SPORT VARIABLES AND STRESS URINARY INCONTINENCE IN NULLIPAROUS COLLEGIATE ATHLETES

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Sport Variables and Stress Urinary Incontinence in Nulliparous Collegiate Athletes

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Abstract

Female athletes have significantly higher prevalence rates of SUI than their non-exercising peers. While exercise appears to be protective against many other disease conditions, it may be linked to the development of SUI in an otherwise healthy population. The purpose of this study was to explore the influence of sports characteristics on SUI in nulliparous female collegiate athletes. A non-experimental study using a cross-sectional design in the form of an online survey explored whether the prevalence of SUI in nulliparous collegiate athletic women was related to the impact and intensity of the sport, training volume, and athlete demographic and training characteristics. Two hundred and nine female nulliparous athletes at Division II universities participated in the study.

Nonparametric testing revealed athletes participating in high impact sports demonstrated greater SUI rates and severity than low and moderate impact sports (p=.03). Other variables associated with an increase in SUI were participation in vigorous physical activity >5days/week (p=.037), and a BMI>25 (p=.05). Athletes with a high BMI or those engaging in high intensity and high impact activity most days of the week have a greater need for pelvic floor muscle training, to strengthen and maintain pelvic floor muscle function to prevent SUI. Efforts are needed for education and early prevention to mitigate development of SUI in this population.

Keywords: stress urinary incontinence, incontinence, female athlete

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Sport Variables Effect on Stress Urinary Incontinence in Nulliparous Collegiate Athletes

While urinary incontinence (UI) encompasses all types of urine leakage, stress urinary incontinence (SUI) is specific to the involuntary loss of urine during coughing, sneezing, or physical activity (Haylen et al., 2010). SUI affects 16-35% of all adult women, with the primary risk factors being older age, obesity, pregnancy, parity, vaginal delivery, diabetes mellitus, and genetic conditions (Stothers & Friedman, 2011). In young women, the rate is lower as these risk factors are less commonly present (Minassian et al., 2017).

While most young women are not affected by SUI, female athletes have significantly higher prevalence rates than their non-exercising peers (Almeida et al., 2016; Carvalhais et al., 2019), with 31.6% reporting urinary leakage (Almousa & Bandin Van Loon, 2019). This is more than double the rate seen in the general female population age 20-29 years (Bedretdinova et al., 2016). When athletes participate in high-impact and/or intensity sport, they are almost three times more likely to experience SUI than non-exercising peers (Almeida et al., 2016; Da Roza et al., 2015). While exercise appears to be protective against many other disease conditions, it may be linked to the development of SUI in an otherwise healthy population. Women who suffered from UI during sport are more likely to have continued and more severe leakage decades later (Bø & Sundgot-Borgen, 2010). Female athletes who experience this condition have worse quality of life scores (Alves et al., 2017; dos Santos et al., 2019; Hagovska et al., 2017; Hagovska et al., 2018) and generally limit their physical activity. In a study of physically active women, 90.3% of those with SUI decreased their exercise intensity, and 80.7% avoided certain activities to avoid leakage (Brennand et al., 2018).

Problem Statement

Many female athletes with SUI are nulliparous and lacking traditional risk factors for the development of SUI. Research to date has focused primarily on investigating prevalence rates of UI in athletes. While prevalence rates help establish hypotheses for athletic SUI based on sport characteristics, causation has not been determined. Studies that have investigated potential risk factors have displayed mixed results. For example, some studies have shown high impact sports have a greater influence on SUI than low impact sports (Carvalhais et al., 2018; Da Roza et al., 2015a), while other studies have reported no differences among sports with varying impact forces (Bø & Sundgot-Borgen, 2010; dos Santos et al., 2018). While some studies have attempted to determine the risk factors for SUI in the athletic population, initial results have been inconclusive (Brennand et al., 2018; Elks et al., 2020; Wikander et al., 2019). Additional research is required to better understand the prevalence and risk factors for this condition, considering a range of potential factors.

Purpose Statement

The purpose of this study is to explore the influence of specific sports characteristics on SUI in nulliparous female collegiate athletes.

Research Questions

This study of nulliparous female collegiate athletes will address the following research questions:

1. Is there a significant difference in stress urinary incontinence between athletes who play a high impact sport compared to athletes who play a low or medium impact sport?
2. Is there a significant difference in stress urinary incontinence between athletes who play high-intensity sports compared to athletes who play lower-intensity sports?

3. Is stress urinary incontinence related to training volume in athletes?
4. Is stress urinary incontinence related to athlete demographics or training variables?

Objectives

To answer the research questions, the following objectives will be investigated by the authors:

1. Determine the prevalence of SUI among nulliparous female collegiate athletes, measured with the International Consultation on Incontinence Questionnaire – Urinary Incontinence Short Form (ICIQ-UI SF) scale.
2. Determine if there is a significant difference in rates and severity of SUI among nulliparous female collegiate athletes who play high, medium, or low impact sports.
3. Determine if there is a significant difference in rates and severity of SUI among varying intensity levels of athletics in nulliparous collegiate athletes, as measured with the International Physical Activity Questionnaire Short Form (IPAQ SF).
4. Determine if there is a significant difference in SUI based on training volume, measured in time spent on sport training (practice or competition) over the past seven days.
5. Determine if there is a correlation between SUI rates to nulliparous female collegiate athlete characteristics, such as BMI or disordered eating.

Significance of the Study

This study investigated the role of impact, intensity, training volume, and other demographic and training variables as risk factors for nulliparous female athletes with stress urinary incontinence, which could lead to improved screening and preventative treatment for this condition. With early identification, rapid intervention could potentially prevent SUI from progressing to more significant incontinence later in life, when females may experience greater risk factors such as increased age, parity, and weight gain (High et al., 2020; Stothers & Friedman, 2011). Understanding the risk factors of SUI among the athletic population could guide coaches and health professionals to develop prevention and treatment strategies for this condition. Utilizing these preventative strategies could reduce the rate of developing SUI among young female athletes and subsequently improve quality of life.

Literature Review

Female athlete participation in sports has drastically increased since Title IX of the Educational Amendments passed in 1972, eliminating sex-based discrimination in sports (United States Department of Justice, 2015). The number of female collegiate athletes increased from almost 30,000 in 1972 to 280,721 athletes in 2019 (Irick, 2019). As more women are playing sports, greater attention must be paid to health concerns that may differ from their male counterparts, such as urinary incontinence.

Definitions of Incontinence

The International Continence Society and the International Urogynecological Association define urinary incontinence (UI) as the involuntary loss of urine, encompassing various subtypes (Haylen et al., 2010). Subtypes include urgency incontinence, associated with an incontrollable urge to urinate; stress incontinence, classified as the involuntary loss of urine as a result of physical effort, such as coughing, sneezing, or exercise; mixed incontinence, a combination of stress and urge incontinence; postural incontinence, associated with a change in body position; nocturnal enuresis, loss of urine during sleep; coital incontinence, where loss of urine occurs during coitus; continuous incontinence, in which there is a continuous loss of urine; and insensible incontinence, in which the individual is not sure how the incontinence occurred (Haylen et al., 2010). Stress urinary incontinence (SUI) will be the focus of this study.

Incidence and Prevalence of UI in the Population

The prevalence rates of urinary incontinence vary widely by sampling and data collection strategies and the definition of urinary incontinence used. UI is much more common in females than males, with SUI being the most common form of UI (Milsom & Gyhagen, 2019). SUI affects 10-13% of women, with prevalence peaking during the 5th decade (Milsom & Gyhagen, 2019; Minassian et al., 2017). In women under 40 years of age, fewer than 2 in 1,000 are affected (Aoki et al., 2017). In a study of nulliparous (never having given birth) university students, aged 18-28 years, only 3.2% experienced SUI (Ural et al., 2020).

Prevalence of SUI among Athletic Population

The prevalence of UI increases significantly in athletes, with rates of SUI varying from 21% to 44% (de Mattos Lourenco et al., 2018; Pires et al., 2020; Teixeira et al., 2018). Among nulliparous athletes, prevalence rates of SUI are 10.3% - 61.1%, with a mean rate of 31.6% (Almousa & Bandin Van Loon, 2019). Urinary incontinence in the athlete appears to vary depending on definitions used and data collection methods (Almousa & Bandin van Loon, 2018). It is also dependent on the sports activity and various other risk factors (Almousa & Bandin Van Loon, 2019; Hagovska et al., 2018; Pires et al., 2020). It is critical to determine the risk factors for developing this condition in young female athletes to design appropriate prevention activities.

Anatomy and Physiology of Continence

Urinary continence is established through a complex coordination of neural, vascular, muscular, and connective tissue support. Injury to any of these components involved in the urethral closure system can lead to SUI (Bo et al., 2014; Mistry et al., 2020).

The urinary tract receives automatic parasympathetic and sympathetic innervation from the second through fourth sacral nerve roots (S2-S4) of the spinal cord (Mistry et al., 2020). The pudendal nerve, which also originates from S2-S4, is responsible for voluntary (somatic) control of pelvic floor musculature (Mistry et al., 2020). The bladder neck and urinary sphincters comprise the primary urethral sphincteric closure system. The bladder neck is structurally continuous with the proximal urethra, and two sphincters are present in this space, the internal urethral sphincter (IUS), the external urethral sphincter (EUS) (Mistry et al., 2020). The IUS contains smooth muscle and operates under involuntary control, while the EUS is composed of striated muscle and is under voluntary control (Jung et al., 2012).

The urethra lies on top of the endopelvic fascia and anterior vaginal wall (in females) and has a lateral attachment through the arcus tendinous fascia. The arcus tendinous fascia runs from the pubic bone to the ischial spine. The levator ani muscle group lies lateral, and the obturator internus muscle lies posterior to the arcus tenineus fasciae pelvis and endopelvic fascia. The bladder maintains a low-pressure environment during the storage phase by inhibiting the parasympathetic input (Mistry et al., 2020). As the bladder stretches, a spinal reflex activates contraction of the IUS as well as co-activation of EUS via the pudendal nerve (Mistry et al., 2020). The sphincteric system automatically contracts in response to bladder filling (Vignoli, 2018). When the threshold has been reached, a signal of the desire to void is sent to the prefrontal cortex, and an individual determines whether to act on that information (Vignoli, 2018). Due to the training received in childhood, adults can consciously control when urination (micturition) occurs, such as when in a socially appropriate setting (Vignoli, 2018). When micturition is desired, the micturition reflex is activated, an inhibitory message is sent to the somatic center, and a stimulatory message is sent to the parasympathetic center (Mistry et al., 2020). Thus, the pelvic floor musculature, including the EUS, levator ani group, and IUS, relaxes, and urine can flow outward from the bladder through the urethra.

Continence is maintained when the urethral closure pressure is greater than the pressure from the bladder (Bo et al., 2014; Vignoli, 2018). At rest, the urethra maintains closure from the urethral smooth muscular wall and appropriate innervation (Mistry et al., 2020). When pressure increases in the abdomen, such as during a cough, the bladder pressure increases, and the urethral closure must also rise to prevent incontinence (Bo et al., 2014). During these times of added force, pelvic floor musculature also contracts and compresses the urethra to add additional support to maintain continence (Bo et al., 2014; Minassian et al., 2017; Mistry et al., 2020).

Micturition in Males vs. Females

Voiding mechanisms differ in males versus females due to anatomical differences. The male urethra travels through the penis and is approximately 20 cm, while the female urethra travels above the vaginal opening and is approximately 4 cm long (Abelson et al., 2018). In men, the detrusor muscle of the bladder is very thick and contracts forcefully to move urine through the urethra, as there is significant resistance (Abelson et al., 2018; Vignoli, 2018). In women, there is very little resistance in the urethra; thus, the detrusor muscle is thinner as it does not need to contract much for urine to flow (Abelson et al., 2018; Vignoli, 2018). Instead, micturition is largely achieved by relaxation of the pelvic floor muscles (60% of women) over detrusor muscle contraction (20% of women) (Vignoli, 2018).

SUI Pathophysiology

SUI has a complex etiology, with various factors influencing its development. More women are affected than men, and there is usually a problem with the closing mechanism of the urinary sphincteric system (Jung et al., 2012). Passive insufficiency from lack of structural support could occur when muscles lose stiffness due to excessive stretching or injury, or there is a lack of innervation to the tissues for appropriate contraction to occur (Ashton-Miller et al., 2001). Additionally, overactive opening due to sphincteric mechanism malfunction could also lead to urethral insufficiency (Teleman et al., 2003). Overall, for the urethra to stay closed, the urethral pressure must be equal to or exceed the abdominal pressure. Additionally, there must be appropriate neural and vascular supply to tissues, functioning striated and smooth sphincteric musculature, proper alignment of structures, and an intact vaginal wall for support (Abrams et al., 2017).

Risk Factors for SUI

Risk Factors for Females

A variety of risk factors have been reported for SUI, such as increased number of pregnancies, parity, age, obesity, and physical activity (Milsom & Gyhagen, 2019). Half of all pregnant women develop UI during pregnancy; however, it largely resolves after childbirth, with only 7-15% having continued incontinence at three months postpartum (Abrams et al., 2017). Vaginal birth is also a significant risk factor for SUI. During vaginal childbirth, there may be trauma to the pelvic floor musculature, fascia, nerve, or vasculature from the process of parturition or the position of the baby (Abrams et al., 2017). There may also be direct injury to the urethra during this process, as well as partial denervation to the pudendal nerve, responsible for innervation of the EUS (Abrams et al., 2017). In a longitudinal study, women who had vaginal births compared to women with cesarean births had significantly lower pelvic floor muscle strength and were more likely to develop SUI within twenty years from childbirth (Blomquist et al., 2020). Vaginal childbirth has been shown to have a 71% higher prevalence of UI than delivery by cesarean (Gyhagen et al., 2013). Obesity is also a significant predictor, with an 8% increased risk per one BMI unit (Gyhagen et al., 2013). As women age, they lose muscle thickness of the pelvic floor, including the EUS, which may impact closure pressure (Bo et al., 2014).

