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KNEE PAIN AMONG SPIKEBALL ATHLETES AND ITS RELATIONSHIP WITH SEX: BASIS FOR AN INJURY PREVENTION PROTOCOL

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Abstract

Spikeball, a growing sport blending volleyball and handball, attracts competitive and casual players. The game requires pivoting and abrupt leg movements, posing players at risk of developing knee injuries while also considering the contribution of biological differences to the prevalence of knee injuries. This study explored knee pain prevalence among 35 spikeball athletes (17 male, 18 female) and sought to understand its relationship with sex and develop injury prevention strategies through a novel protocol. The study used a cross-sectional, correlational research design that took a quantitative approach. Purposive sampling was used to gather respondents, and a self-made questionnaire was utilized, conducted both online and face-to-face. The Chi-squared test, regression, and frequency analysis revealed no significant relationship between knee pain and sex, but older female spikeball athletes with higher body mass indexes (BMI) tended to be more prone to knee pain. The study suggests the need for further research due to the limited sample size, aiming to develop a more effective injury prevention protocol. Specific findings suggested that any pre-game and post-game activities performed at 1-10 minutes was associated with a lower likelihood of knee pain among spikeball athletes.

Keywords: spikeball, athletes, sex, knee pain, injury prevention protocol

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Research Highlights

What is the current knowledge?

- There are little to no studies currently available about spikeball or roundnet and the injuries related to the sport.
- Knee pain or knee injuries are the most common sports-related injuries and have been found to be associated with differences in sex, with women being more affected than men depending on the type of sport, although this is still unclear based on some contradicting studies.
- In Dumaguete City, Negros Oriental in the Philippines, spikeball has become increasingly popular but currently is not reinforced with evidence-based information or injury prevention protocols.

What is new in this study?

- Through a correlational, quantitative approach this study provides information regarding the already well-studied relationship between sex and sports-related knee pain but with a focus on spikeball in Dumaguete City.
- The findings indicated that there was no significant relationship between knee pain and sex in spikeball athletes. Regression studies showed that among female spikeball athletes, increasing age and body mass index (BMI) were predictors of the occurrence of knee pain.
- Based on the generated injury prevention protocol for knee pain in spikeball derived from regression and frequency analysis findings, strengthening, running, stretching, jumping, and endurance-based exercises were recommended as pre-game activities while dynamic stretching, strengthening, relaxation, low-intensity endurance, and spikeball-specific cooldowns were recommended for post-game. During the game, twisting motions during service and attack, bending- down to defend, squatted posturing, and excessive pivoting were recommended to be avoided.

INTRODUCTION

Knee pain is one of the usual complaints among young active athletes and the most common factor in overuse injury in both competitive and recreational sports, as mentioned in a study by Patel et al. (2017). It has been long documented and studied extensively since the 20th century as stated in a study by Hahn et al. (1998) which reported that knee pain was a common finding among athletes, with the occurrence of it was also dependent on what sport they played and how much they participated in it. Slotkin et al. (2018) reported that anterior knee pain (AKP) is a frequent presenting issue for pediatricians and orthopedic surgeons and is frequently observed in young athletes. Patellofemoral instability, patellar tendinitis, and Osgood-Schlatter disease are among the common causes of AKP. It is also known that with sports-related knee pain or knee injuries in general, women are more inclined to experience this compared to males, as evidenced in past studies by Slotkin et al. (2018), Francis et al. (2019), and DeHaven et al (1986), to name a few. Johnston et al. (2018) report a prevalence of 47–75% for pain and/or injury in endurance sporting populations, which is significant among both recreational and elite cohorts.

To add to this found disparity between both sexes in relation to knee-related injuries or knee pain in

general, it was found by Sabnis (2023) that women were more prone to overuse injuries, whereas men were more prone to energy contact injuries. This is said to be because of the structural variations between the male and female bodies, such as muscle shape and bone alignment. However, this notion seems to vary among literature depending on the type of sport. This is evidenced in a study by Naik et al. (2021) where they found that male football athletes were more susceptible to knee pain compared to their female counterparts. Also, apart from the type of sport, Biz et al. (2022) found that there was a difference between both genders, wherein females had more injuries involving the upper extremities, whereas males had more injuries in the lower extremities. In terms of sex, there are significant differences in the frequency and clinical outcomes of sports-related injuries. Boys had a 35% higher risk of injury than girls at high-level international sporting events, with upper leg muscle strains being the most common type of injury (Bassett et al., 2020). The inconclusiveness of evidence tells us that there is still certainly no absolute way to categorize the correlation between sex and knee pain in terms of directionality, especially when other factors are involved, and most especially in understudied sports like spikeball.

One injury that is most common that we can take a look at in recent and more local studies is anterior cruciate ligament (ACL) injuries. According to Webster and Hewett's (2018) research, ACL injury prevention programs result in a significant two-thirds decrease in female athletes' non-contact ACL injuries and a 50% decrease in all athletes' ACL injuries. Tanaka (2019) recommends conventional preventive actions including working on quadriceps dominance, strengthening hamstrings, and enhancing trunk control. Davis et al. (2021) concluded that multicomponent warm-up showed moderate evidence in reducing lower extremity injuries. Neuromuscular exercises performed before games or practices have also been found to reduce injuries as stated by Bonato et al. (2018). The comprehensive study by Attar et al. (2022) highlights that warm-up exercises, especially plyometrics, can reduce non-contact ACL injuries by 60% for athletes of both sexes. The study suggested a warm-up regimen that included running, dynamic stretching, plyometric exercises, balance exercises, and strength training. A study by Atlas et al. (2007) identified sports-related injuries in a Philippine university's college teams that competed in the University Athletic Association of the Philippines (UAAP) season 69 and found that the majority of injuries were extensively seen in the knee, followed by the lower leg and ankle.

