on the impact of stretching immediately prior to activity. One such example has found that static stretching has a negative impact on anaerobic performance (Kurt & Firtin, 2016). This study was performed on 20 professional soccer players and found that when static stretching was included in the warm-up, there was a decrement in anaerobic power and maximal sprint speed. Over a period of one month, subjects were tested on stand and reach flexibility, Illinois agility, and anaerobic sprint tests three separate times. On the first occasion, they were tested following a warm-up consisting of only a light aerobic run (five minutes of a 20m shuttle run). On the second occasion, they were tested following a warm-up consisting of only a light aerobic run and static stretching (five minutes of a 20m shuttle run as well as six different static stretches including standing quadriceps stretch, standing hamstring stretch, standing hip flexor stretch, standing piriformis stretch, standing calf stretch, seated spinal twist, and sitting groin straddle). On the third occasion, they were tested following a warm-up consisting of a light aerobic run and dynamic stretching (five minutes of a 20m shuttle run as well as seven different dynamic stretches including walking hamstring kicks, walking lunges, lateral walking lunges, power high knee, dynamic hip flexor, leg swing towards the opposite side, and explosive hip flexion mobility). The results of the study showed that the warm-up that included static stretching had a significant decrease in relative average power and relative maximum power compared to the warm-ups that did not include static stretching.

The literature and research seems to be divided on whether or not maximal sprint speed is correlated with hamstring flexibility, as evidenced by the studies that follow. One side of the argument there is a study of youth soccer players between the ages of 14 and 18 (García-Pinillos et al., 2015). This study divided its 43 participants into two separate groups: a flexible group and a non-flexible group. Hamstring flexibility was determined by a unilateral passive straight-leg raise test (PSLR). The groups were created based off of the results of a cluster k-means that was performed according to the PSLR test. There were 24 subjects placed into the flexible group and 19 subjects placed in the non-flexible group. The flexible group was found to have a significantly faster sprint speed in a 5, 10, and 20-meter sprint. The flexible group was also found to have performed significantly better on the vertical jump test and the kicking speed tests for both the dominant and non-dominant leg. There was no significant difference in body mass, height, or body mass index (BMI) between the two groups. This research study suggests that there is a correlation between maximal sprint speed and hamstring flexibility.

On the opposite end of the argument is a study of 37 high school track and field athletes (Skaggs et al., 2015). This study analyzed the hamstring flexibility, through the sit-and-reach test and a knee extension angle test, and hip flexor flexibility through the Thomas test. Sprinting speed was measured through a 100-meter dash. The vertical jump was also measured. The measurements of the aforementioned tests were recorded and placed into simple linear regression analyses. The vertical jump and the knee extension angle were inversely related, and were the only two significantly related variables. Neither the sit-and-reach nor the average knee extension angle had a significant relationship with maximal sprint speed. The results of this study showed that there was no relationship between maximal sprint speed and hamstring flexibility. However, the results of this study do suggest that there could be an adverse relationship between hamstring flexibility and the vertical jump.

When examining the physiology of muscle function, the latter study seems more rational. The length-tension relationship of skeletal muscle states that a muscle fiber is capable of maximal force production at 100-130% of its resting length (Floyd, 2015). A muscle operating at greater than 130% of its resting length would not only be non-advantageous, it would actually be disadvantageous. (Floyd, 2015) Therefore, the ability to stretch passed a certain point would not aid in force production. Research has shown that horizontal force production is a reliable predictor of maximal sprint speed (Buchheit et al., 2014). This over-flexibility may result in a hindrance in force production. It would make sense that it would not result in improved sprint performance.

A study of 30 professional soccer players showed that body fat percentage and sprint speed seem to be correlated (Ostojic, 2003). The participants were tested in a 50-meter maximal sprint test and measured for their body composition via skin-fold calipers. These tests were performed at the first conditioning period, at the start of season, in the mid-season, end-season, and at the start of the second conditioning period. The study found that the estimated body fat percentage found via skin-fold measurements was lowest at the end of the season. The fastest sprint times recorded were also found at the end of the season. The simultaneous occurrence of lowest body fat percentage and fastest maximal sprint speed suggests that there is a relationship between sprint speed and body composition. For this reason, subjects in this study were categorized according to their body fat levels for a more in-depth analysis.

## Methods

### Subjects:

Approval for this experiment was sought out and approved by the University of Akron Institutional Review Board. The population studied was the University of Akron football team, who are all 18 to 24 (±1.36)-year-old males. Members of the football team were provided with an explanation of the risks of participation via the informed consent, as well as how their results may be utilized. Additionally, participants were informed that they were in no way obliged to participate in the study and could choose to be removed at any point. Following a verbal explanation, the informed consent page was presented and signed by the individuals. Members of the football team were excluded if they had an injury that prevented them for participating in the study. All participants underwent a standardized warm-up that consisted of thermogenic movements, dynamic stretches, and a brief instruction on the mechanics for a proper start to the 40-yard dash. The exact exercises utilized for the warm-up can be found in Appendix B. The cues given for the 40-yard dash included staggering the feet at a heel-toe relationship, loading the front leg with tension, and pulling the scapulas together throughout the sprint. All testing was completed indoors at the University of Akron campus. The 40-yard dash, vertical jump, and the sit-and-reach were performed at the Stiles Athletic Field House. The BOD POD® was performed in the University of Akron Exercise Science Department's lab room. Participants wore athletic clothing for all testing, as well as football cleats for the 40-yard dash, tennis shoes for the vertical jump, and no shoes for the sit-and-reach. Clothing for the BOD POD® is discussed later. A designed warm-up was chosen over static stretching, because a dynamic warm-up has been shown to produce better maximal sprint speed results (Stewart et al., 2007). The strength and conditioning staff aided in collecting the data from the participants. All staff members were trained in data collection procedures. All staff members had either already obtained or were pursuing bachelor degrees in exercise science. Three staff members were pursuing or had already obtained a master's degree in sport science and coaching.