Risk Factors for Female Athletes

Female athletes have been found to have a 2.5-2.77 times greater risk of SUI than sedentary women (Da Roza et al., 2015a; Teixeira et al., 2018). There are two main theories observed in the literature for this increased risk, as first reported by Bo (2004). The first theory suggests increased intra-abdominal pressure from athletic activities results in weakness and deformation of the pelvic floor musculature. The second theory suggests athletes have strong pelvic floor muscles, but the intra-abdominal pressure from impact causes incontinence. Studies investigating both hypotheses have shown mixed results, and additional factors have been suggested. At this time, potential risk factors for exercise-related incontinence have been reported to include impaired pelvic muscle strength, diminished muscle endurance, involvement in high impact activities, high-intensity exercise, high training volume, and factors related to impaired energy such as relative energy deficiency syndrome (RED-S) (Almousa & Bandin Van Loon, 2019; Bø, 2004; Carvalhais et al., 2018, 2019; Da Roza et al., 2015a; Ree et al., 2007; Simeone et al., 2010; Whitney et al., 2019).

Muscle Strength. In Bo's (2004) first theory, urinary leakage can occur due to weakness of the pelvic floor musculature. Pelvic floor strength has been posited to decrease due to the excessive loading that progressively weakens the pelvic floor musculature (Bø, 2004), but subsequent studies have reported mixed findings. Some studies support this hypothesis, showing non-exercisers to have greater perineal strength than athletes (da Silva Borin et al., 2013), while some have shown no difference in muscle strength (Carvalhais et al., 2018; Middlekauff et al., 2016). Still, others demonstrated the opposite, with increased cross-sectional area and thickness of the pelvic floor musculature (Da Roza et al., 2015a, 2015b) and greater maximal pelvic floor strength compared to sedentary women (de Araujo et al., 2015). While athletes had higher pelvic floor strength, which should, in theory, provide greater support to the urethral closure mechanism, they also had a significantly higher rate of UI (de Araujo et al., 2015). Additionally, multiple studies have shown no correlation between urinary leakage and pelvic floor muscle strength (Da Roza et al., 2015; de Araujo et al., 2015; de Melo Silva et al., 2020). Dias and colleagues (2017) performed a simulated study measuring pelvic floor deformation from a nulliparous female with increased muscle distensibility during a drop jump. Their results indicated decreased levator ani stiffness caused only small changes in urethral mobility during the high impact activity, indicating strength or stiffness of the pelvic floor musculature does not play a significant role in impaired urethral closure in athletes (Dias et al., 2017). This evidence contradicts Bo’s first theory as muscle strength does not appear to be a primary factor in the mechanism for urinary incontinence during athletics; thus, other risk factors must be explored.

Muscle Endurance. Pelvic floor muscles are skeletal muscles and contain both type 1 and type 2 muscle fibers. Type 1 fibers contract slowly but have great endurance. These muscle fibers are responsible for maintaining postural tone and compose 70% of the pelvic floor musculature (Marques et al., 2010). The other 30% are type 2, quick contracting fibers. This fiber type contracts rapidly but also fatigues quickly and is designed for turning on during explosive and rapid movements like running and jumping (Marques et al., 2010). While the pelvic floor is comprised predominantly of type 1 slow-twitch fibers, they are not completely resistant to fatigue (Teng et al., 2018).

Hodges and colleagues (2010) suggested that pelvic floor musculature may experience greater central fatigue versus peripheral fatigue experienced in limb musculature. They suggested this may be due to diminished excitability of the descending pathways from the motor cortex, which serves to prevent fatigue of voluntary pelvic floor muscle function. Thus effort may be reserved for involuntary efforts to maintain continence (Hodges et al., 2010). Middlekauff and colleagues demonstrated an immediate lowering effect on the pelvic floor, indicating decreased support, after both strenuous and nonstrenuous exercise (2016). In a landmark study on nulliparous women with SUI, Ree and colleagues (2007) determined the pelvic floor musculature experienced short-term fatigue following 90 minutes of strenuous physical exercise. Wikander supported this finding, determining powerlifting athletes reported greater leakage after repetitive heavy lifts (2019). A large percentage of elite (55.6-98%) and high school (43%) athletes also experienced UI in the middle or end of training or competition (Carvalhais et al., 2018; Logan et al., 2018; Skaug et al., 2020).

In a recent systematic review, both high impact and low impact sports had similar UI prevalence rates, although the type of UI was not reported (Teixeira et al., 2018). Muscle fatigue may explain the presence of UI in low-impact activities. Simeone et al. (2010) posited that maintaining constant pressure on the pelvic floor musculature over long periods sustains a greater risk of incontinence than impact alone. Repeated intra-abdominal pressure may create fatigue in the pelvic floor muscle, reducing the efficacy of the continence mechanism. While muscular fatigue is certainly a potential hypothesis for athletic incontinence, there are no standardized physical examinations or urodynamic methods for measuring fatigue. Thus only indirect signs of fatigue can be evaluated (Teng et al., 2018).

Impact. Bo's (2004) second theory on impact appears to have more support in the literature. In addition to supporting bowel and bladder continence, the pelvic floor musculature also dissipates shock from the lower limbs to the spine (Casey & Temme, 2017). In a novel study by Nygaard and colleagues (1996), nulliparous collegiate athletes who experienced UI during sport had decreased ability to dissipate ground reaction forces in the arches of the feet, which they extrapolated to a diminished ability of the pelvic floor to dissipate shock as well. Alves and colleagues (2017) performed a study investigating the role of impact on nulliparous athletes and determined 55.5% of the women who reported any type of UI played high impact sports while 44.5% played low impact sports. The high-impact athletes in the study reported a greater frequency of UI, which was statistically significantly greater than those playing low-impact sports. The authors also found a greater volume of physical activity was correlated with increased leakage (Alves et al., 2017).

A recent systematic review corroborated the higher prevalence of UI in high-impact sports versus low-impact sports (58.10% vs. 12.48%, respectively) (de Mattos Lourenco et al., 2018). Sports with the highest prevalence were trampolining, gymnastics, dancing, volleyball, and basketball (Abrams et al., 2017; Da Roza et al., 2015a; Hagovska et al., 2018; Schettino et al., 2014; Simeone et al., 2010; Vitton et al., 2011). Females who participated in high-impact exercise were eight times more likely to report involuntary urine loss than non-exercisers (Almeida et al., 2016). Movements that appeared to provoke urinary leakage were activities exhibiting greater ground reaction forces such as jumping, running, dismount landings, and high-intensity interval training exercise (Almousa & Bandin Van Loon, 2019; Brennand et al., 2018; Vitton et al., 2011). "Double unders" or "triple unders" (when a jump rope passes two or three times under the feet when jumping rope), box jumps, and jumping rope were noted as top provocative activities (Dobrowolski et al., 2020; Yang et al., 2019). These high-impact activities can create higher forces that can be transmitted to the pelvic floor, stressing tissues and affecting the continence mechanism (Almousa & Bandin Van Loon, 2019; Teixeira et al., 2018). However, athletes in sports exhibiting no impact, such as swimming and weightlifting/powerlifting, also experienced athletic incontinence, which is not consistent with the impact hypothesis (Elks et al., 2020; Wikander et al., 2019). Bo and Borgen (2010) also did not identify differences in UI rates among low, medium, and high impact activities among former elite athletes, which is inconsistent with the impact hypothesis. Thus, impact requires additional investigation as a risk factor for SUI in the athletic population.

Intensity. In a sample of nulliparous athletes, intensity was found to be a significant risk factor for UI, with high-intensity activities correlating with greater UI (Hagovska et al., 2018). High intensity was defined as greater than 3,000 MET minutes/week using the International Physical Activity Questionnaire (IPAQ), a validated physical activity intensity assessment (Craig et al., 2003). While Alhababi and colleagues (2019) reported there was no change in SUI prevalence among middle-aged women performing high-intensity exercise versus all intensity levels, they defined high intensity as 32.2 MET hours/week, which falls in the moderate MET range as classified by the IPAQ. Thus, this study may have failed to capture the true effect of "high-intensity" exercise on SUI.

A study of CrossFit athletes conducted during quarantine from the COVID-19 pandemic, when CrossFit gyms were inaccessible, showed CrossFit athletes decreased intensity of their workouts by 64% and had a subsequent 14% decrease in UI (de Araujo et al., 2020). This finding supports intensity of exercise as a risk factor for the development of SUI.

Intra-abdominal Pressure. High-impact activities, such as running or jumping, creates rapid increases in intra-abdominal pressure (IAP), as does lifting weights (Goldstick & Constantini, 2014). Pelvic floor musculature ideally responds automatically to the increased IAP with a concentric contraction to keep the urethral sphincter closed against the vaginal fascia by mechanical compression (Casey & Temme, 2017). If abdominal pressure rises suddenly, the external urethral sphincter, comprised of mostly type 1 slow-twitch or endurance fibers, may not be able to react in time to match the external pressure, and the urethra will not remain closed.

IAP increases with increased speed, intensity, and greater loads to stabilize the spine and protect against high acceleration impact forces (de Gennaro et al., 2019; Dietze-Hermosa et al., 2020). During athletics that involve rapid change of direction movements, running, and tackles, such as rugby, players have reported high (54%) rates of UI. Those experiencing UI reported that urine loss occurs most frequently during competition (90%) and during tackles (88%), and less commonly during running (41%) and weightlifting (18%) (Sandwith & Robert, 2021). Tackling generates a higher IAP than running and is often unexpected, thus type 1 fibers may be unable to react in time. A game situation involving running, tackling, and rapid change of direction movements may overwhelm the pelvic floor, promoting UI (Sandwith & Robert, 2021).

Brennand and colleagues (2018) studied women performing recreational exercise and found those performing classic weightlifting, such as deadlifts, clean and jerk, and shoulder press, were less likely to experience leakage than those women performing impact activities. Conversely, Wikander (2019) found a 41% prevalence of UI during powerlifting, a non-impact sport that sustains high intra-abdominal pressures during heavy lifts. Women in this study may have been lifting much heavier weights than the women performing recreational weightlifting in the Brennand et al. (2018) study, which may explain the higher prevalence. Additionally, women in Brennand and colleagues' study (2018) were mostly parous (83.1%) and older in age (42.9 +/- 10.9 years), which may not be representative of results in a younger nulliparous population.

CrossFit is a popular high-intensity form of exercise that seems to have a large SUI prevalence rate (Elks et al., 2020; High et al., 2020; de Araújo et al., 2020). High and colleagues (2020) performed a large national cross-sectional survey of CrossFit athletes across the United States, and 26.1% of respondents reported SUI with prevalence ranges from 23-29% in the 20 to 30 years-old age group. De Araújo and colleagues (2020) similarly found a 30% prevalence rate. This is significantly higher than the national statistics for nonathletes.

Seventy-seven percent of CrossFit athletes and 78% of Olympic weightlifting and powerlifting athletes with SUI reported heavy weightlifting activities between 101-200 lbs. to be problematic for leakage (Elks et al., 2020; Skaug et al., 2020). Wikander (2019) noted many women cited the use of a weight belt to be a factor provoking SUI symptoms; weight belts are commonly used for maximal lifts. Furthermore, only 2.2% of female powerlifters experienced UI outside of heavy lifting activities (Wikander et al., 2019). Overall, a rapid increase in IAP, causing an external overload to the sphincteric system, appears to a probable cause of SUI (Wikander et al., 2019).

Disordered Eating. Low energy availability has been hypothesized to be a contributing factor to UI in female athletes. This condition is often attributed to intense exercise and/or disordered eating, resulting in decreased estrogen levels (Rebullido & Stracciolini, 2019). Estrogen receptors are found in the pelvic floor structures, and a hypoestrogen state may influence the function of the continence system (Rebullido & Stracciolini, 2019). Disordered eating also robs the body of energy and nutrition to strengthen muscles, ligaments, and fascia (Goldstick & Constantini, 2014; Logue et al., 2018). Several eating disorders, such as bulimia nervosa, induce repeated vomiting, creating high intra-abdominal pressure on the pelvic floor (Goldstick & Constantini, 2014). In the female athlete, disordered eating can be considered a “subclinical” eating disorder, and many times the athletes do not meet the full diagnostic criteria as outlined in the DSM V (Knapp et al., 2014). Beals and Manore (2000) examined the behavioral and psychological characteristics commonly present in athletes with a subclinical eating disorder. They determined subclinical eating disorders by scores on the Eating Disorder Inventory (EDI), the Body Shape Questionnaire (BSC), and the Eating Disorder Inventory Symptom Checklist (EDI-SC). Scores were correlated with a 7-day weighted food record and activity logs and a 30-120 min in depth interview (Beals & Manore, 2000). Eight criteria emerged for diagnosing this condition: 1) Preoccupation with food or body weight, 2) distorted body image, 3) body weight influencing self-esteem, 4) intense fear of weight gain at normal or underweight, 5) weight loss attempts through a pathological method, 6) using rules to govern food consumption with self-hate if a rule is broken, 7) absence of medical disorder explaining low body weight or weight loss, and 8) menstrual dysfunction.

Due to the impaired bioavailability of nutrients, decreased estrogen, and repeated intra-abdominal pressure associated with disordered eating, even low-impact athletes have a higher risk for incontinence (Goldstick & Constantini, 2014). In a study on elite Portuguese athletes and nonathletes, athletes who exhibited disordered eating had a three times higher rate of UI than nonathletes (Carvalhais et al., 2019b). Whitney and colleagues (2019) found similar results in adolescent female athletes.

Conversely, several studies have failed to link disordered eating with SUI in a variety of impact and nonimpact sports (Carvalhais et al., 2019b; Gram & Bø, 2020; Skaug et al., 2020, 2020). Each of the studies reviewed utilized different methods for measuring disordered eating. These mixed results may be influenced by the variety of definitions and measures used.

Training Volume. The pelvic floor can withstand repeated impact over a period of time but has been shown to fatigue in endurance studies (Ree et al., 2007; Simeone et al., 2010). Therefore, it is reasonable to hypothesize a high load of training volume in which athletes are subjected to long durations of repeated stresses on the pelvic floor may reach a continence threshold.

In a sample of nulliparous high school athletes, participation in vigorous athletics for a greater number of seasons was the chief factor associated with incontinence (Logan et al., 2018). This finding has been reproduced in a study of amateur and elite volleyball players but not in cheerleading and gymnastics (da Silva Pereira et al., 2020; Skaug et al., 2020).

Increased practice time has also been associated with UI. Athletes who spent a greater amount of time training in a week experienced more significant SUI (da Silva Pereira et al., 2020; Skaug et al., 2020). Training 4 days or more each week was associated with 2.3 times higher odds of SUI than those who trained less (Skaug et al., 2020). The risk of developing UI has been shown to increase by 15.3% for each additional hour practiced in a sample of rugby players (Sandwith & Robert, 2021). Nygaard and colleagues (2015) investigated lifetime physical activity and determined women with greater longevity of physical exercise were statistically significantly more likely to experience SUI. Interestingly, women in this study who had significant vigorous exercise during their teen years had a much higher rate of SUI in adulthood. The authors speculated that these time periods could be vulnerable for soft tissue injury, as many hormonal, skeletal, and muscular changes occur rapidly (Nygaard et al., 2015).

