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*Original Article*

# Association between lower extremity movement compensations in the presence of PFPS among female collegiate football athletes: a cross-sectional study

Consuelo Suarez[a], Saul Anthony Sibayan[a], Jocel Regino[b], Masayoshi Kubo[c], Mark Lyndon Van Aldaba[a], Pauline Keith Alviz[a], Miguel Carlo Aytona[a], Jan Franchesca Bustria[a], Ivana Paulina Pastrano[a], Pablo Maria Rafael Ramos[a], Roxanne Fernandez[b]

[a]University of Santo Tomas, College of Rehabilitation Sciences- Department of Sports Science; [b]University of Santo Tomas, College of Rehabilitation Sciences- Department of Physical Therapy; [c]Niigata University of Health and Welfare- Department of Physical Therapy

Correspondence should be addressed to: Saul Anthony Sibayan[a]; saulsibayan@gmail.com

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## Abstract

**Introduction**: Fifteen to fifty percent of all sports injuries commonly occur in the knee joint. Active women are more susceptible to Patellofemoral Pain Syndrome (PFPS) than men. Aims: This study aims to associate the presentation of different movement compensations at the different body segments such as the hip, knee, and foot with the presence of PFPS among female collegiate football players at the University of Santo Tomas. **Methods**: In this descriptive observational cross-sectional study, purposive sampling was used to recruit participants. A total of 11 participants were included. PFPS has a strong association with Anterior Knee Pain (AKP), and it was diagnosed using the Physical Examination questionnaire. With the use of dynamic and transitional assessments, namely overhead squat test (OST) and tuck jump test (TJT), movement patterns were observed using standardized data sheets and video analysis. **Results**: Among those 11 female participants (mean age 19 ± 1.7 years old), 8 were diagnosed with PFPS and 3 were negative of PFPS. An association between different compensations and PFPS was sought using Fisher's exact statistical tool. In the OST, compensations such as the foot turning out, foot flattening, knee directing inward and outward, lumbo-pelvic-hip complex patterns. In the TJT, PFPS was associated with three general compensations: foot placement, landing contact noise, and lower extremity valgus. **Conclusion**: There was no direct association found between movement compensations and PFPS in dynamic and transitional assessments among female collegiate football players in this study. Although there are a few associations between different lower extremity movement compensations with PFPS. The majority of those with PFPS had knee out and LPHC compensations with the OST. With the TST, those with PFPS have positive foot placement compensations as compared to the majority of those without PFPS.

*Keywords*: PFPS, movement assessments, knee valgus, compensations

## INTRODUCTION

Musculoskeletal injuries commonly correspond to 80% of all disorders encountered by athletes.[1] Among all the sports, football has the highest incidence of injuries both during practices and in games.[2] Loes et al. reported that males have an incidence rate of 0.75 (0.47/1.03 CI 95%) and females with 0.95 (0.67/1.22 CI 95%) incidence rate per 10,000 hours.[3]

Fifteen to fifty percent of the entire sports injuries commonly occur in the knee joint,[3], especially in those that deal with running and jumping since the force affecting this joint, can reach up to ten times of the person's body mass.[1] History of knee injury is a determining factor for the development of the most common knee injury known as Patellofemoral Pain Syndrome (PFPS) or Anterior Knee Pain (AKP).[4] In a systematic review, it was stated that PFPS is historically described as chondromalacia, which is associated with patellar pain, surrounding retinaculum, and anterior aspect of the knee.[5, 6]

Booling et al. reported that "the incidence rate for PFPS was 22 cases per 1000 person-years (p-y) (95% CI). The incidence rate in females was 33 cases per 1000 p-y. (95% CI) while the incidence rate in males was 15 cases per 1000 p-y (95% CI). Gender is a significant predictor of PFPS development (P50.01) based on the Poisson regression analysis. Females with 2.23 times higher probability to develop PFPS as compared to males (95% CI)".[7] Active women are more susceptible to PFPS is than men.[7, 8, 9, 10] Incidence of PFPS in men is only at 7.4% as compared to 20% in women.[10] The increased incidence of PFPS in females can be due to structural limitations as well as in proximal and distal muscle strength that leads to PFPS.[11]