The participants were tested in the 40-yard dash, the vertical jump, the sit-and-reach test, and, body composition analysis through air plethysmography. While undergoing testing, some student-athletes were unable to complete certain tests as a result of schedule conflicts, not wanting their data recorded for a specific test, or something of the like. All athletes in the study performed both the sit-and-reach and the 40-yard dash, as well as having their height and weight recorded. For the body composition testing, 64 of the 65 participants provided usable data. For the Vertical Jump, 63 of the 65 participants provided usable data. These tests are explained in further detail next.

### *40-Yard Dash*

The participants ran a full speed 40-yard dash sprint on the indoor turf field at the University of Akron. The strength and conditioning staff timed the 40-yard sprints on handheld stopwatches and the average time was taken down and recorded to the nearest hundredth of a second for each athlete. Each athlete ran individually and were organized in alphabetical order, according to their last names. The participants were instructed to start in a three-point stance and the timer was started on their first movement. Although electronic timers are considered the ultimate standard for measuring sprint performance, they were not deemed a necessity for this study. Research has shown that there is no significant difference in the precision and reliability of handheld stopwatches versus an electronic timing system (Mann et al., 2015). The electronic times were significantly higher and most likely more accurate, but this study was not reliant on accuracy. Because reliability and precision of timing were the only elements necessary for this study, an electronic timing system was not allocated.

### *Vertical Jump:*

On the same day following the 40-yard dash, a measurement of maximal vertical jump was performed on the same day. Participants were given as much time as they deemed necessary to fully recover, which was approximately 5 minutes. The maximal distance that the participants could jump off the ground was measured using a Vertec™ (Sports Imports, Hilliard, Ohio) apparatus. The participants' maximal standing reach was measured and used to set the height of the Vertec$^{TM}$. The participant then stood directly under the Vertec$^{TM}$ tabs, squatted down, jumped as high as they could, and gently tapped the highest tab they could. Participants were given two attempts to obtain the best result possible. The better of the two attempts was recorded to the nearest half inch.

### *Sit-and-Reach*

On the same day following the vertical jump, the Sit-and-Reach test was performed. Participants were given as much time as they deemed necessary to fully recover, which was approximately 1 minute. The sit-and-reach test was performed using Figure Finder Flex-Tester boxes. Participants were instructed to remove their shoes and sit on the ground. The soles of the participants' feet were placed against the box with the legs completely straight. Participants were instructed to place one hand on top of the other so that their fingertips were layered on one another. In a slow and controlled motion, participants flexed at the waist and tried to push the sliding metal piece on top as far as they could. Participants were not to bend their knees in any way. Participants were given three attempts to obtain the best result they could. The best of the three attempts was then recorded to the nearest half centimeter.

### *Body Composition*

Body Composition was determined using air plethysmography in a BOD POD$^{TM}$ (COSMED, Rome, Italy). The calibration and testing was done by a University of Akron Exercise Science department graduate assistant. The body density estimation measurements were completed twice and the average was taken. However, if the two original measurements were not in agreement, within 150mL of each other, the computer mandated that a third trial be run. The body density obtained was then plugged into the Siri equation and turned into percent body fat.

All participants were instructed to fast from food and water for at least 10 hours prior to their body composition testing. When undergoing testing, participants wore only skin tight compression shorts and a skull cap to cover their hair. All results were recorded in percent body fat.

### *Statistical Analysis*

All statistical analyses were done using Microsoft Excel. A linear regression was performed between the sit-and-reach and the 40-yard dash test, the sit-and-reach and the vertical jump, and the sit-and-reach and body composition. Furthermore, the athletes were segmented by body composition for further analysis.

Additionally, subjects were divided into five possible body composition groups: less than 10.0% body fat (<10.0% BF), between 10.0 and 14.9% body fat (10.0-14.9% BF), between 15.0 and 19.9% body fat (15.0-19.9%BF), between 20.0 and 24.9% body fat (20.0-24.9% BF), and greater than or equal to 25.0% body fat (≥25.0% BF).

From these segmented portions, an additional linear regression was performed between the sit-and-reach and the 40-yard dash test, as well as between the sit-and-reach and the vertical jump test.

Results were taken to be significant if the p-value was less than or equal to (≤) 0.05. Results were taken to be correlated if the $R^2$ value was greater than or equal to (≥) 0.850.

## Results

The study obtained usable data from 65 participants. The mean height of the participants was 72.99 (±2.58) inches and the mean weight was 234.42(± 46.88) pounds.

The results of the tests are found in the tables below. Significance means that it is statistically unlikely that relationship between the two variables is caused by random chance. Conversely, insignificance means that it is not unlikely that the relationship between the results is caused by random chance. A positive correlation means that the two variables are directly related (as one variable increases, the other increases). A negative correlation means the two variables are inversely related (as one variable increases, the other decreases.) No correlation means that there is no relationship between the two variables (the direction of one variable has no impact on the other variable).

The sit-and-reach versus the 40-yard dash ($p < 0.001$, $R^2 = 0.111$) shows that there is significance in that there is no correlation between the two variables. The sit-and-reach versus the vertical jump ($p < 0.001$, $R^2 = 0.051$) shows that there is significance in that there is no correlation between the two variables. The sit-and-reach versus body fat percentage ($p < 0.001$, $R^2 = 0.191$) shows that there is significance in that there is no correlation between the two variables. The sit-and-reach versus 40-yard dash for all body composition segments was found to be insignificant and uncorrelated. The p-values and $R^2$ values for these and the previously mentioned tests can be found in Table 1 below.

