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Differences In Lower Body Strength, Power Between Genders

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DIFFERENCES IN LOWER BODY STRENGTH, POWER, AND AGILITY BETWEEN GENDERS

by

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ABSTRACT

INTRODUCTION: Athletic individuals have many characteristics, which make them more elite than the average individual. When determining an individual's physical fitness level, strength, power, and agility are commonly examined. When measuring strength, power, and agility in elite athletes the scores are compared to some portion of body composition such as muscle cross-sectional area and fat-free mass. When looking at the same factors in recreationally trained individuals the research mostly normalized to body weight. PURPOSE: To examine the differences in lower body strength, power, and agility in male and female recreationally trained individuals when normalized to body mass, fat-free mass, and absolute mass. METHODOLOGY: This study consisted of 43 (males: n= 20, females: n= 23) recreationally trained individuals with ages ranging from 18-29 years of age. The participant completed a one repetition maximum test, countermovement jump, and a reactive shuttle run, and they participated in a body composition test, via air displacement plethysmography. All raw scores were recorded for both males and females for the One Repetition Maximum (1RM), Countermovement jump (CMJ), and Reactive Shuttle Run. Data analysis were performed using IBM SPSS Statistics. The best trial for each test were normalized to each individual's body mass (BM), fat-free mass (FFM), and fat mass (FM). To check for the distribution of the data tests of skewness, kurtosis, histogram analysis, Kolmogorov-Smirnov, and Shapiro-Wilks were used to check normality. Pearson's product moment correlations were used to determine the associations between FFM, FM, and body mass compared to raw scores. Two-tailed independent T-tests, with an alpha level of 0.05, were conducted to determine if significant differences existed between males and females within the 1RM, CMJ, and Reactive Shuttle Test for raw scores. RESULTS: There were no significant differences between male and female strength ($p=0.33$; $d=0.05$) power (CMJ: $p=0.29$; $d=0.07$; Peak Power: $p=0.70$; $d=0.51$) and agility ($r=0.42$, $p<0.01$) when normalized to FFM, but there were an observed difference when normalizing strength ($p<0.01$; $d=0.46$), power (CMJ: $p<0.01$; $d=0.43$, $p<0.01$; $d=0.60$) and agility (($r=0.38$, $p<0.01$) FM. DISCUSSION: The results of this study may be largely due to fat distribution differences in males and females and strength-to-mass ratio. From the literature, it was found that individuals with a higher percentage of FFM were able to lift significantly more weight than individuals of the same body mass with more FM and the 1RM scores are strongly correlated to body weight, which could explain the results seen in the 1RM of this study. Abidin& Adam, (2013) stated that the amount of muscle mass plays an important role in the force production in a jump. This could explain why there was a strong correlation between CMJ and FFM. It was also suggested that individuals with a higher BMI tend to have a lower reaction time, which could be caused by larger individuals taking longer to get their center of gravity in motion than a smaller individual. This could explain the results of the correlation seen in this study. CONCLUSION: This information is important because it shows the importance of the cross-sectional area and how normalizing to body composition factors can more accurately help determine the differences more accurately between males and females. Future studies should look at the differences between male and female upper body strength, power, and agility when normalized to FM, FFM, and BM.

INDEX WORDS: Fat mass, Strength, Power, Agility, Body mass, Normalization, Males, Females, Gender.

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Introduction:

Comprehensively, the display of this information will help better establish the evidence related to differences in strength, power, and agility between recreationally trained male and female athletes. Past literature found that strength, power, and agility are important for an athlete to develop skills, and that there are key differences in these aspects between males and females (Baker & Newton, 2008; Sekulic, Spasic, Mirkov, Cavar, & Sattler, 2013; Delextrat, & Cohen, 2009; Váczi, Tollár, Meszler, Juhász, & Karsai, 2013), but there is little to no research of these differences being based on the normalization of strength, power, and agility of recreationally trained individuals. Thus, the purpose of this review is to provide an understanding of the relationship between strength, power, and agility normalizations in both males and females through previous literature.

Difference in Gender Development:

Males and females have many genetic, hormonal, and physiological traits that play a key role in their differences. One difference that occurs between males and females is on a chromosomal level. Males have an XY chromosome while females have XX chromosomes, which are responsible for determining the differences in the type of gonads, sex hormones, internal reproductive anatomy, and external genitalia (Skuse, 2000). These same genetic differences can also result in neurological differences (Ruigrok, Salimi-Khorshidi, Lai, Baron-Cohen, Lombardo, Tait, & Suckling, 2014).

Neurologically males and females differ by the parts of their brain they can access. According to Zhang & Sejnowski (2000), females use almost ten times more white matter than do males. This portion of the brain is the connection between the gray matter and other processing centers. White matter was also found to be responsible for the quick adaptation to change in females. While males were found to have almost seven times more gray matter than females. Gray matter is the information and action-processing centers of the brain and were found to cause high levels of focus on a given task or game in males (Zhang & Sejnowski, 2000). Erikson et al. (2014) found that exercise and physical activity can increase gray matter volume, which resulted in an increase in memory restoration, brain atrophy, and concentration. They also found that this increase in gray matter correlated with an increase in cardiorespiratory fitness (Erickson, Leckie, & Weinstein, 2014).

Males and females also have developmental differences. Gallahue, Ozman, & Goodway (2012) found that males develop gross motor skill and skills that emphasize force and power, such as jumping, sprinting, and lifting earlier than females. While females tend to develop, fine motor skills, skills emphasizing balancing, and coordination as those seen in dance and gymnastics earlier than males (Gallahue, Ozman, & Goodway, 2012). These physiological differences seen between males and females play an important role in the physical/athletic difference that these individuals display. The remainder of the review will examine how these differences effect male and female's physical ability.

Muscle Strength and Endurance:

Male individuals are found to have a higher percentage (at least ten percent) of muscle mass than females (Hoeger Werner, Hopkins, Barette, & Hale, 1990). Males and females develop muscles at the same rate, but male's muscles develop larger than females, and they also have a high percentage of fast-twitch muscle fibers (Laubach, 1976; Decker, Torry, Wyland, Sterett, & Steadman, 2003). This allows males to display greater strength and power outputs, which result in benefits such as greater acceleration (Decker, Torry, Wyland, Sterett, & Steadman, 2003).

Females are more efficient at anaerobically converting glycogen to energy than their male counterparts (Gnacinski, Ebersole, Cornell, Mims, Zamzow, & Meyer, 2016). This type of energy production is commonly used in high intensity exercise because individuals are not able to take in enough oxygen to keep up with the demands of the body, and aerobic respiration is no longer able to keep up with energy demands. This is generally caused by the increase in respiratory rate and muscle contracting. An increase in anaerobic capacity benefits an individual by increasing the amount of work an individual can do without getting fatigued (Marquart, Huffman, Zelonis, Brown, & Sanders, 2017). Males are also better at aerobic conversions of glycogen then females. This is due to males having larger lungs as well as a higher oxygen-carrying capacity (males have higher hemoglobin levels than females) (Gnacinski, Ebersole, Cornell, Mims, Zamzow, & Meyer, 2016).

Importance in Sports:

In athletes, strength is generally established through resistance training, which causes development by increasing muscle fiber sizes as well as improves the nerves' ability to communicate with the muscle (Enoka & Duchateau, 2008). This allows the muscles to become more coordinated and improves the individual movements (Enoka, 1988). Strength is important in sports because it helps to maximize performance and gives the athlete's a foundation to improve explosive/ jumping ability (Suchomel, Nimphius, & Stone, 2016), while also improving their sprinting, and ability to change of direction by allowing them to generate more force. Suchomel, Nimphius, & Stone (2016) found that muscle strength is one of the most important underlying determinants of performance, and stronger athletes outperform their weaker counterparts in sports that require strength, power, and endurance.

Strength testing: One Repetition maximum:

The one repetition maximum (1RM) test is considered the gold standard for assessing strength and has a 95-percent test-retest reliability (Levinger, Goodman, Hane, Jerums, Toia, & Selig, 2009). 1RM is the maximum amount of force that an individual can generate in one maximal muscle contraction (Mayhew, Ball, Arnold, & Bowen, 1992). This value can be directly measured or estimated from a 3RM, 5RM, and a 10 RM, and can be conducted in both lower and upper extremities (Mayhew, Ball, Arnold, & Bowen, 1992).

Males:

According to Bianco, Flingeri, Pasli, & Palma, (2005) trained males were found to lift 15-25% more than their body mass, and about 35-40% more than their FFM. Colliander & Tesch, (1990) suggested that males can push their muscles thirty percent more than their estimated 1RM, meaning that during a 1RM test a male athlete can normally lift thirty percent more in one rep then in a continuous repetition workout. This could result in a 1RM score that is two to three times more than the individual's body weight. Another way the research determined that an individual could increase their 1RM scores were through resistance training (Myer, Ford, Palumbo, & Hewett, 2005). According to Cassilhas, Viana, Grassmann, Santos, Santos, Tufik, & Mello (2007) resistance training can improve muscular mass and strength by about twenty percent after nine weeks of participation for elderly individuals. While Glowacki, Martin, Maurer, Baek, Green, & Crouse (2004) found that after 16-week resistance training program active individuals had a significant increase in their 1RM compared to individuals who did not participate (p=0.023). Strength training has also been shown to influence jumping ability, throwing velocity, flexibility, sprint times, and change of direction skills (Granados, Isquierdo, Banez, Bannabau, Gorostiaga, 2007; Glowacki, Martin, Maurer, Baek, Green, & Crouse, 2004; & Hoffman & Kang, 2003).

Females:

The 1RM is also commonly used in females to determine their strength. According to ACSM's Guidelines for Exercise Testing and Prescription, (2014) in an untrained female, their 1RM back squat score on average is 80 pounds (lbs.) (36.28 kg), in novice females 95 lbs. (43.09 kg), in intermediately trained females 115 lbs. (52.16 kg), and in advanced or elite trained females 145 lbs. (65.77 kg). These values show that training can improve a female overall 1RM score. This was also supported by Myer, Ford, Palumbo, & Hewett (2005), where they found participation in a twelve-week strength training program increased the amount of weight an individual can lift from 60-percent of the individuals 1RM to 68-70-percent of the individual's 1RM. Increasing strength can also benefit other factors in their physiology and sports abilities.

According to Maughan, Hannon, Leiper, Sale, & Delmen, (1986), participating in strength training also improves a female’s muscle endurance causing the females isometric endurance time to be 20-percent greater than males when compared to maximal voluntary contractions. Further research found that strength and conditioning can cause an increase in 1RM and power output in female softball players, resulting in an increase in pitching/ throwing velocity (Granados, Isquierdo, Banez, Bannabau, & Gorostiaga, 2007). Strength training can have many effects on athletes, and there are many similarities in these effects between males and females. Myer, Ford, Brent, and Hewett (2006) found that there were significant increases in

Bench press, hang cleans, and squats in female athletes when participating in plyometric and dynamic training, compared to the control group (*p*<0.01).