In a retrospective study on adolescent girls with UI, 85% of those with pelvic floor laxity played vigorous sports, supporting Nygaard's theory (Bauer et al., 2018).

Pelvic Floor Muscle Training in Athletes

During a pelvic floor muscle contraction, the pelvic floor musculature lifts upward and inward, closing the urethra and stabilizing the bladder neck and urethra from descent (Bo, 2004). When the pelvic floor musculature is contracted prior to a cough ("the knack"), bladder neck descent was reduced, and continence was improved (Miller et al., 2001). Pelvic floor muscle training (PFMT) has been shown to reduce SUI symptoms and is recommended as the initial treatment for individuals with this disorder (Belushi et al., 2020; Bø, 2004; Lasak et al., 2018). This exercise training improves the strength, endurance, and/or power of the pelvic floor muscles as well as control and timing of pelvic floor contractions to improve continence (Belushi et al., 2020; Lasak et al., 2018; Miller et al., 2001).

In a study of elite volleyball athletes with SUI, a 12-week PFMT program decreased the amount of urine loss by almost 30% and significantly improved pelvic floor muscle strength (Pires et al., 2020). This program had three phases: improving the athlete's awareness of the pelvic floor, isolated strength training, and sport-specific training (Pires et al., 2020). Ferreira et al. (2014) also demonstrated a decreased amount and frequency of urinary leakage in 45% of nulliparous female elite athletes after PFMT. These results suggest that the addition of a PFMT program may be an important complement to an athlete's training regimen to improve symptoms of SUI in athletes.

Conclusion

Urinary incontinence is prevalent in the athletic population, and mechanisms for stress incontinence differ for athletes than the non-athletic population. The pathophysiology of UI appears to be complex and multifactorial. Sport variables such as training intensity, impact, and training volume, along with individual variables such as disordered eating or muscular fatigue, should be investigated in further depth to determine the most significant risk factors for the nulliparous athlete. Additionally, pelvic floor muscle training has been shown to be beneficial in combating SUI. Incorporating a PFMT program into sport-specific training may be helpful to prevent the development of SUI, although no studies have investigated this currently.

Method

Study Design

A non-experimental study using a cross-sectional design in the form of an online survey explored whether the prevalence of stress urinary incontinence in nulliparous collegiate athletic women was affected by the impact and intensity of the sport, training volume, and athlete demographic and training characteristics. The study took place from January 2021 to February 2021. The Institutional Review Board at the University of Indianapolis deemed this study exempt from IRB review. The IRB study number is 01329.

Participants

Convenience sampling was used to recruit female collegiate athletes from three division II colleges/universities in the Midwestern United States. Inclusion criteria included nulliparity, age 18-29 years, and current participation in a Division II college sport. Exclusion criteria included individuals with a history of current or prior pregnancy or prior childbirth.

Sample Size

An a priori sample size estimate was calculated using G*Power, version 3.1.9.7 (Faul et al., 2009). The calculation was based on one-way ANOVA using the following parameters: two-tailed test, two degrees of freedom, three groups, alpha of .05, power of .80, and moderate effect size of .25. As effect sizes have not been reported in the literature on this topic, a medium effect size was chosen. Based on this calculation, it was estimated a minimum sample size of 159 participants was needed for the study.

Data

Data was collected using Qualtrics (Qualtrics, Provo, UT), an online survey platform. Participant demographics (height, weight, age), history of disordered eating, incontinence status, physical activity intensity, and sport/activity characteristics (type of sport, years of sport participation, and volume of sport training) were collected in February 2021. BMI was calculated using the athlete's self-reported height and weight.

Operationalization of Variables

Impact. The impact of an activity involves the magnitude of ground reaction forces being transmitted through the body and was categorized by the investigator as low impact, medium impact, or high impact. Impact was classified by the protocol used by de Mattos et al. (2018): High impact: activities that demand jumps (>4x bodyweight); Medium impact: activities that involve sprints and rotational movements (2-4x bodyweight); Low: activities that require lifting some weight (<1-2x bodyweight).

Training Volume. The volume of sport training was defined as the measure of sports activity performed in the prior week. Volume was calculated by multiplying the time in minutes of physical activity each day by the weekly frequency of practice (Alves et al., 2017).

Incontinence. SUI was defined as the involuntary loss of urine during coughing, sneezing, or physical activity, in accordance with International Continence Society guidelines (Haylen et al., 2010). Thus, a classification of SUI status required a total score of >0 on the ICIQ

UI-SF total score, indicating some form of UI in addition to an answer of "cough or sneeze" or "when physically active/exercising" on question 6 on the ICIQ UI-SF, to indicate SUI.

Disordered Eating. Disordered eating status was defined and listed in the survey according to the criteria outline in Beals and Manore (2000). Criteria include: 1) Preoccupation with food or bodyweight, 2) distorted body image, 3) body weight influencing self-esteem, 4) intense fear of weight gain at normal or underweight, 5) weight loss attempts through a pathological method, 6) using rules to govern food consumption with self-hate if a rule is broken, 7) absence of medical disorder explaining low body weight or weight loss, and 8) menstrual dysfunction. Participants checked either yes or no or unsure as a response to these survey items.

Body mass index (BMI) was calculated by the participants' self-reported height and weight information. After calculating BMI, scores were divided into two categories for analysis, <25 and ≥ 25. Scores of 25 or greater are consistent with the National Institutes of Health's "overweight" category while scores 18.5 to 24.9 fall into the "healthy weight" category (National Heart, Lung, and Blood Institute, n.d.). Scores of less than 18.5 were considered underweight (National Heart, Lung, and Blood Institute, n.d.).

Instruments

Incontinence Questionnaire – Urinary Incontinence Short Form

The ICIQ UI-SF was used to classify incontinence. The ICIQ UI-SF has three diagnostic questions that are scored; the first two relate to the frequency and severity of urine leakage, and the third asks about the impact of urine leakage on quality of life (Appendix B) (Bristol Urological Institute, 2020). The last question is unscored and asks under what circumstances urine leaks (Bristol Urological Institute, 2020). This question was used to classify the type of incontinence. The ICIQ UI-SF is scored by the sum of all questions (0=no leak; 1-5=slight; 6-

12=moderate; 13-18=severe; 19-21=very severe). The primary investigator was granted permission from the Bristol Urological Association to use the ICIQ-UI-SF for this research study (Appendix A).

The ICIQ UI-SF is a valid and reliable measure for assessing incontinence in the adult female population. It displays excellent test-retest reliability with ICC ranging from .91-.96 (Gotoh et al., 2009; Lim et al., 2017) and excellent intra-rater reliability with ICC ranging from .84- .96 (Hajebrahimi et al., 2004; Tubaro et al., 2006). Internal consistency measures range from adequate to excellent with Cronbach's alpha ranging from .60-.97 (Al-Shaikh et al., 2013; Avery et al., 2004; Gotoh et al., 2009; Hajebrahimi et al., 2012; Huang et al., 2008; Lim et al., 2017; Tubaro et al., 2006).

The ICIQ UI SF displays excellent validity as well. Prior studies have shown excellent criterion validity Pearson's r=.48-.62 and Spearman's ρ .55-.74 (Gotoh et al., 2009; Karantanis et al., 2004; Klovning et al., 2009), excellent convergent validity Pearson's r=.93 and Spearman's ρ=.63 (Hajebrahimi et al., 2012; Karmakar et al., 2017), content validity k=.70 (Hajebrahimi et al., 2012), construct validity ICC=.84 between urodynamic testing (Hajebrahimi et al., 2012) and face validity (Avery et al., 2004; Huang et al., 2008).

International Physical Activity Questionnaire Short Form (IPAQ SF)

To assess the intensity of physical activity, the IPAQ SF was used. This form is free, publicly available, and validated in adult populations aged 18 to 65 years of age (Craig et al., 2003). In a large, multi-country validity and reliability study, the IPAQ SF displayed excellent test-retest reliability (Spearman's ρ .76) and moderate concurrent (Spearman's ρ .58) and criterion validity (Spearman's ρ .30) (Craig et al., 2003). While validity measures are only moderate, this scale has similar validity as other scales that monitor physical activity (Danquah et al., 2018). As these types of questionnaires rely on self-report of activity, recall bias is a potential source of error. Using an accelerometer to estimate physical activity would be much more exact (Lee et al., 2011) but was cost-prohibitive for this study and unsuitable for the survey methodology.

The IPAQ Short Form has seven questions with four questions regarding time and level (low, medium, high) of physical activity (Appendix C) (The IPAQ Group, 2020). The questionnaire defines low, medium, and high intensity according to metabolic equivalent, or MET. METS are used to estimate the energy used by the body during physical activity and thus can be used as an estimate of intensity (Ainsworth et al., 2000). The IPAQ SF score provided the cumulative MET-minutes per week. This was calculated by multiplying the activity level MET with the amount of time spent performing the activity weekly for walking, moderate activity, and vigorous activity data (The IPAQ Group, 2020). Scores were divided into high, moderate, or low depending on the MET minute per week score. High intensity required vigorous intensity activity on at least three days per week achieving a minimum of 1500 MET minutes per week or seven or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum total of 3000 MET minutes per week. This study utilized the former definition for its definition of high intensity and those failing to achieve the definition for high intensity were classified as “low to moderate” intensity for this study.

Procedures

Recruitment

Participants were recruited from three universities with Division II athletics in the Midwestern United States. Athletic directors at each university were contacted by the investigator with information about the study and a request for approval to recruit their student-athletes. Athletic directors or athletic training staff forwarded the study invitation to all female student athletes at the university. The email invitation described the details of the study, provided the contact information of the lead investigator for any questions, and included a link to the study (Appendix F). Four reminder emails were sent to increase the response rate (Dillman, 2011). An incentive, consisting of five $50 gift cards, was used to increase the response rate (Dillman, 2011). At the end of the survey, participants were redirected to another survey, thanking them for participation and asking about interest in entering a gift-card raffle. Participants who indicated an interest were directed to a form wherein they could provide an email address. Participants who declined were directed to an exit page. This method allowed the research responses to remain anonymous and keep the raffle entries from links to identifying data.

Informed Consent

Potential participants were required to consent to participate via a consent form located on a secure online data collection portal before being given access to the survey (Appendix D). Participants had the option to indicate consent and proceed to the survey or deny consent and exit the survey. The participant was required to select the option that they consented to the study before being allowed access to the survey.

Data Collection

Potential participants received a link to the survey via email to be completed at their convenience over a period of five weeks (Appendix E). After the participant read the informed consent form and agreed to be in the study, she was asked to provide demographic information such as height, weight, and age along with sport-specific information, such as sport played and years of sport participation. Two validated questionnaires, the ICIQ UI-SF and IPAQ SF, were also used to collect data on urinary incontinence and physical activity frequency and intensity.

Data Management

Data was gathered on Qualtrics (Qualtrics, Provo, UT), a secure cloud-based data collection portal with access only by the primary investigator. Data was exported from Qualtrics into IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY) on a password-protected private laptop securely stored at the investigator's home. Data was backed up by a password protected external hard drive as well as in the University supplied Google Drive. Email addresses for the gift card were not linked to individual answers on the survey.

Statistical Analysis

All data was analyzed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY). Descriptive statistics were examined to show the distribution and central tendencies of the variables within the data. Frequencies and percentages were reported for nominal data. Means and standard deviations were reported for normally distributed interval or ratio data, while medians and interquartile ranges were reported for non-normally distributed data. The normality of data was determined using the Shapiro-Wilk test. All comparisons were two-tailed, and test significance values less than .05 were considered statistically significant.

RQ1: Is there a significant difference in stress urinary incontinence between athletes who play a high impact sport compared to athletes who play a low or medium impact sport?

Hypothesis: Athletes who play a high-impact sport will have significantly greater ICIQ UI SF scores than athletes who play low and mid-intensity sports.

To answer this question, a one-way ANOVA was conducted to determine if there was a significant difference in ICIQ UI SF scores between impact groups. Assumptions for this test included independent groups, a normal distribution for each group with equality of variance, and interval or ratio scale of measurement. Central tendency values, Fisher's skewness and kurtosis, and Shapiro-Wilk values were examined. While the data failed the Shapiro-Wilk test for normality, variances were equal among groups. The one-way ANOVA is a robust measure and has been found to be accurate in a variety of conditions, including deviance from normal distribution and with measures of skewness and kurtosis ranging from -1 to 1, thus low, moderate, and high impact groups were compared using this method (Blanca et al., 2017). Due to the small sample size of the low impact group, the low and moderate impact groups were then grouped together and compared to the high impact group using a nonparametric Mann Whitney *U* test.

RQ2: Is there a significant difference in stress urinary incontinence between athletes who play high-intensity sports compared to athletes who play lower intensity sports?

Hypothesis: Athletes who play high-intensity sports will display significantly greater scores on the ICIQ UI SF than athletes who play lower intensity sports.

Since the ICIQ UI SF scores and intensity scores were not normally distributed, a nonparametric Mann-Whitney *U* test was performed to determine if there was a between-group difference between the high and low-intensity groups. Assumptions for this test included two categorical, independent groups, a dependent variable at the interval level, and independence of observations.

RQ3: Is stress urinary incontinence related to training volume in athletes?

Hypothesis: Athletes who have a high training volume will have a significantly greater ICIQ UI SF score than athletes with a low or moderate training volume.

Training volume and ICIQ UI SF score data both violated normality assumptions, so a nonparametric test was required for this hypothesis. This comparison included two categorical, independent groups, a dependent variable at the interval level, and independence of observations so a Mann Whitney *U* was performed to answer this research question.

RQ4: Is stress urinary incontinence related to athlete demographics or training variables?

Hypotheses: Athletes with a BMI of 25 or greater will have greater ICIQ UI SF scores than athletes with BMI scores <25. Athletes with greater years of sports training will have greater ICIQ UI SF score than athletes with fewer years of sports training. Athletes who report disordered eating will have greater ICIQ UI SF scores than athletes without disordered eating.