Stair climbing, squatting, jumping and running are examples of physical activities that can aggravate PFPS.[12] It is possible that the presence of PFPS may be due to dynamic dysfunction between the segment of the lumbopelvic hip complex (LPHC) region, knee, and foot.[13] External factors that can contribute to PFPS in football players include errors done in training, poor equipment, training surfaces, and psychosocial variables.[14] In repeated weight-bearing impact in activities like running and jumping, a force is directed to the anterior part of the knee during practices and games.[15]

Waryasz et al. identified clear probable predisposing component for the occurrence of PFPS.[4] These includes functional testing weakness; tightness of gastrocnemius,[16, 17, 18] hamstring,[16, 17, 19, 20] quadriceps,[16, 17, 18, 19, 20, 21] or iliotibial band;[20, 22, 23, 24] generalized ligamentous laxity;[16, 25, 26] deficient hamstring[18, 20, 27] or quadriceps strength;[28, 29, 30, 31, 32, 33, 34] weakness of hip musculature;[17, 35, 36, 37, 38, 39, 40, 41] excessive quadriceps angle;[16, 18, 31, 32, 42, 43, 44, 45, 46, 47] patellar tilting[24, 29, 42] and abnormal VMO reflex timing[16, 48].

Changes that occur in during puberty would be increases in lower-limb-segment lengths in both male and female; increases in medial knee motion in females; side to side differences in valgus inclination at landing in female athletes; increases in knee muscle peak torque with maturation in male but not in female athletes; changes in motor control of the knee in adolescent athletes; and changes in landing from a jump by adolescent athletes.[49] Female athletes demonstrate higher dynamic valgus during landing from a jump.[50] This is due to the maturation of females happening in the puberty stage. Decreased motor control of the knee happens more often in females than in males. Thus, the occurrence of PFPS in females is higher than in males.[49]To strengthen the claim that the aforementioned factors may contribute to PFPS development, different outcome measures can be used such as the Physical Examination (PE) questionnaire, overhead squat test, and tuck jump.

The overhead squat test is a transitional movement assessment that involves movement without changes in the base of support. It is designed to assess core strength, balance and overall motor control.[51]

The tuck jump test is a dynamic movement assessment that involves movement with a change of basal support.[51] It is designed to identify the movement abnormalities of the lower extremity during landing and plyometric activity.[52, 53]

The study aims to determine the association between the presence of PFPS and different movement compensations in the hip, knee, and ankle through dynamic and transitional assessments. Movement compensations pertain to movement dysfunctions at the major joints in the kinematic chain.[54] The movement assessments aim to identify asymmetries in movement quality that could otherwise be missed and to help ensure a safe starting point for training.[54]

## METHODS

**Ethics Approval.** The study was approved by the University of Santo Tomas - College of Rehabilitation Sciences - Ethics Review Committee with approval number SI-2016-029-R3. Before participation in the study, all participants gave written informed consent.

**Study Design.** This study is a descriptive observational cross-sectional study design.

**Participants.** Eleven members of the University of Santo Tomas (UST) women's football team participated in the study. Purposive nonprobability sampling was used in the recruitment process. The participants were assessed by the physiatrists (CGS, MB, CLA) in determining if they could be included in the study. Data collection happened from November 2016 to February 2017.

The inclusion criteria were the following: 1) player of the UST women's football team who competed in the UAAP; 2) aged 18-25 years old. The exclusion criteria were the following: 1) they were 17 years old and below; 2) They had past surgery in the hip, knee, or ankle a year preceding testing day; 3) They had fractures and dislocations that may delay the results of the study; 4) They had other lower extremity physical problems such as patellar tendinopathy, ACL/MCL/PCL tear, meniscal tear, and others.