Fundamental skills in sports are movements as basic as throwing, kicking, running, jumping, catching, changing of directions, or hopping applied to a specific sport situation (Karcher et al., 2014). Spikeball involves cutting maneuvers and squats, which are linked to ankle and knee injuries (Do, 2022) as well as ACL injuries and patellofemoral pain syndrome (PFPS). Cutting actions are associated with a disregarded mechanism of noncontact ACL damage (Golden et al., 2009; Donelon et al., 2020). Moreover, squatting is also an important skill in receiving and setting the ball due to the nature of the sport. According to Pereira et al. (2022), repetitive squats can lead to PFPS due to the excessive anterior displacement of the knee "in relation to the toe whenever the knee is flexed to 60° to 90°." These biomechanical factors and injuries involving the knee are important to note clinically, as they are highly involved in the inability of athletes to perform and in the physical rehabilitation process.

To further study how injuries can occur and subsequently be prevented, we took a look at previous frameworks that were in line with sports. The sports injury risk factors model in Figure No. 1, adapted from Bahr et al. (2003), explains the several factors that lead to injury and was highly observed during the conceptualization of the protocol.

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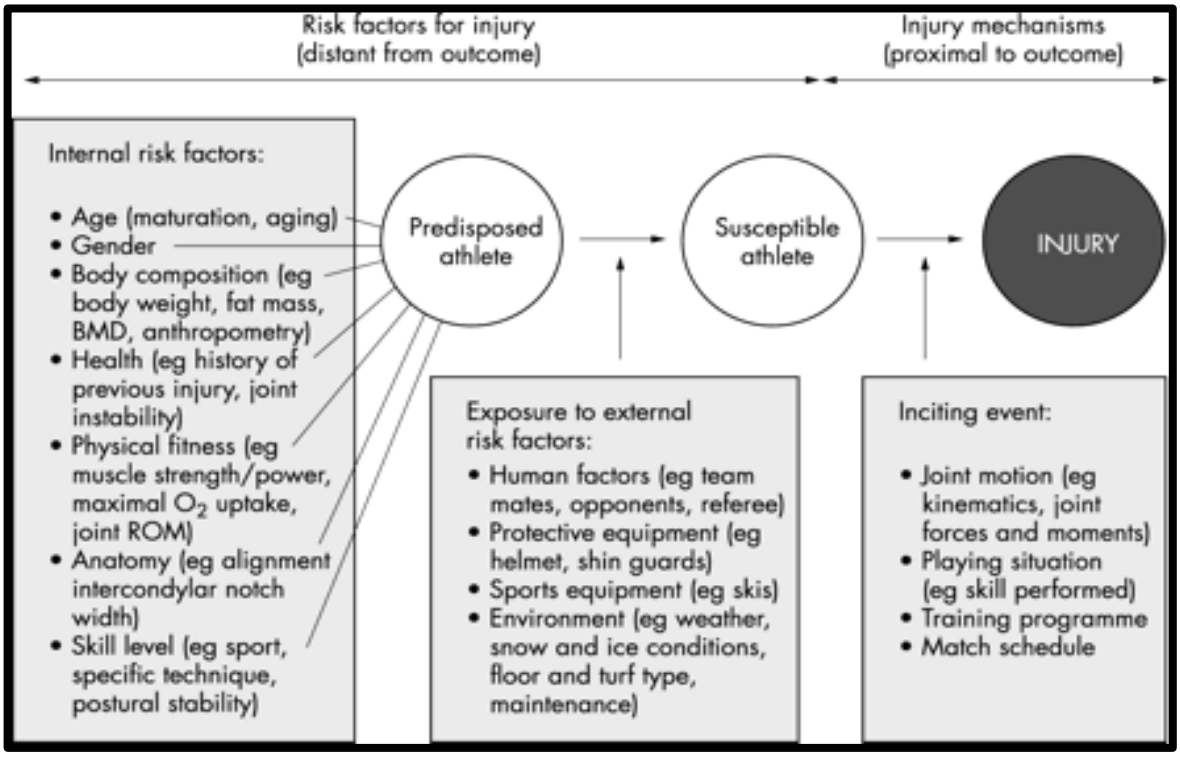
Figure 1

Sports Injury Risk Factors Model



The framework depicts three main contributors to injury: "internal factors, external factors, and inciting events." Internal factors include the following: age, gender, body composition, health, physical fitness, anatomy, and skill level. These factors predispose an athlete to injuries. Internal factors combined with external factors increase an individual's risk of injury, making these athletes susceptible to injury. Injury may happen to susceptible athletes during participation in several inciting events, such as during training or competition. This framework demonstrates a linear concept of the build-up factors that may lead to injury. What we can learn from this framework are the specific factors that can be involved that may lead to an injury in any sport, including spikeball.

On a global scale, it seems quite insignificant to directly make studies and protocols about just spikeball specifically, but as it continues to grow in more and more remote areas from its origin, it becomes of best interest for those who perform in the sport and those who oversee those who perform the sport to maintain longevity and be free from injury. The time spent healing from these injuries negatively affects both the progress of the athlete's skills and the investment of their benefactors. Other traditional sports have incorporated extensive research on injury incidence and their contributing factors with the intent to maximize the athlete's performance while preventing the occurrence of said injuries. This study may offer insights for physical therapists to curate a more specific plan of care, as well as how coaches can provide spikeball-specific exercises that spikeball athletes are able to benefit from.

In Dumaguete City, Negros Oriental, Philippines, the player base for spikeball, or more appropriately

known as roundnet, has seen exponential growth in recent years. The city, sometimes considered a "university town," houses a large number of students and athletes, both experienced and inexperienced in sports. Due to the sport's increasing popularity, roundnet became an official competitive sport in the recently concluded Silliman University Intramurals for the academic year 2022-2023. The sport was invented in 1989 by Jeff Knurek and has since appeared on the popular television series "Shark Tank" in 2015 during its 6th season from the company, Spikeball Inc., and has since gained popularity in other parts of the world. Several countries also participated in the 2022 Spikeball Roundnet Championship in Belgium (Spikeball Inc., 2022). The pervasiveness of the sport within the locality warrants more research concerning the risk of acquiring any spikeball-related injuries. In studying these different contributors, physical therapists may be able to provide services that not only alleviate the present symptoms but also prevent injuries from recurring, especially for sports that highly involve the lower extremities.