Combination:

According to Parchmann & McBride (2011), in their study testing maximum strength (1RM) there was a significant difference in back squat 1RM scores when comparing division 1 males and females to recreationally trained males and females, and that there was a strong negative correlation between strength and the 10-m agility sprint time (r=-0.812). However, when elite athletes are compared to recreationally trained individuals there was a significant difference. They also found that there was a significant difference between elite males and both elite females and recreationally trained females, but there was not a significant difference between elite females and recreationally trained males. Other studies have found using computerized topographical scanning that females were approximately 52% as strong as males in the upper body and 66% as strong as males in lower body respectively (Miller, Macdougall, Tarropolsky, & Sales, 1993). While Ireda, Kijma, Kawabata, Fuchimoto, & Ito, (2006) found that there was no significant difference in parallel squats and bench press peak power 1RM scores when compared to FFM. When looking at recreationally trained individuals it was found that, there was a significant difference in male and female strength and power output compared to body weight. They also found that there is a strong positive correlation between power output and kilograms of 1RM (Baker & Nance, 1999)

Power

Importance in Sports:

Power in athletes refers to the maximum muscular contraction exerted instantly in an explosive burst of movements. The two main components of power are strength and speed (Power=Force x Velocity), which allow an athlete to apply maximum force in minimum time (Driss, Vandewalle, Quièvre, Miller, & Monod, 2001). Athletes generally develop power from combining strength training with plyometric training (Driss, Vandewalle, Quièvre, Miller, & Monod, 2001), which causes an improvement in jumping ability, explosive movement and sprinting ability (Young, James, & Montgomery, 2002)

Power Test:

A common method that is used to measure power in athletes is the countermovement jump. A countermovement jump is a jump that begins with the individual standing upright, and then squatting downward at the knees and exploding up off the ground using swinging in the arms as momentum in the jump (McGinnis, 2005). This jump can be used to determine power production, force production, as well as velocity in an athlete (Cormie, McBride, & Mccaulley, 2009), and it has a high-test retest reliability and validity (Markovic, Dizdar, Jukic, &Cardinale, 2004).

The vertical jump is similar to a countermovement jump in movement, but the difference is that it is measured by the individual pushing as many tabs on a Tandem Sport Vertical challenger at the peak of their jump (Thomas, Jones, Rothwell, Chiang, & Comfort, 2015). The vertical jump along with plyometric training and maximal power training is widely used in both the elite and untrained population to develop strength. This activity requires substantial muscular effort from the ankles, knee, and hip joints (Lees, Vanrenterghem, & Clercq, 2004). The vertical jump also has high reliability and validity in measuring power and acceleration sprinting performance (Moir, G., Button, Glaister, & Stone, 2004).

A squat jump is similar to the countermovement jump, but the individual begins in the squat position and explodes up from that position. This technique is not commonly used to measure power production but is generally used to measure ground reaction force (Zajac, 2002). The squat jump is a common exercise that combines lower body tone alongside cardiovascular training and is popular in high-intensity interval training. This jump is said to be one of the most popular exercises in the female population over back squats (Weber, Brown, Coburn, & Zinder, 2008). When measuring power from a squat jump the reliability is slightly lower than a countermovement jump (Earp, Kraemer, Cormie, Volek, Maresh, Joseph, & Newton, 2011).

The depth jump is a jump were an individual drops off a box and lands, and immediately jumps back up as high as possible. This method is not commonly used to measure power production but can provide accurate predictions of power (Holcomb, Lander, Rutland, & Facsm, 1993). The depth jump has become a major part of training protocols in athletes and is the technique which box jump was developed. This method of jumping is also commonly used in cardiovascular training and high-intensity interval training (Clutch, Wilton, Mcgown, & Bryce, 1983). The depth jump causes a lot of strain on knee joints due to the initial landing in the jump, but it does have moderate reliability and validity when measuring power and jump height (Flanagan, Ebben, & Jensen, 2008).

Males:

A countermovement jump is a very complex movement, but when conducted correctly it can provide a lot of information about an athlete's physical ability. According to Bailey, Sato, Barnett, and Stone (2005), the countermovement jump is one of the best ways to measure force production, and in males, results in the greatest power output production compared to any other method of measuring power. McMahon & Comfort, (2017) also found in males that the countermovement jump can be improved resulting in an increase in power output by participating in sports. When it comes to countermovement jumps in athletes it was found the power production is significantly correlated with leg extensions when normalized to both FFM as well as body mass (Impellizzeri, Raminini, Maffiuletti, and Marccora, 2007). Elite male athlete's power output was also found to be significantly higher than untrained athletes in a countermovement jump. It was also found that the more balance and agility the individual had the greater the jump height (Bailey, Sato, Burnett, & Stone, 2015).

In males, a vertical jump is another method of determining power out. It is commonly used in the combines of sports such as basketball and football. It was found that there is a strong positive correlation between 1RM scores and vertical jumping height/ power production in males. This was found to be due to the fact that when you increase the force an individual can produce you increase the power they generate (Impellizzeri, Rampinini, Maffiuletti, & Marcora, 2007). Impellizzeri and colleague, (2007) concluded that participating in strength training or plyometric train could cause an increase in power production. Holt &Lambourne (2008) found that participating in static stretching improves power output significantly in males because it loosens the muscle of the individual creating more flexibility. Power output and vertical jump height can also be predicted using physical capacity level, calf girth, and standing balancing with less than a ten percent error (Davis, Briscoe, Markowski, Saville, & Taylor, 2003).

In elite male athletes it was found that there was a strong correlation between squat jump height and strength, and sprinting ability (Castagna, Helgerud, Jones, & Hoff, 2004). This similarity results were also found to be true in recreationally trained adolescent males (McBride, Nuzzo, Triplett, & Jared, 2011). When looking at squat jump comparisons between untrained and trained males there was a significant difference in jump height/ peak power production in male athletes in both countermovement jumps & squat jumps (McBride, Kirdy, Haines, & Skinner, 2010).

The depth jump is generally just used with a box to jump off, but it was found that when you add a hurdle to the jump there is significantly less ground force and contact compared to a normal depth jump. It was also found in male athletes that the hurdles depth jump produced higher amounts of ground reaction force than normal depth jumps which results in more power (Smith, Kerrozek, Thomas, Kline, & Wright, 2011). It was also found that male muscle performance/ power output increases were equal between depth jump and countermovement jump training, and caused high levels of muscle soreness (Mirzaei, Norasten, Villarreal, Asadi, 2014). Mirzaei et al 2014 also found that there was not a significant difference between advanced trained individuals and recreationally trained individuals.

Females:

In females, the countermovement jump is commonly used to measure force production. A study found that although females cannot jump as high as their male counterparts their ability to generate power is similar to males (Baker & Nance, 1999). Impellizzeri, Raminini, Maffiuletti, & Marccora, (2007) found that females produce power asymmetrically, with their dominant leg being significantly stronger than the non-dominant leg. They stated that this occurs because of the difference in weight distribution during the jump (Impellizzeri, Raminini, Maffiuletti, and Marccora, 2007). When comparing elite athletes untrained and recreationally trained females, power production was significantly lower, and peak power production was similar in elite female volleyball players (McMahon, Murphy, Rej, & Comfort, 2017).

In females, the vertical jump is not commonly used in many sports, but it is used sometimes in female basketball. A study found in elite female basketball that power production was significantly greater in the dominant leg, and the players bilateral jump was conducted with more weight distributed on the dominant leg (Earl, Monteiro, & Snupler, 2007). Sarborn (2006) also found that when comparing trained and untrained females there was a significant difference in power production before the water-training period, and after the training, the difference dropped almost significantly.

It was found that squat jumps are a common exercise in the female population to tone lower extremity muscle instead of using things such as back squats, and the more flexible the individual is the greater the squat jump height and the better the form of the squat (Cachane & Stannard, 2005). Females also generate more power performing squat jumps in water then they do on land (Colado, Garci, Masso, Triplet, Mayo, & Merce, 2010). When comparing trained and untrained females it was found in both that females produced more power the higher there 1RM (Marques, Tilaar, Vescovi, & Gonzalez-Badillo, 2008).

The depth jump is not commonly used for females because they are not able to generate as much power after landing, but Faulkinbury, Stieg, Tran, Brawn, Coburn, & Judelson (2011) found in a depth jump study that there is no difference between depth jump height and box jump height in females. They also found that there is a difference in jump depth jump height between elite and junior volleyball players (Faulkinbury, Stieg, Tran, Brawn, Coburn, & Judelson 2011). It was also found that there was an increase in depth jump height when females participated in plyometric training. This finding showed an increase in power output improving soccer players kicking ability (Rubley, Haase, Holocomb, Girouard, & Tandy, 2011). Strength training can also significantly increase depth jump height in both trained and untrained females (Brown, Wells, Schade, Smith, & Fechling, 2007).

Combination:

In the countermovement jump, it was found that males and females have some asymmetry in their bodies; with males having a lot less asymmetry in their jumps. They also found that when looking at power production bilaterally that there was no difference in males and females when separated between similar strength (Thomas, Dos'Santos, Comfort, & Jones, 2017). It was also found that elite males and females did not have a difference in power production when compared using cross-sectional mass. There is also a significant difference in peak power production between elite males and females compared to novice and untrained individuals (McMahon, Rej, & Comfort, 2017).

One of the biggest findings when comparing power production between advanced male and female athletes was that when comparing single leg vertical jump there was not a significant difference between genders, and males did not produce a significant difference between legs were females did (Lider & Ziv, 2000). It was also found in senior athletes that during a vertical jump females generated significantly less knee flexion and lower leg internal rotation after impact than males, and less maximum angular displacement than males as well (Lephart, Ferris Riemann, Myers, & Freddie, 2001). There were few articles found on untrained athletes, but one study did find that untrained athletes did not have a significant difference between vertical jump height, and this study was conducted on elderly individuals and may not relate to younger individuals (Caserotti, Aagaard, Simonsen, & Puggard, 2001).

Research found that both males and females that peak power production is significantly higher when resistance is added, while peak power development and peak force is significantly different between training levels (Cormie, McBride, & McCauley, 2006). It was also found that squat jump height and peak power was not significantly different between males and females when normalized to FFM (Driss, Driss, Vandewalle, Quièvre, Miller, & Monod, 2001), but Koch et al, (2003) found that there was a significant difference between recreationally trained males' and females' peak power and squat jump height when normalized to body mass.

There were not many studies found comparing males and females in the depth jump, but one study that was found stated that elite athletes tend to have a higher depth jump than recreationally active individuals. They also found that there was not a difference in elite males' and females' depth jump (Beoli, Crosswell, Engel, & Nicol, 1987). When changing the search to box jumps, recreationally trained individuals can jump higher than females, but the power generation is not significantly different (Noyes, Barber-Westin, Fleckenstein, Walsh, & West, 2005). It was also found that when participating in resistance training there is no improvement in box jump height in females, and males have a significant improvement after resistance training (Hewett, Myer, Ford, & Slauterbeck, 2006).