Fisher's exact statistical tool was used to test the significance of statistical comparisons and is useful for categorical data.[55] The fisher's exact statistical tool showed an association between different compensations and PFPS. The data was based on participants with or without PFPS, as well as the compensations being observed for each test.

**Setting.** This study was conducted at the Sports Science Laboratory in the Quadricentennial Pavilion at UST, Manila, Philippines.

**Data Gathering Procedure.** All study participants were members of the UST Women's football team for the 2017 UAAP season. They fulfilled the Data Collection Sheet which included their personal information and playing background.

Anthropometric measurements were performed for baseline measurements. The researchers collected these questionnaires and kept these secure and confidential through a highly confidential coded system.

After the anthropometric measurements, the physician performed a PE that was specific to the knee including the palpation of its tenderness, range of motion, and manual muscle testing. Other tests to rule out other pathologies that may be present were done namely: Clarke's test, Waldron's test, Patellar Apprehension test, Lachman's test, McMurray test, Posterior Drawer's rest, Valgus Stress test, and Varus Stress test.

The physiatrist conducted the PE questionnaire which contains different knee-specific tests that will aid in diagnosing if a participant has PFPS. To assure the blinding of the assessors, all data documented were kept confidential from each of the assessors.

A video-recorded movement assessment test was used for the final assessment of the two assessors for the overhead squat test and two assessors for the tuck jump test.

**Transitional Posture Assessments**

*Overhead Squat*

The NASM Overhead Squat Assessment Form[56] was used as a tool to record the compensations that were observed in the subject during the performance of the squat. This included the compensations that were detected from the anterior, posterior, and lateral views of the participant's overhead squat movement.[57] Compensations such as the foot turning out, foot flattening, knee directing inward and outward, LPHC and upper body compensations were tested if they are associated with the prevalence of PFPS. The reference p-value for the study is 0.05. The Overhead Squat has significant reliability and is capable of evaluating medial knee displacement or movement compensation.[58]

The participants were asked to stand, with feet shoulder-width apart, toes pointed forward and their hands raised. The participant was then asked to squat down as low as she can. This was performed five times for the anterior, lateral, and posterior views. A checklist of compensations on the datasheet was checked if compensation on a specific view occurred such as:

a. Anterior view: Inward or outward translation of the knee
b. Lateral view: Arching and rounding of the back
c. Posterior view: Feet flattening, heel rising, and weight shifting

### Dynamic Posture Assessment

*Tuck Jump*

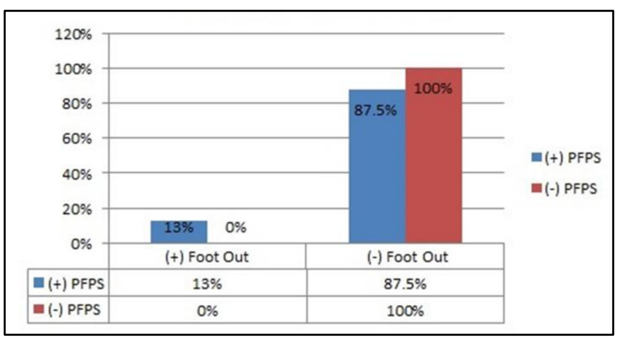
The Tuck Jump Assessment Form[57] is an assessment form with a checklist that was divided into the knee and thigh segment, foot placement, and plyometric technique. The listed compensations were checked if observed while the movement was performed. When comparing scores of the tuck jump test, it has favorable intra-tester and inter-tester reliability.[59]

Participants are asked to jump continuously while lifting the knees to hip height at the peak of each jump to land on the same spot for 10 seconds. Three trials of the tuck jump without time duration were performed.[60] The researchers explained and demonstrated the procedures of the tuck jump test.