Of the few studies being conducted around spikeball, there is currently little to no published research on injuries sustained in the sport, sex-based physiological factors specific to spikeball, and available injury prevention protocols possibly due to its novelty. With spikeball's growing popularity in, there is also a growing need for research that focuses on the possible injuries that local players may be at risk of. The gap in knowledge is pertinent to, but not limited to, sports physical therapists who will be tending to athletes in a sport that is emerging quickly in the mainstream.

This study contributes to the lack of research by determining the following: the demographic profile of the participants in relation to the knee pain among spikeball athletes in terms of sex; the prevalence of knee pain among male and female spikeball athletes; the relationship between knee pain and sex in spikeball athletes; and an injury prevention protocol for spikeball athletes based on the results of the study ,which can help guide spikeball physical therapists, coaches, and athletes in a direction for rehabilitation, overall injury prevention, and risk reduction.

METHODS

Study Aim, Design and Setting

This study aimed to provide a better understanding of the general problems at hand which were the lack of empirical evidence in the sport, the potential musculoskeletal injuries that may have been prevalent within the sport, and how sex could be related to these injuries within the locality of Dumaguete City. It also aimed to develop a preliminary injury prevention protocol specific to the game which was based on regimens and activities that were performed pre-game, during the game, and post-game.

Given the vast amount of literature that usually indicates that women are more prone to injury in sports, it is important to also investigate if the same notion is applicable to spikeball. To do exactly that, this study used a cross-sectional, correlational research design that took a quantitative approach involving data gathering and analysis to identify the relationship between the independent variable, which was sex, and whether or not it had a significant relationship with the dependent variable, which was the presence of knee pain among the spikeball athletes. The study also examined the pre-game, in-game and post-game activities of spikeball participants, which served as the basis for the creation of an injury prevention protocol. The research was conducted in Dumaguete City, Negros Oriental, Philippines, among the spikeball athletes of all ages within the locality.

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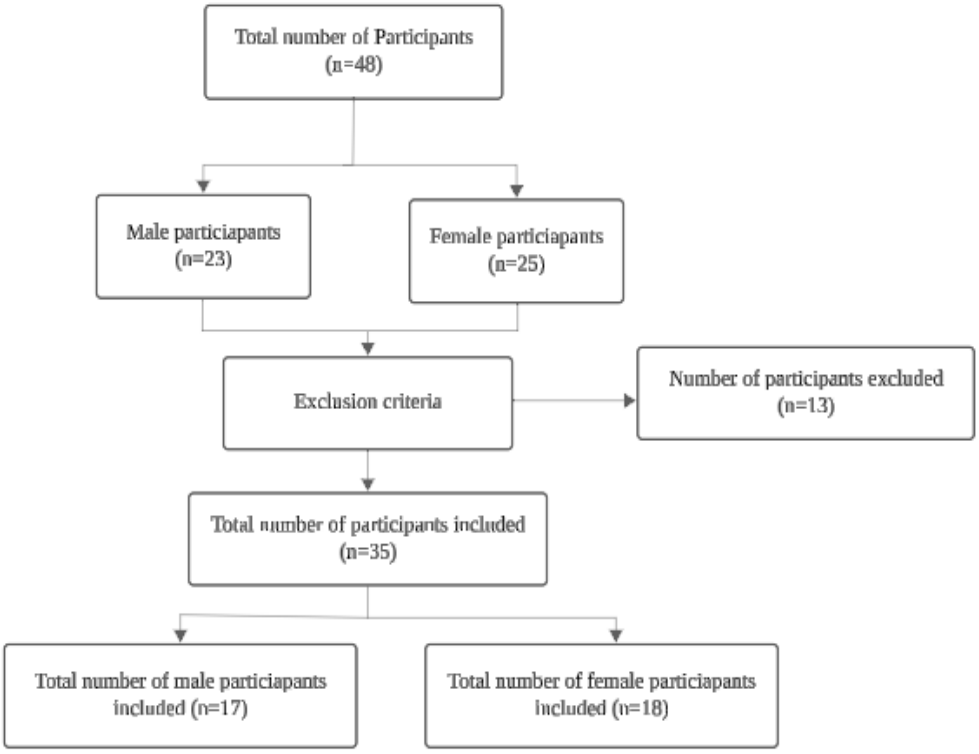
Participants and Sampling

Inclusion criteria were as follows: (1) age over 18 years; (2) at least two months of experience playing spikeball regardless of the type of participation (competitive or recreational); (3) competed/participated in a tournament (official/ unofficial) in Dumaguete City, Negros Oriental. Respondents were excluded from the research if they: (1) had not participated in any spikeball games in the past 2 months; (2) had knee pain that was secondary to a known underlying pathological diagnosis (osteoarthritis, rheumatoid arthritis, fracture, etc.); (3) had a history of recent surgical procedures on the knee joint; and (4) had knee pain before playing/ joining the sport. A flow diagram of participant inclusion is illustrated in Figure 2.

Figure 2

Flowchart of participant inclusion



A purposive sampling method was used so that only people involved in spikeball or those who actively play spikeball were included in the study.

Data Collection Procedure

A self-made questionnaire was utilized which underwent face validity testing as well as pilot testing. The questionnaire was divided into three separate parts: the first part consisted of questions about demographic information, followed by the second part, which contained pre-screening questions to determine if a respondent fit the established eligibility criteria, and the third part, which included the set of questions that helped in answering the study's research questions and in creating a prevention protocol. The third part included items that were adapted from previously existing studies about sports and also from prior informal surveys conducted during the planning phase of the research. Printed questionnaires were given to the participants in envelopes along with a cover letter that informed the participants of the study's objectives and purpose, as well as a statement to protect their anonymity and privacy. The questionnaire was also made available through Google Forms. To address the proposed research questions, the research instrument specifically utilized "*Yes,"" No*," and "*Sometimes"* options to determine the correlation between knee pain among spikeball athletes and sex

Follow-up questions were given to the five respondents with knee pain (three female; two male) as we tried to further understand other outlying factors that may have contributed to the presence of knee pain. Among the five, only four responded (two female; two male) to the follow-up questions.