Agility

Cardiovascular endurance and Flexibility:

Cardiovascular endurance is defined as the ability of the heart, lungs and blood vessels to deliver blood to tissue at the necessary rates demanded by the body (Gnacinski, Ebersole, Cornell, Mins, Zamzow, & Meyer, 2016). This allows athletes to maintain high levels of exercise, produce high energy stores, and maintain healthy heart rates during activities (Bunn & Eschbach, 2014). Bunn and Eschbach (2014) also reported in their research that improving cardiovascular endurance in individuals has several benefits which include a decreased resting heart rate, lower blood pressure, increased cardiac output, increased stroke volume, increased VO_{2max}, increased heart function with the ability to pump more blood, and so much more.

Flexibility is defined as the mobility of the muscles and their range of motion around the joint. This is important to sports because flexibility allows for easy movement throughout the ranges of motion without muscle strains. According to Worrell, Perrin, Gansneder, & Gieclk (1991), flexibility is dependent upon the sport the individual is playing, and if they develop flexibility in the right places, the individual was able to perform more successfully. Mookerjee & Ratamess (1999) found that when individuals have a higher degree of flexion in the joints, they could lift more weight with more repetitions. This, in turn, increases the individual's 1RM

Importance in sports:

Agility in sports refers to an athlete's rapid ability to move and change direction or position quickly and effectively under control. Agility displays an athlete's reflexes, coordination, balance, and speed (Sheppard & Young, 2006). Agility is important to successful performances in many sports. In most sports, there is a territorial aspect in which a defending team attempts to stop an offending team from scoring (Horička, Hianik, & Šimonek, 2014). This requires both defenders and offenders to anticipate and react to movements. In order to do this successfully in this task, it is important for the athlete to use many cognitive functions of agility such as reaction time (Sheppard, Young, Doyle, Sheppard, & Newton, 2006).

Agility Test: Reactive Shuttle test:

The most commonly used agility test in athletes is the reactive shuttle run test (RSR). This test is used in the National Basketball Association (NBA) combine, as well as in the National Football League (NFL) and National Hockey league (NHL) combine in modified versions (Mehran, Williams, Keller, Khalil, Lombardo, & Kharrazi, 2016). The reactive shuttle test evaluates agility, while also testing speed, and change of direction ability (Magalhães, Rebelo, Oliveira, Silva, Marques, & Ascensão, 2009). This test is popular amongst both elite and recreationally trained individuals and has a high test-retest reliability and validity for agility measuring. It was also found that the reactive shuttle run test score has a strong positive correlation with 1RM scores (Liu, Plowman, & Looney, 1992).

Males:

The reactive shuttle test is very commonly used in the male population to determine their agility ability. It was found in male soccer players that after a plyometric training period their time in the reactive shuttle test was significantly reduced in both advanced and junior teams (Vaczi, Tollar, Meszler, Juhasz, & Karsai, 2013). It was also found that agility training in male basketball players resulted in improved dribbling skills/ speed, sprint speed, and crossover speed (Tsitskaris, Theoharopoulos, & Garefis, 2003).

Females:

The reactive shuttle test is also commonly used in females to measure agility levels. It was also found that one of the most common injuries in female athletes is ACL tears, and if they increase their agility and flexibility, they can reduce the risk of ACL injuries by about thirty percent (Wilkerson, Colston, Short, Neal, Hoewischer, &Pixley, 2004).

Combination:

The majority of the research for the reactive shuttle test comparing males and females done for this study, the data was normalized to the individual's weight. They found that bodyweight played a major role in the overall score of the reactive shuttle test in both genders. One study found that there was a correlation between body mass and reactive shuttle test scores, and a low correlation between jump length and agility. They also found that there was a moderate to large correlation between agility, jump height, jumping length, and running speed (Manderoos, Vaara, Karpp, Aunola, Puuka, Surakka, & Malka, 2017).

Conclusion:

Physical fitness is a very prominent part of being an athlete and determining/ testing one's physical abilities. As seen in this chapter literature supports the idea that there are sex differences that exist across strength, power, and agility. When measuring these differences in strength, power, and agility in elite athletes all data is normalized to some form for body composition for weight to FFM, but in recreationally trained individuals, these comparisons are only based on body weight. Research has shown that when comparing these factors amongst the elite athletes that differences seen in strength, power, and agility are small or non-existent when normalized to factors such as FFM and muscle cross sectional area (Castro, Mccann, Shaffrath, & Adams, 1995). This brings forth the purpose of this study, which is to test and examine the differences in strength, power, and agility in athletes compared to weight and FFM between athletes of different genders. It is important to study these factors to determine if there is really a significant difference in athletes' physical fitness between genders.

CHAPTER 1

INTRODUCTION

Physically active individuals possess many characteristics such as strength, speed, endurance, aggressiveness, focus and discipline that enhance athletic performance as compared to the average individual. These characteristics may have a genetic predisposition for some, but for most, they are developed over time by building overall physical fitness and physical capacity (Aggerholm 2014). When determining an individual's physical capacity, strength, power, and agility are factors that are commonly measured. Each one of these factors are affected by a number of factors seen in active individuals including increased muscle mass, speed, bone mass and neurological recruitment (Nimphius, Mcguigan, and Newton, 2010).

The benefits that are observed from measuring the components of physical capacity and their importance to each individual have been well documented throughout the literature. Strength is important in sports because it helps with maximizing performance (e.g., jumping, sprinting, and change of direction ability) (Suchomel, Nimphius, & Stone, 2016). McGuigan, Wright, and Fleck (2012) found that there was a strong relationship between physical capacity and strength. They found that there was a strong correlation between relative strength and speed/ reaction time in female softball players (r=0.69). It was also found that there were strong positive correlations between strength (1RM back squats) and sprint times (r=0.94) as well as strength and vertical jump height (r=0.78) in soccer players (Stone et al. 2003). These authors concluded that strength plays a strong role in the elite athlete's strength and speed/agility as well as jump height. It was also found that there was a significant correlation between lower body strength training and tackling ability in rugby players (r=0.38) (Gabbett, Jenkins, & Abernethy, 2011).

In sports, power generation is important because it allows an athlete to maintain high physical performance in areas such as speed and strength as well as jumping ability, explosive movements, agility, and sprinting abilities (Kraemer et al., 2002; Young, James, & Montgomery, 2002; Randell, Cronin, Keogh, & Gill, 2010;Harries, Lubans, & Callister, 2012). Buchheit, Mendez-Villanueva, Delhomel, Brughelli, and Ahmaidi (2010) found that when an individual is subjected to explosive strength and power training there was an increase in sprinting speed by 3.7 percent, as well as vertical jump height by 13.5 percent. It was also found that when individuals participated in power training that there was about a 24.6 percent increase in acceleration speed and a 16.3 percent increase in throwing velocity (Chelly, Hermassi, and Shephard, 2010).

Agility is determined by an athlete’s reflexes, coordination, balance, and speed (Sheppard & Young, 2006; Sheppard, Young, Doyle, Sheppard, & Newton, 2006).Nimphius, McGuigan, and Newton (2010) found that there was a strong relationship between speed and change of direction ability/ agility through the course of a competitive female softball season. Many studies have found that there are factors that can cause differences in strength, power, and agility, such as: age, fitness level, and gender (Bishop, Cureton, & Collins, 1987; Tipton & Wolfe, 1998; Miller, MacDougall, Tarnopolsky, & Sales, 1993; Castro, Mccann, Shaffrath, & Adams, 1995). These differences can alter the way athletes preform, develop skills, and their components of physical fitness.

Gender plays a role in physiological differences (e.g., neurological, hormonal, chromosomal) as well as physical performance, which in turn effects strength, power, and agility. In active individuals, there are gender-related differences in physique, body composition, and physiology that all play a role in the differences that occur in strength. Concerning absolute strength, females generally possess lower amounts of fat-free mass (FFM), which can account for large decrements (~one-third) in total body strength as compared to males (Bishop, Cureton, & Collins, 1987; Tipton & Wolfe, 1998) However, after examining relative strength, the sex-related differences were significantly reduced (upper body: 52%, lower body: 66%) (Miller, MacDougall, Tarnopolsky, & Sales, 1993). This is due to a larger body mass in males, reaffirming the importance to compare differences in strength relative to body weight, FFM, or muscle cross-section area (Miller, MacDougall, Tarnopolsky, & Sales, 1993). For example, when controlled for FFM, the differences in strength are diminished (18.8%), and when normalized to muscle cross-sectional area there is no significant difference that exists between males (p=0.63) and females (p=0.36) (Castro, Mccann, Shaffrath, & Adams, 1995).

In terms of absolute power output, females generally generate less power than males (Garhammer, 1991). According to Garhammer (1991), male competitive lifters generated 63% more power, relative to body mass, during a maximum power bench press, squat and power clean than their female counterparts. Additionally, Komi & Karlsson (1978) found similar results within an untrained population (84.6%), but when related to FFM the difference between genders began to decrease (61.1%). These gender differences were also found in agility. Sekulic and colleagues (2013) found that when it comes to agility females have a better and more controlled reaction time when changing direction then males. While male individuals are faster and can generate more power.

When measuring strength, power, and agility in elite individuals the scores are compared to the individual's body composition (e.g., FFM and muscle cross sectional area). However, strength, power, and agility measures are only compared to body mass (BM) in recreationally trained individuals. Recreationally trained individuals are more prominent then elite athletes, and they are more representative of the average individual in the population, but in the literature, they are not studied to the same capacity as elite athletes. Due to these findings it is important to understand the differences seem between recreational individuals on a more magnified scale. Thus, the purpose of this study was to determine if differences existed in lower body strength, power, and agility in male and female recreationally trained subjects when normalized to BM, FFM, or fat mass (FM).

CHAPTER 2

METHODOLOGY

Participants:

This study consisted of 42 (males: n= 20, females: n= 22) recreationally trained individuals with ages ranging from 18-29 years of age. Descriptive information for all participants is presented in Table 1. Of the individuals recruited, only participants that were currently physically active were included. In the current study the guideline set forth by Mangine, Ratamess, Hoffman, Faigenbaum, Kang, & Chilakos (2008) were to classify an individual recreationally trained. The guidelines to be considered recreationally trained was that all participants were required to be currently participating in a resistance (i.e., 2-4 times/week for 2-4 hours) and aerobic training (2-4 times a week for 30-45 minutes/session) program for a minimum of six months. Individuals were excluded from testing if they had an injury within the last six months from recruitment.

Experimental Design:

To conduct this study, descriptive information (i.e., weight, height, age, and body composition) and exercise history (how long have/did they participate in their sport, common physical activities they participate in, etc.) for each participant was documented. The participants were given and read a consent form. They were instructed to sign the consent form, as well as fill out a PAR-Q and medical history form. All risk factors that could be triggered by exercise (e.g. cardiovascular disease, asthma, previous injury) were recorded, and any individuals that were considered high risk were not eligible to participate in the study. If the participant answered "yes" to any question on the PAR-Q, then they were not eligible to participate in the current study. Additionally, if the participant marked any boxes or included information on their health history form that indicated signs or symptoms of cardiovascular, metabolic, or respiratory disorders, then the participant was not eligible for this study. Once the physical descriptions were recorded, each participant was prepped for body composition testing via air displacement plethysmography (BODPOD©, COSMED Inc., Rome, Italy)

For the BODPOD, the participants were instructed to fast for approximately 2 hours and to refrain from exercising 24 hours prior to body composition testing. The participants were then instructed to remove all jewelry, accessories, eyeglasses, as well as instructed to dress in compression clothing. Calibration and all testing procedures were held consistent with the manufacturer's recommendations. Once all body composition testing was completed the participants were given a five-minute warm-up consisting of jump squats, jog in place, mountain climbers, air squats and lunges. Each exercise was conducted for 30 seconds with a 30 second rest after. Once the warm-up was completed, the participant then went through a one-repetition maximum (1RM) test.