| **Graph:** | **P-value** | **R-squared** | **Conclusion** |
|---|---|---|---|
| Sit-and-Reach vs 40-Yard Dash | 3.19 x $10^{-9}$ | 0.111 | Significant, no correlation |
| Sit-and-Reach vs Vertical Jump | 1.83 x $10^{-5}$ | 0.051 | Significant, no correlation |
| Sit-and-Reach vs Body Fat % | 2.98 x $10^{-33}$ | 0.191 | Significant, no correlation |
| Sit-and-Reach vs 40 YD (<10% BF) | 0.157 | 0.001 | Not significant, no correlation |
| Sit-and-Reach vs 40 YD (10-14.9% BF) | 0.946 | 0.312 | Not significant, no correlation |
| Sit-and-Reach vs 40 YD (15-19.9% BF) | 0.760 | 0.010 | Not significant, no correlation |
| Sit-and-Reach vs 40 YD (20-24.9% BF) | 0.926 | 0.086 | Not significant, no correlation |
| Sit-and-Reach vs 40 YD (>25% BF) | 0.068 | 0.066 | Not significant, no correlation |

**Table 1:** Table showing the p-values, R-squared values, and their interpretations for all tests statistically analyzed.

| | Mean | Range | Standard Deviation |
|---|---|---|---|
| Height (inches) | 72.99 | 66.50-77.50 | 2.58 |
| Weight (lbs) | 234.415 | 150-338 | 46.88 |
| Age (years) | 20.65 | 18-24 | 1.36 |
| Number of Participants: | 65 | | |

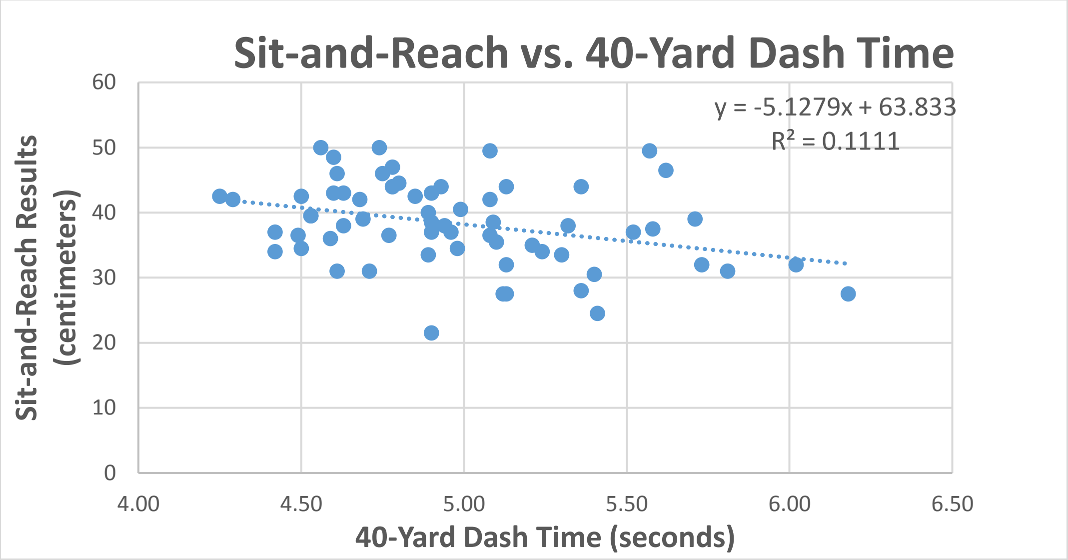
**Table 2:** Table showing the average heights and weights of the participants, along with the sample size.

| | Mean | Range | Numer of Participants |
|---|---|---|---|
| Body Fat (%) | 16.9 | 3.0-32.1 | 64 |
| 40-Yard Dash (seconds) | 4.98 | 4.25-6.18 | 65 |
| Vertical Jump (inches) | 29.1 | 18.5-35.5 | 63 |
| Sit-and-Reach (centimeters) | 38.3 | 21.5-50 | 65 |

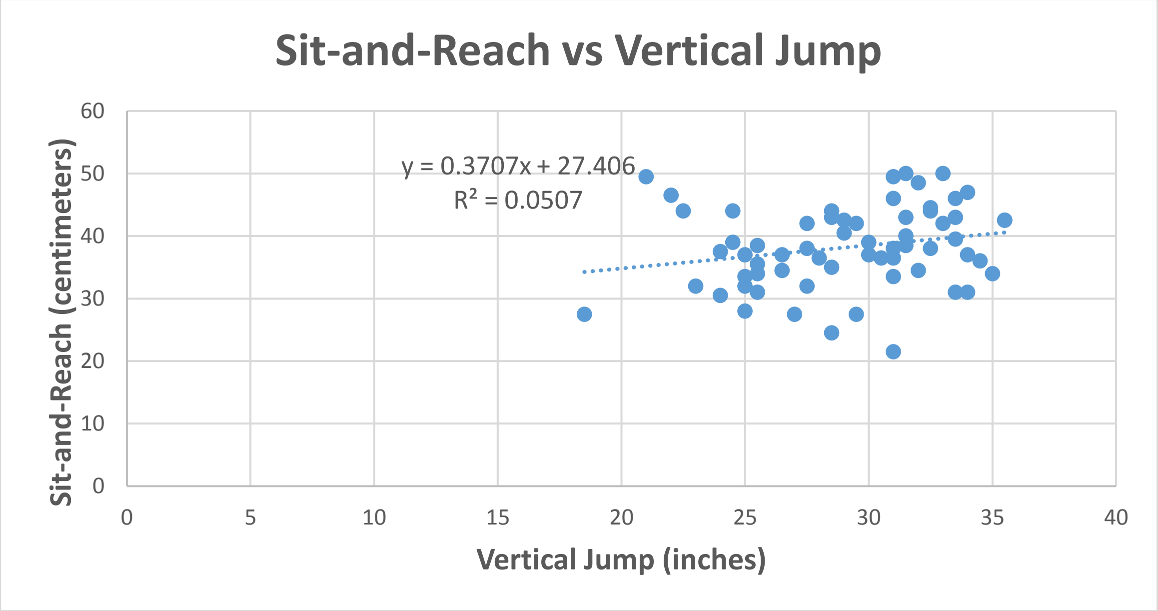
**Table 3:** Table summarizing the average results of the body composition, 40-yard dash, vertical jump, and the Sit-and-Reach tests. The number of participants in each test is also shown.