Data Analysis

A chi-square test was used as the statistical tool to measure the strength of the relationship between knee pain and the sex of spikeball athletes. Descriptive statistics provided an overview of the demographic profile of the population of interest. Logistic regression analysis was also utilized to assess inter-variable relationships between knee pain and the players' pre-game, in-game, and post-game activities. To provide an overview of the remaining data, other extraneous variables were analyzed using frequency analyses. Since an external data analyst was involved, limitations regarding the selection of data analysis methods were present. A power analysis was conducted posthoc to detect the study's statistical power.

Reliability and Validity

The instrument was tested for validity through the use of the Survey Instrument Validation Rating Scale which was distributed to five experts in the corresponding subject matter. Improvements were made in response to experts' feedback regarding its structure and options, which included reformatting suggestions and the removal of questions that did not directly correlate with the research's purpose. Afterward, the instrument was retested with the same measure from the same experts, and scores were quantified and collated, which were entered into The Jamovi Project® 2.1.25, an open statistical software (The Jamovi Project, 2024). Quantitative variables were further studied using the Shapiro-Wilk test, a goodness-of-fit test for a normal distribution, central tendency (mean), and dispersion (standard deviation). The Jamovi platform data displayed a mean of 0.998, which was considered a good fit on a scale of 0 to 1, with a value close to 1 being considered a "good fit" (The Jamovi Project, 2024). A standard deviation (SD) score of 0.497 was also detected by the statistical tool. Overall, in terms of validity, the instrument almost perfectly measured what it was intended to, which was the correlation between the two variables. Pilot testing of the instrument was conducted in a population that was similar in qualities to the target population, more specifically, volleyball players, who are frequently compared to spikeball players, and with it often being used as

a reference to define Spikeball (Seonia, 2016). The Cronbach alpha index was 0.924, indicating that the instrument showed excellent internal consistency and reliability, with consideration that an index higher than 0.9 is considered excellent (Zahreen Mohd Arof et al., 2018).

RESULTS AND DISCUSSION

Table 1 presents the demographic profile of the respondents who participated and the prevalence of knee pain among male and female spikeball athletes.

Table 1

Demographic Profile of the Respondents and Prevalence of Knee Pain among Male and Female Spikeball Athletes in Dumaguete City

Knee Pain Condition	Sex			
	Male		Female	
	Frequency	%	Frequency	%
With knee pain	2	11.8	3	16.7
Without knee pain	15	88.2	15	83.3
Total	17	100	18	100

Note. N = 35

A total of 35 spikeball athletes in Dumaguete were included in the study which consisted of 17 males and 18 females as illustrated in Table 1. Five participants, two males and three females, reported having knee pain after two months of playing spikeball. Additionally, an aching type of pain with an intensity of 5/10 on the Numerical pain rating scale (NPRS) was most commonly felt before, during, and after a game.

Table 2 shows the relationship between knee pain in spikeball athletes and sex, along with the results from the chi-square test of independence, which examined their association.

Table 2

Relationship between Knee Pain and Sex in Spikeball athletes

	Value	df	*p*-value
$\chi 2$	0.712	1	0.679
N	35		

The chi-square test of independence indicated no significant association, χ^2 (1, N = 35) = 0.712, p = .679. This test examined whether there was a statistically significant association between the two categorical variables, namely sex and knee pain. The p-value (0.679) was greater than the conventional significance level of 0.05; thus, we failed to reject the null hypothesis. Since the *p*-value (0.679) was greater than the conventional significance level of 0.05, we failed to reject the null hypothesis. Post-hoc power analysis revealed that with the sample size (N=35), the effect size (Cramer's V≈0.07), and the conventional alpha level (0.05), the study's power is approximately at 8%.

Based on these results, the variables appear to be independent from each other until further, more substantial evidence is found. This contradicts the findings of some related literature as our findings suggest that spikeball is not necessarily more harmful to the knees of female players compared to men. Practically, this could mean that both sexes can be affected by sports-related injuries when playing spikeball, which could lead future research protocols to focus more on generalized guidelines for both sexes instead. But again, the study is underpowered, and the small sample size may have contributed to the strength of the between the two, or the lack thereof. Post-hoc power analysis revealed that the study's ability to form a conclusion based on its statistical power was quite low and may present a high risk for type II error. Thus, hypothetically even if there may have been the presence of an association in actuality, the study's sample size and effect size were not strong enough or sensitive enough to detect it. Still, given the results of the analysis mentioned earlier, it is possible to infer that the majority of suggestions in the injury prevention protocol derived from this study may apply to both men and women.

The results as shown in Tables 3 and 4, regarding the factors related (or not related) to the occurrence or non-occurrence of knee pain in spikeball athletes, are meant to serve as the basis for the injury prevention protocol through predictive and descriptive analyses.