## RESULTS

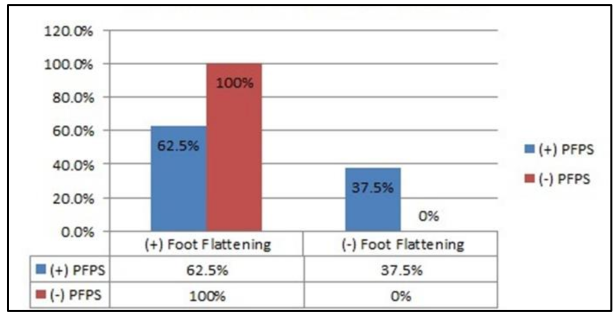
In Figure 1.0, the foot turned out on 13% of the participants with PFPS and 0% for those without PFPS. The p-value was at 1.00. Therefore, the foot turning out as compensation is not directly associated with the presence of PFPS among the population.

Figure 1.0 PFPS with foot turning out



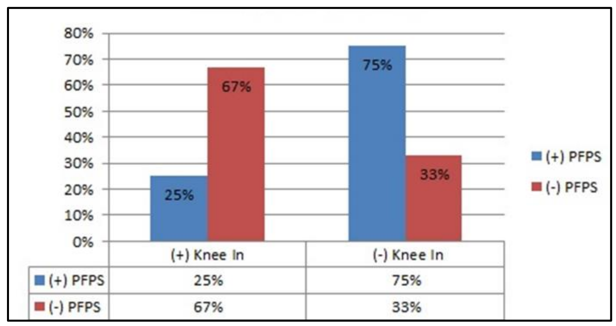

The foot flattening compensation appeared to have no direct association with PFPS which resulted in a p-value of 0.49. In figure 1.1, the foot flattening occurred in 65% of those with PFPS. It was present in 100% of those without PFPS.

Figure 1.1 PFPS with foot flattening



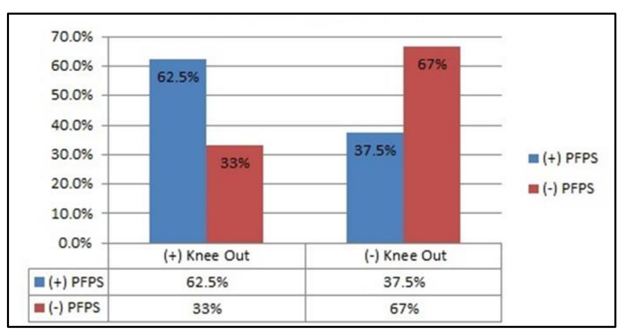

PFPS appeared to have no direct association with the knees going in during the overhead squat test with a p-value of 0.49. Figure 1.2 showed that the occurrence of this is high in those without PFPS (67%) as compared to those with PFPS (25%).

Figure 1.2 PFPS with knees going in



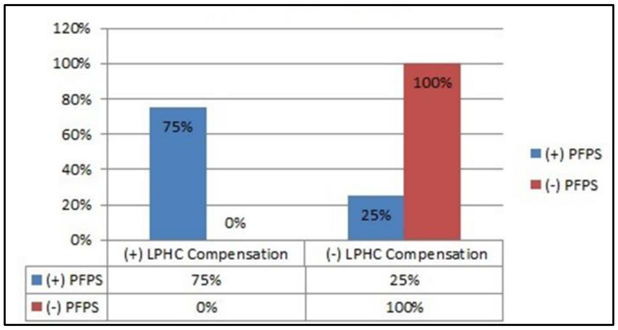

In the overhead squat test, the occurrence of knees going out as compensation is not directly associated with PFPS with a p-value of 0.5. Figure 1.3 showed that the occurrence of this is high in those with PFPS (62.5%) as compared to those without PFPS (33%).