The 1RM leg press began with the participant conducting a warm-up with a light resistance that allows the participant to do eight repetitions. The warm-up load was increased (i.e., 10-20%) to allow the athlete to perform five reps followed by a two-minute break. Then a near-maximal load increase that allowed the participant to complete three reps was applied. This increase was also 30-40 pounds (14-18kg) or 10-20%. The participant was then given a three-minute break followed by another load increase of 30-40 pounds (14-18kg) or 10-20%. The participant was then instructed to perform a 1RM, and if the participant was successful, they were provided a 3-minute rest period and another load increase occurred. If the participant failed, they were provided a 3-minute rest period and the load was decreased 15-20 pounds (7-9kg) or 5-10%. There was a continuation of increasing and decreasing of the load until the participant could or could not complete one rep (Triplett & Trip, 2016). The participant was instructed to lower their leg press until their knees were 2-4 inches away from their chest to be considered proper form. Any rep that did not follow this protocol was eliminated, and the participant was instructed to complete the repetition again following a 3-minute rest. This weight was considered the participants 1RM and was used in the statistical analysis.

For the countermovement jump (CMJ), the participant was instructed to stand upright and as still as possible on the switch mat (Probotics Incorporated, Huntsville, AL) with their weight evenly distributed on both feet. The participant then jumped off the ground as quickly and explosively as possible, landing back on the contact mat with both feet touching the ground at the same time. If the participant did not land properly, the trial was discarded and completed again. The participant performed the jump three times with a minute rest in between each jump, and the best score was recorded for data analysis. During the jump, the participant was instructed to keep their hands placed on their hips throughout the jump to ensure that only lower body power is used. Prior to testing the jump was demonstrated for the participant, and they were given one test jump to get comfortable with the movement. Once the participant was comfortable with the movement, they were given a command of "1, 2, 3 jump." The switch mat calculated jump height upon landing, and the jump height was used in the Harman formula to calculate peak power (equation 1) (Harman, Rosenstein, Frykman, Rosenstein, & Kraemer, 1991; Hartman, Clark, Bemben, Kilgore, & Bemben, 2007).

$$Peak\ power\ (w) = \left(60.7 \times jump\ height\ (cm)\right) + \left(45.3 \times body\ mass(kg)\right) - 2055 \quad (1)$$

To conduct the reactive shuttle test, a 1.83m distance was measured and marked with cones. The start marker was placed at the halfway mark. The participant lined up with their feet straddling the start marker. The participant was given the signal “1, 2, 3 run” and the participant ran in either the left or right direction and touched the side marker. Once the side marker was touched, the participant turned and ran in the opposite direction and touched the furthest cone. The test finished with the participant turning and running back through the start position. If the participant slipped or fell during a run the trial was discarded and repeated. The participant performed three trials with a minute rest between each run and the best score was recorded for data analysis.

Statistical analysis:

All raw scores were recorded for both males and females for the 1RM test, CMJ, and Reactive Shuttle Run. Data analysis was performed using IBM SPSS Statistics (25.0 IBM Corporation, Armonk, New York). The best trial for each test was normalized to each individual’s BM, FFM, and FM. Normality of the data was assessed via test for skewness, kurtosis, histogram analysis, Kolmogorov-Smirnov, and Shapiro-Wilks. Pearson’s product moment correlations were used to determine the associations between FFM, FM, and BM compared to raw scores. Two-tailed independent T-tests, with an alpha level of 0.05, were conducted to determine if significant differences exist between males and females within the 1RM, CMJ, and Reactive Shuttle run test for raw scores. A Cohen’s *d* statistic (Cohen, 1992) was calculated as the effect size of the differences and Hopkin’s scales of magnitude (Hopkins, Marshall, Batterham, & Hanin, 2009) was used where an effect size of 0-0.19 was considered trivial, 0.2-0.59 small, 0.6-1.19 moderate, 1.2-2.0 large, >2.0 very large.

CHAPTER 3

RESULTS

Table one (Figures and tables) shows the raw data collected throughout the study as well as demographic information. All data was reported as mean ± standard deviation, and Table 2 (Figures and tables) show the raw data used for the correlations. When checking the normality of the data, it was found that some data was slightly skewed (see table 3, Appendix A), but the remaining raw data was normally distributed. When checking the normality of the normalized data, the results showed that when each factor was normalized to the individual's FM the data was skewed (Table 3, Figures and tables) and kurtotic (Table 4, Figures and tables). All data that was found to be skewed or kurtotic was analyzed via non-parametric Mann-Whitney U analysis.

Table 1. Raw scores means ± standard deviations for body weight, fat free mass, fat mass, strength, agility and power before the normalization process.

	Age (yrs.)	Height (cm)	Body Mass(kg)	Fat Free Mass (kg)	Fat Mass (kg)	Repetition Maximum (kg)	Counter Movement Jump (cm)	Reactive Shuttle Run (sec)	Peak Power (W)
Females	21.4±2.1	162.8±10.1	66.8±11.1	49.9±6.2	16.8±6.1	183.6±39.9	41.7±6.0	3.8±0.3	1970.3±498.5
Males	20.8±2.3	178.2±6.9	81.6±12.8	66.5±7.6	15.1±8.1	250.3±58.8	57.2±10.5	3.4±0.3	3012.2±506.1

Table 2. Collective means ± standard deviations for strength and power when normalized to body weight, Fat-free mass and fat mass in males and females.

	Body Mass (kg)		Fat-Free mass (kg)		Fat Mass (kg)	
	Female	Male	Female	Male	Female	Male
1RM (kg)	2.77±0.46*	3.10±0.69*	3.68±0.68	3.76±0.78	11.73±3.18**	21.59±13.09**
CMJ (cm/kg)	0.64±0.14	0.73±0.21	0.85±0.16	0.87±0.21	2.80±1.09**	5.17±3.35**
Peak Power (w/kg)	29.16±2.98	36.89±2.82	38.91±5.67	45.08±4.68	122.74±25.07**	247.92±118.54**

1RM = One-repetition maximum; CMJ = Counter movement jump
*Indicated significant difference of p<0.05; ** Indicated a significant difference of p<0.01.

Table 3: This table shows the values of the skewness normality check. All values marked with asterisks were considered skewed and were tested via non-parametric methods.

	Skewness		
	Statistic	Std. Error	Z-scores
Repetition Maximum	0.595	0.365	1.63
Counter Movement Jump	0.81	0.365	2.22*
Reactive Shuttle Run	0.228	0.365	0.62
Peak Power	0.166	0.365	0.45
Normalized 1RM to FM	2.218	0.365	6.08*
Normalized 1RM to FFM	0.315	0.365	0.86
Normalized 1RM to BM	0.326	0.365	0.89
Normalized CMJ to FM	2.299	0.365	6.30*
Normalized CMJ to FFM	0.311	0.365	0.85
Normalized CMJ to BM	0.146	0.365	0.40
Normalized PP to FM	2.045	0.365	5.60*
Normalized PP to FFM	0.114	0.365	0.31
Normalized PP to BM	0.085	0.365	0.23

Table 4: This table shows the values of the kurtosis normality check. All values marked with asterisks were considered kurtosis and were tested via non-parametric methods.

	Kurtosis		
	Statistic	Std. Error	Z-scores
Repetition Maximum	-0.641	0.717	-0.894
Counter Movement Jump	0.295	0.717	0.411
Reactive Shuttle Run	-0.77	0.717	-1.074
Peak Power	-1.175	0.717	-1.639
Normalized 1RM to FM	5.65	0.717	7.880*
Normalized 1RM to FFM	0.094	0.717	0.131
Normalized 1RM to BM	-0.634	0.717	-0.884
Normalized CMJ to FM	7.828	0.717	10.92*
Normalized CMJ to FFM	-0.224	0.717	-0.312
Normalized CMJ to BM	-0.776	0.717	-1.082
Normalized PP to FM	5.338	0.717	7.445*
Normalized PP to FFM	-0.49	0.717	-0.683
Normalized PP to BM	-0.616	0.717	-0.859

Strength:

Males had a statistically higher 1RM when normalized FM (*p*<0.01; *d*=0.46). However, there was no difference seen between 1RM when normalized to BM (*p*=0.07; *d*=0.27) or FFM (*p*=0.71; *d*=0.05). Based on the raw data a strong, positive correlation were observed between 1RM and BM (*r*=0.64, *p*<0.01), as well as 1RM and FFM (*r*=0.69, *p*<0.01). There was no significant correlation between FM and 1RM (*r*=0.20, *p*=0.20) for both males and females

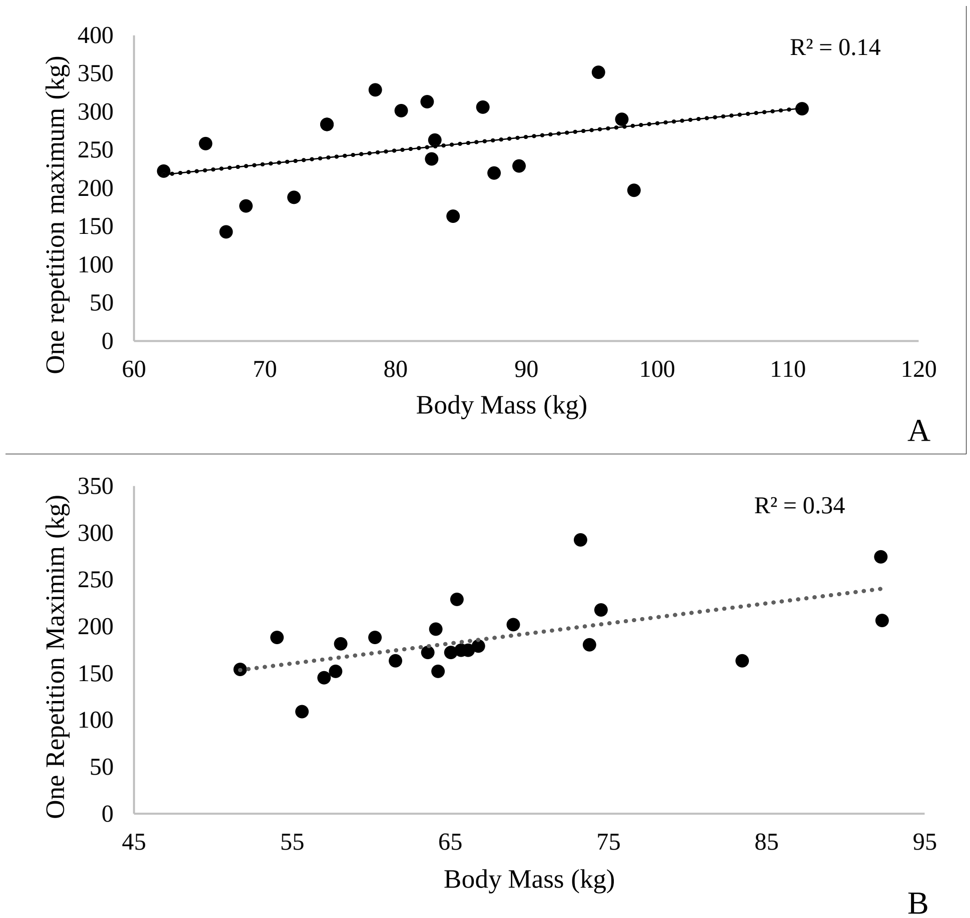


Figure 1A-1B: 1A) Scatterplot demonstrating the relationship between 1RM scores to body mass in males (*r*= 0.14; *p*<0.01), 1B) Shows a comparison of females' 1RM score to females' body mass (*r*= 0.58).