Table 3

Relationship between the Absence of Knee Pain and Sex, Age, and BMI in Spikeball Players

Predictor	Estimate	SE	Z	p	Odds ratio
Intercept	6.9360	5.509	1.259	0.208	1028.654
Sex:					
Female – Male	-0.5512	1.017	-0.542	0.588	0.576
BMI	-0.0718	0.118	-0.610	0.542	0.931
Age	-0.1341	0.173	-0.775	0.438	0.875

Note. Estimates represent the log odds of "Knee Pain = No" vs. "Knee Pain = Yes"

Based on the results of the regression analysis, it was found that females were more likely to be associated with knee pain than males; however, with the limited sample size, additional data gathering is needed to further support these findings. The data corroborates with Sabnis' (2023) findings wherein compared to men, women are more prone to overuse injuries due to their structural differences such as muscle structure and bone alignment, while males are more likely to sustain energy contact injuries possibly due to more high-impact gameplay. Also mentioned by Shmerling in 2020, stress fractures, knee injuries, ankle sprains, shoulder injuries, and plantar fasciitis were the most frequent problems among female athletes. They went on to say that the widely accepted theory supporting the claim that women sustain injuries at higher rate stems from basic physical distinctions between the bodies of men and women, further bolstering the idea that women were are prone to knee injuries than men. This is likely due to women having more biological traits that increase their risk of damage, such as loose joints, ligaments, hormones, and larger Q-angles (Basset et al., 2020).

Although it is worth noting that further analysis of the risks and predictors can still be warranted as there are still some varied results among previous literature, especially when taking into account the type of sport involved. This is evidenced in a study by Naik et al. in 2021, where they found out that in football athletes specifically, men were more susceptible to knee pain, as indicated by their prevalence data on knee pain distribution between male and female football players. In a study in the Philippines among competitive college teams, Atlas et al. (2007) also found that "males (74%) were more commonly injured than females (67%)" and that males had more injuries in the lower extremities compared to females who had more injuries involving the upper extremities (Biz et. al., 2022). Although most literature suggests that men are more prone to knee injuries compared to women, one major factor to consider is the nature of the game. This was supported by Comeau et al.'s (2023) previous findings in their study, wherein female university-age athletes were not necessarily more prone to injury; however, female athletes in some sports had a greater injury risk, which shortened time to injury such as in basketball and volleyball.

Looking at other demographic predictors that were also analyzed, the possibility of having no knee pain decreased as age and BMI increased, especially in women. In other words, spikeball female athletes were more likely to experience knee pain with increased age and BMI. This corroborates a statement from a cross-sectional study by Rogers et al. (2008) where they referenced that the chance of knee pain from osteoarthritis confirmed through radiography increased with each successive elevated BMI category. Osteoarthritis, known as a "wear-and-tear" condition is especially common in older people and occurs in 10% of men and 13% of women as they enter the 60 and above age range (Zhang et al., 2010). Going back to the study, these predictors, albeit not very significant in correlation, showed us where the presence of knee pain, or the lack thereof, will trend. This further provided us with a clear understanding when formulating an injury prevention protocol for both men and women, through suggestions of training or practice improvements in terms of diligence for older women spikeball athletes who have higher BMIs.

Table 4 simply shows a summary of the proposed protocol based on the results of the study's regression analyses as well as frequency analyses of the specific activities for pre-game, during the game, and post-game for both male and female spikeball athletes.

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Table 4

Proposed Injury Prevention Protocol

Perform any of these pre-game activities for at least 1-10 minutes.	During the game, these activities must be performed less as it places a player in greater risk for knee pain, along with increased game duration.	Perform any of these post-game activities for at least 1-10 minutes.
● Strengthening-based exercises ● Running-based exercises ● Static and dynamic stretching ● Jumping/plyometric-based ● Endurance based exercises	● Twisting the body to serve ● Bending down to defend ● Receiving and digging ● Maintaining a squat position throughout the game ● Twisting during attacks ● Pivoting, changing directions	● Dynamic stretching ● Strengthening exercise ● Cool-down techniques ● Low-intensity endurance exercises ● Spikeball-specific drills

Through regression and descriptive analysis of the frequency tables, other predictors of the absence of knee pain were analyzed. All results were found to be non-significant, although the basis for the injury prevention protocol was based on the direction that the collated data was "biased" towards. The contents of Table 4 showed the activities that were considered predictors of the absence of knee pain. To put it simply, when spikeball athletes performed these activities, the occurrence of knee pain was less likely. Injury protocols must be scientifically sound for them to be valid and actually safely usable for athletes; thus, the creation of such protocols must be based on well-proven evidence. Thus, Tables 5-12 present the findings of the regression and frequency analyses involving knee pain and its relation to certain activities and match modifications.

Table 5 shows the warm up activities that were more likely to be associated with the absence of knee pain and which types of pre-game activities males and females benefitted from.

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Table 5

Regression Analysis on the Basis for Protocol for Prevention Injury – Pre-Game Activities in Male and Female Spikeball Athletes

Predictor	Estimate	SE	Z	p	Odds Ratio
			Male Spikeball Players		
Intercept	-76.7	1.29e+6	-5.93e0-5	1.000	-
Do warm up exercises					
2 – 1	-51.1	1.01e+6	-5.05e0-5	1.000	
Static stretch					
2 – 1	51.1	655161	7.80e0-5	1.000	
Dynamic stretch					
1 – 0	3.73e0-9	772786	4.83e-15	1.000	
2 – 0	-51.1	1.08e+6	-4.75e0-5	1.000	
Endurance-based					
1 – 0	-51.1	709849	-7.20e0-5	1.000	
2 – 0	-51.1	655161	-7.80e0-5	1.000	
Strengthening-based					
1 – 0	-3.73e0-9	772786	-4.83e−15	1.000	
2 – 0	51.1	640760	7.98e0-5	1.000	
Spikeball-specific exercises					
2 – 1	51.1	808198	6.33e0-5	1.000	
Jumping/ plyometric					
1 – 0	51.1	579589	8.82e0-5	1.000	
Stability/Balance exercises					
1 – 0	-4.65e−14	305470	-1.52e−19	1.000	
Running-based exercise					
2 – 0	51.1	432000	1.18e0-4	1.000	

