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THE EFFECTS OF DIFFERENT ATHLETIC PLAYING SURFACES ON JUMP HEIGHT, FORCE AND POWER

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THE EFFECTS OF DIFFERENT ATHLETIC PLAYING SURFACES ON JUMP
HEIGHT, FORCE AND POWER

BY

KELLY MURPHY

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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UNIVERSITY OF RHODE ISLAND

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MASTER OF SCIENCE THESIS

OF

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2014

ABSTRACT

Problem Statement and Background: As artificial turfs (AT) become more commonplace, the number of recreational athletes playing on them increases. Some aspects of performance such as speed appear to be better on AT; yet higher rates of injury have been reported. Despite this information, there are still few published studies on outcomes of athletic playing surfaces on athlete performance. Further, there is no research that compares individual performance on AT, hard surfaces and different composite natural surfaces. The purpose of this study was to compare athlete performance on AT against two different natural turf bases and a hard surface.

Methods: Forty-three subjects, twenty-one males (age: 20 ± 1.82 yrs.; height: 177.53 ± 5.87 cm; weight: 78.44 ± 11.59 kg; body fat: 11.17 ± 4.45 percent) and twenty-two females (age: 22 ± 1.32 yrs.; height: 161.37 ± 6.47 cm; weight: 60.94 ± 10.24 kg; body fat: 27.16 ± 7.08 percent) were randomized and performed a single countermovement jump (SCMJ), repeated countermovement jumps (RCMJ), and single depth jump (SDJ) on four different playing turf surface bases; [(peat soil composition turf (NT1), sandy loam composition turf (NT2), one AT, and one hard surface (HS)]. Surface test order was randomized and maximum force (N), power (W) and jump height (cm) was recorded for each jump. Repeated measures ANOVA with Bonferonni post-hoc was used to determine SCMJ, RCMJ and SDJ differences in performance on playing surfaces. Statistical significance was set at $p \leq 0.05$.

Results: There were no significant differences in maximum force or jump height on different surfaces. Males had significantly higher force, power and jump height on all surfaces compared to females. Single counter movement jump power was lower on the

peat/soil structure (NT1) compared to all other surfaces [(NT1: 1530±389W) vs. (NT2: 2369±866W), (AT: 2312±945W), HS: 2245±796W)]. Repeated counter jump power force and power was not significantly different across surfaces.

Conclusions: Differences in performance between genders were observed. The only significant difference in performance on different turfs was lower power during SCMJ on NT1. Greater eccentric loading prior to the concentric portion of jumping enhances power production through the stretch-shortening cycle (SSC). The difference in power between surfaces was not observed when RCMJ and SDJ were performed, and may be due to the increased reactivity of the SSC in repeated jumps and depth jump overcoming the reported decreased density of the peat soil composition of NT1. Due to marginal differences between athletic performance and playing surface type, future research comparing playing surface type and rate of injury should be considered.

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PREFACE

This thesis is written to comply with the University of Rhode Island graduate school Manuscript Thesis Format. This thesis contains one manuscript: *The Effects of Different Athletic Playing Surfaces on Jump Height, Force and Power*. This manuscript has been written in a form suitable for publication in the *Journal of Strength and Conditioning Research*.

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MANUSCRIPT

Publication Status

This manuscript was formatted and prepared for publication in the *Journal of Strength and Conditioning Research*.

ABSTRACT

As artificial turfs (AT) become more commonplace, the number of recreational athletes playing on them increases. Some aspects of performance such as speed appear to be better on AT; yet higher rates of injury have been reported. Despite this information, there are still few published studies on outcomes of athletic playing surfaces on athlete performance. Further, there is no research that compares individual performance on AT, hard surfaces and different composite natural surfaces.

PURPOSE: The purpose of this study was to compare athlete performance on AT against two different natural turf bases and a hard surface. **METHODS:** Forty-three subjects, twenty-one males (age: 20 ± 1.82 yrs.; height: 177.53 ± 5.87 cm; weight: 78.44 ± 11.59 kg; body fat: 11.17 ± 4.45 percent) and twenty-two females (age: 22 ± 1.32 yrs.; height: 161.37 ± 6.47 cm; weight: 60.94 ± 10.24 kg; body fat: 27.16 ± 7.08 percent) were randomized and performed a single countermovement jump (SCMJ), repeated countermovement jumps (RCMJ), and single depth jump (SDJ) on four different playing turf surface bases; [(peat soil composition turf (NT1), sandy loam composition turf (NT2), one AT, and one hard surface (HS)]. Surface test order was randomized and maximum force (N), power (W) and jump height (cm) was recorded for each jump. Repeated measures ANOVA with Bonferonni post-hoc was used to determine SCMJ, RCMJ and SDJ differences in performance on playing surfaces. Statistical significance was set at $p \leq 0.05$. **RESULTS:** There were no significant differences in maximum force or jump height on different surfaces. Males had significantly higher force, power and jump height on all surfaces compared to females. Single counter movement jump power was lower on the peat/soil structure (NT1) compared to all

other surfaces [(NT1: 1530±389W) vs. (NT2: 2369±866W), (AT: 2312±945W), HS: 2245±796W)]. Repeated counter jump power force and power was not significantly different across surfaces. **CONCLUSION:** Differences in performance between genders were observed. The only significant difference in performance on different turfs was lower power during SCMJ on NT1. Greater eccentric loading prior to the concentric portion of jumping enhances power production through the stretch-shortening cycle (SSC). The difference in power between surfaces was not observed when RCMJ and SDJ were performed, and may be due to the increased reactivity of the SSC in repeated jumps and depth jump overcoming the reported decreased density of the peat soil composition of NT1. Due to marginal differences between athletic performance and playing surface type, future research comparing playing surface type and rate of injury should be considered.

INTRODUCTION

As artificial turf structures become more commonplace, the number of athletes playing on them has increased. Artificial turf structures are used at two-thirds of the football stadiums at the professional level and more than 1,500 high school and college fields within the United States (29). From the consumer's perspective, a primary perceived benefit of artificial turf is the reduction in yearly financial cost. Despite the installation price, artificial turf has the ability to maintain durability and strength for up to eight years before replacement becomes a cause for concern. The initial installation price of a standard athletic field is estimated to be between two and four million with an annual maintenance cost of seven thousand dollars. However, the cost fluctuates according to the artificial surface area and style (65). Natural turf surfaces cost approximately twenty-five to thirty thousand dollars to install, yet have an annual nine thousand dollar expense to maintain. This cost, in addition to the time and tools necessary to maintain proper soil firmness, composition, moisture, and water quality, are justification for choosing artificial turf.

However, other reasons should be considered when choosing artificial turf, such as athlete safety and performance. Most of the published literature examines risk factors and injury potential on natural and artificial turfs (4,19,21,23). The conflicting evidence on prevalence and rate of injury when examining the ramifications of playing surface type is substantive (19,21,23-24,29,36,42,59). Despite this information, the published findings comparing markers of performance on multiple playing surfaces are scarce (3,12,40). Additionally, there is little evidence directly comparing athlete performance on different natural turf substrates, artificial turf, and a hard playing

surface.

Minimal research exists on turf playing surface and the power performance effects surface has on the athlete. Some aspects of performance, including speed, appear to be superior on artificial turf, yet the rate of injury has also been reported to be higher (42,59). Athlete performance is dependent on speed, agility, and power. Differences in playing surface and substitute composition impact these variables and others such as, peak torque and rotational stiffness (34,38). As an athlete changes direction, starts, and stops, several forces are transferred to the lower body. The different physical structure between natural and artificial turf surface can change the resultant energy when landing, therefore changing the athlete's power abilities. Other variables such as footwear may also affect an athlete's performance ability (51). Morehouse et al. suggested athletes could run faster and change direction more quickly on a traditional synthetic turf surface compared to a natural turf surface (43). Nonetheless, future research is needed to better pinpoint the performance measures and why they may change across different playing surfaces being used today.

In 2005, Brechue et al. reported that natural grass surfaces impairs spring season performance in football players, but the study design was comparing natural grass to an indoor track surface only. Since football players do not play on solid rubberized surfaces, this data does not translate into applicable evidence for turf athletes (8). Conversely, a similar performance analyst reported that the type of playing surface might not affect speed, agility and energy expenditure (50).

In 2011, Sassi et al. investigated eight amateur soccer players to examine the metabolic cost of running. One natural turf surface, one third-generation artificial

surface and one asphalted track were compared. For each surface, the standard vertical deformation and percentage of shock absorption were measured. The energy expenditure was not found to be significantly different when running on any of the three playing surfaces. The researchers suggest this result may be due to the marginal differences in shock absorption, which strongly relates to the hardness of each playing surface (50).

Playing surface density influences the amount of muscular force athletes need to push off the surface. The denser the surface, the more muscular force is needed to alter the ground reaction forces needed to produce movement (11,12,15-16). However, previous findings are primarily based upon speed and acceleration performance, which fail to correctly assess an athlete's full potential of stored energy (13). The continuous movements required for an athlete to start, stop, and change direction need to be applied to prospective research to properly examine how turf surface and soil composition may influence performance (34,42,54). Vertical ground reaction forces during dynamic movement are an important aspect of power production. The power produced during movements in sport translates to the peak speed, vertical jump height and agility.