Figure 1.3 PFPS with knees going out



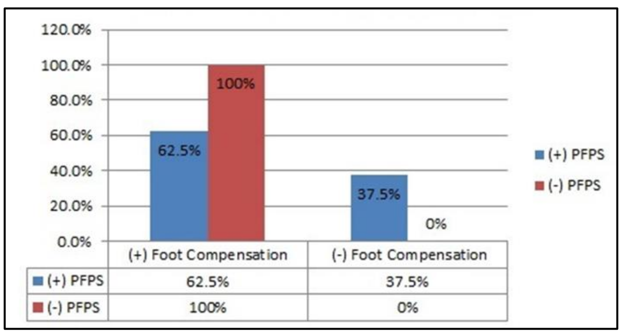

There was no direct association between LPHC compensations and PFPS that was proven with a p-value of 0.06. Figure 1.4 showed that the occurrence of this is high in those with PFPS (75%) as compared to those without PFPS (0%).

Figure 1.4 PFPS with LPHC compensations



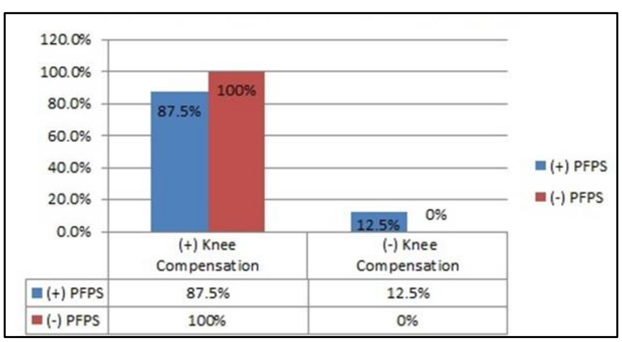

No direct association was found between PFPS and foot compensations with the p-value of 0.49. Figure 1.5 showed that the occurrence of this is higher in those without PFPS (100%) as compared to those with PFPS (62.5%).

Figure 1.5 PFPS with foot compensations




Knee compensations were not precisely associated with PFPS in this study resulting in a p-value of 1.00. Figure 1.6 showed that the occurrence of this is higher in those without PFPS (100%) as compared to those with PFPS (87%).

Figure 1.6 PFPS with knee compensations




In the tuck jump test, the majority of those with PFPS also demonstrated foot placement, landing contact noise, and lower extremity (LE) valgus compensations based on Figures 2.0, 2.1, and 2.2. While the majority of those without PFPS didn't have any foot placement compensations.

In Figure 2.0, the presentation of the foot placement compensations occurred on 75% of the participants with PFPS condition and 33% in those without PFPS. However, with a p-value of 0.49, there was no direct association found between the foot placement compensation during the tuck jump test and the presence of PFPS in the study.

Figure 2.0 PFPS with foot placement compensations

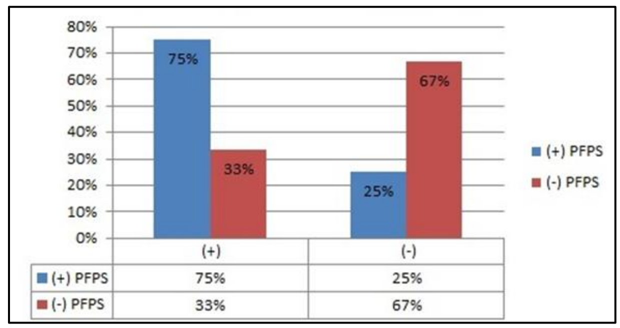



Figure 2.1 showed that only 75% of those with PFPS have presented an excessive landing contact noise in comparison to 100% presentation on those without PFPS. There was no direct association found between the landing contact noise and PFPS with a p-value of 1.00 in this study.