Female Spikeball Players

Predictor	Estimate	SE	Z	p	Odds Ratio
Intercept	163.280	1.75e+8	9.33e-7	1.000	8.16e+70
Do warm up exercises					
2 – 1	20.038	7.35e+7	2.73e-7	1.000	5.04e0+8
Static stretch					
1 – 0	-157.752	1.47e+8	-1.07e−6	1.000	3.08e-69
2 – 0	0.470	393126	1.20e-6	1.000	1.600
Dynamic stretch					
2 – 1	-98.580	1.64e+8	-6.00e−7	1.000	1.54e-43
Endurance-based					
1 – 0	39.271	6.00e+7	6.54e-7	1.000	1.14e+17
2 – 0	19.234	7.35e+7	2.62e-7	1.000	2.26e0+8

Table 5, Continued					
Strengthening-based					
1 – 0	-0.332	9.49e+7	-3.50e−9	1.000	0.717
2 – 0	-48.251	9.49e+7	-5.08e−7	1.000	1.11e-21
Spikeball specific exercise					
1 – 0	-99.384	1.90e+8	-5.24e−7	1.000	6.89e-44
2 – 0	-20.038	7.35e+7	-2.73e−7	1.000	1.99e0-9
Jumping/ plyometric					
1 – 0	69.896	7.35e+7	9.51e-7	1.000	2.27e+30
Stability/balance					
1 – 0	-10.254	6.00e+7	-1.71e−7	1.000	3.52e0-5
2 – 0	-8.979	6.00e+7	-1.50e−7	1.000	1.26e0-4
Running-based exercise					
1 – 0	-29.821	7.35e+7	-4.06e−7	1.000	1.12e-13
2 – 0	-39.604	1.12e+8	-3.53e−7	1.000	6.31e-18

Note. Estimates represent the log odds of "Knee Pain = No" vs. "Knee Pain = Yes."

The males who did not have knee pain performed strengthening-based and running-based warm- ups, while the females performed static-stretching exercises, endurance-based exercises, and jumping/plyometric-based exercises. These findings for the males' pre-game activities reflect the study by Lauersen et al. (2018), which stated that strengthening-based warm ups decrease the occurrence of sports injuries. Moreover, the findings for the females' pre-game activities reflect the study by Stojanović et al. (2022), where the implementation of combined running exercises with stretching, plyometrics, balance, and strength significantly lowered the incidence of lower extremity injuries among basketball players. As our study accounted only for static stretching, another study by Azuma (2020), corroborated the finding that static stretching decreases knee injury occurrence. The Heel-Buttock Distance (HBD) was used in the study to objectively quantify the benefits of static stretching. It was discovered that knee injuries were significantly less common in the intervention group when the HBD was lower. Thus, strengthening-based and running-based warm up exercises in the protocol were recommended for male spikeball athletes and static stretching, endurance-based exercises, and jumping/ plyometric-based exercises for the females. In creating the protocol, suggestions regarding the specific warm-up activities mentioned above that are more associated with an absence of knee pain may be provided.

In-game behaviors in relation to knee pain were surveyed as shown in Table 6. The behaviors that increased this risk were twisting the body to serve, bending down to defend, receiving and digging, squatting throughout the game, pivoting, and changing directions. Pereira et al. (2022) had similar findings wherein prolonged squatting, bending down, and receiving/digging increased the risk of knee pain. The study proceeded to suggest weight training protocols for the hip and quadriceps muscles to counteract the muscle imbalance from these movements and decrease knee pain. This is further supported by Tanaka (2019) who recommends preventive actions such as targeting quadriceps dominance, strengthening hamstrings, and enhancing trunk control. A study by Weiss et al. (2015) also suggested that neuromuscular training and skill-specific training should focused on to correct the mechanics during high- risk maneuvers especially during altered planes mechanics at the knee and hip in the frontal and sagittal planes, to decrease the prevalence of both ACL and PFPS.

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Table 6

Basis for Protocol for Prevention Injury - In-Game Activities that Elicit Pain

Predictor	Estimate	SE	Z	p	Odds ratio
			Male Spikeball Players		
Intercept	20.993	10973	0.00191	0.998	1.31e0+9
Bending down to serve					
2 – 0	1.43e-7	41341	3.47e-12	1.000	1.00
Twisting the body while serving					
2 – 0	-20.530	42772	-4.80e0-4	1.000	1.21e0-9
Bending down to defend ball					
2 – 0	-11.090	4.75e+7	-2.34e0-7	1.000	1.53e0-5
Pivoting while trying to switch directions					
2 – 0	0.573	51808	1.11e0-5	1.000	1.77
Side stepping to reach and receive ball					
2 – 0	42.137	53660	7.85e0-4	0.999	1.99e+18
Digging to receive ball					
2 – 0	11.090	4.75e+7	2.34e0-7	1.000	65513.80
Squat position for whole game					
2 – 0	-41.563	20886	-0.00199	0.998	8.90e-19
			Female Spikeball Players		
Intercept	21.6	9744	0.00221	0.998	2.32e0+9
Bending down to serve					
2 – 0	-62.7	49451	-0.00127	0.999	5.67e-28
Twisting the body while serving					
2 – 0	3.91e-8	58465	6.69e-13	1.000	1.000
Twisting the body while attacking					
2 – 0	-41.2	63714	-6.46e0-4	0.999	1.32e-18
Bending down to defend the ball					
2 – 0	41.2	48481	8.49e0-4	0.999	7.60e+17
Pivoting while trying to switch directions					
2 – 0	-4.29e−8	30814	-1.39e−12	1.000	1.000
Side stepping to reach and receive ball					
2 – 0	.	.	.	.	.
Digging to receive ball					
2 – 0	-42.2	34281	-0.00123	0.999	4.94e-19
Squat position for whole game					
2 – 0	42.2	46094	9.14e0-4	0.999	2.02e+18

Note. Estimates represent the log odds of "Knee Pain = No" vs. “Knee Pain = Yes.” Not all coefficients could be estimated (likely due to singular fit).

Thus, suggestions for the protocol included that the aforementioned actions may be performed less frequently to decrease the likelihood of experiencing knee pain. Additionally, as some of the mentioned in-game activities are necessary in the sport and cannot be avoided, efficient training and awareness of body movements/ positions are emphasized in the protocol to further decrease the likelihood of getting knee pain.