A countermovement jump is a vertical jump that is known as a crucial motor skill in many sports. The outcome of this movement strongly depends on the capability of an athlete to jump with explosiveness and to reach maximal height. Several studies have shown strong statistical associations between vertical jump performance and power measures (7,21,47,57). To date, the countermovement jump has consistently shown high test-retest validity and reproducibility for estimating the

muscle power in physically active adults (33). The countermovement jump (CMJ) is more often used to evaluate athlete performance variables because it produces greater power when compared to different performance tests (6,10,34). Earlier studies have shown superior use of elastic energy, faster start speed, and improved power output in the counter movement jump (60). Hence, it is reasonable to conclude that CMJ vertical height is a good indicator of peak power capability. Two variables that define vertical jump height are the vertical ground reaction force produced and the body mass of the individual (3,6-7,9-10,14,20).

The magnitude of the stored energy may be dependent upon the physical properties of playing surface and substrate (62). As previously noted, there has been some research investigating artificial turf, natural turf, hard playing surface and substrate or infill (63). However, soil composition may also affect athlete performance due to differences reflected in playing surface density (16). Thus, a difference in density between each playing surface may equate to ground reaction force variances and further power changes.

The effect of different soil composition on peak power of athletic performance has not been tested in humans. Field et al. discovered a negative correlation between the bulk density of turf soil and the winning time for horses (27). The relationships showed that wetter soils delivered lower penetration resistances and consequently slower winning times (40,47).

Overall, the current published research is very limited concerning markers of athlete performance between varying natural surface, artificial turf surface and substrates. More research is needed to determine the playing surface substrate quality

that maximizes athletic performance. Therefore, the purpose of this study is to determine how athletic substrate and surface type affects markers of athletic performance. The null hypotheses were that (1) subject vertical jump peak power production, peak resultant ground reaction force, and peak vertical jump height would not be different across type of playing surface or substrate and (2) no significant difference would be found in subject's vertical jump peak power production, peak resultant ground reaction force and peak vertical jump height between genders.

METHODOLOGY

Experimental Approach to the Problem

Potential subjects were familiarized with the experimental procedures and after consent was given to participate were asked to perform a series of exercises on three different turf surface substrates and a solid surface. In this crossover design, trials were randomized to avoid potential order effect, and each trial was separated by a minimum of 48 hours. Subjects were asked to schedule three visits in total. Visit 1 consisted of the administration of the consent form, medical history questionnaire, and a questionnaire assessing level of physical fitness and overall diet. During visits 2 and 3, subjects were asked to perform the jump protocol on two different randomized surfaces each day.

Subjects

Fifty healthy, college-age men were recruited for this study as seen in Table 1. All past or current injury that affected performance during any jumping trial was cause for exclusion from the study.

Procedures

Anthropometric measurements were recorded prior to jump trials. Body weight was measured to the nearest 0.1kg using a Tanita digital read scale (Tanita Corporation, Japan). The scale was calibrated before each measurement, and subjects were asked to remove shoes, excess clothing, and jewelry. Height was measured by use of a stadiometer to the closest 0.5 cm (216, SECA, Hanover, MD). The measurement was taken with each subject's feet flat on the floor, with the head in a neutral position facing the researcher. Body composition was estimated via air

displacement plethysmography (BODPOD, version 2.14 Body Composition System; Life Measurements, Concord, CA). Daily calibration of the BOD POD chambers was also performed prior to each test based on manufacturer specifications.

Surfaces

Subjects performed each jump performance test protocol on two different natural grass surfaces, one artificial turf surface and one force plate. The four playing surface types included in the study were (1) sand-peat root zone mix Kentucky bluegrass (*Poa pratensis* L.; 44.5" X 44.5"), (2) sandy loam soil perennial ryegrass (*Lolium perenne* L.; 44.5" X 44.5"), (3) a synthetic infill artificial turf (Astro Turf GameDay 3D 60H), and (4) AccuPower Force plate 600 Hz (Accupower Advanced Mechanical Technologies Inc., Watertown, MA).

All turf-type surfaces were housed in a module that included the grass, root zones, and drainage system for the turf. All surfaces were in a thermostat controlled temperature setting, and temperature and humidity levels in degrees Celsius were taken throughout each visit. Twice a week, turf was checked soil moisture levels for the soil and sand natural composites. The Clegg impact soil tester that quantified soil hardness was recorded after each day of testing (18). A Clegg was dropped from a specified height of eighteen inches that recorded the peak deceleration of the Clegg hammer as it contacted the turf surface. Five drops were performed on each sample and were performed at the same geographical section points for every surface. The center point of each turf sample model was utilized in the statistical analysis to measure the significance of the changes in density on each surface as well as

comparing the natural loam to the sandy loam soil substrates. The weight within the Clegg was 2.25 kg, the most commonly used weight for testing athletic fields (48).

Performance Measures

Ground reaction force and power was assessed using the Myotest PRO performance measuring system (Durango, CO). The Myotest PRO was attached to the subject's waistband for the duration of the jump trials during visits 2 and 3. The Myotest PRO is a small device, about the size of a pedometer that measures power and force output during athletic movements, such as countermovement jump. The Myotest PRO was used as a post-hoc validation for the force plate's force and power analysis. In addition to the Myotest PRO, ground reaction force, peak power output and peak vertical jump height was documented during jump trial performance upon the hard playing surface (i.e. the force plate). Each subject completed each of the following jumps in chronological order. Subjects were randomized to each of the four playing surfaces using the Latin Square method.

Single Countermovement Jump

Participants were asked to stand on each turf surface and the force plate surface with hands on both hips. As instructed each subject performed a single vertical jump, keeping their hands on their hips at all times.

Repeated Countermovement Jump

Participants were asked to stand on each turf surface and the force plate surface with both hands on hips. As instructed each subject performed three rapid vertical jumps, keeping hands on both hips at all times.

Standing Depth Jump

Participants were asked to stand on a plyometric box that is 2 feet higher than the force plate or turf module. Subjects placed their hands on both hips and were instructed to step off with one foot and land on each turf surface or force plate with both feet. Immediately, the subjects performed a single vertical jump as high as possible one time before returning to a neutral standing position.

Perceived Exertion

Post-jump, for each individual jump performance test, subjects were asked to estimate their perceived exertion level using the Borg CR-10 scale with magnitude estimation (5).

Controlled Subject Variables

Subjects were asked to wear the same footwear and shorts for all three trials to control for differences in shoe type and weight that may affect performance results (19,34). In addition, subjects were asked to refrain from caffeine, food and drink at least two hours before each jump testing appointment. Otherwise normal individual diet was maintained throughout the study. Each subject was asked to provide a twenty-four hour recall diet log upon arrival for jump testing appointments. Visits 2 and 3 were scheduled within a certain timeframe with no more or less than 48 hours between visits. The subjects were required to schedule both performance trials within the same hourly time of day to minimize any possible differences in eating and sleeping patterns. Time and date of each subject's last workout and meal consumed was

recorded on the data collection sheet. Controlling for these factors remained vital to adherence and possibility of interference in the performance statistics being measured.

STATISTICAL ANALYSES

Statistical Package for the Social Sciences (SPSS) version 22.0 was used to analyze results, with significance set at $p \leq .05$. Results from analyses are presented in text, tables, and figures as mean (M) \pm standard deviation of the mean (SD). An ANOVA with repeated measures was used to test effects of different surfaces, gender, and possibility of an interaction between the two for the performance measures of peak jump force, power, and height. Bonferroni post-hoc tests were conducted to determine specific differences amongst groups.

RESULTS

Pairwise comparisons were completed to assess change in density of the peat loam and sandy loam surface individually and in relation to each other. Table 2 lists the density of NT1 and NT2 from each time point the Clegg measured the natural turf substrates. As seen in Table 2, the peat root zone surface, (NT1) and the sand silt loam modified surface, (NT2) both increased significantly in surface density over the duration of the project with $p < 0.029$ and $p < 0.023$ respectively. There were no statistical significance found when examining the two natural turf substrates in comparison to each other, suggesting NT1 and NT2 did not increase surface density at a different rate. This finding translates to the result that the two natural turf substrates became firmer individually over time, but did not influence markers of the subject's athletic performance. Table 2 lists the density of NT1 and NT2 from each time point the Clegg measured the natural turfs.

There were no significant differences found across surfaces for peak jump force or peak jump height. The men had significantly higher force, power and jump height on all surfaces compared to women, as shown in Table 3.

For men and women the findings for single counter movement jump (SCMJ) peak power were significantly lower on the peat root zone mix soil (Kentucky Bluegrass) when compared to all other playing surfaces ($1530 \pm 389W$ vs. $2369 \pm 866W$, $2312 \pm 945W$, $2245 \pm 796W$) (Figure 1). Statistical analysis for the repeated counter movement jump (RCMJ) and the single depth jump (SDJ) found the ground reaction force (Figure 2); peak power (Figure 1) and vertical jump height (not shown) were not significantly different across any of the four surfaces for all subjects.