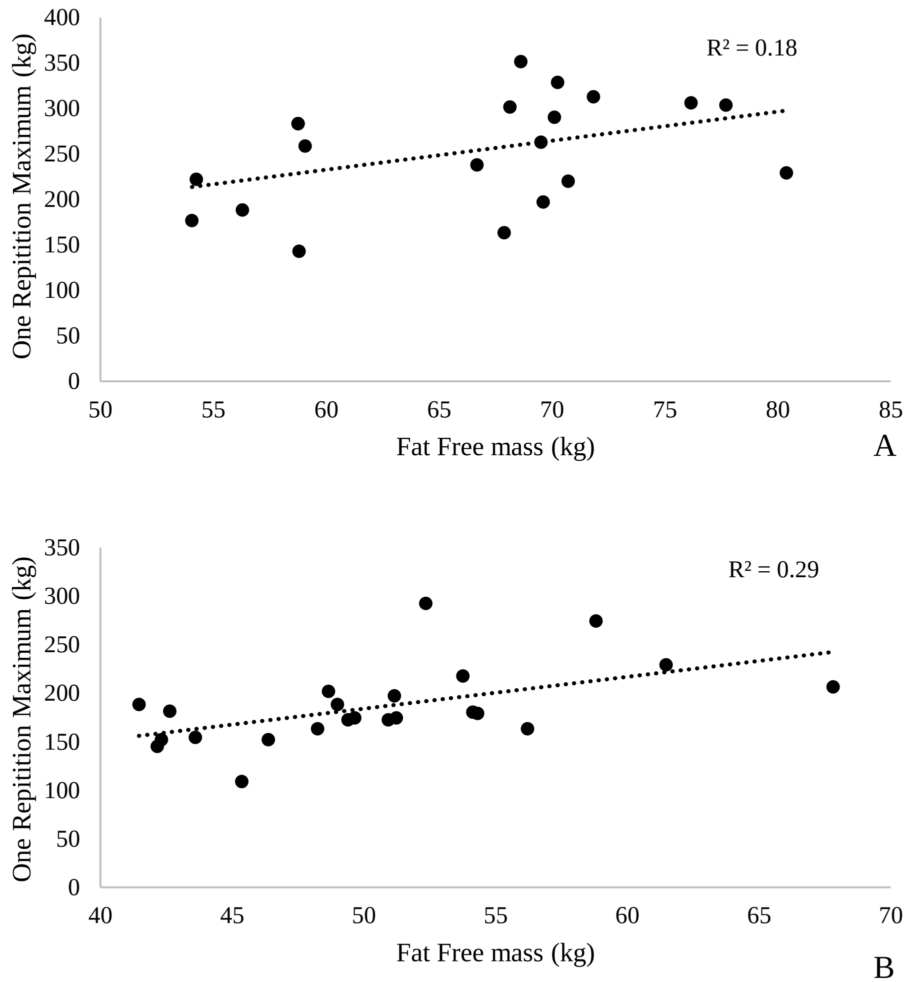


Figure 2A-2B: 2A) Scatterplot demonstrating the relationship between 1RM scores to fat free mass in males (r= 0.42), 2B) Shows a comparison of females' 1RM score to females' fat free mass (r= 0.54; p<0.01).

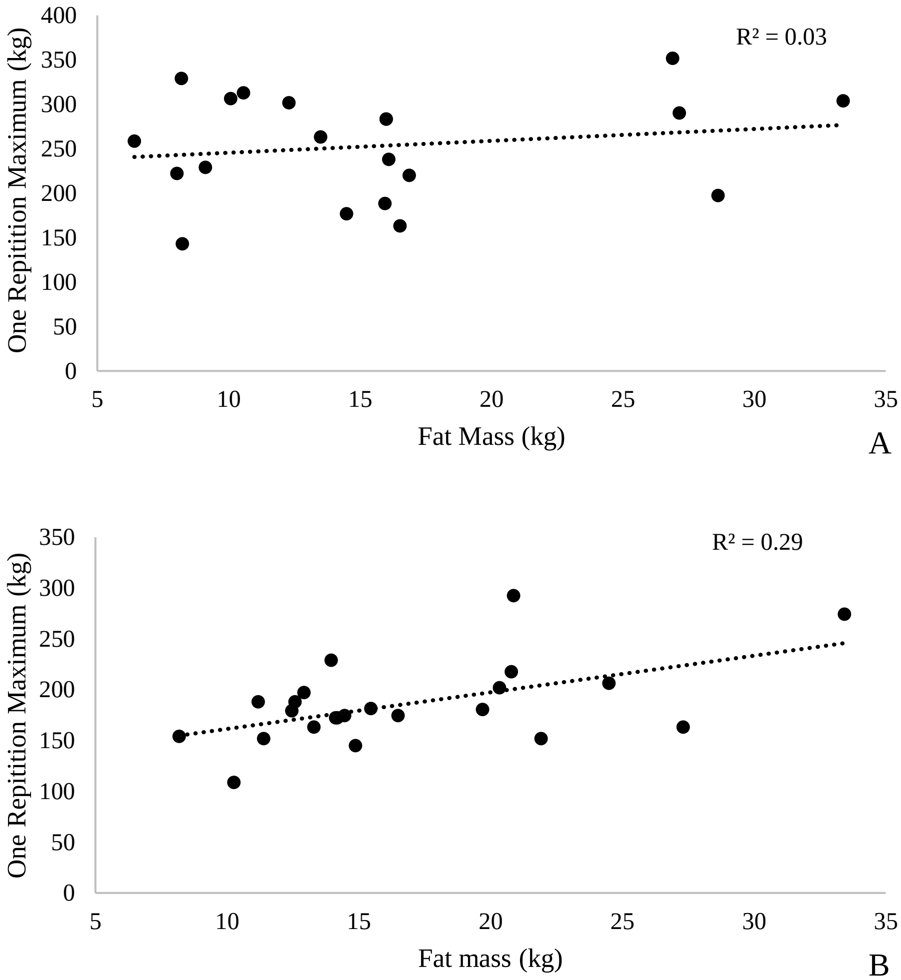


Figure 3A-3B: 3A) Scatterplot demonstrating the relationship between 1RM scores to fat mass in males (*r*= 0.17), 3B) Shows a comparison of females' 1RM score to females' fat mass (*p*= 0.20; *r*= 0.54).

Power:

Males had a statistically higher CMJ when normalized to FM (*p*<0.01; *d*=0.43); however, there was no difference when normalized to BM (*p*=0.12; *d*=0.24) or FFM (*p*=0.62; *d*=0.07). Males also had a statistically higher peak power when normalized to FM (*p*<0.01; *d*=0.60), BM (*p*<0.01; *d*=0.80), and FFM (*p*<0.01; *d*=0.51). Based on the data a moderately strong, positive correlation were observed between CMJ and FFM (*r*=0.43, *p*<0.01) with male individuals having a greater significance than females. As well as moderately strong negative correlation between

CMJ and FM (*r*=-0.45, *p*<0.01) for both males and females. There was no correlation between BM and CMJ (*r*=0.13, *p*=0.41) for both males and females. Additionally, a significant very strong, positive correlation was observed between peak power and FFM (*r*=0.93, *p*<0.01) and BM (*r*=0.93, *p*<0.01), as well as a moderate, positive correlation with FM (*r*=0.45, *p*<0.01) for both males and females.

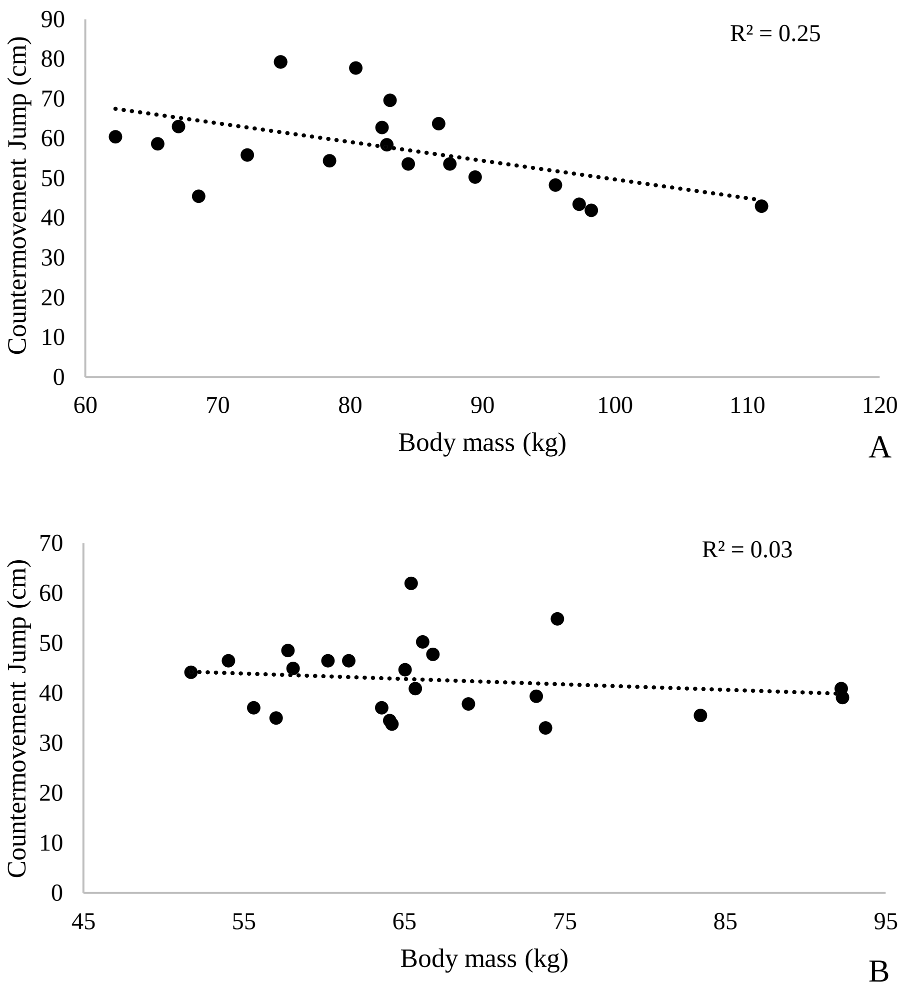
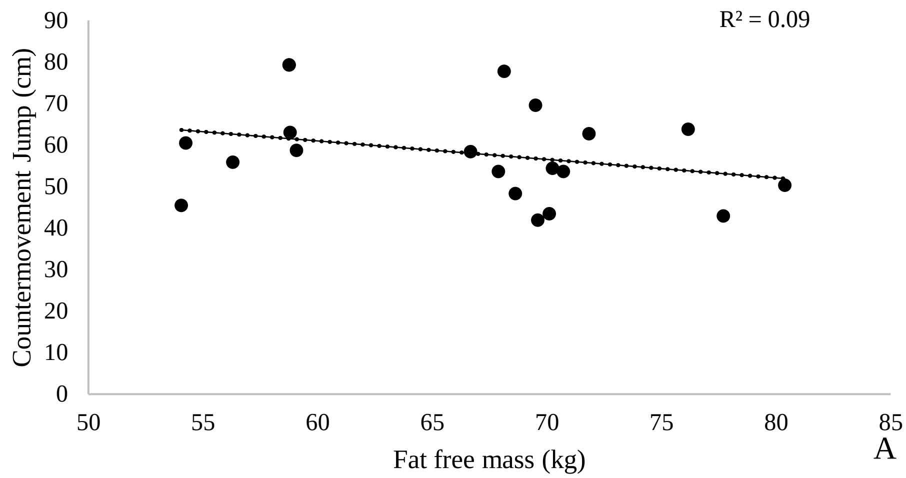