Another basis for a protocol on knee pain avoidance in sports would be concerned with the post-game activities which typically refer to cool down exercises that were also surveyed among the respondents with findings in Table 7.

Table 7

Basis for Protocol for Prevention Injury: Postgame Activities in Male and Female Spikeball Athletes

Predictor	Estimate	SE	Z	p	Odds ratio
			Male Spikeball Players		
Intercept	-1.87e−16	1.41	-1.32e−16	1.000	1.000
Do cool down exercises:					
1 – 0	3.79e0-9	29976.38	1.27e-13	1.000	1.000
2 – 0	6.86e0-9	31967.46	2.15e-13	1.000	1.000
Static stretch:					
1 – 0	21.6	57477.09	3.75e0-4	1.000	2.32e0+9
2 – 0	21.6	43114.21	5.00e0-4	1.000	2.32e0+9
Dynamic stretch:					
1 – 0	9.79e0-9	34358.29	2.85e-13	1.000	1.000
2 – 0	43.1	60391.99	7.14e0-4	0.999	5.40e+18
Low-intensity endurance cooldown:					
1 – 0	-2.06e0-8	36833.21	-5.59e−13	1.000	1.000
2 – 0	.	.	.	.	.
Strengthening-based exercise:					
1 – 0	1.54e0-8	48951.23	3.14e-13	1.000	1.000
2 – 0	-43.1	64072.57	-6.73e0-4	0.999	1.85e-19
Spikeball specific exercise:					
1 – 0	-1.26e0-8	51237.43	-2.46e−13	1.000	1.000
2 – 0	-3.17e0-8	39151.99	-8.09e−13	1.000	1.000
			Female Spikeball Players		
Intercept	25.231	105456	2.39e-4	1.000	9.07e+10
Do cool down exercises:					
1 – 0	-0.509	167458	-3.04e−6	1.000	0.60122
2 – 0	44.480	1.93e+6	2.30e-5	1.000	2.08e+19
Static stretch:					
1 – 0	5.204	1.91e+6	2.73e-6	1.000	182.06870
2 – 0	.	.	.	.	.

Table 7, Continued					
Dynamic stretch:					
1 – 0	-0.217	279728	-7.77e−7	1.000	0.80458
2 – 0	9.705	2.71e+6	3.58e-6	1.000	16406.86478
Low-intensity endurance cooldown:					
1 – 0	0.923	259640	3.56e-6	1.000	2.51722
2 – 0	-8.946	2.71e+6	-3.31e−6	1.000	1.30e0-4
Strengthening-based exercise:					
1 – 0	-59.632	2.69e+6	-2.22e−5	1.000	1.27e-26
2 – 0	0.869	257352	3.38e-6	1.000	2.38355
Spikeball specific exercise:					
1 – 0	3.990	1.92e+6	2.08e-6	1.000	54.04815
2 – 0	-5.935	1.92e+6	-3.09e−6	1.000	0.00265

Note. Estimates represent the log odds of "Knee Pain = No" vs. "Knee Pain = Yes." Not all coefficients could be estimated (likely due to singular fit).

According to the data, engaging in post-game activities was generally linked to a lower chance of developing knee pain. Dynamic stretching and strengthening exercises were suggested as cool-down techniques, and low-intensity endurance exercises and spikeball-specific drills were also proposed in the protocol.

Pre-game rituals were assessed among the respondents as possible covariates to the occurrence of knee pain in the athletes. The findings are mentioned in Table 8.

Table 8

Frequency Analysis of Pre-game Rituals

Pre-game Rituals	Frequency	Percentage
No	23	65.71%
Sometimes	6	17.14%
Yes	6	17.14%
Total	35	100%

The data indicated that 65.71% of spikeball athletes do not engage in pre-game rituals, whereas 17.41% do perform pre-game rituals. Based on the patterned information, the results note that pre-game rituals were not necessarily significant to perform; however, further research may be needed to see if they are predictors of knee pain, particularly for spikeball athletes, due to other factors such as psychological components (Congsheng et al., 2022) and ground conditions (Twomey et al., 2014). Previous studies have already shown the importance of warm-up intervention programs in decreasing the risk of injury when playing sports (Ding et al., 2022), which provides an overview of an optimal spikeball player's game routine and gives clinicians an opportunity to educate players on the importance of having a curated pre-game ritual.

Other significant findings from frequency analyses included those from surveying the duration of pre-game activities as shown in Table 9.

Table 9

Frequency Analysis of Duration of Pre-Game Activities

Duration of pre-game	Frequency	Percentage
0 minutes	3	8.57%
1-10 minutes	23	65.71%
11-20 minutes	8	22.86%
21-30 minutes	1	2.86%
Total	35	100%

Upon further patterning of the data, such as the low knee pain prevalence among spikeball athletes in general and the majority duration of 1-10 minutes, both findings were considered to come up with a safe suggestion for a 1-10 minute warm-up inthe protocol. Although it is also worth noting that previous literature (Romaratezabala et al., 2018) has already stated that neither long nor short duration warm-ups contributed to improved physical performance, a “happy medium” time, as well as what the current population was already doing, proved to be not as harmful.

Game duration was also a factor considered with Table 10 showing the duration of the spikeball games.

Table 10

Frequency Analysis of Duration of Game

Duration of game	Frequency	Percentage
11-20 minutes	13	37.14%
21-30 minutes	12	34.29%
31-40 minutes	5	14.29%
41 -50 minutes	3	8.57%
51-60 minutes	2	5.71%
Total	35	100%

Results showed that 37.14% of respondents lasted 11-20 minutes, followed by 34.29% who lasted 21-30 minutes, 14.29% who had a game duration of 31-40 minutes, 8.57% who had a game duration of 41-50 minutes, and 5.71% who lasted 51-60 minutes. The results corroborated with a study by Tummala et al. (2022) stating that among professional basketball players, there was a higher likelihood of having a structural knee injury with increased duration of the game, as one of the main predictive factors. Hence, the data will be used in the protocol wherein a duration of 11-30 minutes of playing a game of spikeball is generally recommended to decrease such pain.