Figure 2.1 PFPS with landing contact noise compensations

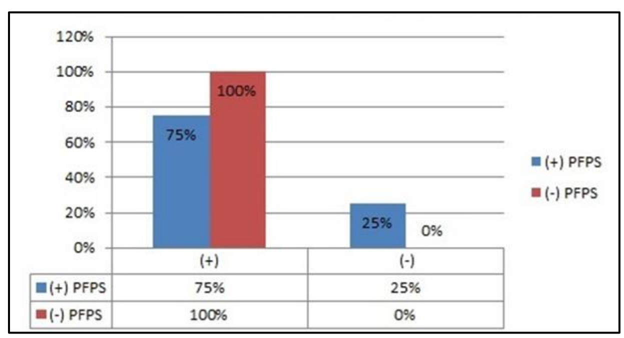
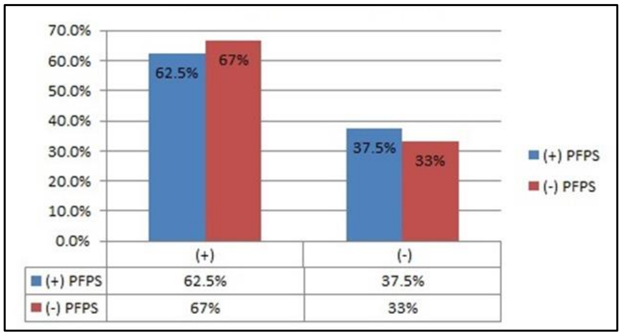



Figure 2.2 showed that 62.5% of those with PFPS presented a lower extremity valgus on their knee while doing the tuck jump. In those without PFPS, 65% presented this compensation. The statistical tests showed a p-value of 1.00 that indicates that in this study, there was no direct association found between LE valgus and PFPS in the tuck jump test.

Figure 2.2 PFPS with lower extremity valgus




The results from the tuck jump test have shown no direct association between PFPS and the compensations usually seen in the tuck jump test which may be due to the lack of occurrence of the landing contact noise, and lower extremity valgus and an increase of foot placement compensations observed in landing.

The existing studies and this study's results as a basis, the lack of association in PFPS and movement compensations may be due to the neuromuscular strength of the athletes. They may have shown an increase in foot compensation during landing, but muscular strength still could have been an important factor that affected the results. Lower extremity valgus usually happens in individuals with poor muscular control that's why ligament dominance happens. With an indefinite assessment of the participants' strength, the probable reason to why the landing contact noise is low even though the foot placement compensation is high may still be due to the good motor control which athletes normally possess.

## DISCUSSION

The purpose of this study is to determine the association between the existence of PFPS among female collegiate football players and the different movement compensations in the hip, knee, and ankle through dynamic and transitional movement assessments. Based on the results gathered, there were variations on the presentation of movement compensations on the subjects during the overhead squat test and tuck jump test. There are compensations observed even in the majority of those without PFPS in the overhead squat test: foot flattening, knees going in, foot and knee compensations. While the knees going in compensation was not observed in the majority of those with PFPS in the overhead squat test. For the tuck jump test, the majority those without PFPS had the following compensations: landing contact noise and lower extremity valgus.

The overhead squat test is a well-known tool in assessing movement patterns. It is commonly used to screen the quality of movement that challenges mobility through the ankle, knee, and hips and thoracic spine body segments. This usually exposes different movement compensations on the ankle, knee, LPHC, and shoulders.[55]

The foot turning out or the axis of the ankle joint, and the motion between rearfoot and lower extremity may lead to foot pronation which may lead to tibial rotation.[61] Foot flattening is said to be a factor why the lower extremity rotates internally. Studies suggest that the lower extremity (leg and thigh segments) normally undergo an external rotation rather than an internal rotation.[62] With this, medial translation of the patella can contribute to its diminished varus positioning and increased valgus positioning may happen.[63] This is associated with an increase in quadriceps angle which is usually present in females.[63] The LPHC, knee, and foot dynamic dysfunctions are said to predispose individuals to PFPS. Movements associated with dynamic knee valgus are one of the many factors that cause PFPS due to the alteration of compressive forces in movements such as squatting. Taking that into consideration, an increased contralateral pelvic hip drop may lead to an increased knee valgus orientation on weight-bearing exercises such as squatting.[61]

Based on the studies that were gathered, movement compensations may be associated with PFPS if the foot turns out as the foot pronates which may then lead to a shift in weight that may be due to a neuromuscular inefficiency. Whenever individuals shift their weight, an increased pelvic hip drop on one side may occur which will then contribute to a valgus alignment of the knee which is the common cause of PFPS.