DISCUSSION

The purpose of this study was to quantify differences in the countermovement jump, repeated countermovement jumps, and a single depth jump across four different playing surface areas and between genders. The force and jump height for all subjects upon all surfaces were not statistically different from each other. The results for all performance measures support the hypothesis that men had significantly greater power, force, and vertical jump height measurements on all surfaces. The only significant within subject differences in performance was a decreased power in the single countermovement jump (SCMJ) on the NT1. This study suggests that there are negligible differences in jumping performance when an eccentric movement precedes a countermovement jump. This has applied importance as sprinting, running or repetitive jumping movements have an eccentric component that precedes jumping performance in many recreational and competitive athletic events.

Vertical jump performance by gender should be taken into account because research has shown that the peak power ability of male and female athletes is different (44). Height and body fat percentage were the two hypothesized factors as to why men produced more power and resultant force to jump higher than women on all four playing surface types. On average, the men in this study were sixteen centimeters taller and were significantly leaner than the women. Men commonly have higher leg power than women possibly due to less body fat mass and more lean body mass (44). While muscle quality is similar between men and women, men have greater amounts

of lean body mass, translating to higher absolute and relative power and force production, thus providing them with a greater biomechanical advantage.

Power is the product of force applied on the athlete and the velocity of the athlete (61). Vertical jump is commonly used as an index for the power of the lower limb or explosive leg power. The ability to generate high human power output is instrumental to performance in many sports (20). Vertical jump is a validated test of athletic power and is highly correlated to an individual's overall performance capability (46). The level of the stored energy, or resultant force, returned to the athlete when touching the ground depends on elastic properties of muscles and potentially the physical properties of a playing surface, such as density (54).

At the start of testing, the Clegg surface density analysis suggested that the surface densities of the peat loam (NT1) and sandy loam (NT2) both increased their level of hardness over the course of the study, but the change in NT1 and NT2 were not statistically significant when compared to each other. The peat loam and sandy loam natural turf surfaces were subject to the same temperature, humidity, maintenance and athletic use. As seen in figure 2, the NT1 natural turf surface had a lower average density than NT2 throughout the study period however these differences were not statistically significant, although there was a trend ($p=0.07$). Surprisingly, there was no significant difference in the rate of change in surface hardness between surfaces, suggesting both natural surfaces increased density from the jump trials similarly. The similar rate in which density increased for both NT1 and NT2 was likely due to the randomization process of each subject for each turf type sample. The same numbers of subjects were asked to jump on each sample of NT1 and

NT2 to prevent overuse on any one natural turf sample. Therefore, it is unlikely that density was the primary reason for decreased power on NT1.

Similar to the current performance study, Sassi et al. previously determined that the shock absorption characteristics of natural grass and artificial turf are similar. However, the mechanical characteristics of the artificial turf indicate that the field used was not of high quality and was potentially the cause for lack of evidence in support of their hypothesis. Thus, the researchers concluded through the measurement of energy expenditure that surfaces with different densities would alter the muscular force necessary to push off the ground. The denser the playing surface, the more muscular force in the last phase of the stretch shortening cycle is needed to alter the ground reaction forces that are returned to the body with each stride or landing movement, such as a vertical jump.

In terms of performance on a surface, three mechanical properties affect the outcome: energy storage, energy loss and surface friction. Energy storage is directly related to the density of the surface. The two natural surfaces, the peat-loam soil and the sand soil, were not statistically significant in relation to their density differences even though the percentage of soil composition type was not exactly the same. The modification of each of the natural turf composites is common to numerous athletic playing fields. The peat loam soil, Kentucky blue Grass was a mixed composition of ninety percent peat and ten percent sand, while the Rye Grass was seventy percent peat-loam soil and thirty percent sand soil. The surface density can energy storage or loss, therefore, affects the eccentric and concentric muscle action by preventing the athlete from having adequate stability on different natural playing surface composites.

Over the nine trials of Clegg measurement, only one time point between April 22- April 23 did the researchers see significant difference in the density for peat loam (NT1) and the sandy loam surface (NT2). The lack of variance in the density of the natural playing surfaces is another hypothesized explanation as to why most markers of performance were not statistically different.

Energy loss may have played a role in the significant decreased power observed in the SCMJ. The stretch shortening cycle (SSC) has been known to affect athletic performance due to the individual trained ability of the elasticity of muscle and tendons. The stretch shortening cycle is vital in many sport-related movements including sprinting and jumping. The SSC is typically characterized by an eccentric (lengthening) muscle action, amortization phase followed by a concentric (shortening) muscular contraction (60). Energy stored during the eccentric component when optimized by load or height may lead to higher levels of potential stored energy resulting in a more powerful concentric action. In the present study, the counter movement jump did not incorporate a heavy eccentric action prior to the concentric action of the jump. Therefore, due to absence of a heavy eccentric component, the SSC was not optimized during the counter movement jump. The RCMJ and the SDJ did have an eccentric component, which may have overcome other factors of surface density related energy loss and friction.

Previous research has provided evidence that support the insignificance of force and jump height outcomes in our analysis and discuss the athlete's ability to adjust leg stiffness to compensate for differing playing surface density (3,25). Leg stiffness when performing on different surfaces can associate to peak loads and sprint

performances that are not necessarily related to the ground's surface composition. It has been suggested that this is due to the athlete subconsciously being able to adjust the stiffness of his or her leg prior to heel strike, and having the knowledge of their current playing surface type (18).

For decades, research has been connecting leg stiffness and sports performance. Leg stiffness varies depending on an individual's connective tissue, bone density and the collaboration of their skeletal muscle (52). Investigators propose leg stiffness as an important marker for force conduction on any playing surface, natural or artificial. Vertical leg stiffness is the quotient when ground reaction force is multiplied by the center of mass displacement (3,10,24-26,34,41,44,50,52,54,57,59). Serpell et al. (2012) reviewed 67 published articles that examined subjects' leg stiffness when running, sprinting or performing a wide variety of athletic jumping and hopping movements. Vertical leg stiffness has been found to be the best way to measure leg stiffness while performing countermovement jumps and depth jumps. Arampatzis et al. (2001) measured leg stiffness on fifteen subjects by having them perform a single depth jump followed by repeated jumps. The jump tests were completed from three different starting depths with each jump test faster than the previous jump test. Researchers concluded vertical leg stiffness to be strongly correlated to ground contact time. Many authors believe the decreased ground contact time leads to a greater return of the elastic energy stored during the contact phase of the stretch shortening cycle (60). The results from Arampatzis study suggest the subjects decreased their ground contact time when jumping faster, therefore providing increased return of the elastic energy giving the subjects more power to jump with

more speed and velocity. More importantly, the subject's leg stiffness increased as the jumps were performed faster (3). This translates to our research in examination of the RCMJ and SDJ power analysis compared to the SCMJ on NT1. The decreased ground reaction time during these quick performed jumps as well as the possibility of greater leg stiffness may be the mechanism behind why performance markers for RCMJ and SDJ do not prove to be significant on NT1. The decreased ground reaction time during these quickly performed jumps, along with the possibility of greater leg stiffness, may be the mechanism behind why RCMJ and SDJ power did not prove to be significant on NT1.

Limitations

The current study solely measured performance markers representing vertical component of force. Horizontal performance testing measures such as running and sprinting drills are crucial to field athletes, but vertical force analysis has been shown to predict peak power capacity and is highly correlated to on-field performance (47,57,63).

Many football, soccer, track, etc. training programs aim to improve their athlete's speed, agility and power. A significant inverse relationship exists between ground contact time and maximum sprint speed (1,6). This inverse relationship suggests that the necessary force needs to be reached in a short period of time during sprinting, and is also connected to the quick contact phases during landing when running. Barnes and colleagues also stated a significant correlation between sprint and vertical jump tests. Authors suggested that vertical force production might be crucial to sprinting. More importantly, there was a significant correlation between jumping

performance and maximal running velocity (41). Thus, vertical jump does serve as an appropriate measurement tool to assess possible change in power over time.

As with other studies measuring markers of athletic performance, conditions carried out in a laboratory setting may produce different results when completed outdoors. Although temperature was controlled, the fact that NT1 and NT2 were in a different room than AT and HS may also be seen as a limitation. Another limitation, as with any performance study, is the use of indirect estimation of ground reaction forces via the Myotest accelerometer. Technical difficulties with user load and placement of the device on each participant was evident when analyzing some of the subject data and may have added to the standard deviation. Moreover, the normal rate of the leg movement when performing athletic movements such as running, sprinting or a counter movement jump, can alter the displayed data in the frequency range of the Myotest device. This is seen as another limitation due to the possibility of a slight increase or decrease displayed on the Myotest, possibly changing the represented numerical result (44). To account for these proposed discrepancies, peak values were obtained from multiple trials. Therefore the highest values from all three trials in the three jumps were used for analyses and consistency of the data.

The density characteristics of natural turf are greatly influenced by athletic playing time and more importantly multiple variables sometimes out of the researchers control. For example, soil type, thatch presence, moisture content, vegetative state and even mowing height all affect impact attenuation. Physical maintenance of the turf was difficult over time due to the immense volume of traffic over the six weeks of subject testing. The high levels of use also lead to faster than normal deterioration of

NT1 and NT2 possibly leading to decreased shock absorption. Also, the maintenance schedule for mowing and watering the grass was consistent, but the light necessary from outdoors to keep the natural surfaces healthy may not have been enough for the full duration of the study.