Apart from pre-game rituals, post-game ritual participation was also assessed among the respondents, as shown in Table 11.

Table 11

Frequency Analysis of Post-Game Rituals

Post-game Rituals	Frequency	Percentage
No	24	68.57%
Sometimes	9	25.71%
Yes	2	5.71%
Total	35	100%

Similarly to Table 8 under pre-game rituals, the post-game rituals were not as significant to the majority of the athletes' need to perform. This trend hearkens back to the overall low prevalence of knee pain among the spikeball players; thus, it was postulated that the pre- or post-game rituals are not needed. Although, it may be worth noting that in future literature, it may be beneficial to study more of the psychological vs the physical effects of routines and rituals as these activities have been noted to have their merits. For Example, McCann (2008) explained that these "routines," as they would call them, provide mental, emotional, and behavioral effects that produce better results in terms of performance.

Cooldown duration showed to be less significant for the majority of athletes who did not complain of knee pain, mostly participating in only short-duration cooldowns or not doing them at all. Results of these are shown in Table 12.

Table 12

Frequency Analysis of Duration of Post-Game Activities

Duration of post-game activities	Frequency	Percentage
0 minutes	8	22.86%
1-10 minutes	19	54.29%
11-20 minutes	5	14.29%
21-30 minutes	2	5.71%
51-60 minutes	1	2.86%
Total	35	100%

Results showed that 22.86% of the respondents did not perform post-game activities, whereas 54.29% took 1-10 minutes' worth of post-game rituals, 14.29% took 11-20 minutes, 5.71% took 21-30 minutes, and lastly, 2.86% took 51-60 minutes. A sizable portion of the participant athletes (22%) did not perform cooldowns that lasted for more than a minute, while the majority (54.29%) performed the post-game activities for only a minimal 1-10 minutes. Since the overall prevalence of knee pain among the spikeball athletes is already relatively low, there should not be any drastic changes made to the duration of their post-game activities. This finding is affirmed by a randomized controlled trial by Law et al. (2007) that found that cool-downs do not actually reduce delayed-onset muscle soreness when performed immediately after eccentric exercise. This is particularly important because spikeball involves movements with a lot of eccentric load forced upon the knee, just like playing volleyball or any other ground activities that require jumping, turning, bending, or hopping.

From the respondents who were concurrently experiencing knee pain during data collection, follow-up surveys gathered the following data: Two out of four played spikeball recreationally, whereas the remaining two played the sport competitively. Three of the respondents played other sports aside from spikeball, such as volleyball, basketball, pickleball, and cycling. Two respondents reported having no pain when playing other sports, but one claimed to have lesser knee pain when playing pickleball and cycling as compared to engaging in spikeball due to sudden changes of direction. Lastly, three respondents reported feeling knee pain after performing routines aside from spikeball, specifically the lack of consistency in the routine and when engaging in physical activities for a prolonged period. All of which may have affected the results of the study.

Limitations

The study was conducted with a limited sample size of 35 respondents which may restrict the generalizability of the study findings due to its local scope and the possibility that the domestic spikeball scene is still growing. It is at high risk for type II error as the data gathered cannot provide sufficient insights into knee pain in spikeball athletes, thereby affecting the ability a credible injury prevention protocol. Thus, the proposed protocol should only be used as a basis for future studies. In the future, recruiting more respondents will enhance data accuracy and reduce the margin of error.

CONCLUSION

Based on the findings, it can be concluded that there was no association between the presence of knee pain and sex among spikeball athletes. Knee pain has a relatively low prevalence rate, and female athletes are most prone to experiencing knee pain when playing spikeball. Sex should not be used as a singular basis as to why a spikeball athlete may develop a knee pain injury. Men and women have equal chances of incurring knee-related injuries in this case; thus, protocols for spikeball injury prevention can likely be generalized for both sexes.

Also, sex, BMI, and age cannot predict knee pain among spikeball athletes Hence, older women who have higher BMI values might be the most susceptible to incurring knee pain or injury that is directly related to spikeball.

For the creation of an injury prevention protocol, although the available data were not strong enough to generate a highly dependable protocol, it showed the tendencies of how performing pre-game and post-game activities can be beneficial in increasing the likelihood of having no knee pain in a game of spikeball.

Overall, the findings of the study can be used as a foundation for future researchers who are interested in spikeball and sports health to continue detailed investigations on the topic. The injury prevention protocol benefit both spikeball athletes and coaches alike, since these are "non-harmful" and could allow for better longevity in such a lower-extremity heavy sport. Finally, rehabilitation process for spikeball-related knee injuries could be improved given that rehabilitative science professionals now possess better understanding of the effects of particular activities.

List of Abbreviations

AKP - anterior knee pain
ACL - anterior cruciate ligament
BMI - body mass index
PFPS - patellofemoral pain syndrome
UAAP - University Athletic Association of the Philippines

Declarations

Ethics approval and consent to participate
This study was reviewed and approved by the Silliman University Research Ethics Committee (approval date: February 2024). Ethical oversight was provided by committee members: Dr. Theorose Bustillo, Mr. Rehel Diaz, and Prof. Cyflor Putong. Informed consent was obtained from all participants prior to their involvement in the study.

Consent for publication
The study does not contain any personal data requiring additional consent for publication. All participant data were anonymized, stored securely, and will be disposed of one year after the completion of the research.

Availability of data and materials

All data relevant to this study are presented within the article. Since no additional datasets were created or analyzed during this study, data sharing is not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

This manuscript represents the sole authorship of the contributors, who independently conceptualized the study and the instrument, derived the protocol based on the study's own results, and conducted both quantitative and qualitative data collection, interpreted findings, reviewed and finished the manuscript.

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About this Article

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