There are probable reasons why no direct association between PFPS and the different compensations was found. This could be due to lack of results that presented foot turning out, foot flattening, and knees going in and an increase on knee turning out which was normal. These may be observed in the results of the study. Also, the factor of strength was not considered in this study which may be one of the determining factors as to why LPHC compensations still happened without the foot turning out and pronating.

Tuck jump test is usually used to assess the predisposition of females to injuries.[64] With the continuous explosive movement pattern done by the participant, compensations with the factor of fatigue that may lead to an injury is being observed and assessed as well.[65]

Neuromuscular imbalance is said to be the reason why foot placement compensations happen. This may lead to a lower extremity valgus during the landing in a jump since the muscles are not able to control and absorb the force from the movement during landing. There is a tendency for ligament dominance to occur, where the ground reaction forces are absorbed by the ligaments of the knee instead of letting the muscles absorb it.[52]

**Implications.** Although no direct association was found between the presence of PFPS and different compensations on functional tests such as overhead squat test and tuck jump test, this study may be the start of further researches to prove the possible association that may be present. This study may be useful for Filipino athletic trainers, sports scientists, and clinicians who seek for an effective tool for injury prediction and prevention. Due to the limited sample size, the results of this study will not be able to generalize into a bigger population. Further research involving larger groups of participants with gender differences is highly encouraged.

**Reliability and Validity.** During testing, two assessors were present for the tuck jump and two assessors for overhead squat tests. A video was taken while the athletes performed the test as the assessors observed the movement compensations that occurred. Afterward, they reviewed the recorded video to obtain their conclusion. Cohen's kappa statistic was used to account for chance agreement and to account for the possibility of raters on at least some variables due to uncertainty.[66] The inter- and intra-rater reliability of the two assessors for each assessment was excellent for all of the individual criteria in both the tuck jump assessment and overhead squat assessment. Assessor bias was eliminated since the assigned assessors for each test both watched the recorded video and came up with only one observation.

Studies show that instead of using chi-square test in dealing with a frequency of five or less on the cells, the use of Fisher's exact test is more appropriate.[67]

**Limitations.** As mentioned above, a limitation of this study is the absence of a current gold-standard diagnostic tool for detection of PFPS.[68] Muscular strength assessment which may be an important factor to back up the presence and absence of compensations among the participants in different functional tests was not focused and performed in this study. It was not done since this paper is part of a bigger research effort and a different group that focused on strength assessments. Lastly, the limited period for testing was given to the researchers since the UST women's football players were involved in the UAAP competition. With this, fewer participants were recruited which resulted in a small number of sample size that may decrease the power of the study.

## CONCLUSIONS

There are a few associations among the different lower extremity movement compensations in the presence of PFPS among female collegiate football athletes as shown in this study. Trends among the occurrence of different compensations should not be ignored. The majority of those with PFPS had knee out and LPHC compensations with the overhead squat. Based on the tuck jump assessment, those with PFPS had positive foot placement compensations, while the majority of those without PFPS didn't have this movement compensation. The authors of the study concluded that with the certain limitations encountered, further studies that would exclude these limitations are recommended.

### Individual author's contributions

C.S., S.A.S., J.R., M.K.; Conceptualization, designed the methodology, analysis of data, and co-wrote the paper. S.S.; Supervised the data collection. M.L.A., P.A., M.C.A., J.B., I.P., P.R., R.F.; data collection and co-wrote the paper.

### Disclosure statement

This paper did not receive any funding.

### Conflicts of interest

The authors of this paper declare no conflicting interest.

### Supplementary file

[Appendix A. Overhead Squat Assessment Form]

[Appendix B - Tuck Jump Assessment Form]

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