Past research has controlled for shoe type, asking all subjects to wear the same footwear (26,53,56,57). This additional method of control was not done for this study. The researchers of this study decided it is more applicable to have subjects wear their own footwear. However, subjects were required to wear the same footwear for both jump trials to control for proper performance analysis. This choice was made in order to generalize performance outcomes for both recreational and professional field athletes (14,28). The randomization of surface order on both jump-testing days allowed the subjects to act as their own control throughout the project.

CONCLUSION

Sports surfaces are constructed with the intention of reducing excessive loading and improving performance. Natural playing surfaces cost more each year to maintain, but maintenance is key to injury prevention and athletic performance. Natural playing surfaces with good quality traction, cushioning and resiliency can aid in reducing injury while still allowing athletes to be successful and powerful. Athletic fields whether they are natural turf or artificial turf are maintenance challenges for professional and recreational facilities alike.

Currently, the most frequent injuries on any playing surface are those affecting the lower limbs, particularly knees and ankles due to the constant change of direction necessary to perform sports like football, soccer and lacrosse. Surface properties can affect the markers of athletic performance negatively especially if the surface is affected by the climate and subject to overuse. Since this study concludes that performance is similar across surfaces, injury prevention should be a primary concern in the decision of what playing surface to install. Findings from this project are representative of a generalized healthy young adult population. Further investigated research is needed in this area to properly justify how playing surfaces can impact dynamic markers of athletic performance and injury prevention.

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Table 1. Subject Characteristics: Age & Anthropometrics

Subjects	Age (Years)	Body Mass (Kg)	Height (cm)	Body Fat (percent)
Men (N=21)	20±1.82	78.44±11.59	177.53±5.87	11.17±4.45
Women (N=22)	22±1.32	60.94±10.24	161.37±6.4	27.16±7.08

Values are represented as mean ± SD.

TABLE 2. Descriptive Statistics for Clegg Surface Density Measurements for NT1 (Kentucky blue Grass) and NT2 (Rye Grass)

Time points Measured	Surface Type	Mean	Std. Deviation	N
1	NT1	4.23	0.32	3
	NT2	5.23	1.27	3
	Total	4.73	0.99	6
2	NT1	4.70	0.26	3
	NT2	4.87	0.23	3
	Total	4.79	0.24	6
3	NT1	4.83	0.68	3
	NT2	5.03	1.55	3
	Total	4.93	1.08	6
4	NT1	5.10	0.79	3
	NT2	6.60	1.35	3
	Total	5.85	1.29	6
5	NT1	5.73	0.93	3
	NT2	6.73	0.23	3
	Total	6.23	0.82	6
6	NT1	5.53	0.25	3
	NT2	6.93	0.40	3
	Total	6.23	0.82	6
7	NT1	5.10	0.36	3
	NT2	6.53	0.68	3
	Total	5.82	0.92	6
8	NT1	5.10	0.66	3
	NT2	5.90	0.66	3
	Total	5.50	0.73	6
9	NT1	4.90	0.53	3
	NT2	6.17	0.60	3
	Total	5.53	0.86	6

*Time = Dates Clegg Measurement Taken

*N= number of samples

TABLE 3. Mean Performance Markers on all Surfaces for Men & Women

Measure (I)	Gender	Mean	Standard Error
<i>Peak Vertical Force (N)</i>	Men	1754.000*	75.826
	Women	1346.195	72.297
<i>Peak Vertical Power (w)</i>	Men	2569.100*	112.874
	Women	1701.149	107.622
<i>Peak Vertical Height (cm/s)</i>	Men	40.010*	1.332
	Women	25.045	1.270

*Significantly different from Women, $p < 0.05$

(N) = Newton

(w) = Watts

(cm/s) = centimeters per second

FIGURE 1. Comparison of Men and Women Peak Power for SCMJ

Values are presented as mean. Represents all subjects' mean peak power for Single Countermovement Jump (SCMJ) for each surface. Power is measured in (watts).

*Significantly different change in mean peak power for NT1 compared to NT2, AT and HS.

Significantly different between playing surface

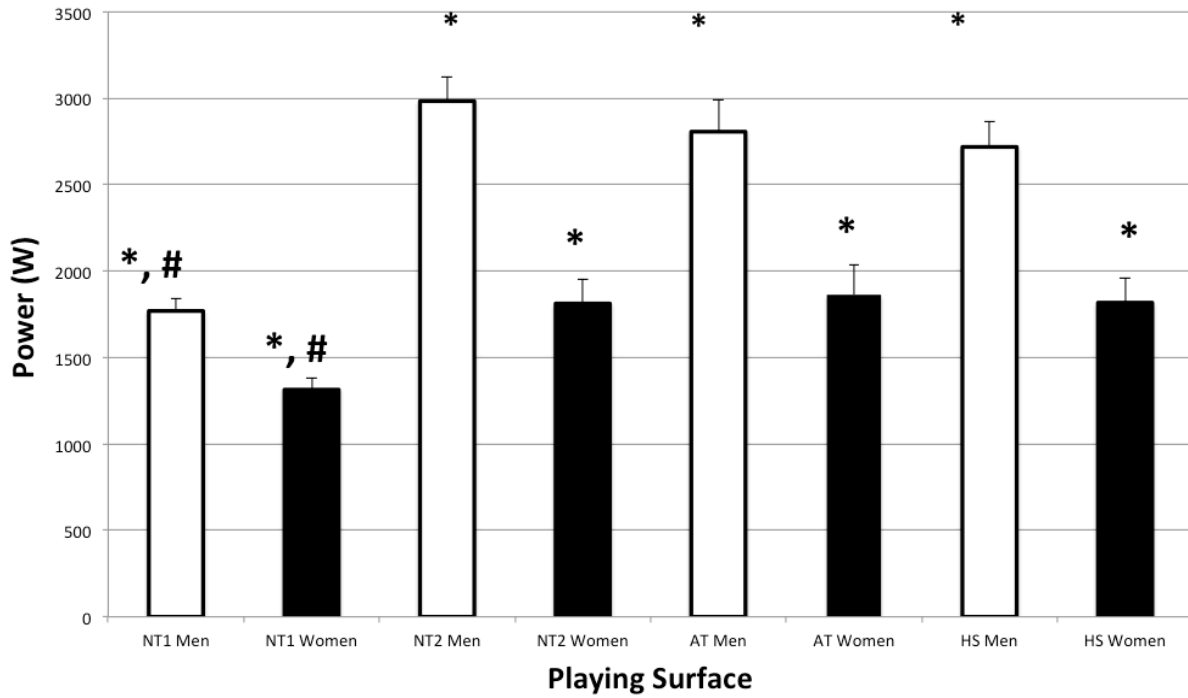


Figure 2. Comparison of Men and Women Peak Force for SCMJ

Values are presented as mean. Represents all subjects' mean maximum force for Single Countermovement Jump (SCMJ) for each surface. Force is measured in (Newtons).

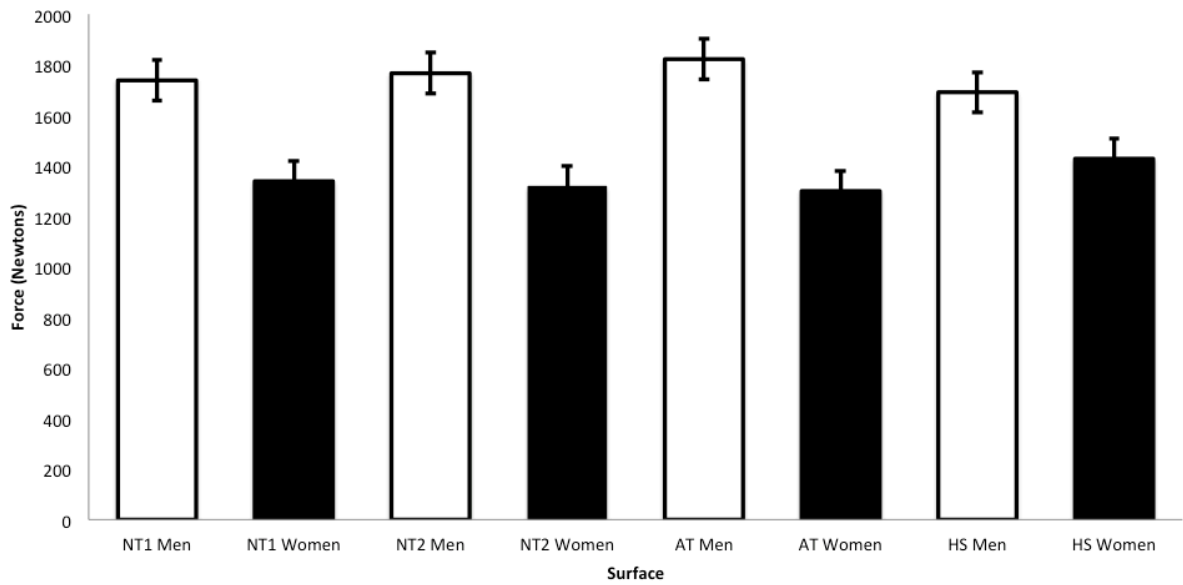
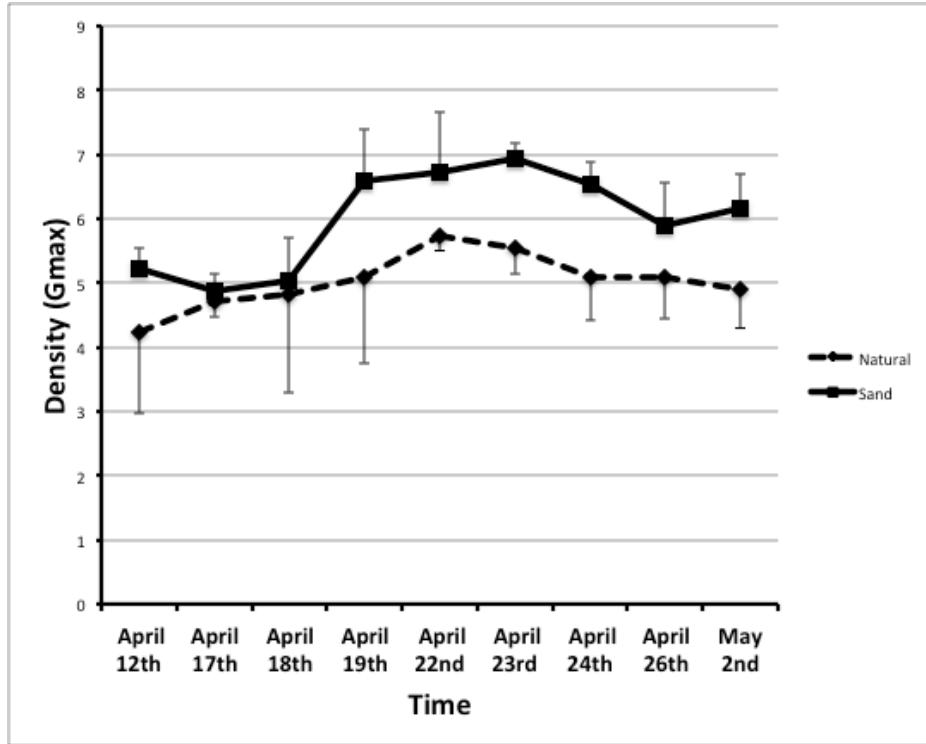