Figure 4A-4B: 4A) Scatterplot demonstrating the relationship between CMJ scores to body mass in males (*r*= 0.50), 4B) Shows a comparison of females' CMJ score to females' body mass (*r*= 0.17; *p*= 0.41).



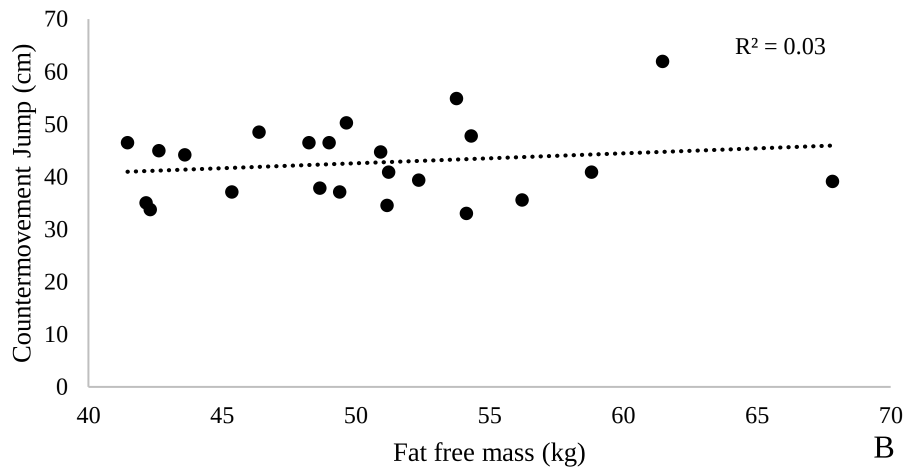
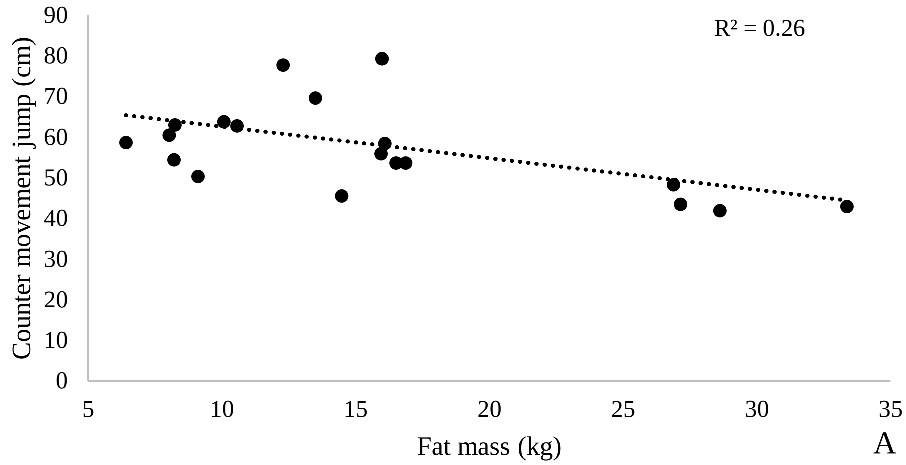


Figure 5A-5B: 5A) Scatterplot demonstrating the relationship between CMJ scores to fat free mass in males (r= 0.3; p<0.01), 5B) Shows a comparison of females' CMJ score to females' fat free mass (r= 0.17).



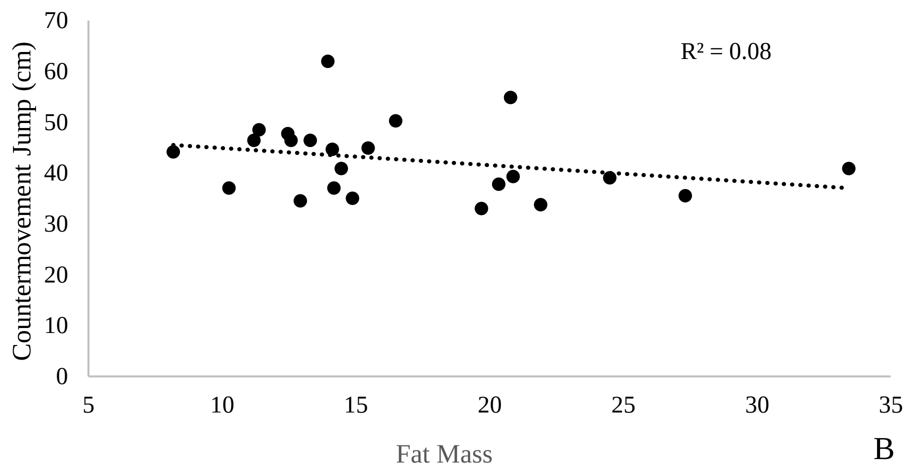


Figure 6A-6B: 6A) Scatterplot demonstrating the relationship between CMJ scores to fat mass in males (r= 0.51), 6B) Shows a comparison of females' CMJ score to females' fat mass (r= 0.28; p<0.01).

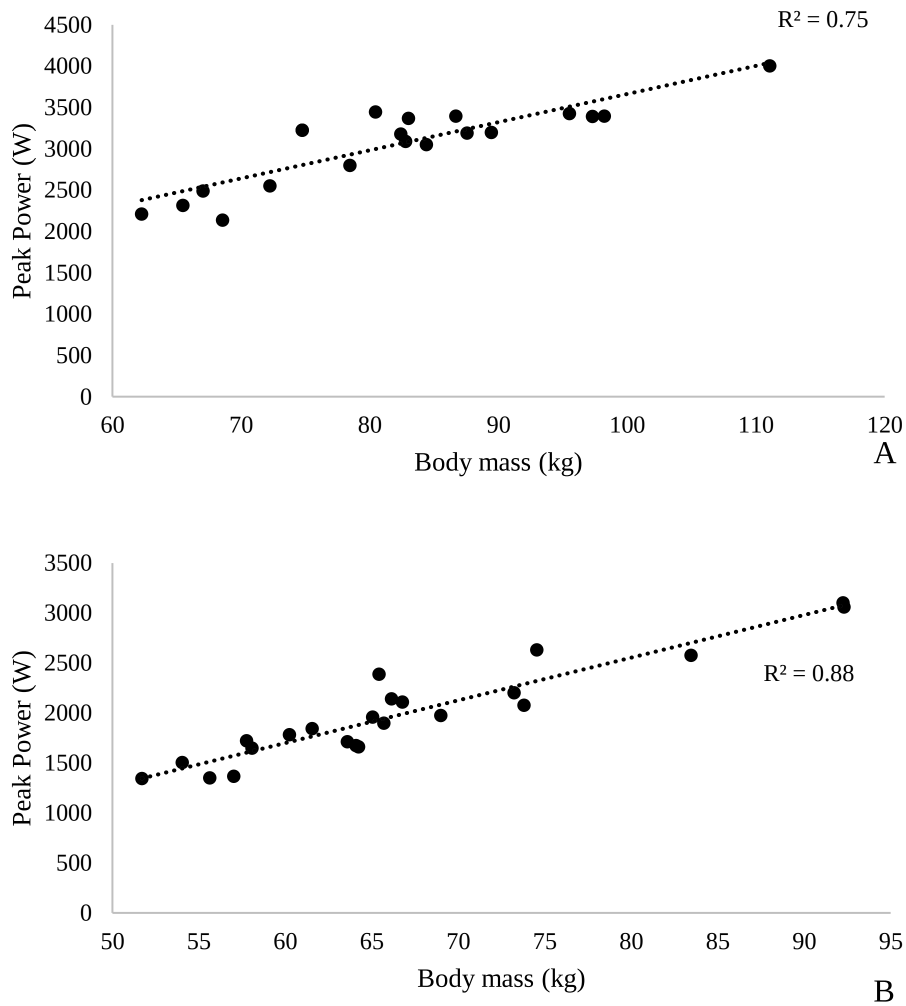


Figure 7A-7B: 7A) Scatterplot demonstrating the relationship between peak power to body mass in males (r= 0.87), 7B) Shows a comparison of females' peak power to females' body mass (r= 0.93; p<0.01).