| Subject | Height (in) | Weight(lbs) | Body Fat % | 40 yard dash (s) | Vertical Jump (in) | Sit-and-Reach (cm) | Position |
|---|---|---|---|---|---|---|---|
| 1 | 72.50 | 246 | 23.0 | 5.24 | 25.5 | 34 | TE |
| 2 | 69.00 | 192 | 6.8 | 4.63 | 32.5 | 38 | DB |
| 3 | 74.50 | 220 | 15.8 | 4.90 | 31.5 | 38.5 | LB |
| 4 | 74.00 | 211 | 18.7 | 4.94 | 31 | 38 | LB |
| 5 | 74.25 | 280 | 21.8 | 4.96 | 30 | 37 | DL |
| 6 | 72.75 | 190 | 7.7 | 4.60 | 32 | 48.5 | DB |
| 7 | 77.00 | 285 | 25.0 | 5.13 | 27.5 | 32 | OL |
| 8 | 72.00 | 203 | 10.5 | 4.78 | 28.5 | 44 | SP |
| 9 | 74.50 | 242 | 21.5 | 5.08 | 28 | 36.5 | TE |
| 10 | 73.50 | 281 | 26.2 | 5.21 | 28.5 | 35 | DL |
| 11 | 67.25 | 178 | 8.0 | 4.56 | 33 | 50 | WR |
| 12 | 72.50 | 271 | 25.4 | 5.09 | 25.5 | 38.5 | DL |
| 13 | 75.50 | 318 | 32.1 | 6.02 | 23 | 32 | OL |
| 14 | 73.75 | 185 | 8.5 | 4.59 | 34.5 | 36 | WR |
| 15 | 67.75 | 204 | 12.5 | 4.50 | 32 | 34.5 | RB |
| 16 | 74.75 | 298 | 29.1 | 5.73 | 25 | 32 | OL |
| 17 | 75.00 | 289 | 24.6 | 5.62 | 22 | 46.5 | OL |
| 18 | 72.00 | 187 | 5.0 | 4.60 | 33.5 | 43 | DB |
| 19 | 71.50 | 165 | 6.0 | 5.10 | 25.5 | 35.5 | SP |
| 20 | 72.00 | 288 | 22.8 | 5.08 | 27.5 | 42 | OL |
| 21 | 72.00 | 222 | 10.0 | 4.42 | 35 | 34 | LB |
| 22 | 74.00 | 206 | 15.9 | 5.13 | 24.5 | 44 | SP |
| 23 | 72.25 | 212 | 15.2 | 4.71 | 34 | 31 | WR |
| 24 | 73.50 | 202 | 9.8 | 4.75 | 31 | 46 | WR |
| 25 | 76.50 | 304 | 24.2 | 5.32 | 27.5 | 38 | DL |
| 26 | 73.25 | 223 | 12.2 | 4.89 | 31.5 | 40 | LB |
| 27 | 68.75 | 170 | NR | 4.42 | 34 | 37 | DB |
| 28 | 71.00 | 193 | 13.7 | 4.53 | DNT | 39.5 | DB |
| 29 | 74.50 | 213 | 17.7 | 5.30 | 25 | 33.5 | QB |
| 30 | 76.00 | 264 | 19.7 | 4.99 | 29 | 40.5 | DL |
| 31 | 71.00 | 182 | 5.3 | 4.50 | 35.5 | 42.5 | DB |
| 32 | 74.50 | 211 | 8.3 | 4.61 | 33.5 | 46 | DL |
| 33 | 68.00 | 200 | 14.5 | 4.80 | 32.5 | 44.5 | RB |
| 34 | 73.25 | 302 | 25.3 | 5.40 | 24 | 30.5 | OL |
| 35 | 73.50 | 195 | 3.0 | 4.49 | 31 | 36.5 | LB |
| 36 | 72.75 | 226 | 19.4 | 4.98 | 26.5 | 34.5 | TE |
| 37 | 75.75 | 321 | 32.0 | 6.18 | 18.5 | 27.5 | OL |
| 38 | 76.00 | 234 | 10.2 | 4.90 | 28.5 | 43 | TE |
| 39 | 75.00 | 303 | 23.4 | 5.41 | 28.5 | 24.5 | OL |
| 40 | 69.50 | 189 | 9.8 | 4.78 | 34 | 47 | WR |
| 41 | 75.50 | 338 | 22.8 | 5.12 | 29.5 | 27.5 | OL |
| 42 | 70.50 | 212 | 13.1 | 4.69 | 30 | 39 | LB |
| 43 | 76.50 | 311 | 27.8 | 5.81 | 25.5 | 31 | OL |
| 44 | 72.25 | 203 | 13.5 | 4.68 | 29.5 | 42 | WR |
| 45 | 71.25 | 195 | 8.6 | 4.53 | 33.5 | 39.5 | WR |
| 46 | 73.50 | 221 | 8.8 | 4.74 | 31.5 | 50 | DL |
| 47 | 67.50 | 192 | 7.9 | 4.61 | 33.5 | 31 | RB |
| 48 | 66.50 | 150 | 9.2 | 4.25 | 35.5 | 42.5 | WR |
| 49 | 77.00 | 295 | 25.0 | 5.52 | 26.5 | 37 | OL |
| 50 | 71.00 | 189 | 16.6 | 5.08 | 31 | 49.5 | SP |
| 51 | 75.00 | 261 | 16.0 | 4.78 | 32.5 | 44 | DL |
| 52 | 73.50 | 284 | 32.0 | 5.36 | 25 | 28 | OL |
| 53 | 73.00 | 221 | 7.9 | 4.85 | 29 | 42.5 | LB |
| 54 | 76.25 | 297 | 22.7 | 5.71 | 24.5 | 39 | OL |
| 55 | 74.50 | 286 | 26.3 | 5.58 | 24 | 37.5 | OL |
| 56 | 75.00 | 267 | 24.7 | 5.36 | 22.5 | 44 | OL |
| 57 | 74.50 | 281 | 26.6 | 5.57 | 21 | 49.5 | OL |
| 58 | 69.00 | 200 | 14.6 | 4.90 | 25 | 37 | RB |
| 59 | 70.75 | 208 | 12.8 | 4.77 | 30.5 | 36.5 | DB |
| 60 | 77.50 | 217 | 19.3 | 5.13 | 27 | 27.5 | QB |
| 61 | 75.50 | 237 | 18.5 | 4.90 | 31 | 21.5 | DL |
| 62 | 72.00 | 273 | 22.0 | 4.89 | 31 | 33.5 | DL |
| 63 | 72.75 | 186 | 7.2 | 4.63 | 31.5 | 43 | WR |
| 64 | 73.25 | 228 | 19.0 | 4.93 | DNT | 44 | QB |
| 65 | 73.25 | 180 | 15.0 | 4.29 | 33 | 42 | WR |