FIGURE 3. Comparison of NT1 and NT2 Surface Density Over Time



Natural Surface NT1

Natural Sand NT2

Time is measured in time points of Clegg testing. Estimated Marginal Means is measured in G max units.

APPENDIX A

Literature Review

Artificial turfs have become more common over the last twenty-five years

(29). Artificial turfs cover at least two thirds of the football stadiums at the professional level and more than 1,500 high school and college fields within the United States (29). From the consumer's perspective, a primary advantage using artificial turf is the reduction in yearly financial cost due to lower maintenance costs. Artificial turf also has the ability to maintain durability and strength for almost a decade before deterioration becomes a cause for concern. The initial install price is approximately \$700,000, however it fluctuates according to the artificial surface area and style (44). Natural turf surfaces cost approximately \$150,00 to \$200,000 to install, yet have an annual \$10,000 expense to maintain (44). This cost, the time and tools necessary to maintain proper soil hardness, composition, moisture, and water quality suggest that artificial turf is the smarter option from a financial standpoint.

Aside from financial reasons, performance and athletic safety are important when considering a transition from natural to artificial turfs. Since the 1960's artificial turf has evolved to improve both athletic safety and performance. Third and fourth generation artificial turf now contains a sand layer at the base, a shock-pad layer directly under the turf surface and a tire crumb layer in between (25). Advocates of artificial playing surfaces hype their practicality and durability in a range of conditions. However, the effects on strength and performance have yet to be clearly tested when compared to natural surfaces.

Very little research exists on turf playing surfaces and the confounding performance effects it has on the athlete. Most of the published literature examines the

risk factors and injury potential on natural and artificial turfs (4,16,18,20). Athletic performance is dependent on speed, agility and power (31). Differences in playing surface composition will impact variables such as an athlete's speed, agility, peak torque, rotational stiffness and overall running mechanics (35). As an athlete changes direction, starts and stops, several forces are transferred to the lower body. The different physical structure between natural and artificial turf surface can change the resultant energy when landing and therefore vary the athletic power abilities. Also, it has been suggested that traction characteristics of a cleated shoe can heighten an athlete's abilities (37). Morehouse et al. suggested athletes could run faster and change direction more quickly on a traditional synthetic turf surface compared to a natural turf surface (40). Nonetheless, future research is needed to better pinpoint the differences in performance measures across different playing surfaces being used today.

Performance with Differing Surfaces

McMahon and Greene in 1979 were the first to publish a manuscript to review an improvement in overall speed performance due to the turf playing surface type. Their model implied that adjusting the turf surface density of a field track to balance a runner's stride movements could possibly increase the maximal speed during sprinting performance. The researchers measured leg stiffness on eight young adult male athletes when running on seven tracks of various densities. Each subject's speed, stride length and ground contact time on each stride by biomechanical film analysis was determined. The researchers used a concrete asphalt surface, packed cinder block track surface, board track surface, a pillowed track at 1.67 grams and two types of varied stiffness wooden tracks. A huge increase in foot ground reaction force, up to

five times body weight, was found on hard surfaces, such as concrete and the packed cinder surface. However, this finding was not evident when the athletes ran on the softer pillow and experimental wooden tracks. Both ground contact time and step length increased when running on surfaces of decreased density such as the pillow track, leading to moderately reduced running speeds. Yet, ranges of density measurements were discovered between playing surfaces, which can increase or decrease athlete's speed. A crucial point to McMahon and Greene's findings is the assumption that leg stiffness is the same unrelated to the density of playing surface. This hypothesis appeared acceptable at the time, based on the idea that the stretch reflex during a subject's running stride would sustain constant muscle stiffness. Since the late 1970's the majority of the studies have revealed that an increase in leg stiffness enhances running speed (54) or jumping performance (23, 44) but have measured them utilizing numerous different performance measures and playing surface areas.

Ferris et al found that runners alter their leg stiffness for their first step when beginning to run on a new running surface (26). Six healthy female subjects between 21 and 25 years of age participated in this study. The researchers found a decrease in leg stiffness of about 29% between the last footstep on a playing surface with a lower density and the first step on a hard surface decreasing 10.7 kN m⁻¹ to 7.6 kN m⁻¹. By quickly adjusting leg stiffness each subject therefore made an easy transition between the playing surfaces causing the path of their body's center of gravity mass unaffected by the changes in surface stiffness.

Conversely in 2002, Tillman and colleagues found that the kind of playing surface has no significant effect on lower extremity kinematics in running. The objective of this study was to determine the possible changes in physical structure when the athlete makes contact with different playing surfaces. Shoe reaction forces were also evaluated. Eleven fit adult males aged 22.9 ± 3.2 years were recruited to run on four different surfaces: asphalt, concrete, grass, and a synthetic track. Plantar pressure technology was used to measure force on the actual running surfaces outside the laboratory. Data were collected at 250 Hz using a Parotec-plantar pressure measurement system. The male subjects ran at the same speed for each of the playing surfaces. Significant differences were detected among the surfaces for shoe reaction forces, contact time and impulse ($P > 0.05$). This implies that runners who choose to run on stiffer surfaces are not exposing themselves to additional risk as a result of loading but possibly because of internal compensatory mechanisms. However, these results may not apply to all runners. The results of Tillman and colleagues research have also proposed that it is not realistic to overgeneralize the performance outcomes across different sports surfaces. However, these findings should be interpreted with caution because the density measures across each surface were similar.

Playing surface density and energy return from a stiffer sports surface is currently believed to allow an athlete to perform athletic movements more proficiently. Energy storage is directly related to the firmness of the surface. Stefanyshyn and Nigg demonstrated that energy storage is related to both surface density and to the square of the greatest surface deformation (54). This suggests the idea that a higher surface density will produce an increase of energy storage and

decrease a surface's deformation which impacting the ground reaction forces. The internal energy loss caused from a turf surface is suggested to be due to the surface density and internal energy loss over time, suggesting an increased surface density will improve athlete performance.

In 2005, Brechue et al. reported that natural grass surfaces impair spring performance in football players, but the study design was comparing natural grass to an indoor track surface only. Since football players do not play on rubberized surfaces, the applications of these research findings are limited (7). Moreover, similar performance analysis reported that the type of playing surface might not affect speed, agility and energy expenditure (47).

In 2008, Stiles et al examined how certain measures of a surface's ground reaction forces can vary when eight male soccer or rugby players performed two separate running trials on a clay loam natural turf, sandy loam natural turf and a root zone natural turf surface. For both visits, the field athletes (n=8) were asked to perform ten trials on each of the three surfaces For analysis of the ground reaction forces, the subject's right foot was required to make contact with the ground over the force plate. (48). A Clegg was utilized to measure the mean soil stiffness before and after each trial at the center, bottom left corner and top right corner of each surface. The sandy loam surface was the densest prior to testing began, while the clay loam was the least dense. In contrast, to findings by Stefanyshyn and Nigg, when analyzing the data after the subjects ran on the surfaces, researchers reported the peak active force during the propulsive phase of ground contact was not significantly higher when performed on the clay loam. However, the athlete's change of direction data was

tested; the clay loam turf surface performance trials were significantly higher when compared to the results from the sandy loam and root zone turf surfaces. This research implies that the relationship between the overall mechanical properties of the turf and the biomechanical factors of athletic movements and response to surface density is more prominent and significant when the athlete is changing direction. Still, future research is necessary to analyze multiple natural turf playing surfaces to more than one artificial turf-playing surface.