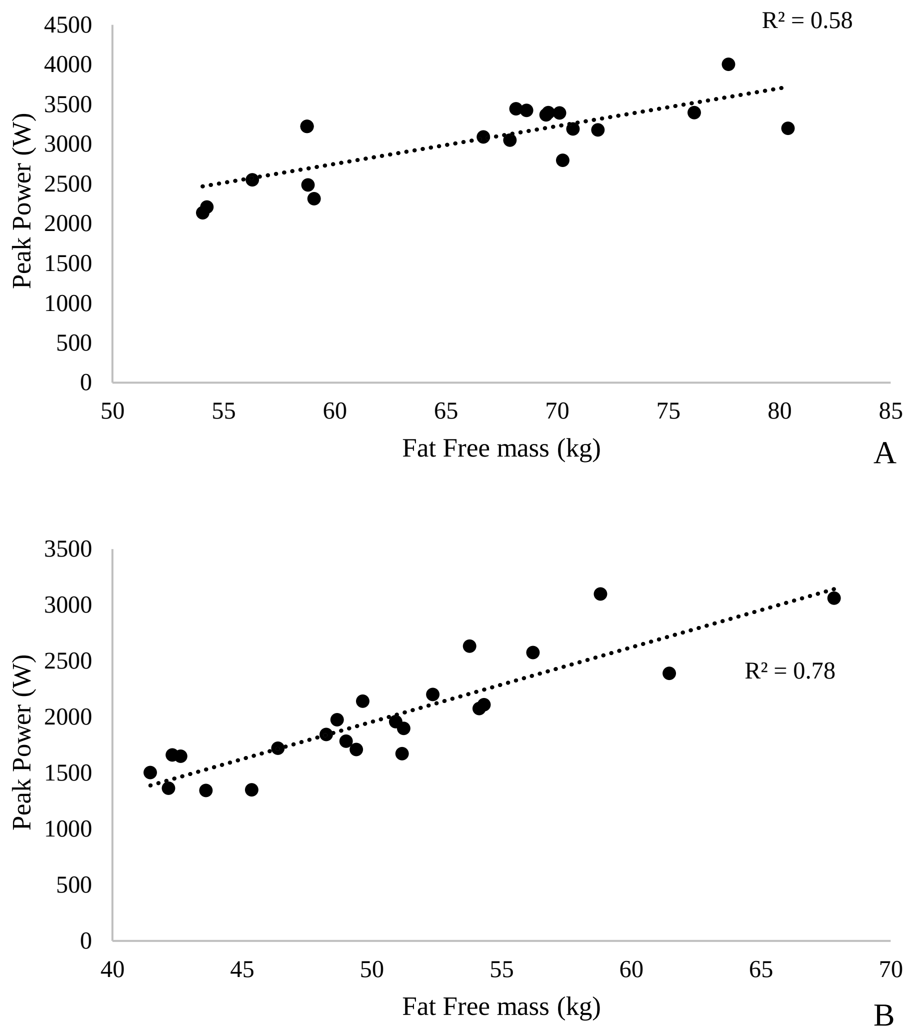


Figure 8A-8B: 8A) Scatterplot demonstrating the relationship between peak power to fat free mass in males (r= 0.76), 8B) Shows a comparison of females' peak power to females' fat free mass (r= 0.88; p<0.01).

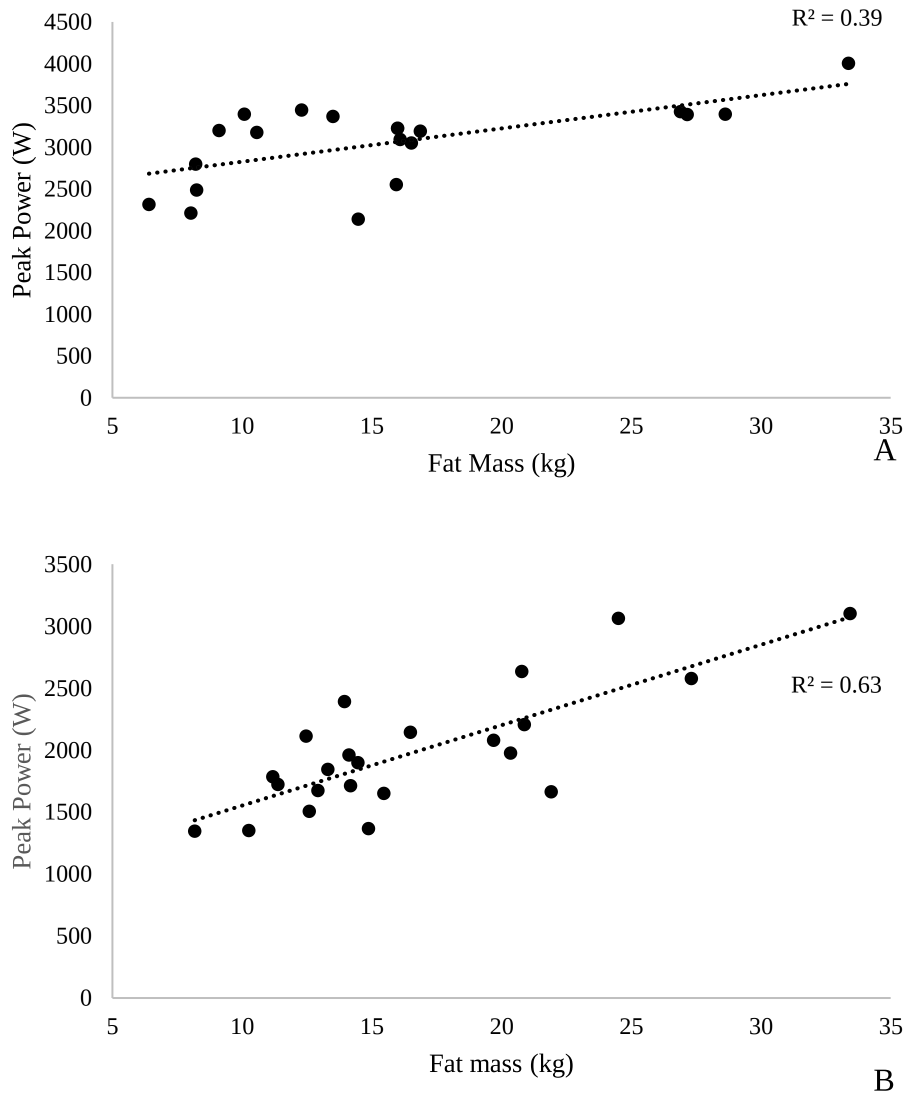
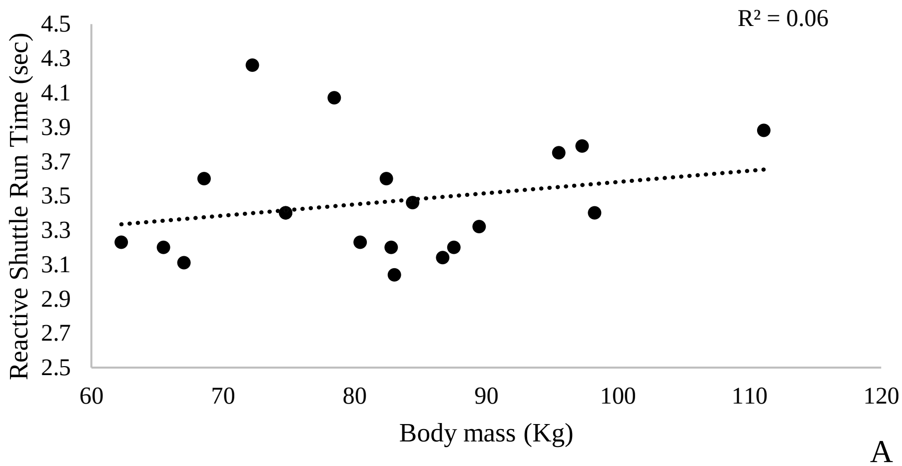


Figure 9A-9B: 9A) Scatterplot demonstrating the relationship between peak power to fat mass in males (r= 0.62), 9B) Shows a comparison of females' peak power to females' fat mass (r= 0.75; p<0.01).

Agility:

Based on the raw data, negative moderate correlations were observed between RSR and FFM (r=-0.42, p<0.01), with female individuals having a greater significance than males. As well as a positive correlation between RSR and FM (r=0.38, p<0.01), with male individuals having a greater significance than females. Although, there was no correlation between BM and RSR (*r*=0.14, *p*=0.39) for both males and females. There was also a significant difference between males and females RSR times (*p*<0.01, *d*=0.48).



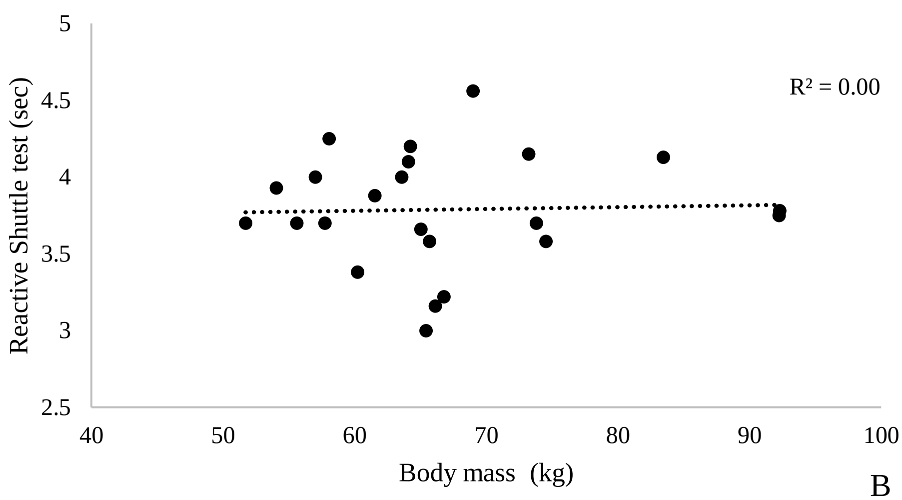


Figure 10A-10B: 10A) Scatterplot demonstrating the relationship between RSR scores to body mass in males (*r*= 0.24), 10B) Shows a comparison of females' RSR score to females' body mass (*r*= 0.14; *p*=0.39).

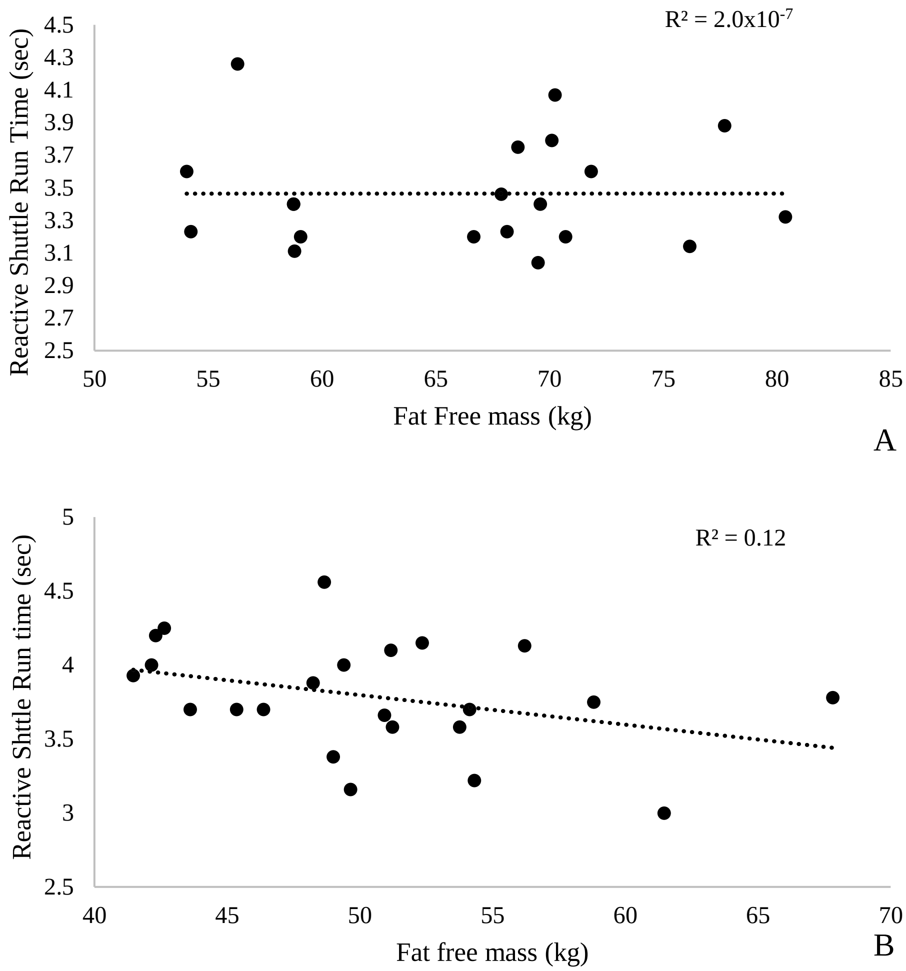
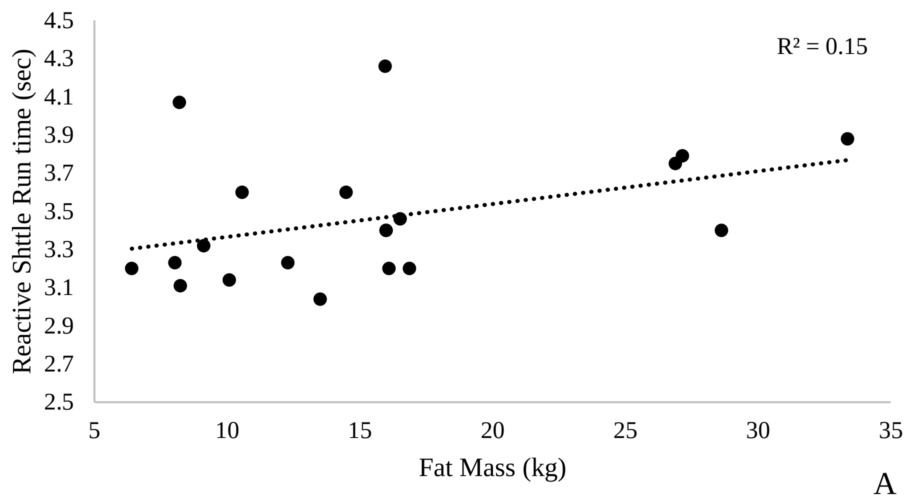