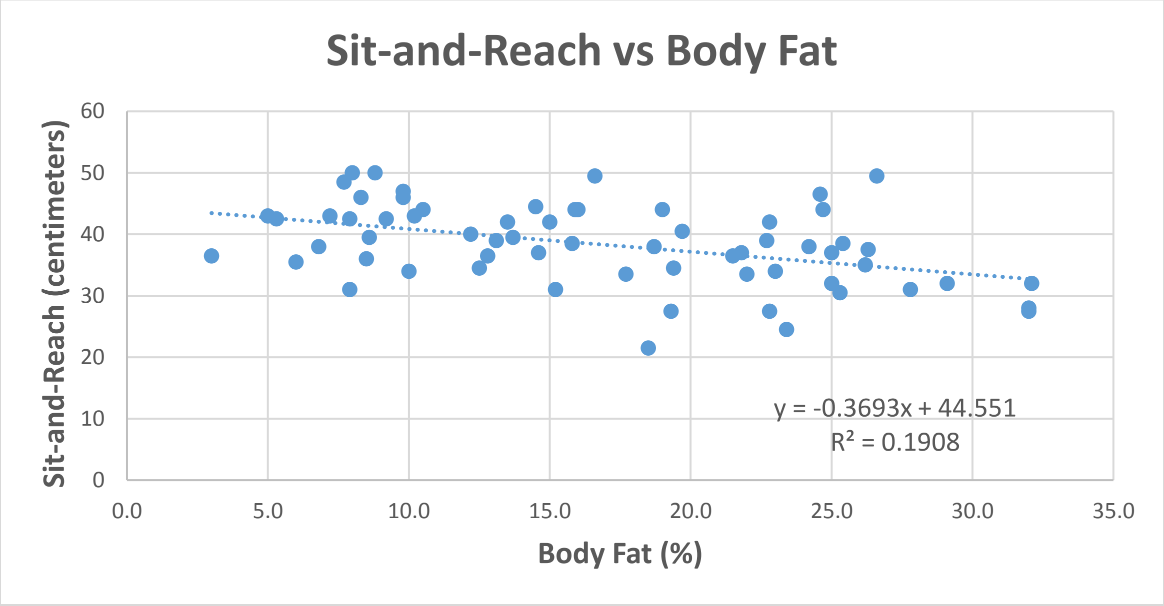
**Table 4:** Table summarizing all data collected in the experiment. For tests where subjects did not test, DNT is placed where the result would be.



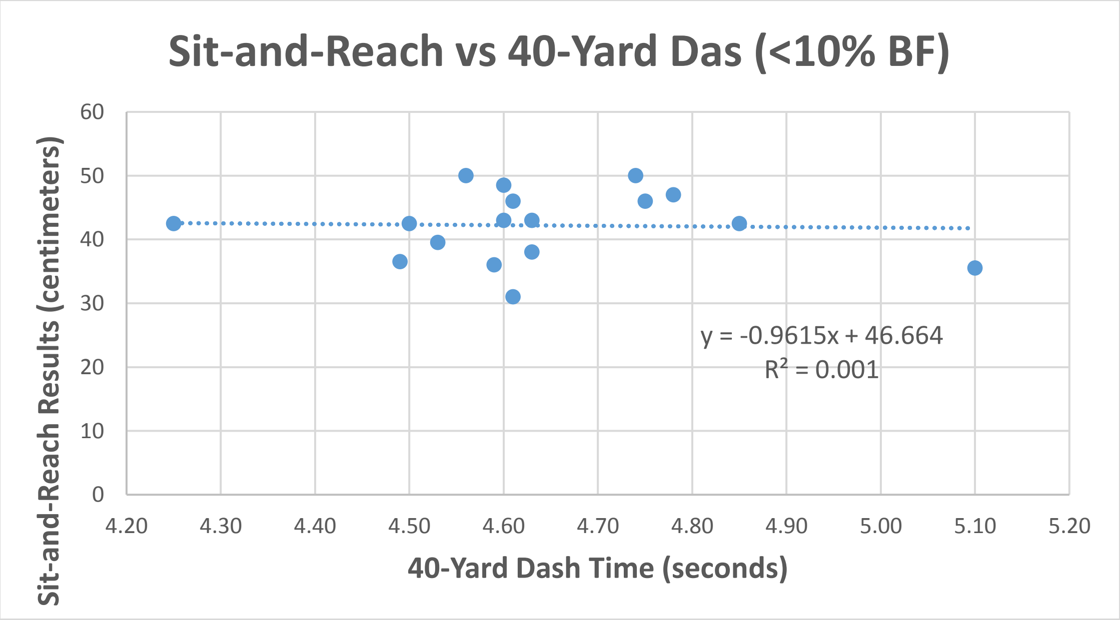
**Graph 1:** Scatter plot showing the relationship between the Sit-and-Reach and 40-Yard Dash results. The equation for the line as well as the r-squared value are displayed on the graph. The p-value was determined to be $3.19 \times 10^{-9}$.