The relationship between surface composition and sport performance has been suspected to be parallel between surface composition and muscle performance. Katkat et al performed a study utilizing seven different playing surfaces to measure muscle performance (34). The leg strength of twenty-two male basketball players of the elite level between the ages of 17-28 were measured at rest and after a training protocol for vertical jump height and leg strength. During vertical jumping test, subjects were required to have both hands on their hips and maintain full leg flexion from the standing prior to performing each vertical jump. These jump test were monitored with a digital jump meter which recorded the peak jump height of each subject. The seven different sport surfaces used for the pilot study were asphalt, synthetic grass, natural grass, tile powder, soil, wooden parquet and Ethylene Propylene Diene Monomer (EPDM). Katkat and colleagues measured the velocity of a five-kilogram medicine ball on video camera to measure surface stiffness. The medicine ball was dropped thirty five times to each surface type, focusing on calculating the height of the first bounce after reaching the surface after being suspended one hundred centimeters in the air. The Asphalt playing surface and synthetic grass were the most strenuous

surfaces metabolically. Natural grass, soil and tile powder were moderately strenuous; while parquet and EPDM were the least strenuous sport surfaces. Results suggest that it is less strenuous on the athlete's muscles to use parquet and EPDM in creation of indoor sport surfaces. If a playing surface is less strenuous, the athlete playing on that surface can reach a particular training program's goal utilizing less oxygen consumption than when being compared to a more physically fatiguing sports surface.

Sassi et al completed a performance analysis while measuring energy expenditure and found running on natural turf may affect athletic performance by decreasing the player's ability to achieve maximal speed and agility (50). Results suggest running on grass and artificial turf surfaces required more metabolic energy than running on a denser surface used such as the asphalt track-playing surface. The research from this performance analysis suggest the resultant energy returned to the subject from the natural and artificial turf surface to be nearly identical in numerical value. Past findings have proposed that playing surfaces with widely varied densities will alter the muscular force needed by the players to push off the ground. This known numerical difference in surface density between natural and artificial turf is what causes the difference in power, force and other performance factors. The researchers concluded that the energy mechanics from this study resulted in insignificant differences between performance on the natural and artificial turf surfaces. The conflicting results from this published study serves as evidence that markers of performance across different playing surfaces are still a topic that needs to be investigated.

Recently, Zanetti et al added practical research to the literature with a study comparing the mechanical and biomechanical responses of two types of artificial turf compared to a natural turf field surface. The study's aim was to recognize a consistent explanation of the turf surface properties while analyzing the player to surface interaction (43). Zanetti et al tested each surface by measuring athletes' energy storage, energy loss and surface traction coefficient. Eight male athletes wore the same shoes and accelerometers during testing. Subjects were asked to perform the following tests on three different turf surfaces: straight running with a heart rate of 168 beats per minute, straight running with a heart rate of 200 beats per minute, tight slalom and zigzag running. Each test was performed ten times per athlete on different days to control for experimental validity and standard of error. The results suggested the natural turf surface was denser and had lower traction coefficient than both of the artificial surfaces. The two artificial surfaces varied from each other by 23% in surface density. In reference to running, peak vertical speeds were lower on the artificial turf composed of thermoplastic rubber granules. The horizontal peak speed was higher for both artificial surfaces when compared to the natural field surface. Many aspects concerning the performance of modern infill artificial surfaces still need investigation due to conflicting analysis according to Zanetti and colleagues. A limitation noted by the researcher that was attained from measurable statistical findings confirms the results for energy storage show high variability. This finding is most likely due to spatial unevenness of the turf surface. Uneven playing surface can skew data analysis and alter performance measures like force and power due to density differences upon a single turf surface area.

Field Athletes, Performance, Vertical Jump

Much of the research on athletic surfaces has focused on the running performance when in comparison to an athlete's performance. The change of movement necessary to start, stop and laterally change direction markedly increases the energy expended. Due to this theory, research is needed to measure an athlete when performing activities that fully engage the stretch shortening cycle. The dynamics of the stretch shortening cycle is vital to understanding performance when changing direction in any sportive movement. The stretch-shortening cycle is described as the combination of eccentric (muscle lengthening) and concentric (muscle shortening) actions. The stretch-shortening cycle does takes place throughout daily actions such as walking and running, yet, it is exaggerated significantly through exercises that aim to improve an athlete's speed and agility performance ability. Refining speed and agility training will aid in improving an athlete's change of direction skills. Training the stretch shortening cycle via plyometric movements such as the vertical jump and drop jump directly correlates to performance variables like force and power that can positively effect change of direction and individual ability to start and stop on the field (5). There are notable research gaps in speed performance studies that effect data findings. This may be due to the fact that these types of studies are solely measuring speed performance. The vertical jump is one of the best-known predictors in measuring an athlete's maximal performance ability (25). Gaps in the research noted by Feehery et al included the subject's limited athletic profile and the fact that speed performance fails to examine an athlete's maximal speed, power, agility and potential to utilize stored energy in the muscle (25).

Vertical Jump relationship to athletic performance

In terms of athletic performance capability across different playing surfaces, the three important mechanical properties important to understand are energy storage, energy loss and surface friction. Energy storage is directly related to the stiffness of the surface (42). The vertical jump is an important component of fitness in field sports and can drastically affect an athlete's performance potential. Many football, soccer, and lacrosse training programs aim to improve their athlete's vertical jump height due to strong correlations to success or failure in competition on the field (14,43,50,52,60). The reasoning behind the effectiveness and importance of the vertical jump is the involvement of the stretch shortening cycle, which can increase the individual's power of athletic movements through the natural elasticity of the muscles and tendons related to a single maximal jump (17). The stretch shortening cycle is made three phases: the eccentric phase which is the storing of potential energy, the amortization phase, also known as the transitional phase, and the concentric phase or the use of the potential of stored energy. The most important of these three phases in the stretch shortening cycle is the amortization phase (14). This suggestion by researchers is due to the importance in relation to athletic performance to complete this phase as fast as possible. The longer the amortization phase lasts during a single maximal jump, the more stored potential energy that could be used for fast muscle contraction is lost as heat, resulting in decreased power. Therefore, the density, specifically lower density, of a playing surface can affect the athlete's length of time within this phase. Differences in playing surface density and can vary the athlete's power upon leaving the surface while also affecting the force needed to leave the playing surface.

Vertical jump and relation to speed and power

The ability to generate high human power output is instrumental to performance. Power output depends on numerous factors especially joint range of motion, strength of muscle groups and ground reaction force properties (1,27,52,58). Athletic power from a vertical jump can be used as a predictor of an athlete's speed and agility. Sprinting and running are known as multipart motor skills and are one of the most significant objective essentials of performance in sports such as soccer, lacrosse and football (30). Little research has been done measuring possible performance differences when playing on artificial grass versus natural grass. Kanaras and colleagues recently compared sprint performance on natural and artificial fifth generation playing surfaces (33). Sixty-eight young male soccer players ran thirty-meter sprints with and without the soccer ball upon both the natural and artificial grass surface. The subjects were also split evenly into two groups, children ages 12.1 ± 0.5 years and adolescents 14.2 ± 0.4 years old. A record of the subject's speed on the playing surfaces was taken at the time points of 0-10 m, 10-30 m and 0-30 m distances. It was found after analysis that the children were significantly faster on artificial turf as opposed to the natural grass whether they were handling the soccer ball or not. However, the adolescent group was found to be significantly faster when running on the artificial grass only when not handling the soccer ball. Authors concluded that the children most likely perform equivalently well with or without the ball, while the adolescents may not due to the greater skill vital to chase a soccer ball moving faster on the artificial playing surface than the natural surface.

Estimation of power ability generated during an activity can produce insight to coaches and trainers as to how the athlete will perform when completing other sportive movements, like running. A prime example of how vertical jump can estimate power and relate to speed is when two athlete's with differing body weights may be able to jump vertically the same height, but the heavier athlete would be showing the ability to exude more power, which can provide insight to power in other activities and physical capability.

Many activities in sports require landing form a jump. The vertical ground reaction forces on the body during landing can be determinants of injury. Elite basketball teams average 70 jumps per game, while volleyball players average around 60 jumps an hour on the court. The relevance of how important vertical jump is to many sports and how the need to train athlete's to jump higher and faster is key to improving performance (43)

APPENDIX B
Borg CR-10 Scale

Borg CR-10 Scale of Perceived Exertion

0	Nothing at all	
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	“Maximal”
11		
	• Absolute Maximum	Highest possible

APPENDIX C

CONSENT FORM FOR RESEARCH

You have been asked to take part in a research project described below. The researcher will explain the project to you in detail. You should feel free to ask questions at any time. If you have more questions later, Disa Hatfield, Ph.D. (401-874-5183), or Justin Nicoll (401-874-2980), the individuals responsible for this study, will discuss them with you. You must be at least 18 years old to be part of this research project.

Description of the project:

We are inviting you to participate in a research study examining the effect of different types of turf on jumping performance.