As ICIQ UI SF scores, BMI, and years of sports training data failed to meet normality standards, nonparametric tests were performed. While the Disordered Eating variable technically had three groups, only the definitive yes and no groups were analyzed. Thus, each of these variables had two independent groups, independence of observations, and a continuous dependent variable, so Mann-Whitney *U* tests were used to analyze the data to answer this research question.

Results

There were 251 survey responses, which exceeded the a priori sample size estimates of 159. One participant did not consent and was thus not directed to the questionnaire. Thirty-four participants completed less than 60% of the survey and these incomplete responses were eliminated from the data. An additional nine responses demonstrated contradictory results in response to the urinary incontinence questions (e.g., answering urine never leaked and then that they leaked multiple times per day). Therefore, their data were excluded from analyses. This removal of responses did not significantly alter the power of the study.

Of the remaining responses, some participants had missing data fields and some extreme outliers were present, which were then removed during data cleaning. Interpolation was used to estimate responses to the missing fields based on their sports team's characteristics. With this method, the data file was divided by sport and the mean values for each sport were used in place of the missing data point.

Of the valid responses, 209 athletes' data were analyzed. Eleven sports were represented, with nine athletes participating in two sports. If athletes participated in more than one sport, they were prompted to list all sports they participated in on the survey. The investigator compared the impact level of all sports in which the athlete participated and in all cases the impact level was the same across both sports. Individuals participating in both track and cross country were labeled as cross country as it was likely those athletes participating in both sports were more likely to be distance runners and not field athletes, thus cross country was likely a better grouping. Tennis and lacrosse have similar movements and activities thus the one athlete that responded to playing both was randomly allocated to the lacrosse group. Table 1 lists the sport frequencies with the re-grouping of dual-sport athletes.

General Participant Characteristics

Descriptive statistics of athletes' characteristics are presented in Table 2. The sample of 209 athletes had a mean (standard deviation) age of 20.19 (1.47) years. Mean BMI was 23.74 (3.35), with mean weight and height of 145.76 (23.1) lbs. and 65.76 (3.35) inches, respectively. One hundred twenty (57.4%) athletes reported disordered eating.

Sport Specific Characteristics

Twenty-four athletes (11.5%) participated in low impact sports, 84 (40.2%) in moderate impact level, and 101 (48.3%) in high impact level sports. Among the sample, athletes reported a mean of 11.49 (3.95) years of participation in their sport. They reported performing vigorous activities 5.06 (1.45) days/week for 1.8 (0.79) hours and moderate activity 3.62 (2.21) days for

1.23 (0.82) hours on average. The mean energy expenditure was calculated from these responses according to the IPAQ protocol and totaled 6010.07 (3380.66) MET minutes/week.

Urinary Incontinence Characteristics

Two hundred and eight respondents answered questions regarding urinary leakage. Of the sample, 94 (45%) were determined to have some form of urinary incontinence while 74 (35.4%) met the criteria stress urinary incontinence. Of the 74 athletes presenting with SUI, the mean ICIQ UI SF score was 5.01, with individual component scores of 1.45 for frequency, 2.03 for amount, and 1.47 for quality of life. These results are indicated in Table 2 and represent frequency ranges from once per week to two-to-three times/week, small leakage amounts, and a small self-rated effect on quality of life.

Research Question 1: Is there a significant difference in stress urinary incontinence between athletes who play a high impact sport compared to athletes who play a low or medium impact sport?

A Levene's test showed the variances for ICIQ UI SF score were equal, $F(2,204)=1.582$, $p=.208$. A one-way ANOVA was performed to analyze this question, $F(2,204)=2.48$, $p=.086$. However, a post-hoc power analysis revealed this test was underpowered. Low and moderate impact sports were then grouped together and compared against high impact sports using a nonparametric test. The Mann-Whitney *U* test, $Z=-2.176$, $p=.03$ indicated the groups differed significantly at an alpha .05 level. The effect size was small ($d=.31$). Figure 1 demonstrates the difference in median ICIQ UI SF score among these two groups, with the high-impact athletes demonstrating higher ICIQ UI SF scores.

Research Question 2: Is there a significant difference in stress urinary incontinence between athletes who play high-intensity sports compared to athletes who play lower intensity sports?

Due to the number of significant outliers in the data on walking, the alternative definition of intensity using the IPAQ was used, using only vigorous activity to calculate intensity. This definition specified high-impact as vigorous intensity activity on at least three days/week for greater than 1500 MET minutes/week. Using these criteria for vigorous activity, 25 athletes were classified as low intensity and 84 were classified as high intensity. Statistical analysis indicated there were no differences between the groups at an alpha .05 level (p=.584). When the groups were divided into high and low-intensity groups by the median MET minute result (5400 MET minutes), the Mann Whitney U approached significance, p=.057, with higher intensity displaying higher scores. The effect size was small (d=.27) indicating that a larger sample would be needed.

When high intensity exercise was examined in conjunction with exercise frequency, statistically significant results emerged. Athletes performing intense physical activity six or seven days of the week had greater SUI than athletes performing high intensity exercise less than six days per week (p=.037). The high frequency of exposure to IAP from intense exercise may result in a synergic overload to the pelvic floor musculature, decreasing the ability to support the continence mechanism (Khowailed et al., 2020).

Research Question 3: Is stress urinary incontinence related to training volume in athletes?

Training volume was defined as the number of hours per week spent performing moderate or vigorous physical activity. The median of 13.5 hours/week was used to divide the groups into high and low training volume for the statistical analysis. The results of the Mann Whitney *U* test, (Z=-1.37, *p*=.17) determined that the groups failed to differ significantly at an alpha .05 level. Components of training volume were also examined separately to determine if there was a relationship with ICIQ UI SF scores. Only >five days/week of vigorous activities appeared to be related. The Mann Whitney U test, Z=-2.09, p=.037 indicated athletes exercising vigorously more than five days per week differed significantly at an alpha .05 level from those exercising less than or equal to five days/week. The effect size was small (d=.29).

Research Question 4: Is stress urinary incontinence related to athlete demographics or training variables?

BMI was divided into two groups <25 and ≥25. Years of sports training was a continuous variable and was classified into "high" and "low" by splitting the data based upon the median values. Disordered eating was grouped into two groups from the survey, disordered eating and normal eating, based on self-report. As the dependent variable ICIQ UI SF score data failed normality assumptions, Mann Whitney U tests were performed to analyze the relationships among BMI, years of sport training, and disordered eating on ICIQ UI SF scores. The Mann Whitney U test (Z=-1.96, p=.05) indicated the BMI groups differed significantly with athletes who had higher BMI values having greater ICIQ UI SF scores. The effect size was small (d=.31). There were no differences between disordered eating groups (Z=-.59, p=.56) or between years of sports training groups (Z=-.33, p=.74).

Discussion

Stress urinary incontinence is prevalent throughout the female athletic population; however, its etiology is poorly understood. Prior research attempts have been focused on determining the risk factors for SUI in the athletic population (Brennand et al., 2018; Elks et al., 2020; Wikander et al., 2019). Therefore, the purpose of this study was to explore the influence of sports characteristics on SUI in nulliparous female collegiate athletes. Multiple measures, including standardized assessments and self-report estimates were examined. These entailed athlete BMI, disordered eating status, sport impact level, intensity of physical activity, weekly training volume, and years of sport training. The ICIQ UI SF score was utilized to classify athletes with SUI and to quantify the frequency and severity of SUI.

Nine participants answered the survey questions on urinary incontinence inconsistently and could not be used in the data analysis. Six athletes answered “urine never leaks” to the question asking under what circumstances urine leaks, however, then answered that they did have urine leakage when asked about their frequency, amount, and the effect on their quality of life. Additionally, three participants answered that urine never leaked and that quality of life was not altered but then reported leakage during coughing and sneezing. One continent participant answered that her quality-of-life score was a 1/10 in terms of urinary incontinence, which could indicate misunderstanding the question or possibly that she was worried about urinary leakage but was not currently affected. Finally, two participants reported no UI but answered the question “when does urine leak” as “leaks before you can get to the bathroom”. For these two instances, their ICIQ scores were not used due to the inconsistency of responses.

These answers may indicate participant data entry errors or a confusion of the young athletes on what constitutes urine leakage. Incomplete answers have been noted in prior research in this population (L. Forner, personal communication, March 23, 2021. McKenzie et al., 2016). Contradictory responses have also been noted; Rodríguez-López and colleagues asked athletes “Do you think you have or have had UI?” and only 9% answered affirmatively, although 22.7% indicated they had experienced urine leakage during training (Rodríguez-López et al., 2020). It is likely these athletes do not truly understand UI. Prior studies have indicated that the majority of young women display poor knowledge about pelvic floor function and health (Cardoso et al., 2018; Falvey et al., 2021; Howard-Thornton et al., 2011; Parden et al., 2016). Thus, athletes in this current study may not have fully understood the terminology utilized or that the leakage they may have experienced was technically UI.

Prevalence and Impact of SUI

The prevalence of UI in the sample was 45% with SUI occurring in 35.4%. This is consistent with previous studies in which 48% of nulliparous athletes had UI and 37.5% SUI (dos Santos et al., 2018). SUI appears to be the most prevalent subtype of UI of the nulliparous athlete population (Alves et al., 2017; Da Roza et al., 2015b; Skaug et al., 2020).

The mean ICIQ UI SF score was 5.01 in the sample with scores ranging from 1/21 to 15/21. This score indicates mild severity of incontinence (Klovning et al., 2009), with frequency ranges from once per week to two-to-three times/week (score 1.45), small leakage amounts (2.03), and a small self-rated effect on quality of life (1.47). Prior studies corroborate this finding, reporting mean scores of 4.7- 5.3 among nulliparous female athletes (Gram & Bø, 2020; Hagovska et al., 2017).

Impact Level

A statistically significant difference was found in the high and low/moderate impact sport groups. These findings are consistent with prior research indicating ICIQ UI SF scores were significantly different amount high and low impact sports (dos Santos et al., 2018). Sports with higher impact levels appear to have higher UI prevalence rates and greater impacts of UI on quality of life (Da Roza et al., 2015a; Dobrowolski et al., 2020).

During a high impact activity such as jumping, the pelvic floor deforms in response to the compression of the falling organs against the decelerating pubic bone (Dias et al., 2017). The organs, including the bladder, “bounce back” and become compressed against the vaginal wall and levator ani musculature, increasing the pressure between the urine and bladder wall (Dias et al., 2017). Performing impact activity, such as a long jump, creates a ground reaction force up to 16x higher than body weight (Almousa & Bandin Van Loon, 2019). As the pelvic floor musculature acts as a shock absorber for the lower extremities, it follows that an increase in impact could overload the continence system (Casey & Temme, 2017). Thus, women who participate in high impact sports display greater rates of SUI.

Intensity

There were no statistical differences between the high and low intensity groups using the definition of high intensity from the IPAQ. Most athletes fell into the high intensity group (n=84) versus the low intensity group (n=25). The small number of athletes in the low intensity group may have led to a diminished power to detect a change. The effect size was small (d=.27), indicating a greater sample size would be required to detect a change than was originally calculated. Additionally, the athletes in this study had higher MET minutes of vigorous activity than found in prior studies. While Hagovska and colleagues (2017) found a significant difference in SUI among intensity levels in their study, their athletes' average vigorous intensity MET minutes were 2811.3±2060.3, which is considerably lower than the 4705±2963.38 MET minutes the athletes in this study reported. There were additional details regarding the studies that were different, with one major result being the difference in the type of athlete. Hagovska and colleagues (2017) surveyed club sport athletes while investigators in this study surveyed collegiate athletes. Athletes participating at the collegiate level are likely to have exercise practices that support high intensity to promote fitness and performance. In a prior study using the IPAQ, collegiate athletes reported 3952±2549.41 MET minutes/week, which is closer to the results found in this study. Using the IPAQ definition of high intensity as "vigorous activity at least three days/week for greater than 1500 MET minutes/week" may not be sufficiently high to detect any true differences at the collegiate level.

Training Volume

There were no statistical differences on SUI with training volume. This is consistent with some prior studies (Cardoso et al., 2018; Jácome et al., 2011) but not all (Alves et al., 2017; Da Roza et al., 2015a; da Silva Pereira et al., 2020; Sandwith & Robert, 2021). Da Silva Pereira and colleagues (2020) found a significant difference in UI comparing the physical activity and sport specific training weekly among amateur and professional athletes, however professional athletes exercised twelve hours/week while amateur athletes performed six hours/week. Athletes in Alves and colleagues' study exercised 5.4 ±3.5 (high impact) and 6.24+4.12 (low impact) hours/week. The athletes in the current study performed physical activity 14.99 ±7.98 hours/week (median 13.5). Therefore, the athletes in this study may have been exercising at a sufficiently high physical activity level that differences were not noted between groups. Rugby athletes in Sandwith and Robert's (2021) study reported similar training hours per week (14.9 ±4.4 hours/week) as the athletes in this study, but with a conflicting finding. They determined the risk of UI increased 15.3% with each additional hour of training (Sandwith & Robert, 2021). While demographic and training variables were similar in these studies, all athletes in Sandwith and Robert's study played rugby, a high impact sport, which may explain the different results. In this study, when training volume was isolated to high intensity exercise only, a significant difference was found for those training >5 days/week ($p=.037$). It is possible that training volume in isolation is not a risk factor for SUI, but rather the cumulative effect of intensity and/or impact with training volume.

BMI

Being overweight is a known risk factor for females in the general population (Nygaard et al., 2015), however prior studies have not identified links between BMI and UI (Da Roza et al., 2015a). BMI levels tend to be lower in athletes and previous literature only examined BMI ranges in the "normal" range of <25 (Da Roza et al., 2015a; Torstveit & Sundgot-Borgen, 2012). Thus, values may have been too low to reflect a true difference in the relationship for UI. In the current study, several athletes had BMI values ≥25, which was statistically significantly related to SUI. BMI grossly exaggerates the overweight category in athletes that have significant muscle mass and many have less subcutaneous fat than BMI-matched non-athletic peers (Wallner-Liebmann et al., 2013). BMI does accurately reflect the increased weight relative to height of the athlete, which can affect pelvic floor function. Consequently, even though an athlete has greater fat free mass, the greater weight on the system may predispose an athlete toward incontinence.

Disordered Eating

Disordered eating has displayed mixed results in connection with SUI in the literature (Carvalhais et al., 2019a; Goldstick & Constantini, 2014; Gram & Bø, 2020; Skaug et al., 2020, 2020, 2020), and did not appear to be related to SUI in the current study. Of interest was the high rate of disordered eating in the sample (57.4%). These findings are significantly greater than rates found in prior studies, however different criteria were used to assess disordered eating (Carvalhais et al., 2019b; Whitney et al., 2019). The current research was performed during the COVID-19 pandemic, which may explain some of the increased prevalence.