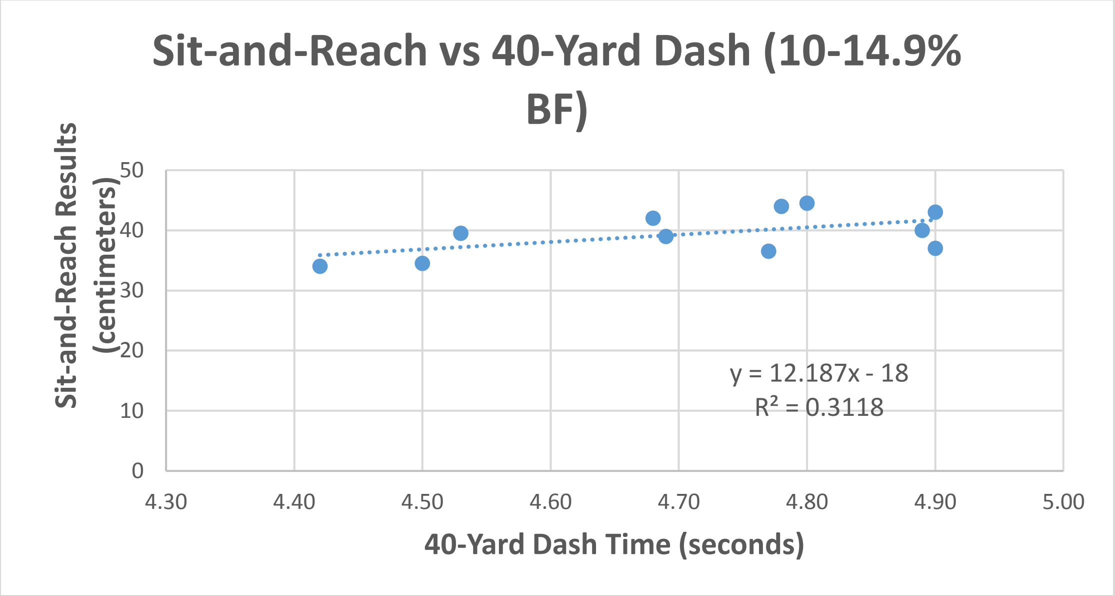
**Graph 2:** Scatter plot showing the relationship between the Sit-and-Reach and the Vertical Jump. The equation for the line as well as the r-squared value are displayed on the graph. The p-value was determined to be $1.83 \times 10^{-5}$.



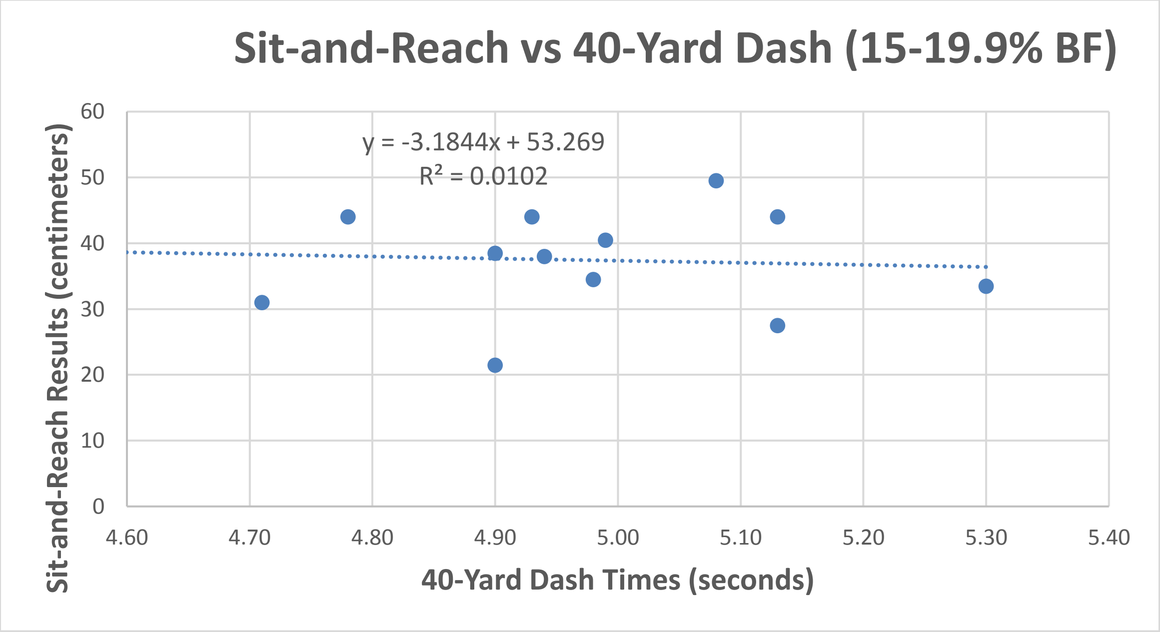
**Graph 3:** Scatter plot showing the relationship between the Sit-and-Reach and Body Fat composition. The equation for the line as well as the r-squared value are displayed on the graph. The p-value was determined to be 2.98 x$10^{-33}$.