What will be done:

If you decide to take part in this study here is what will happen:

You will visit the Human Performance Laboratory on five occasions. The first visit will be for preliminary testing and will last approximately 2 hours. During this session you will complete a medical history questionnaire, a nutritional questionnaire, and we will measure your percentage of body fat. We will assess your body fat percentage using a device called the BodPod. We will also show you the five types of exercises you will be performing in the performance trials and let you practice them.

During each of the other four visits, we will only ask you to perform the five exercises on one of four surfaces (a different one each time). These visits will take approximately 30 minutes each, and should be separated by at least 2 days in between each visit.

The preliminary visit will involve the following:

1. **Body Composition Measurements:** we will record the following characteristics: age, height, and body weight. Your percentage of body fat will be determined by something called air displacement plesmography. For this measurement, you will be asked to sit inside the BodPod machine and comfortably rest for 2-5 minutes while your body fat percentage is estimated. Your body fat is estimated in this fashion by calculating the amount of air you displace inside the known area of the BodPod.

2. Questionnaires: We will ask you to complete a medical health history questionnaire and a nutrition/activity profile to ensure that you don't have any known medical conditions such as recent or reoccurring muscle or bone injuries, or tendon or ligament injuries that would prohibit you from taking part in this study.

3. We will show you the 5 exercises you will be performing and let you practice them. These exercises are a vertical jump, a single leg hop, running in place, landing after jumping off a 24-inch box, and a vertical jump immediately after stepping off of a 24-inch box.

The performance trials will involve the following:

1. Vertical Jump: Your vertical jump height and power will be assessed in this study during all four-exercise trials. For height, you will be asked to jump as high as you can to touch the highest marker on a device called a VERTEC. For power, we will ask you to perform three jumps in a row as high and as fast as you can on a different turf surface.
2. Balance: To assess dynamic balance on the different surfaces, we will ask that you perform three jumps in a row using only one leg as high and as fast as you can.
3. Running Form: To assess running form, we will ask you to run in place for 30-seconds, bringing you knees up as high as possible with each repetition.
4. Landing Form: To assess you landing form, we will ask you to perform two exercises that require to step off of a box that will be two feet higher than the surface. For the first step-off, we will ask you to step off with one foot and land on the force plate or turf module with both feet and subsequently jump as high as possible one time. For the second step-off, we will ask you to step off with one foot and land on the force plate or turf module with both feet and simply return to a standing position (no jump).
5. Diet Logs: We will ask to follow the same or as close to the same diet as you can that you did during the first trial. During each visit, we will ask you to write down what you ate and drank that day.
6. Questionnaires: For each performance trial, we will ask you to rate how fatigued you feel before and after the exercises on a scale of one to five. We will also ask you how to rate how hard you think you are working after each exercise.

7. Measurements: During each performance trial, we will ask you to clip a small device called a Myotest onto your waistband. This device is about the size of a large wristwatch and will record the force and power you are exerting during each exercise. In addition, we will record each of your exercises with a video camera so that we can evaluate your landing form on the different surfaces.

You may not exercise or consume any drugs 24 hours prior to each exercise trial session. This includes over-the-counter anti-inflammatory (such as ibuprofen), herbal remedies, supplements, topical analgesics (such as Icy Hot), or prescription drugs that may affect the results of the study (such as narcotic-containing drugs.) You must also refrain from caffeine for 1 day prior to each performance trial. This includes all caffeine containing beverages and foods (chocolate, cocoa, tea, caffeinated soda, energy drinks). You must also refrain from all strenuous physical activity 24 hours prior to testing. For instance, walking to and from class, light housework, and other normal daily activities are acceptable. You should refrain from recreational activities such as basketball, jogging, softball, etc. for this period of time.

Please wear the same athletic shoes and shorts for all performance trials.

Risks or discomfort:

There are no known risks for the following procedures: height, weight, and use of the BodPod.

The exercise trials may make you feel tired. The performance of strenuous activity like jumping may make you sore. This soreness may last for a day. Every effort will be made to minimize risks and the risk of injury by medical history screening and monitoring procedures that are designed to anticipate and exclude the rare individual for whom exercise might be injurious.

It is possible that the exercise may result in muscle/tendon/ligament injury, or muscle soreness. All these risk are no greater than those that may occur during the normal course of training. The Investigator does not have a plan to cover the cost of any injuries in the course of participation. If you are injured during your participation in any way, you will be given first aid and evaluated by the University of Rhode Island Health Services and referred to your personal doctor, if needed. If you have any difficulty completing the protocol because of muscular soreness, illness, or another injury unrelated to the study, the exercise protocol will be terminated for that day.

Benefits of this study:

You will receive a report of your personal measurements, including body fat percent, how much force and power you can produce, and how high you can jump.

Confidentiality:

Any information obtained from you during the study will remain confidential and you will not be identified by name in any publication or reports that result from this study. All records will be coded and stored by subject identification codes. Records of codes will be locked and stored in a file cabinet in Dr. Disa Hatfield's office in 25 West Independence Way at the University of Rhode Island. The researchers will be the only people to have access to these records. Records will be kept for 3 years and then destroyed. Any data entered into a computer program will contain only subject codes to ensure anonymity and no names will be published. After 3 years, the data files will be destroyed. Each subject will receive a random numerical code (ie odd numbers for women, even for men.) Only one document will exist that links these subject codes to their names, and will be kept in Dr. Hatfield's filing cabinet in 25 West Independence Way, Ste. P. These file will be destroyed after 3 years.

In case there is any injury to the subject: (If applicable)

It is not the policy of the University of Rhode Island to compensate subjects in the event that a research procedure results in physical or psychological injury. The University of Rhode Island will, however, make its best effort to refer you to appropriate services, upon request, if injury does occur. You may discuss this question with Disa Hatfield at (401) 874-5183. You may also call the office of the Vice President for Research, 70 Lower College Road, University of Rhode Island, Kingston, Rhode Island, telephone: (401) 874-4328. However, if you experience any problems related to this study you should contact your personal physician.

Decision to quit at any time:

The decision whether or not to take part in this study is entirely up to you. You do not have to participate in this study. If you decide to take part in this study, you may quit at any time. Whatever you decide will be accepted and there is no way you will be penalized. Your decision to participate and/or terminate your participation will not affect your grades in any classes. If you wish to quit, simply inform Justin Nicoll at 401-874-2980 or Disa Hatfield at (401)-874-5183 of your decision. We may terminate your participation in this study at any time if you show obvious signs of non-compliance with the study protocols (ie not showing up to your performance trials.)

Rights and Complaints:

If you are not satisfied with the way this study is performed, you may discuss your complaints with Justin Nicoll at 401-874-2980 or Disa Hatfield (401)-874-5183, anonymously if you choose. In addition, if you have questions about your rights as a research participant, you may contact the office of the Vice President for Research, 70

Lower College Road, Suite 2, University of Rhode Island, Kingston, Rhode Island, telephone: (401) 874-4328.

I, the undersigned, have received, in my opinion, an adequate explanation of the nature, duration and purpose of this research investigation, the means by which the study will be conducted, and any possible inconvenience, discomforts, risks or adverse effects on my health which could result from my participation.

Video recording:

Please initial one of the following to indicate your choice:

I do not give my permission to be photographed or videotaped as part of this study.

I give permission for photographs or videotapes of me to be used in publications or presentations.

I do not give permission for photographs or videotapes of me to be used in publications or presentations.

You have read the Consent Form. Your questions have been answered. Your signature on this form means that you understand the information and you agree to participate in this study.

Signature of Participant

Signature of Researcher

Typed/printed Name

Typed/printed name

Date

Date

Please sign both consent forms, keeping one for yourself

APPENDIX D
Nutritional History Questionnaire

1. Do you use alcohol? Yes No
If yes, how many times per week.
What is the total amount?
2. Do you drink caffeinated coffee or colas? Yes _____ No
If yes, how many per week?
3. Are you now or have you ever been on a diet? Yes No
If yes, please explain
4. Do you consider yourself overweight? Yes No
Do you consider yourself underweight? Yes No
5. Number of meals you usually eat per day:
6. Do you usually eat breakfast? Yes No
7. Number of times per week you usually eat the following:
___ Beef ___ Fish ___ Pork ___ Chicken
___ Desserts ___ Fried Foods ___ Fast Food
8. Do you regularly use any of the following? (please circle)
Butter Sugar Sweeteners Salt Whole
Milk
9. How would you describe your nutrition habits? (please circle)
good fair poor
10. Please describe your knowledge of nutrition. (please circle)
very knowledgeable knowledgeable no knowledge

11. Do you regularly use any vitamin or mineral supplementation?

Yes No
If yes, please list:

12. Do you use any other form of supplementation (i.e. herbal remedies, food supplements, performance enhancing drugs, etc?)

Yes No
If yes, please list:

13. Have you ever taken protein, casein protein, soy protein, sports nutrition bars, protein shakes or smoothies?

Yes No

If yes, are you currently using these products now on a regular (weekly) basis?

Yes No

Please list the manufacture and name of any of these products you have ever had:

If you are currently using any of these products, how many times per week do you eat/drink each product?:

If you aren't currently taking any of these product, but have in the past, how often did you use them?:

When was the last time you used them and which type did you have?:

APPENDIX E
Physical Activity Questionnaire

Cardiovascular/Aerobic Exercise

Do you currently engage in cardiovascular exercise on a regular basis?