Several studies have reported a negative impact on mental health and an increase in disordered eating since the start of the COVID-19 pandemic in March 2020 (Buckley et al., 2021; Chan & Chiu, 2021; Nutley et al., 2021; Ramalho et al., 2021; Rodgers et al., 2020). Qualitative reports indicated participants felt the COVID-19 pandemic directly contributed to increasing disordered eating behavior due to increased stress, frustration, and feelings of isolation (Nutley et al., 2021). Rodgers and colleagues (2021) proposed eating disorders may have been exacerbated by restrictive food diets to decrease contracting COVID-19 or minimizing its effects during the pandemic.

Years of Training

There were no significant results between years of training and SUI. While greater years of training was associated with SUI in high impact athletes (Cardoso et al., 2018; Da Roza et al., 2015a), this sample pool consisted of low, moderate, and high impact sport types. In studies conducted in elite athletes that included all impact levels, reports are mixed, with some studies indicating no relationship between UI and years of training (Rodríguez-López et al., 2020; Skaug et al., 2020) while others found that greater years of training were related to greater SUI prevalence (Keyla M. dos Santos et al., 2019). Participating in a sport over multiple years does not appear to have a clear relationship to SUI.

Limitations

There were several limitations of this study, particularly the cross-sectional nature, unknown effect size in a priori sample calculations, and challenges related to the COVID-19 pandemic. The cross-sectional design of this survey is a significant limitation as causality cannot be determined, nor can long-term effects of exercise on stress urinary incontinence. Additionally, data from all 2020-2021 athletes were gathered in the spring, so athletes playing fall sports may not have been at peak activity levels, thus impacting results.

As effect sizes have not been reported in the literature on this topic, a moderate effect size of .25 was used to calculate an a priori sample size. The study sample (n=209) collected exceeded the a priori calculation (n=159), however due to the effect size noted in this study, a larger study population is recommended for future studies. Future studies should determine sample size calculations based upon small effect sizes noted in this study.

Collecting data during a pandemic could also have affected the nature of the results. As in-person research was halted, the study was required to be disseminated in an online format. There were several variant answers from respondents on the IPAQ and ICIQ-UI-SF that were improbable or impossible. Hagovska and colleagues noted in their 2017 study that many participants had difficulty with the questionnaire and a research member was available on site to give clear instructions and assist in ensuring accurate data. Utilizing an in-person group administration method by an independent research assistant would have been preferable, and was the initial choice of administration method, but was not possible during the COVID-19 pandemic. This method would have allowed participants to ask clarifying questions and the research assistant could check for completeness of responses.

The COVID-19 pandemic also greatly affected athletics. Universities and high schools closed in person sports in March 2020 (McGuine et al., 2020; B. Gerlach, personal communication, April 8, 2021). Training routines were interrupted, affecting the quality, quantity, and type of training (Andreato et al., 2020). Mental health of athletes suffered, with an increase in disordered eating (Buckley et al., 2021; Chan & Chiu, 2021; Nutley et al., 2021; Ramalho et al., 2021; Rodgers et al., 2020). Limited training was allowed from August 2020 until January 2021, when all sports had resumed training and competition (B. Gerlach, personal communication, April 8, 2021). As the survey was disseminated the last week in January 2021, data may be different than previously published studies due to these pandemic-related changes in collegiate athletics. Additionally, the use of a face mask during exercise may have changed athletes' perceptions of activity intensity, which was a subjective report in this survey. Studies have shown that exercising with a face mask can lead to a hypercapnic hypoxia condition (Islam et al., 2020). Thus, the amount of "vigorous intensity" exercise responses noted in the sample may be inflated due to the greater cardiorespiratory demands of exercising with a mask.

Real World Implications

This study confirms that SUI is highly prevalent in nulliparous female athletes. Athletes most at risk, such as those with a high BMI or those engaging in high intensity and high impact activity most days of the week, have a greater need for pelvic floor muscle training, to strengthen and maintain pelvic floor muscle function to prevent SUI. Sport teams should incorporate pelvic floor muscle training into their strength and conditioning routines. Pelvic health specialists should work closely with the collegiate sports medicine, athletic training, and strength and conditioning teams to develop an appropriate program.

Additionally, while SUI affects over one-third of nulliparous female athletes, many do not seem to understand the condition. The athletes in this study, as well as those in prior studies, noted confusion about what constituted urinary incontinence and whether leakage that only occurred during sport activities was truly urinary incontinence (Hagovska et al., 2017, L. Forner, personal communication, March 27, 2021). More education should be disseminated to this at-risk population for improved pelvic floor dysfunction identification, classification, and prevention efforts. A pelvic health physical therapist may be a key asset to female sports teams to provide the recommended education and training to coaching staff, athletic training staff, and athletes.

Future Directions

Athletes in this study and in prior studies, have consistently shown poor comprehension and inconsistent responses to existing standardized questionnaires. Investigating health literacy in the female student-athlete population should be considered for future studies and is important from a public health perspective. A qualitative study examining an athlete's perception of urinary leakage during physical activity, or perception of meaning of survey questions, could provide a first step in understanding cognitive dissonance related to the questionnaire language and actual experiences. As SUI is highly prevalent in this demographic, it is critical to establish a tool that is successful in collecting accurate data. Including questions regarding sport specific activities would be beneficial for assessing provocative activities related to UI.

Second, this study as well as others have noted inconsistencies in using self-report physical activity data due to the subjective nature (Hagovska et al., 2017). Using accelerometers would improve the accuracy of responses. Accelerometers can estimate energy expenditure, which is required for intensity calculations (Li et al., 2016). Accelerometers provide more precise measures of low and moderate intensity physical activity, as these are often under-reported by the IPAQ SF (Oyeyemi et al., 2014). Additionally, highly active individuals tend to under-report physical activity using the IPAQ SF (Rääsk et al., 2017). Thus, use of a wearable accelerometer to categorize physical activity quantity and intensity would be preferred to self-report in a future study.

Conclusion

Female collegiate athletes display high rates of SUI. Athletes participating in high impact sports, high intensity activity >5 days a week, and those with BMI over 25 appear most at risk. Athletes should be screened for UI as part of their pre-participation health screening, allowing early intervention as needed. Collegiate sports medicine professionals, coaches, and athletes should receive education on pelvic floor dysfunction to identify abnormalities and refer for treatment when necessary. Pelvic floor muscle training should be added to sport team strengthening programs, especially for those most at risk, for prophylaxis and treatment of SUI.

References

Abelson, B., Sun, D., Que, L., Nebel, R. A., Baker, D., Popiel, P., Amundsen, C. L., Chai, T., Close, C., DiSanto, M., Fraser, M. O., Kielb, S. J., Kuchel, G., Mueller, E. R., Palmer, M. H., Parker-Autry, C., Wolfe, A. J., & Damaser, M. S. (2018). Sex differences in lower urinary tract biology and physiology. *Biology of Sex Differences*, *9*(1), 45–58. https://doi.org/10.1186/s13293-018-0204-8

Abrams, P., Cardozo, L., Wagg, A., & Wein, A. (Eds.). (2017). *Incontinence* (6th ed.). International Continence Society.

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., O Brien, W. L., Bassett, D. R., Schmitz, K. H., & Emplaincourt, P. O. (2000). Compendium of physical activities: An update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise*, *32*(9; SUPP/1), S498–S504.

Alhababi, N., Magnus, M. C., Joinson, C., & Fraser, A. (2019). A prospective study of the association between physical activity and lower urinary tract symptoms in parous middle-aged women: Results from the Avon Longitudinal Study of Parents and Children. *The Journal of Urology*, *202*(4), 779–786. https://doi.org/10.1097/JU.0000000000000360

Almeida, M. B., Barra, A. A., Saltiel, F., Silva-Filho, A. L., Fonseca, A. M., & Figueiredo, E. M. (2016). Urinary incontinence and other pelvic floor dysfunctions in female athletes in Brazil: A cross-sectional study. *Scandinavian Journal of Medicine & Science in Sports*, *26*(9), 1109–1116. https://doi.org/10.1111/sms.12546

Almousa, S., & Bandin van Loon, A. (2018). The prevalence of urinary incontinence in nulliparous adolescent and middle-aged women and the associated risk factors: A systematic review. *Maturitas*, *107*, 78–83. https://doi.org/10.1016/j.maturitas.2017.10.003

Almousa, S., & Bandin Van Loon, A. (2019). The prevalence of urinary incontinence in nulliparous female sportswomen: A systematic review. *Journal of Sports Sciences*, *37*(14), 1663–1672. https://doi.org/10.1080/02640414.2019.1585312

Al-Shaikh, G., Al-Badr, A., Al Maarik, A., Cotterill, N., & Al-Mandeel, H. M. (2013). Reliability of Arabic ICIQ-UI short form in Saudi Arabia. *Urology Annals*, *5*(1), 34–38. https://doi.org/10.4103/0974-7796.106964

Alves, J. O., Luz, S. T. D., Brandão, S., Da Luz, C. M., Jorge, R. N., & Da Roza, T. (2017). Urinary incontinence in physically active young women: Prevalence and related factors. *International Journal of Sports Medicine*, *38*(12), 937–941. https://doi.org/10.1055/s-0043-115736

Aoki, Y., Brown, H. W., Brubaker, L., Cornu, J. N., Daly, J. O., & Cartwright, R. (2017). Urinary incontinence in women. *Nature Reviews Disease Primers*, *3*(1), 1–20. https://doi.org/10.1038/nrdp.2017.42

Ashton-Miller, J. A., Howard, D., & DeLancey, J. O. L. (2001). The functional anatomy of the female pelvic floor and stress continence control system. *Scandinavian Journal of Urology and Nephrology Supplementum*, *207*, 1–7.

Avery, K., Donovan, J., Peters, T. J., Shaw, C., Gotoh, M., & Abrams, P. (2004). ICIQ: A brief and robust measure for evaluating the symptoms and impact of urinary incontinence. *Neurourology and Urodynamics*, *23*(4), 322–330. https://doi.org/10.1002/nau.20041

Bauer, S. B., Vasquez, E., Cendron, M., Wakamatsu, M. M., & Chow, J. S. (2018). Pelvic floor laxity: A not so rare but unrecognized form of daytime urinary incontinence in peripubertal and adolescent girls. *Journal of Pediatric Urology*, *14*(6), 544.e1-544.e7. https://doi.org/10.1016/j.jpurol.2018.04.030

Beals, K. A., & Manore, M. M. (2000). Behavioral, psychological, and physical characteristics of female athletes with subclinical eating disorders. *International Journal of Sport Nutrition and Exercise Metabolism*, *10*(2), 128–143. https://doi.org/10.1123/ijsnem.10.2.128

Bedretdinova, D., Fritel, X., Panjo, H., & Ringa, V. (2016). Prevalence of female urinary incontinence in the general population according to different definitions and study designs. *European Urology*, *69*(2), 256–264. https://doi.org/10.1016/j.eururo.2015.07.043

Belushi, Z. I. A., Kiyumi, M. H. A., Al-Mazrui, A. A., Jaju, S., Alrawahi, A. H., & Mahrezi, A. M. A. (2020). Effects of home-based pelvic floor muscle training on decreasing symptoms of stress urinary incontinence and improving the quality of life of urban adult Omani women: A randomized controlled single-blind study. *Neurourology and Urodynamics*, *39*(5), 1557–1566. https://doi.org/10.1002/nau.24404

Blanca, M. J., Alarcón, R., Arnau, J., Bono, R., & Bendayan, R. (2017). Non-normal data: Is ANOVA still a valid option? *Psicothema*, *29*(4), 552–557. https://doi.org/10.7334/psicothema2016.383

Blomquist, J. L., Carroll, M., Muñoz, A., & Handa, V. L. (2020). Pelvic floor muscle strength and the incidence of pelvic floor disorders after vaginal and cesarean delivery. *American Journal of Obstetrics and Gynecology*, *222*(1), 62.e1-62.e8. https://doi.org/10.1016/j.ajog.2019.08.003

Bo, K., Berghmans, B., Morkved, S., & Kampen, M. V. (2014). *Evidence-based physical therapy for the pelvic floor - E-Book: Bridging science and clinical practice*. Elsevier Health Sciences.