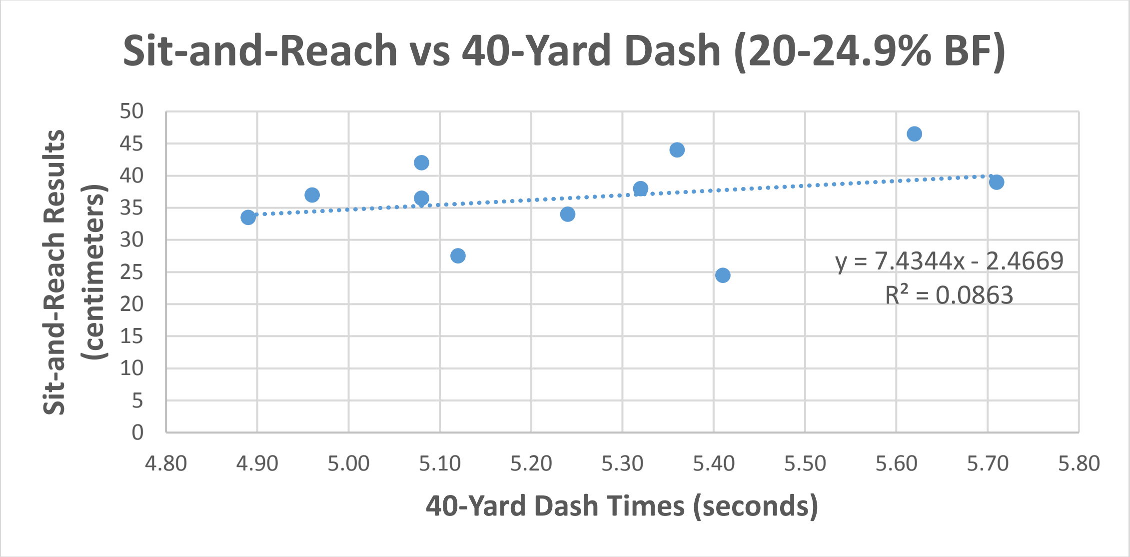
**Graph 4:** Scatter plot showing the relationship between the Sit-and-Reach and 40-Yard Dash for participants with less than 10.0% body fat. The equation for the line as well as the r-squared value are displayed on the graph. The p-value was determined to be 0.157.



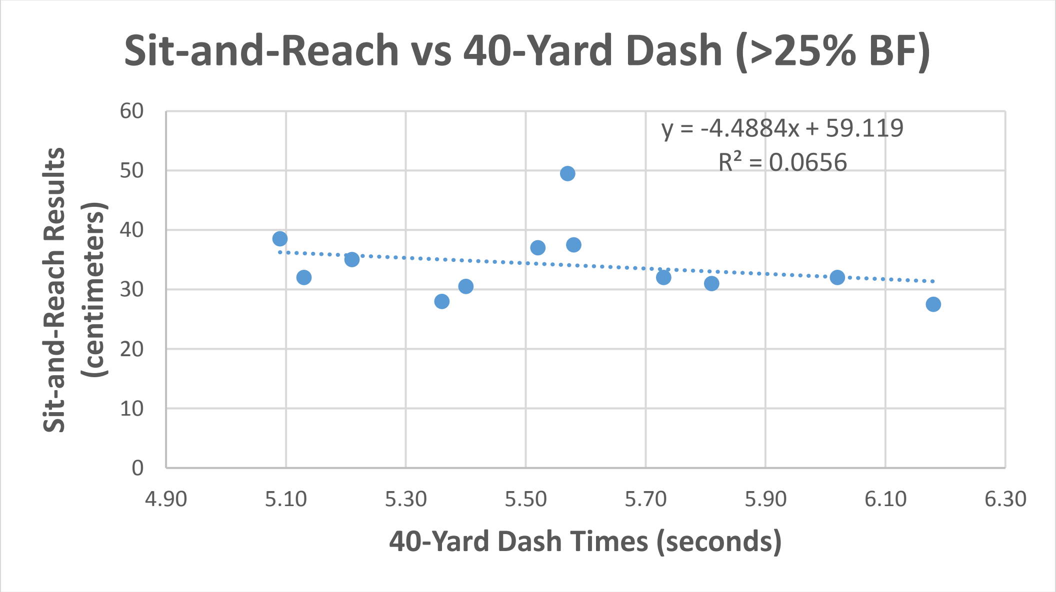
**Graph 5:** Scatter plot showing the relationship between the Sit-and-Reach and 40-Yard Dash for participants with between 10.0-14.9% body fat. The equation for the line as well as the r-squared value are displayed on the graph. The p-value was determined to be 0.946.



**Graph 6:** Scatter plot showing the relationship between the Sit-and-Reach and 40-Yard Dash for participants with between 15.0-19.9% body fat. The equation for the line as well as the r-squared value are displayed on the graph. The p-value was determined to be 0.760.



**Graph 7:** Scatter plot showing the relationship between the Sit-and-Reach and 40-Yard Dash for participants with between 20.0-24.9% body fat. The equation for the line as well as the r-squared value are displayed on the graph. The p-value was determined to be 0.926.



**Graph 8:** Scatter plot showing the relationship between the Sit-and-Reach and 40-Yard Dash for participants with greater than or equal to 25.0% body fat. The equation for the line as well as the r-squared value are displayed on the graph. The p-value was determined to be 0.068.

## Discussion

The data collected suggests that there is no correlation between sprint speed and hamstring flexibility. This relationship was upheld even when categorizing the participants according to body composition. Additionally, there was no relationship found between hamstring flexibility and the vertical jump, nor hamstring flexibility and body composition.

The results of this study support the hypothesis that there is hamstring flexibility does not affect sprint speed. As mentioned in the literature review section, the previous research was inconclusive. The findings of this study regarding hamstring flexibility and sprint speed were similar to those found in the study of 37 high school track and field athletes (Skaggs et al., 2015). In that study, there was no significant relationship between maximal sprint speed and hamstring flexibility.

However, the findings of this study are in opposition with the findings of a study of 43 youth soccer players between the ages of 14 and 18 (García-Pinillos et al., 2015). That study found that there was a significant positive correlation between maximal sprint speed and hamstring flexibility.

The differences observed here could be the result of a multitude of factors. There was a much larger sample size in this study than there were in either of the other two studies mentioned. Additionally, one of the most likely reasons for the difference in results is the method of measurement of hamstring flexibility. Both studies that found no relationship between sprint speed and hamstring flexibility utilized the sit-and-reach as a method of hamstring flexibility measurement. The study that found a significant relationship (García-Pinillos et al., 2015) utilized a passive straight leg raise test to measure hamstring flexibility. The possible errors of utilizing the sit-and-reach as a hamstring measurement tool are discussed below. It is also possible that the elite level of athlete that was analyzed in this study could provide results that would be skewed when compared to the general or untrained population.