Yes No

If yes, what mode(s) of exercise do you perform?

How many times per week do you perform this/these exercise(s)?

What is the duration and intensity of exercise (ex: 30 minutes at 3.2 mph, 3.0% grade on the treadmill)?

For how many years have you been performing this type of exercise?

Have you participated in any other physical activity (other than resistance exercise) on a regular basis in the last 5 years?

Yes No

If yes, what type?

Resistance Exercise (Weight Training)

Do you currently engage in cardiovascular exercise on a regular basis?

Yes No

If yes, how many days per week?

List some examples of common exercises you perform.

APPENDIX F

Medical History Form

HUMAN PERFORMANCE LABORATORY MEDICAL HISTORY QUESTIONNAIRE

Study Name _____ Street _____ City _____ State _____ Zip _____ Email _____

Subject # _____ Sex _____ Age _____ DOB _____ Phone _____

PLEASE ANSWER ALL OF THE FOLLOWING QUESTIONS AND PROVIDE DETAILS FOR ALL "YES" ANSWERS IN THE SPACES AT THE BOTTOM OF THE FORM.

<table border="1" style="width: 100%; height: 100%; border-collapse: collapse;"> <tr><td style="text-align: center;">YES</td></tr> <tr><td style="text-align: center;">NO</td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> </table>	YES	NO									<table border="1" style="width: 100%; height: 100%; border-collapse: collapse;"> <tr><td style="text-align: center;">YES</td></tr> <tr><td style="text-align: center;">NO</td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> <tr><td style="text-align: center;"> </td></tr> </table>	YES	NO									<ol style="list-style-type: none"> 1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor? 2. Has your doctor ever denied or restricted your participation in sports or exercise for any reason? 3. Do you ever feel discomfort, pressure, or pain in your chest when you do physical activity? 4. In the past month, have you had chest pain when you were not doing physical activity? 5. Do you lose your balance because of dizziness or do you ever lose consciousness? 6. Does your heart race or skip beats during exercise? 7. Has a doctor ever ordered a test for you heart? (i.e. EKG, echocardiogram) 8. Has anyone in your family died for no apparent reason or died from heart problems or sudden death before the age of 50? 9. Have you ever had to spend the night in a hospital? 10. Have you ever had surgery? 11. Please check the box next to any of the following illnesses with which you have ever been diagnosed or for which you have been treated. <table border="0" style="width: 100%; margin-top: 5px;"> <tr> <td style="width: 33%;"><input type="checkbox"/> High blood pressure</td> <td style="width: 33%;"><input type="checkbox"/> Elevated cholesterol</td> <td style="width: 33%;"><input type="checkbox"/> Diabetes</td> </tr> <tr> <td><input type="checkbox"/> Asthma</td> <td><input type="checkbox"/> Epilepsy (seizures)</td> <td><input type="checkbox"/> Kidney problems</td> </tr> <tr> <td><input type="checkbox"/> Bladder Problems</td> <td><input type="checkbox"/> Anemia</td> <td><input type="checkbox"/> Heart problems</td> </tr> <tr> <td><input type="checkbox"/> Coronary artery disease</td> <td><input type="checkbox"/> Lung problems</td> <td><input type="checkbox"/> Chronic headaches</td> </tr> </table> 	<input type="checkbox"/> High blood pressure	<input type="checkbox"/> Elevated cholesterol	<input type="checkbox"/> Diabetes	<input type="checkbox"/> Asthma	<input type="checkbox"/> Epilepsy (seizures)	<input type="checkbox"/> Kidney problems	<input type="checkbox"/> Bladder Problems	<input type="checkbox"/> Anemia	<input type="checkbox"/> Heart problems	<input type="checkbox"/> Coronary artery disease	<input type="checkbox"/> Lung problems	<input type="checkbox"/> Chronic headaches
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DETAILS:

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Please list all allergies you have. <table border="0" style="width: 100%; margin-top: 5px;"> <tr> <td style="width: 60%;">Substance</td> <td style="width: 40%;">Reaction</td> </tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> </table> 18. Have you smoked? <table border="0" style="width: 100%; margin-top: 5px;"> <tr> <td style="width: 30%;">Cigarettes</td> <td style="width: 20%;">If yes, #/day</td> <td style="width: 20%;">Age Started</td> <td style="width: 30%;">If you've quit, what age?</td> </tr> <tr> <td>Cigars</td> <td> </td> <td> </td> <td> </td> </tr> <tr> <td>Pipes</td> <td> </td> <td> </td> <td> </td> </tr> </table> 19. Do you drink alcoholic beverages? <table border="0" style="width: 100%; margin-top: 5px;"> <tr> <td style="width: 40%;">If yes, how much?</td> <td style="width: 60%;">How often?</td> </tr> <tr><td> </td><td> </td></tr> </table> 20. Do you have a family history of any of the following problems? If yes, note who in the space provided. <table border="0" style="width: 100%; margin-top: 5px;"> <tr> <td style="width: 50%;"><input type="checkbox"/> High blood pressure</td> <td style="width: 50%;"><input type="checkbox"/> Heart disease</td> </tr> <tr> <td><input type="checkbox"/> High cholesterol</td> <td><input type="checkbox"/> Kidney disease</td> </tr> <tr> <td><input type="checkbox"/> Diabetes</td> <td><input type="checkbox"/> Thyroid disease</td> </tr> </table> 21. Please check the box next to any of the following body parts you have injured in the past and provide details. <table border="0" style="width: 100%; margin-top: 5px;"> <tr> <td style="width: 33%;"><input type="checkbox"/> Head</td> <td style="width: 33%;"><input type="checkbox"/> Hip</td> <td style="width: 33%;"><input type="checkbox"/> Calf/shin</td> </tr> <tr> <td><input type="checkbox"/> Neck</td> <td><input type="checkbox"/> Thigh</td> <td><input type="checkbox"/> Shoulder</td> </tr> <tr> <td><input type="checkbox"/> Upper back</td> <td><input type="checkbox"/> Knee</td> <td><input type="checkbox"/> Upper arm</td> </tr> <tr> <td><input type="checkbox"/> Lower back</td> <td><input type="checkbox"/> Ankle</td> <td><input type="checkbox"/> Elbow</td> </tr> <tr> <td><input type="checkbox"/> Chest</td> <td><input type="checkbox"/> Foot</td> <td><input type="checkbox"/> Hand/fingers</td> </tr> </table> 22. Have you ever had a stress fracture? 23. Have you ever had a disc injury in your back? 24. Has a doctor ever restricted your exercise because of an injury? 25. Do you currently have any injuries that are bothering you? 26. Do you consider your occupation as? <table border="0" style="width: 100%; margin-top: 5px;"> <tr> <td style="width: 40%;"><input type="checkbox"/> Sedentary (no exercise)</td> <td style="width: 60%;"><input type="checkbox"/> Inactive-occasional light activity (walking)</td> </tr> <tr> <td><input type="checkbox"/> Active-regular light activity and/or occasional vigorous activity (heavy lifting, running, etc.)</td> <td><input type="checkbox"/> Heavy Work-regular vigorous activity</td> </tr> </table> 27. List your regular physical activities <table border="0" style="width: 100%; margin-top: 5px;"> <tr> <td style="width: 30%;">Activity</td> <td style="width: 20%;">How often do you do it?</td> <td style="width: 20%;">How long do you do it?</td> <td style="width: 30%;">How long ago did you start?</td> </tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> </table> 	Substance	Reaction							Cigarettes	If yes, #/day	Age Started	If you've quit, what age?	Cigars				Pipes				If yes, how much?	How often?			<input type="checkbox"/> High blood pressure	<input type="checkbox"/> Heart disease	<input type="checkbox"/> High cholesterol	<input type="checkbox"/> Kidney disease	<input type="checkbox"/> Diabetes	<input type="checkbox"/> Thyroid disease	<input type="checkbox"/> Head	<input type="checkbox"/> Hip	<input type="checkbox"/> Calf/shin	<input type="checkbox"/> Neck	<input type="checkbox"/> Thigh	<input type="checkbox"/> Shoulder	<input type="checkbox"/> Upper back	<input type="checkbox"/> Knee	<input type="checkbox"/> Upper arm	<input type="checkbox"/> Lower back	<input type="checkbox"/> Ankle	<input type="checkbox"/> Elbow	<input type="checkbox"/> Chest	<input type="checkbox"/> Foot	<input type="checkbox"/> Hand/fingers	<input type="checkbox"/> Sedentary (no exercise)	<input type="checkbox"/> Inactive-occasional light activity (walking)	<input type="checkbox"/> Active-regular light activity and/or occasional vigorous activity (heavy lifting, running, etc.)	<input type="checkbox"/> Heavy Work-regular vigorous activity	Activity	How often do you do it?	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ADDITIONAL DETAILS:

APPENDIX G
Study Flyer

**The Human Performance Laboratory
at the University of Rhode Island**

Is seeking

**Healthy men and women (between 18-25 years
old) to participate in a**

Jump Power Study

**Examining the influence of different grass
surfaces on jumping height and power**

Interested participants call Kelly Murphy
or Justin Nicoll at *The Human Performance*

Jump Power Study
Call Justin at 401-874-
2980
jumppowerstudy@hotmail.com

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