Bø, K., & Sundgot-Borgen, J. (2010). Are former female elite athletes more likely to experience urinary incontinence later in life than non-athletes? *Scandinavian Journal of Medicine & Science in Sports*, *20*(1), 100–104. https://doi.org/10.1111/j.1600-0838.2008.00871.x

Bø, Kari. (2004). Urinary incontinence, pelvic floor dysfunction, exercise and sport. *Sports Medicine*, *34*(7), 451–464. https://doi.org/10.2165/00007256-200434070-00004

Brennand, E., Ruiz-Mirazo, E., Tang, S., & Kim-Fine, S. (2018). Urinary leakage during exercise: Problematic activities, adaptive behaviors, and interest in treatment for physically active Canadian women. *International Urogynecology Journal*, *29*(4), 497–503. https://doi.org/10.1007/s00192-017-3409-1

Bristol Urological Institute. (2020). *International Consultation on Incontinence Questionnaire*. https://iciq.net/

Carvalhais, A., Araújo, J., Natal Jorge, R., & Bø, K. (2019a). Urinary incontinence and disordered eating in female elite athletes. *Journal of Science and Medicine in Sport*, *22*(2), 140–144. https://doi.org/10.1016/j.jsams.2018.07.008

Carvalhais, A., Araújo, J., Natal Jorge, R., & Bø, K. (2019b). Urinary incontinence and disordered eating in female elite athletes. *Journal of Science and Medicine in Sport*, *22*(2), 140–144. https://doi.org/10.1016/j.jsams.2018.07.008

Carvalhais, A., Roza, T. D., Vilela, S., Jorge, R. N., & Bø, K. (2018). Association between physical activity level and pelvic floor muscle variables in women. *International Journal of Sports Medicine*, *39*(13), 995–1000. https://doi.org/10.1055/a-0596-7531

Casey, E. K., & Temme, K. (2017). Pelvic floor muscle function and urinary incontinence in the female athlete. *The Physician and Sportsmedicine*, *45*(4), 399–407. https://doi.org/10.1080/00913847.2017.1372677

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J. F., & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise*, *35*(8), 1381–1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB

Da Roza, T., Brandão, S., Mascarenhas, T., Jorge, R. N., & Duarte, J. A. (2015a). Volume of training and the ranking level are associated with the leakage of urine in young female trampolinists. *Clinical Journal of Sport Medicine*, *25*(3), 270–275. https://doi.org/10.1097/JSM.0000000000000129

Da Roza, T., Brandão, S., Mascarenhas, T., Jorge, R. N., & Duarte, J. A. (2015b). Urinary incontinence and levels of regular physical exercise in young women. *International Journal of Sports Medicine*, *36*(09), 776–780. https://doi.org/10.1055/s-0034-1398625

Da Roza, T., Brandão, S., Oliveira, D., Mascarenhas, T., Parente, M., Duarte, J. A., & Jorge, R. N. (2015). Football practice and urinary incontinence: Relation between morphology, function and biomechanics. *Journal of Biomechanics*, *48*(9), 1587–1592. https://doi.org/10.1016/j.jbiomech.2015.03.013

da Silva Borin, L. C. M., Nunes, F. R., & de Oliveira Guirro, E. C. (2013). Assessment of pelvic floor muscle pressure in female athletes. *PM&R*, *5*(3), 189–193. https://doi.org/10.1016/j.pmrj.2012.09.001

Danquah, I. H., Petersen, C. B., Skov, S. S., & Tolstrup, J. S. (2018). Validation of the NPAQ-short – A brief questionnaire to monitor physical activity and compliance with the WHO recommendations. *BMC Public Health*, *18*, 601–611. https://doi.org/10.1186/s12889-018-5538-y

de Araujo, M. P., Brito, L., Ejnisman, B., Sartori, M., Girão, M., & Pochini, A. (2020). Impact of quarantine due to COVID-19 on female urinary incontinence during exercise in CrossFit practitioners: An observational study. *Europe PMC*, *Ahead of print.* https://doi.org/10.21203/rs.3.rs-43711/v2

de Araujo, M. P., Parmigiano, T. R., Negra, L. G. D., Torelli, L., Carvalho, C. G. de, Wo, L., Manito, A. C. A., Girão, M. J. B. C., Sartori, M. G. F., Araujo, M. P. de, Parmigiano, T. R., Negra, L. G. D., Torelli, L., Carvalho, C. G. de, Wo, L., Manito, A. C. A., Girão, M. J. B. C., & Sartori, M. G. F. (2015). Avaliação do assoalho pélvico de atletas: Existe relação com a incontinência urinária? *Revista Brasileira de Medicina Do Esporte*, *21*(6), 442–446. https://doi.org/10.1590/1517-869220152106140065

de Gennaro, J. D., de Gennaro, C. K., Shaw, J. M., Petelenz, T. J., Nygaard, I. E., & Hitchcock, R. W. (2019). The relationship between intra-abdominal pressure and body acceleration during exercise. *Female Pelvic Medicine & Reconstructive Surgery*, *25*(3), 231–237. https://doi.org/10.1097/SPV.0000000000000523

de Mattos Lourenco, T. R., Matsuoka, P. K., Baracat, E. C., & Haddad, J. M. (2018). Urinary incontinence in female athletes: A systematic review. *International Urogynecology Journal*, *29*(12), 1757–1763. https://doi.org/10.1007/s00192-018-3629-z

de Melo Silva, R., Rodrigues, M. E. S., Puga, G. M., Dionisio, V. C., Baldon, V. S. P., & Resende, A. P. M. (2020). The relationship between running kinematics and the pelvic floor muscle function of female runners. *International Urogynecology Journal*, *31*(1), 155–163. https://doi.org/10.1007/s00192-019-03968-z

Dias, N., Peng, Y., Khavari, R., Nakib, N. A., Sweet, R. M., Timm, G. W., Erdman, A. G., Boone, T. B., & Zhang, Y. (2017). Pelvic floor dynamics during high-impact athletic activities: A computational modeling study. *Clinical Biomechanics*, *41*, 20–27. https://doi.org/10.1016/j.clinbiomech.2016.11.003

Dietze-Hermosa, M., Hitchcock, R., Nygaard, I. E., & Shaw, J. M. (2020). Intra-abdominal pressure and pelvic floor health: Should we be thinking about this relationship differently? *Female Pelvic Medicine & Reconstructive Surgery*, *26*(7), 409–414. https://doi.org/10.1097/SPV.0000000000000799

Dillman, D. A. (2011). *Mail and Internet Surveys: The Tailored Design Method -- 2007 Update with New Internet, Visual, and Mixed-Mode Guide*. John Wiley & Sons.

Dobrowolski, S. L., Pudwell, J., & Harvey, M.-A. (2020). Urinary incontinence among competitive rope-skipping athletes: A cross-sectional study. *International Urogynecology Journal*, *31*(5), 881–886. https://doi.org/10.1007/s00192-019-04048-y

dos Santos, K. M., Da Roza, T., da Silva, L. L., Wolpe, R. E., da Silva Honório, G. J., & Tonon da Luz, S. C. (2018). Female sexual function and urinary incontinence in nulliparous athletes: An exploratory study. *Physical Therapy in Sport*, *33*, 21–26. https://doi.org/10.1016/j.ptsp.2018.06.004

dos Santos, K. M., Da Roza, T., Mochizuki, L., Arbieto, E. R. M., & Tonon da Luz, S. C. (2019). Assessment of abdominal and pelvic floor muscle function among continent and incontinent athletes. *International Urogynecology Journal*, *30*(5), 693–699. https://doi.org/10.1007/s00192-018-3701-8

Elks, W., Jaramillo-Huff, A., Barnes, K. L., Petersen, T. R., & Komesu, Y. M. (2020). The stress urinary incontinence in CrossFit (SUCCeSS) study. *Female Pelvic Medicine & Reconstructive Surgery*, *26*(2), 101–106.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Ferreira, S., Ferreira, M., Carvalhais, A., Santos, P. C., Rocha, P., Brochado, G., Ferreira, S., Ferreira, M., Carvalhais, A., Santos, P. C., Rocha, P., & Brochado, G. (2014). Reeducation of pelvic floor muscles in volleyball athletes. *Revista Da Associação Médica Brasileira*, *60*(5), 428–433. https://doi.org/10.1590/1806-9282.60.05.010

Goldstick, O., & Constantini, N. (2014). Urinary incontinence in physically active women and female athletes. *British Journal of Sports Medicine*, *48*(4), 296–298. https://doi.org/10.1136/bjsports-2012-091880

Gotoh, M., Homma, Y., Funahashi, Y., Matsukawa, Y., & Kato, M. (2009). Psychometric validation of the Japanese version of the International Consultation on Incontinence Questionnaire-Short Form. *International Journal of Urology*, *16*(3), 303–306. https://doi.org/10.1111/j.1442-2042.2008.02237.x

Gram, M. C. D., & Bø, K. (2020). High level rhythmic gymnasts and urinary incontinence: Prevalence, risk factors, and influence on performance. *Scandinavian Journal of Medicine & Science in Sports*, *30*(1), 159–165. https://doi.org/10.1111/sms.13548

Gyhagen, M., Bullarbo, M., Nielsen, T. F., & Milsom, I. (2013). The prevalence of urinary incontinence 20 years after childbirth: A national cohort study in singleton primiparae after vaginal or caesarean delivery. *BJOG: An International Journal of Obstetrics & Gynaecology*, *120*(2), 144–151. https://doi.org/10.1111/j.1471-0528.2012.03301.x

Hagovska, M., Ján, Š., Buková, A., Horbacz, A., Dračková, D., Švihrová, V., & Kraus, L. (2017). Prevalence of urinary incontinence in females performing high-impact exercises. *International Journal of Sports Medicine*, *38*(3), 210–216. https://doi.org/10.1055/s-0042-123045

Hagovska, M., Svihra, J., Bukova, A., Horbacz, A., & Svihrova, V. (2018). The impact of physical activity measured by the International Physical Activity Questionnaire on the prevalence of stress urinary incontinence in young women. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *228*, 308–312. https://doi.org/10.1016/j.ejogrb.2018.07.011

Hagovska, Magdaléna, Švihra, J., Buková, A., Dračková, D., & Švihrová, V. (2018). Prevalence and risk of sport types to stress urinary incontinence in sportswomen: A cross-sectional study. *Neurourology and Urodynamics*, *37*(6), 1957–1964. https://doi.org/10.1002/nau.23538

Hajebrahimi, S., Corcos, J., & Lemieux, M. C. (2004). International consultation on incontinence questionnaire short form: Comparison of physician versus patient completion and immediate and delayed self-administration. *Urology*, *63*(6), 1076–1078. https://doi.org/10.1016/j.urology.2004.01.005

Hajebrahimi, Sakineh, Nourizadeh, D., Hamedani, R., & Pezeshki, M. Z. (2012). Validity and reliability of the International Consultation on Incontinence Questionnaire-Urinary Incontinence Short Form and its correlation with urodynamic findings. *Urology Journal*, *9*(4), 685–690. https://doi.org/10.22037/uj.v9i4.1800

Haylen, B. T., de Ridder, D., Freeman, R. M., Swift, S. E., Berghmans, B., Lee, J., Monga, A., Petri, E., Rizk, D. E., Sand, P. K., & Schaer, G. N. (2010). An international urogynecological association (IUGA)/international continence society (ICS) joint report on the terminology for female pelvic floor dysfunction. *Neurourology and Urodynamics*, *29*(1), 4–20. https://doi.org/10.1002/nau.20798

High, R., Thai, K., Virani, H., Kuehl, T., & Danford, J. (2020). Prevalence of pelvic floor disorders in female CrossFit athletes. *Female Pelvic Medicine & Reconstructive Surgery*, *26*(8), 498–502. https://doi.org/10.1097/SPV.0000000000000776

Hodges, P., Schabrun, S., & Stafford, R. (2010). Pelvic floor muscles have greater central fatigue during voluntary contractions than muscles of the limbs. *Abstracts from the Joint Meeting of the International Continence Society and the International Urogynecological Association*, *21*, S206–S207.

Huang, L., Zhang, S., Wu, S., Ma, L., & Deng, X. (2008). The Chinese version of ICIQ: A useful tool in clinical practice and research on urinary incontinence. *Neurourology and Urodynamics*, *27*(6), 522–524. https://doi.org/10.1002/nau.20546

Irick, E. (2019). *Student-athlete participation 1981-82-2018-19: NCAA sports sponsorship and participation rates report.* National Collegiate Athletic Association. https://ncaaorg.s3.amazonaws.com/research/sportpart/2018-19RES_SportsSponsorshipParticipationRatesReport.pdf

Jung, J., Ahn, H. K., & Huh, Y. (2012). Clinical and functional anatomy of the urethral sphincter. *International Neurourology Journal*, *16*(3), 102–106. https://doi.org/10.5213/inj.2012.16.3.102

Karantanis, E., Fynes, M., Moore, K. H., & Stanton, S. L. (2004). Comparison of the ICIQ-SF and 24-hour pad test with other measures for evaluating the severity of urodynamic stress incontinence. *International Urogynecology Journal and Pelvic Floor Dysfunction*, *15*(2), 111—6; discussion 116. https://doi.org/10.1007/s00192-004-1123-2

Karmakar, D., Mostafa, A., & Abdel-Fattah, M. (2017). A new validated score for detecting patient-reported success on postoperative ICIQ-SF: A novel two-stage analysis from two large RCT cohorts. *International Urogynecology Journal*, *28*(1), 95–100. https://doi.org/10.1007/s00192-016-3070-0

Klovning, A., Avery, K., Sandvik, H., & Hunskaar, S. (2009). Comparison of two questionnaires for assessing the severity of urinary incontinence: The ICIQ-UI SF versus the incontinence severity index. *Neurourology and Urodynamics*, *28*(5), 411–415. https://doi.org/10.1002/nau.20674

Knapp, J., Aerni, G., & Anderson, J. (2014). Eating disorders in female athletes: Use of screening tools. *Current Sports Medicine Reports*, *13*(4), 214–218. https://doi.org/10.1249/JSR.0000000000000074

Lasak, A. M., Jean-Michel, M., Le, P. U., Durgam, R., & Harroche, J. (2018). The role of pelvic floor muscle training in the conservative and surgical management of female stress urinary incontinence: Does the strength of the pelvic floor muscles matter? *PM&R*, *10*(11), 1198–1210. https://doi.org/10.1016/j.pmrj.2018.03.023

Lee, P. H., Macfarlane, D. J., Lam, T., & Stewart, S. M. (2011). Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *8*(1), 115. https://doi.org/10.1186/1479-5868-8-115

Lim, R., Liong, M. L., Lau, Y. K., & Yuen, K. H. (2017). Validity, reliability, and responsiveness of the ICIQ-UI SF and ICIQ-LUTSqol in the Malaysian population. *Neurourology and Urodynamics*, *36*(2), 438–442. https://doi.org/10.1002/nau.22950

Logan, B. L., Foster-Johnson, L., & Zotos, E. (2018). Urinary incontinence among adolescent female athletes. *Journal of Pediatric Urology*, *14*(3), 241.e1-241.e9. https://doi.org/10.1016/j.jpurol.2017.12.018

Logue, D., Madigan, S. M., Delahunt, E., Heinen, M., Mc Donnell, S.-J., & Corish, C. A. (2018). Low energy availability in athletes: A review of prevalence, dietary patterns, physiological health, and sports performance. *Sports Medicine*, *48*(1), 73–96. https://doi.org/10.1007/s40279-017-0790-3

Marques, A., Stothers, L., & Macnab, A. (2010). The status of pelvic floor muscle training for women. *Canadian Urological Association Journal*, *4*(6), 419–424.