Figure 11A-11B: 11A) Scatterplot demonstrating the relationship between RSR scores to fat free mass in males (*r*= 0.01), 11B) Shows a comparison of females' RSR score to females' fat free mass (*r*= 0.35; *p*<0.01).



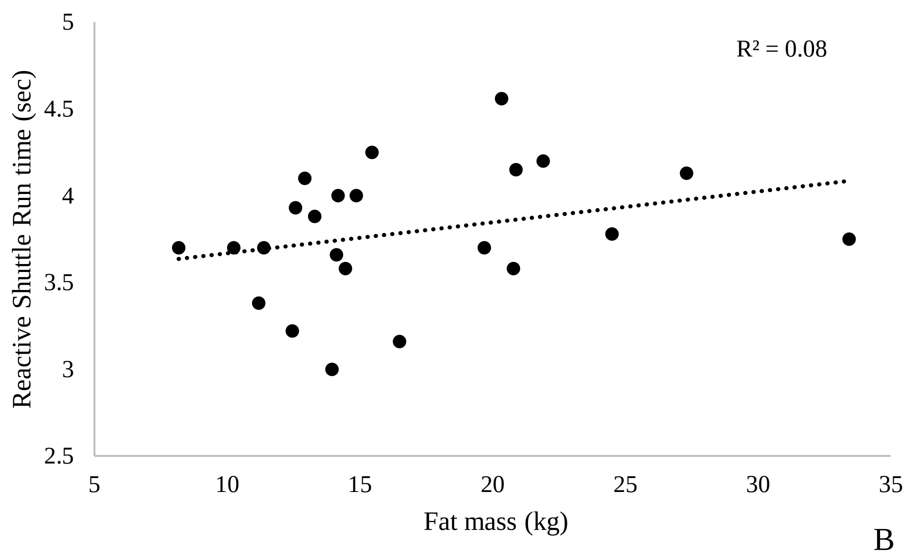


Figure 12A-12B: 12A) Scatterplot demonstrating the relationship between RSR scores to fat mass in males (r= 0.39; p<0.01), 12B) Shows a comparison of females' RSR score to females' fat mass (r= 0.28).

CHAPTER 4

DISCUSSION

While most of the current literature examines differences in performance metrics in elite or collegiate individuals between genders, there is limited research on recreationally trained individuals. Thus, the purpose of this study was to determine if differences existed in lower body strength, power, and agility in male and female recreationally trained subjects when normalized to BM, FFM, or FM. The key findings of the current investigation demonstrate that when normalized to FFM there were no significant differences between strength, CMJ, and agility in males and females. However, inconsistent with previous literature there were significant differences between males' and females' peak power when normalized to FFM ((Holmberg, Lindinger, Stoggl, Bjorklund, Muller, 2006; Bilsborough, Greenway, Opar, Livingstone, Cordy, Bird, & Coutts, 2015; Lockie, Dawes, Kornhauser, and Holes, (2017).When normalized to FM, all performance measures showed significant differences. There was also a significant difference between males and females reactive shuttle run times.

McBride, Triplett-McBride, Davie, & Newton (1999) found that male powerlifters and Olympic lifters had lower FM and lifted significantly more weight in a back squat than the control group (runners) (p<0.05). These findings led the authors to conclude that individuals with a higher FFM were able to lift significantly more weight than individuals of the same BM with more FM. These findings may be largely dependent on the strength-to-mass ratio. This is possibly due to the muscles' contractile forces being proportional to the muscle cross-sectional area. Muscle cross-sectional area is a major predictor of force production in the muscle, and it can represent the amount of muscle mass in the body (Folland & Morris, 2008). Therefore, an individual with a higher cross-sectional area should have a higher amount of force production generating more strength and power (Jones, Bishop, Woods, & Green, 2008). These findings could explain the lack of statistical significance in the current study when normalizing strength and power to FFM (i.e., increased FFM relates to a greater muscle cross sectional area) (Kanehisa, Ikegawa, &Fukunaga, 1998). For the current study it can be interpreted that FM does not play a vital role in strength; whereas, muscle mass may play an important role.

In this study, there was a significant difference between males' and females' peak power when normalized to FFM, FM, and BM. The differences seen between males and females can be explained by the biological differences between the sexes. These differences are largely impacted by males having a higher level of greater muscle mass and a lower proportion of body fat (Holmberg, Lindinger, Stoggl, Bjorklund, Muller, 2006). According to Sattler, Hadžić, Dervišević, &Markovic, (2015) male's volleyball players had lower body fat percentages, and males also had a significantly higher vertical jump than (arm swing: $p<0.05$; without arm swing $p=0.028$) than females. The suggested that these founding were due to the greater force production($p<0.001$), and power production ($p<0.001$) that males generate than females. It was also found in Bilsborough et al (2015) there was a positive correlation ($r= 0.53$) between FFM and power production when measuring peak power from a CMJ in Australian football players. Lockie, Dawes, Kornhauser, and Holes, (2017) found similar results when testing lower body peak power using a vertical jump test when normalized to muscle cross-sectional area between male and female police officers. With male officers jumping 36 cm higher than female officers. The results of this study suggest that BM, FFM, and FM all play a role in an individual's peak power, which is not consistent with what is seen in the literature. It was found in the literature that FM doesn't play a role in peak power production, but FFM does (Sarabia, Moya-Ramón, Hernández-Davó, Fernandez-Fernandez, &Sabido, 2017). These findings suggest that there are other factors that must have played a role in the results that were seen in this study such as neurological effects.

The results of the current study showed a moderately strong, positive correlation between BM and FFM, and a weak positive correlation between FM when compared to 1RM. These findings agree with Jakovljević, Karalejić, Pajić, Janković, & Erčulj, (2015) that demonstrated 1RM back squat values were directly related to BM (r=0.69) and FFM (r=0.93) in basketball players. Similar findings were demonstrated in Monterio et al. (2016) research when looking at the difference between male and female upper and lower body 1RM to their body weight. They found that there was a significant difference in male and female back squats 1RM when normalized to BM (p=0.02). Monterio et al. (2016) also found a significant moderate correlation (r=0.49) when comparing 1RM and FFM. These finding suggest that FFM has a positive effect on an individuals' jumping ability, whereas FM does not have an effect jumping ability. These findings are reflective of what was seen in this study and may justify the results that were examined.

In regard to jump height, previous research has demonstrated that while BM may not play a role in performance, body composition components (i.e., FFM) may elicit significant effects. For instance, Abidin & Adam (2013) Found no significant effect on jump height when compared to BM(p=0.10); however, elicited a positive correlation was observed between jump height and FFM in soccer players (r=0.68) (Nikolaidis, 2014). The authors concluded that body composition as well as other factors such as age and height play a key role in the individuals jumping ability (Nikolaidis, 2014). Additionally, Nikolaidis (2013) found a negative correlation between vertical jump height and FM(r=0.45) in volleyball athletes. The results of the current investigation are consistent with previous research. These findings indicate that the lower an individuals' FFM or increased FM, the lower overall jump height that was produced.

The results of the current study show no relationship between BM and RSR. While a moderate negative correlation between FFM and a low, strength positive correlation between FM was seen when compared to RSR time. Nene, Pazare, and Sharma, (2011) found that individuals with a higher body fat percentage had a slower reaction time to auditory and visual stimuli. They observed young females and found that when there was a moderate strength correlation between response time and BMI (r=0.58, p=0.03). They suggest that this may be due to the amount of time it takes larger individuals to get their center of gravity in motion compared to smaller individual. The study also suggested that the more muscle the individual has the quicker they can move their center of gravity. The current study suggests that the FFM has a positive impact on an individual's reaction time, where FM has a negative impact on reaction time. This research may support the findings seen in this study.

This study is not without limitations. First, participants were asked to refrain from high-intensity, lower-body exercise or supplementation/caffeine use 24 hours prior to participation; however, a 24-hour history was not assessed. To try and prevent this limitation the participants were asked if they participated in any high intensity exercise prior to testing. Second, the time of day was not held consistent for all participants; therefore, performance metrics may have been affected for those who exercise at a different time of day compared to participation in the current study (Seo, Lee, Kim, Ko, Rhee, Park, & Han, 2013). The third limitation was the assumption that all participants gave maximum effort for all performance test. Encouragement to give maximum effort was provided throughout testing to prevent this limitation.

CHAPTER 5

CONCLUSION

The purpose of the current study was to examine the differences in lower body strength, power, and agility between recreationally trained males and female. The study focused on recreationally trained individuals because they are more representative of the general population and make up the majority of active individuals. The results of this investigation determined that performance measures (i.e., 1RM, CMJ, and RSR), when normalized to FFM, showed no significant differences between recreationally active males and females. However, when normalized to overall BM and FM significant mean differences were observed. These findings demonstrated that FFM has a positive impact on an individual's strength, jumping ability, and reaction time, while FM has no impact on the factors. The results also showed that some other factors play a role in individual's peak power beside FFM.FM. or BM such neurological effects. These findings relay the importance of normalization to FFM because it allows a more accurate depiction of an individual's overall performance, and force production. This could allow a better understanding of how to train males and females to maximize their strength, power, and agility. Future research should examine the differences in upper body strength, power, and agility between males and females normalized to FFM, FM, and BM.

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