This study was not without its limitations. The first and most evident factor is the study design. In an effort to provide a large number of participants, a correlational study design was chosen over a causal study design. Maximal sprint speed is effected by a multitude of factors, and this study is not able to control for individual persons variables. A suggested follow-up study should measure participants' initial flexibility and maximal sprint speed prior to administering a six to twelve week static stretching protocol designed to increase flexibility. At the end of the protocol, the participants' flexibility and maximal sprint speed should be measured again. This study design controls for other variables outside of flexibility that could affect sprinting speed.

Another area of improvement for this study involves the measurement of flexibility. A study of tennis players, canoeists, kayakers, and cyclists examined the validity of the sit-and-reach test (Muyor et al., 2014). The results of the study showed that the sit-and-reach was a reliable predictor of spine flexibility and pelvic tilt range of motion, but not hamstring flexibility. A suggestion for a future improvement could be using a Myrin goniometer as opposed to the sit-and-reach boxes. A Myrin goniometer was found to be a more valid measuring tool of hamstring flexibility (Bakirtzoglou, 2010).

This study suggests that the notion of flexibility increasing sprinting performance is not an accurate statement. However, this study does not diminish the importance of flexibility both in the athletic performance domain, as well as the general health world. Flexibility can be an extremely useful tool in injury prevention as well as muscle recovery (Chen et al., 2011).

Flexibility is an important part of a healthy exercise routine, but should not be promoted by strength and condition professionals as a means to increase speed.

# Appendix A

**Image 1:** Vertec apparatus used to assess the vertical jump.

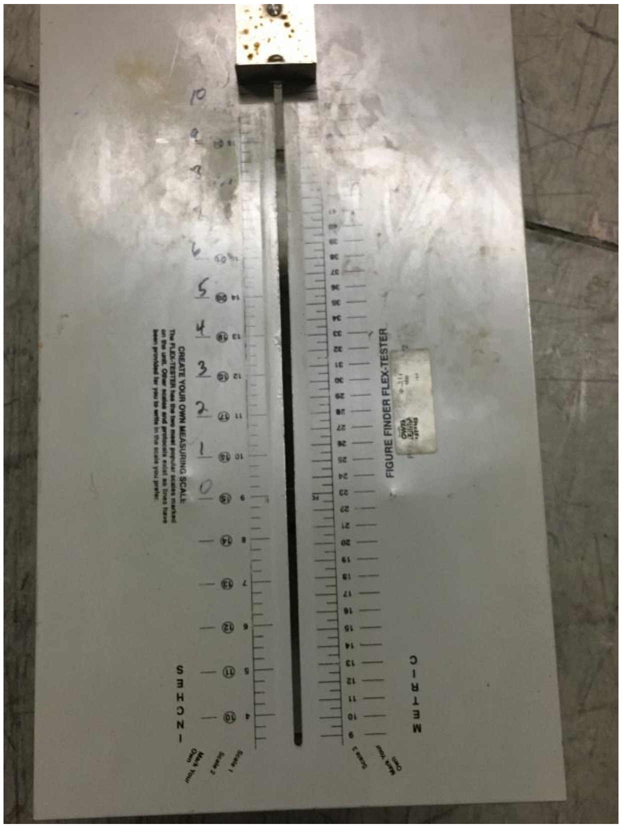


**Image 2:** Figure Finder Flex Tester apparatus used to administer the Sit-and-Reach test to assess hamstring flexibility (top view).

**Image 3:** Figure Finder Flex Tester apparatus used to administer the Sit-and-Reach test to assess hamstring flexibility (front view).

**Image 3:** Robic Stopwatches used to measure maximal sprint speed through the 40-Yard Dash.

# Appendix B

| Winter 2017 University of Akron Speed Performance Prep | | | |
|---|---|---|---|
| Speed & Agility | | | |
| Exercise | Set | Rep | Yard |
| **Muscle Activation** | | | |
| Supine Leg Kick | 1 | 10e | |
| Kneeling Hip/ Quad | 1 | :30e | |
| Single Leg Buck | 1 | 10e | |
| Frog Hip Lifts | 1 | 10 | |
| Tibialis Anterior (Gas Pedal) (Hands behind head) | 1 | :15e | |
| Seated Leg Raise (Hands behind head) | 1 | 10e | |
| **Arm Swings** | | | |
| Week 5: Standing Weighted (**Singles, Doubles, Triples, Rapid Fire)** | 3 | | |
| **Dynamic Speed Preparation (Stationary -> Transit)** | | | |
| Ankle Hops | | 1 | 10 |
| Ankle Flips | | 1 | 10 |
| Ankling | | 1 | 10 |
| Straight Leg March/ Walking Toe Pull | | 1 | 10/10 |
| Straight Leg Shuffle | | 1 | 10 |
| A Skip | | 1 | 10 |
| SL A Skip | | 1 | 5e |
| Hurdle Walk Front/Back | | 1 | 10/10 |
| High Knees | | 1 | 10 |
| Hamkicks | | 1 | 10 |
| Transit World's Greatest | | 1 | 10/10 |
| B Skip | | 1 | 10 |
| Alternating Fast Leg | | 1 | 10 |
| Lateral Bounding | | 2 | 20 |
| Bounding | | 2 | 20 |
| 40 Start | | 1 | 10 |
| 10 plus 50 -------→ 43% | 2 | | |
| 20 plus 40 ------→82% | 2 | | |
| 30 plus 30 -----→ 90% | 2 | | |
| 40 plus 20 -------- 94% | 2 | | |
| | 2 | | |

**Table B1:** Warm-up provided used by the University of Akron Strength and Conditioning staff to prepare participants for activities.

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