Middlekauff, M. L., Egger, M. J., Nygaard, I. E., & Shaw, J. M. (2016). The impact of acute and chronic strenuous exercise on pelvic floor muscle strength and support in nulliparous healthy women. *American Journal of Obstetrics and Gynecology*, *215*(3), 316.e1-316.e7. https://doi.org/10.1016/j.ajog.2016.02.031

Miller, J. M., Perucchini, D., Carchidi, L. T., DeLancey, J. O. L., & Ashton-Miller, J. (2001). Pelvic floor muscle contraction during a cough and decreased vesical neck mobility. *Obstetrics & Gynecology*, *97*(2), 255–260. https://doi.org/10.1016/S0029-7844(00)01132-7

Milsom, I., & Gyhagen, M. (2019). The prevalence of urinary incontinence. *Climacteric*, *22*(3), 217–222. https://doi.org/10.1080/13697137.2018.1543263

Minassian, V. A., Bazi, T., & Stewart, W. F. (2017). Clinical epidemiological insights into urinary incontinence. *International Urogynecology Journal*, *28*(5), 687–696. https://doi.org/10.1007/s00192-017-3314-7

Mistry, M. A., Klarskov, N., DeLancey, J. O., & Lose, G. (2020). A structured review on the female urethral anatomy and innervation with an emphasis on the role of the urethral longitudinal smooth muscle. *International Urogynecology Journal*, *31*(1), 63–71. https://doi.org/10.1007/s00192-019-04104-7

Nygaard, I. E., Glowacki, C., & Saltzman, C. L. (1996). Relationship between foot flexibility and urinary incontinence in nulliparous varsity athletes. *Obstetrics & Gynecology*, *87*(6), 1049–1051. https://doi.org/10.1016/0029-7844(96)00079-8

Nygaard, I. E., Shaw, J. M., Bardsley, T., & Egger, M. J. (2015). Lifetime physical activity and female stress urinary incontinence. *American Journal of Obstetrics and Gynecology*, *213*(1), 40.e1-40.e10. https://doi.org/10.1016/j.ajog.2015.01.044

Pereira, F. da S., Haupenthal, A., Roza, T. H. D., Mazo, G. Z., & Virtuoso, J. F. (n.d.). Urine loss during a volleyball competition: Comparison between amateur and professional athletes. *PM&R*, *n/a*(n/a). https://doi.org/10.1002/pmrj.12502

Pires, T., Pires, P., Moreira, H., & Viana, R. (2020). Prevalence of urinary incontinence in high-impact sport athletes: A systematic review and meta-analysis. *Journal of Human Kinetics*, *73*(1), 279–288. https://doi.org/10.2478/hukin-2020-0008

Poli de Araújo, M., Brito, L. G., Rossi, F., Garbiere, M. L., Vilela, M. E., & Bittencourt, V. F. (2020). Prevalence of female urinary incontinence in Crossfit practitioners and associated factors: An internet population-based survey. *Female Pelvic Medicine & Reconstructive Surgery*, *26*(2), 97–100. https://doi.org/10.1097/SPV.0000000000000823

Rebullido, T. R., & Stracciolini, A. (2019). Pelvic floor dysfunction in female athletes: Is relative energy deficiency in sport a risk factor? *Current Sports Medicine Reports*, *18*(7), 255–257. https://doi.org/10.1249/JSR.0000000000000615

Ree, M. L., Nygaard, I., & Bø, K. (2007). Muscular fatigue in the pelvic floor muscles after strenuous physical activity. *Acta Obstetricia et Gynecologica Scandinavica*, *86*(7), 870–876. https://doi.org/10.1080/00016340701417281

Sandwith, E., & Robert, M. (2021). Rug-pee study: The prevalence of urinary incontinence among female university rugby players. *International Urogynecology Journal*, *32*(2), 281–285. https://doi.org/10.1007/s00192-020-04510-2

Schettino, M. T., Mainini, G., Ercolano, S., Vascone, C., Scalzone, G., D'Assisi, D., Tormettino, B., Gimigliano, F., Esposito, E., Di Donna, M. C., Colacurci, N., & Torella, M. (2014). Risk of pelvic floor dysfunctions in young athletes. *Clinical and Experimental Obstetrics & Gynecology*, *41*(6), 671–676.

Simeone, C., Moroni, A., Pettenò, A., Antonelli, A., Zani, D., Orizio, C., & Cosciani Cunico, S. (2010). Occurrence rates and predictors of lower urinary tract symptoms and incontinence in female athletes. *Urologia*, *77*(2), 139–146.

Skaug, K. L., Engh, M. E., Frawley, H., & Bø, K. (2020). Prevalence of pelvic floor dysfunction, bother and risk factors and knowledge of the pelvic floor muscles in Norwegian male and female powerlifters and Olympic weightlifters. *Journal of Strength and Conditioning Research*. https://doi.org/10.1519/JSC.0000000000003919

Stothers, L., & Friedman, B. (2011). Risk factors for the development of stress urinary incontinence in women. *Current Urology Reports*, *12*(5), 363. https://doi.org/10.1007/s11934-011-0215-z

Teixeira, R. V., Colla, C., Sbruzzi, G., Mallmann, A., & Paiva, L. L. (2018). Prevalence of urinary incontinence in female athletes: A systematic review with meta-analysis. *International Urogynecology Journal*, *29*(12), 1717–1725. https://doi.org/10.1007/s00192-018-3651-1

Teleman, P. M., Gunnarsson, M., Lidfeldt, J., Nerbrand, C., Samsioe, G., & Mattiasson, A. (2003). Urethral pressure changes in response to squeeze: A population-based study in healthy and incontinent 53- to 63-year-old women. *American Journal of Obstetrics and Gynecology*, *189*(4), 1100–1105. https://doi.org/10.1067/S0002-9378(03)00539-8

Teng, M., Kervinio, F., Moutounaïck, M., Miget, G., Charlanes, A., Chesnel, C., Breton, F. [Le, & Amarenco, G. (2018). Review of pelvic and perineal neuromuscular fatigue: Evaluation and impact on therapeutic strategies. *Annals of Physical and Rehabilitation Medicine*, *61*(5), 345–351. https://doi.org/10.1016/j.rehab.2018.06.006

The IPAQ Group. (2020). *International Physical Activity Questionnaire*. https://sites.google.com/site/theipaq/home

Tubaro, A., Zattoni, F., Prezioso, D., Scarpa, R. M., Pesce, F., Rizzi, C. A., Santini, A. M., Simoni, L., Artibani, W., & Flow Study Group. (2006). Italian validation of the International Consultation on Incontinence Questionnaires. *BJU International*, *97*(1), 101–108. https://doi.org/10.1111/j.1464-410X.2006.05885.x

United States Department of Justice. (2015, August 6). *Title Ix of the education amendments of 1972*. https://www.justice.gov/crt/title-ix-education-amendments-1972

Ural, Ü. M., Gücük, S., Ekici, A., & Topçuoğlu, A. (2020). Urinary incontinence in female university students. *International Urogynecology Journal*. https://doi.org/10.1007/s00192-020-04360-y

Vignoli, G. (2018). Physiology of micturition in female. In G. Vignoli (Ed.), *Urodynamics for urogynecologists: A pocket guide for clinical practice* (pp. 1–15). Springer International Publishing. https://doi.org/10.1007/978-3-319-74005-8_1

Vitton, V., Baumstarck-Barrau, K., Brardjanian, S., Caballe, I., Bouvier, M., & Grimaud, J. C. (2011). Impact of high-level sport practice on anal incontinence in a healthy young female population. *Journal of Women's Health (2002)*, *20*(5), 757–763. https://doi.org/10.1089/jwh.2010.2454

Whitney, K. E., Holtzman, B., Parziale, A., & Ackerman, K. E. (2019). Urinary incontinence is more common in adolescent female athletes with low energy availability. *Orthopaedic Journal of Sports Medicine*, *7*(3), 2325967119S00115. https://doi.org/10.1177/2325967119S00115

Wikander, L., Cross, D., & Gahreman, D. E. (2019). Prevalence of urinary incontinence in women powerlifters: A pilot study. *International Urogynecology Journal*, *30*(12), 2031–2039. https://doi.org/10.1007/s00192-019-03870-8

Yang, J., Cheng, J. W., Wagner, H., Lohman, E., Yang, S. H., Krishingner, G. A., Trofimova, A., Alsyouf, M., & Staack, A. (2019). The effect of high impact crossfit exercises on stress urinary incontinence in physically active women. *Neurourology and Urodynamics*, *38*(2), 749–756. https://doi.org/10.1002/nau.23912

Table 1

Collegiate Sport Participation, Adjusted for Multiple Sports

Sport	Frequency	Percent
Basketball	10	4.8
Cheerleading	2	1.0
Soccer	37	17.7
Lacrosse	19	9.1
Tennis	15	7.2
Volleyball	18	8.6
Cross Country	20	9.6
Track & Field	26	12.4
Softball	38	18.2
Golf	6	2.9
Swimming and/or Diving	18	8.6
Total	209	100.0

Note: Of the 12 athletes that participated in >1 collegiate sport, 11 participated in Track & Field and Cross Country, while one participated in Tennis and Lacrosse. Both Track & Field and Cross Country and Tennis and Lacrosse were classified as the same impact level, thus were coded as Cross Country and Tennis, respectively for the data analyses.

Table 2

Characteristics of Study Participants

	Mean	Std Dev
Demographics (n = 209)		
Age (years)	20.19	1.47
Weight (lbs)	145.76	23.1
Height (in)	65.76	3.35
BMI	23.74	3.35
Prevalence of Urinary Incontinence (n=208)	**Percentage**	
Any type UI (n = 94)	45.00%	
SUI (n = 74)	35.40%	
Disordered Eating		
Yes (n = 120)	57.4%	
No (n = 75)	35.9%	
Unsure (n = 13)	6.2%	
Sport Impact Level		
Low (n = 24)	11.5%	
Moderate (n = 84)	40.2%	
High (n = 101)	48.3%	

Figure 1

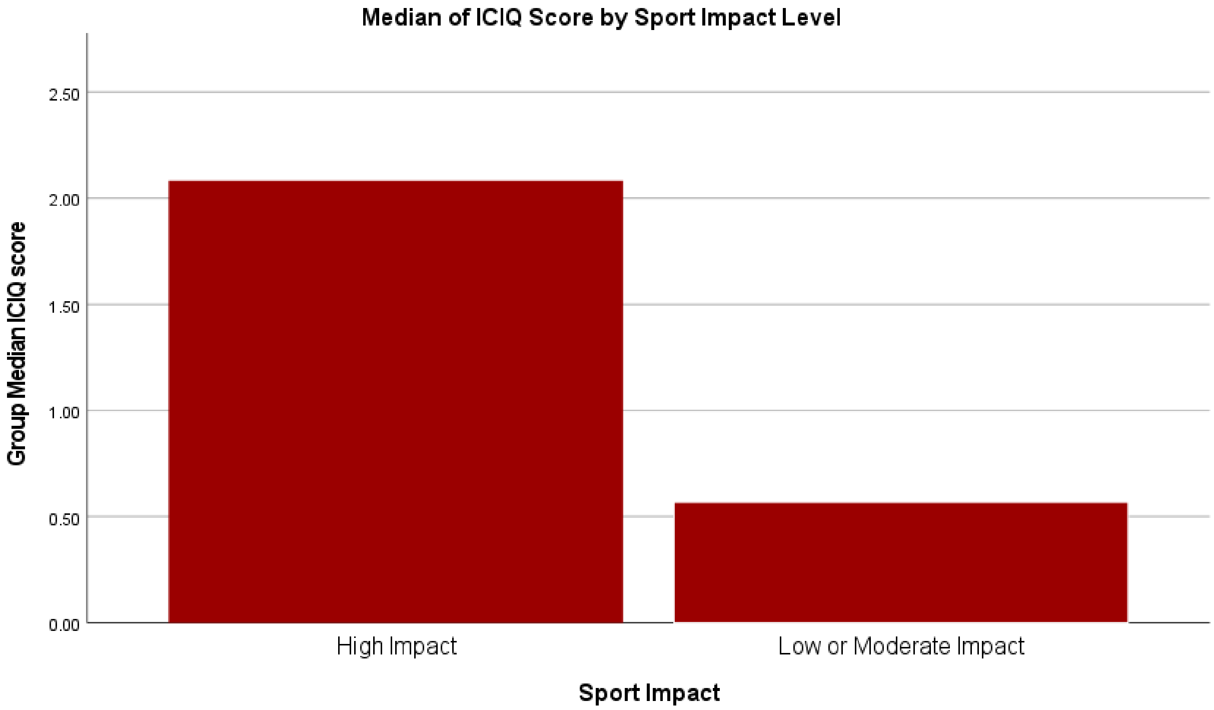
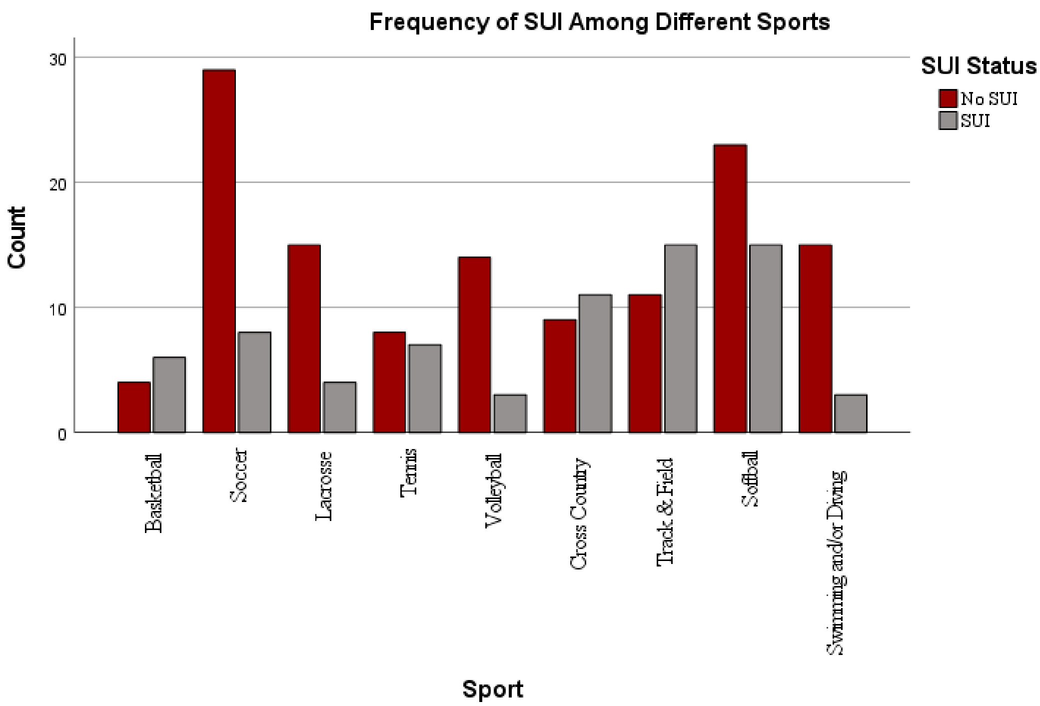

Median of ICIQ Score by Sport Impact Level
Group Median ICIQ score
2.50
2.00
1.50
1.00
0.50
0.00
High Impact
Low or Moderate Impact
Sport Impact

Figure 2


Frequency of SUI Among Different Sports
SUI Status
No SUI
SUI
Count
30
20
10
0
Basketball
Soccer
Lacrosse
Tennis
Volleyball
Cross Country
Track & Field
Softball
Swimming and/or Diving
Sport

Appendix A

Permission for Use for ICIQ-UI SF

11/11/2020 University of Indianapolis Mail - Rebeccaparrpt

Becky Parr <parrr@uindy.edu>

Rebeccaparrpt

ICIQ <ICIQ@nbt.nhs.uk> Fri, Nov 6, 2020 at 8:50 AM
To: Becky Parr <parrr@uindy.edu>

Dear Dr. Parr,

Thank you for your email. You may download the ICIQ-UI SF for your new project as it is still for academic purposes so there is no fee. Please let me know if there is anything else I can help with.

Kind regards,

Megan

Megan Pardoe

Research Assistant

Bristol Urological Institute

3rd Floor Learning and Research

Southmead Hospital

Bristol

BS10 5NB

UK

Appendix B

The ICIQ UI SF instrument

ICIQ-UI Short Form (US English)

CONFIDENTIAL

Subject number ☐☐☐☐☐ Subject initial ☐☐☐

Today's date: D D / M M M / Y Y

Many people leak urine some of the time. We are trying to find out how many people leak urine, and how much this bothers them. We would be grateful if you could answer the following questions, thinking about how you have been, on average, over the PAST FOUR WEEKS.

1 Please write in your date of birth: DAY ☐☐ MONTH ☐☐☐ YEAR ☐☐

2 Are you *(check one)*: Female ☐ Male ☐

3 How often do you leak urine? *(Check one box)*

never	☐	0
about once a week or less often	☐	1
two or three times a week	☐	2
about once a day	☐	3
several times a day	☐	4
all the time	☐	5

4 We would like to know how much urine <u>you think</u> leaks.
How much urine do you <u>usually</u> leak (whether you wear protection or not)?
(Check one box)

none	☐	0
a small amount	☐	2
a moderate amount	☐	4
a large amount	☐	6

5 Overall, how much does leaking urine interfere with your everyday life?
Please circle a number between 0 (not at all) and 10 (a great deal)

0 1 2 3 4 5 6 7 8 9 10

not at all ... a great deal

ICIQ score: sum scores 3+4+5 ☐ ☐

6 When does urine leak? *(Please check all that apply to you)*

never – urine does not leak	☐
leaks before you can get to the bathroom	☐
leaks when you cough or sneeze	☐
leaks when you are asleep	☐
leaks when you are physically active/exercising	☐
leaks when you have finished urinating and are dressed	☐
leaks for no obvious reason	☐
leaks all the time	☐

Thank you very much for answering these questions.

Appendix C

The International Physical Activity Questionairre

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

_____ **days per week**

☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ **days per week**

☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

SHORT LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised August 2002.

Appendix D

Online Survey Consent Form
Sport Variables and Stress Urinary Incontinence Among Nulliparous Collegiate Athletes

Start of Block: Informed Consent

Consent You are invited to participate in a research study. This study is focused on the training variables that may be related to urinary leakage in the female athlete. The purpose of this study is to better understand how different aspects of sport training can influence urinary leakage (pee accidents) that occur during exercise.
We are inviting you to participate in this study because you are a female collegiate athlete. If you agree to participate in this study, you will be asked to complete a one-time web-based survey regarding your physical exercise, sport, and urinary leakage. We will also ask some demographic questions. The survey should take no longer than 10 minutes to complete. You will receive an initial invitation to participate along with reminders, when possible, to complete this survey. Participation in the survey is optional, and if you wish to cease participation, you are free to do so without penalty. If you do not wish to participate in this study, simply do not complete the study. If you do not wish to answer any questions, you may stop the survey at any time.
The survey does not collect any personal identifiers and, therefore, the information gathered will be anonymous. You will not benefit personally from participating in this study. However, we hope that others may benefit in the future from what we learn as a result of this study. This study does not expose you to any more risk than you would experience in everyday life, however some questions may make you feel uncomfortable.

CONSENT TO PARTICIPATE IN RESEARCH STUDY
Sport Variables and Stress Urinary Incontinence Among Nulliparous Collegiate AthletesStudy Principal Investigator (PI): Ed Jones, PT, DHScUIndy Email: joneser@uindy.eduUIndy Telephone: 317-788-8013
Ed Jones, PT, DHSc from the Krannert School of Physical at the University of Indianapolis (UIndy) and Rebecca Parr, PT, DPT, OCS from the Department of Interprofessional Health & Aging Studies at the University of Indianapolis (UIndy) are conducting a research study.
You were selected as a possible participant in this study because you are a female athlete playing a collegiate sport in the 2020-2021 season. Your participation in this research study is voluntary.
Why is this study being done?The results of the research may help researchers understand the variables that lead to urinary leakage during sport which could lead to improved screening and preventative treatment for this condition. With early identification, rapid intervention could potentially prevent SUI from progressing to a more significant problem later in life.
What will happen if I take part in this research study?
If you volunteer to participate in this study, the researcher will ask you to do the following:
- Perform a ten-minute online survey

How long will I be in the research study?
Participation will take a total of about ten minutes

Are there any potential risks or discomforts that I can expect from this study?
Questions regarding urinary leakage or disordered eating may make you feel uncomfortable or embarrassed. You can skip items if you would prefer not to answer a question. All information will be collected in an anonymous manner (no names or IP addresses collected) and only research team members will have access to data.
Are there any potential benefits if I participate?
While there are no direct benefits from participating in this study, you may experience personal benefits from participating in a study that have the potential to improve the lives of others.
What other choices do I have if I do not wish to participate?Participation is voluntary. If you choose not to participate in this study, there is not a penalty.
Will I be paid for participating?
You may enter a drawing to win one of five $50 gift cards
Will information about me and my participation be kept confidential? The results of this study may be published in a scholarly book or journal, presented at professional conferences or used for teaching purposes. However, only aggregate data will be used. Personal identifiers will not be collected and thus cannot be used in any publication, presentation or teaching materials.Will the data from my study be used in the future for other studies?It is possible that de-identified data from this study could be used for future research or shared with other researchers for use in studies, without additional informed consent. De-identified means that any codes and personal information that could identify you will be removed before the data is shared.
What are my rights if I take part in this study?
• You can choose whether or not you want to be in this study, and you may withdraw your consent and discontinue participation at any time.• Whatever decision you make, there will be no penalty to you, and no loss of benefits to which you were otherwise entitled. • You may refuse to answer any question/s that you do not want to answer and still remain in the study.
Who can I contact if I have questions about this study?
If you have any questions, comments or concerns about the research, you can talk to the one of the researchers. Please contact:
The principal investigator Ed Jones, PT, DHSc at joneser@uindy.eduThe study coordinator Rebecca Parr, PT, DPT, OCS at parrr@uindy.edu
Additionally, you can contact the Director of the Human Research Protections Program (HRPP):If you have questions about your rights as a research participant, or you have concerns or suggestions and you want to talk to someone other than the researchers, you may contact the Director of the Human Research Protections Program, by either emailing hrpp@uindy.edu or calling 1 (317) 781-5774 or 1 (800) 232-8634 ext. 5774.
How do I indicate my informed consent to participate in this study?
If you consent to participate in this study, then you affirm that you satisfy inclusion criteria and your consent is voluntary. Inclusion criteria include being age 18 years of age or older, a female athlete engaged in collegiate athletics and no current or prior pregnancy. To indicate your voluntary consent and proceed with the questionnaire, select one of the following options:

- [ ] I voluntarily consent to participate in this study (1)
- [ ] I do NOT consent to participate in this study (2)

Skip To: End of Survey If You are invited to participate in a research study. This study is focused on the training variabl... = I do NOT consent to participate in this study

Appendix E

Online Survey

Sport What competitive sport do you play for your college/university?

- ◯ Basketball (14)
- ◯ Cheerleading/STUNT (15)
- ◯ Soccer (16)
- ◯ Lacrosse (17)
- ◯ Tennis (18)
- ◯ Volleyball (19)
- ◯ Cross Country (20)
- ◯ Track & Field (21)
- ◯ Softball (22)
- ◯ Golf (23)
- ◯ Swimming and/or Diving (24)
- ◯ I play more than one competitive sport (25)
- ◯ I do not play a competitive sport for my college/university (26)

Skip To: End of Survey If What competitive sport do you play for your college/university? = I do not play a competitive sport for my college/university

Display This Question:
If What competitive sport do you play for your college/university? = I play more than one competitive sport

Multiple Sports What sports do you play for your university?

____

*

YearsSport How many years have you participated in that particular sport? (not just in college)

____

Page Break

Q4 The next few questions will ask about your physical activity in the last week (7 days). Please think of all the time you spent being physically active, **both in your sport practice/competition and outside of sport activities.**

Page Break

DaysVigEx Think about all the vigorous activities that you did in the **last 7 days**. **Vigorous** activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only of those activities that you did for at least 10 minutes at a time.
During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, fast bicycling, running, or aerobics?

- ○ 1 day (1)
- ○ 2 days (2)
- ○ 3 days (3)
- ○ 4 days (4)
- ○ 5 days (5)
- ○ 6 days (6)
- ○ 7 days (7)
- ○ I did not do any vigorous activity (8)

Skip To: DaysModEx If Think about all the vigorous activities that you did in the last 7 days. Vigorous activities refe... = I did not do any vigorous activity

HoursVigEx 1. How much time did you usually spend doing vigorous exercise on **one** of those days?
Please type the length of time in hours, e.g. 2 hours and 30 minutes would be entered as "2.5"

____

Page Break

DaysModEx Think about all the moderate activities you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those activities you did for at least 10 minutes at a time.

During the **last 7 days**, how many days did you do moderate physical activities like bicycling at regular pace or doubles tennis? Do not include walking.

○ 1 day (1)

○ 2 days (2)

○ 3 days (3)

○ 4 days (4)

○ 5 days (5)

○ 6 days (6)

○ 7 days (7)

○ I did not do any moderate activities (8)

Skip To: DaysWalk If Think about all the moderate activities you did in the last 7 days. Moderate activities refer to... = I did not do any moderate activities

*

HoursModEx How much time did you usually spend doing **moderate** exercise on one of those days?
Please type the length of time in hours, e.g. 2 hours and 30 minutes would be entered as "2.5"

____

DaysWalk Think about all the time you spent walking in the last 7 days. This includes at work, at home, at school, walking to travel from place to place, and any other walking that you have done

solely for recreation, sport, exercise, or leisure.
During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

○ 1 day (1)

○ 2 days (2)

○ 3 days (3)

○ 4 days (4)

○ 5 days (5)

○ 6 days (6)

○ 7 days (7)

HoursWalk How much time did you usually spend walking on one of those days?
Please type the length of time in hours, e.g. 2 hours and 30 minutes would be entered as "2.5"

____

HoursSit This question is about the time you spent sitting on **weekdays** in the last 7 days. Include time spent at work, at home, while doing coursework and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch TV.
During the last 7 days, how much time did you spend sitting on **1 WEEK DAY**?
Please type the length of time in hours, e.g. 2 hours and 30 minutes would be entered as "2.5"

____

Page Break

UIFreq These next questions will ask you about *any* urine leakage ("pee accidents") that you may experience.

How often do you leak urine?

- ○ Never (0)
- ○ About once a week or less often (1)
- ○ Two or three times a week (2)
- ○ About once a day (3)
- ○ Several times a day (4)
- ○ All the time (5)

UIAmount We would like to know how much urine <u>you think</u> leaks. How much urine do you <u>usually</u> leak (whether you wear protection or not)?

- ○ None (0)
- ○ A small amount (2)
- ○ A moderate amount (4)
- ○ A large amount (6)

UIQOL How much does leaking urine interfere with your everyday life?
Please select a number between 0 (not at all) and 10 (a great deal)

	0 10
Please select a number between 0 (not at all) and 10 (a great deal) ()	

UIWhen When does urine leak? Please mark all that apply to you)

- ☐ Never-urine does not leak (1)
- ☐ Leaks before you can get to the toilet (2)
- ☐ Leaks when you cough or sneeze (3)
- ☐ Leaks when you are asleep (4)
- ☐ Leaks when you are physically active/exercising (5)
- ☐ Leaks when you have finished urinating and are dressed (6)
- ☐ Leaks for no obvious reason (7)
- ☐ Leaks all the time (8)

Page Break

DisEat Do any of the below statements seem like you?

- I am preoccupied with food or body weight
- I have a distorted body image
- My body weight influences my self-esteem
- I have an intense fear of weight gain
- I have attempted to lose weight through an extreme method
- I use rules to govern my eating and I hate myself if I break a rule
- I have menstrual dysfunction, such as missing periods

○ Yes (1)

○ No (2)

○ Unsure (3)

Page Break

*

Age These next questions will collect demographic information.

What is your age in years?

____

*

Weight What is your weight in pounds?

____

*

Height What is your height in inches? e.g. 5'5 would be 65 inches

____

End of Block: Informed Consent

Appendix F

Recruitment Email

Subject line of email: Research Study on Student-Athletes, Chance to Win a $50 Gift Card

Hello University of ****** Student-Athlete,

We hope you will participate in this research study, *Sport Variables and Stress Urinary Incontinence Among Nulliparous Collegiate Athletes Study*. The purpose of this study is to explore the influence of sports characteristics on stress urinary incontinence in female collegiate athletes. As a female collegiate athlete, you are in a unique position to provide information on these variables *whether or not* you experience urinary leakage, which can be used to help other athletes in the future.

Your participation in this research study is strictly voluntary but is very important in contributing to our understanding of issues affecting female collegiate athletes.

Key Points

- It should only take 10 minutes
- For your time, you will be **entered to win a $50 gift card**
- Your participation in this survey is completely voluntary and all your responses are anonymous. None of the responses will be connected to identifying information.

Please complete this survey by **Friday, February 26, 2021**.

Take the survey now

If you have any questions about this survey, or difficulty in accessing the site or completing the survey, please contact Dr. Rebecca Parr, the study coordinator, at parrr@uindy.edu

Thank you for your participation in this important research.

Sincerely,

Dr. Rebecca Parr
University of Indianapolis
Doctor of Health Science Program
(269) 274-7043
parrr@uindy.edu