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Original Article

Comparison of Core Stability and Hip Muscular Strength in Selected Collegiate Football Players with and without Patellofemoral Pain Syndrome (PFPS)

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Abstract

Background: Muscular imbalance in the core and hip is one of the major risk factors associated with PFPS. There is evidence that decreased strength of the hip musculature is present in individuals with PFPS. This decrease in hip strength can also affect the stability of the core and further predisposes an athlete to injury. **Objectives:** This is a cross-sectional study that compares the hip muscle strength and core stability of collegiate football players with and without PFPS. **Methods:** 25 participants (10 with PFPS and 15 without PFPS) participated in the study. Hip strength was measured using a digital handheld dynamometer. Core stability was assessed through the McGill Core Strength test and the 8-stage stability test. **Results**: The hip adductors showed to be significantly weaker in those with PFPS as compared to those without PFPS (p=0.040). No differences were found in the hip flexor (p=0.812), hip extensor (p=0.460) and abductors (p=0.126) strength while the core musculature showed that there is a statistically significant difference on the endurance of the lateral core musculature (p<0.001) and trunk flexors (p=0.027) between the two groups. **Conclusion:** Football athletes without PFPS in this study demonstrated greater core stability and hip adductor muscle strength compared to those without PFPS.

Keywords: patellofemoral pain syndrome, lower extremity, core, strength, football

INTRODUCTION

Patellofemoral pain syndrome is the most common injury among professional and recreational athletes.[1] PFPS is characterized by pain due to increased subchondral bone stress in the posterior surface of the patella or distal femur.[2] Ten percent of visits by physically active individuals was attributed to PFPS.[3] Football is one of the sports that have the highest incidence of PFPS (13.68 %).[4] This could be due to the repeated stress in the patellofemoral joint during running and jumping that causes excessive loading.[5] There is no gold standard in the diagnosis of PFPS. Crossley et a.l in 2016, developed a criterion in the diagnosis of PFPS.[6] The criteria is based on the symptoms presented (e.g. pain around the patella) assessed by the Victorian Institute of Sport Assessment (VISA-P scale) questionnaire and different imaging techniques. A systematic review showed that MRI and a CT scan were the most valid method is assessing PFPS.[7] Two features with a large standardized mean difference (SMD) on meta-analysis were an increased MRI bisect offset at 0 degrees knee flexion under load (0.99; 95% CI: 0.49, 1.49) and an increased CT congruence angle at 15 degrees knee flexion, both under load (1.40 95% CI: 0.04, 2.76) and without load (1.24; 95% CI: 0.37, 2.12). There was limited evidence exists to support the association of PFPS with other features of MRI, US, CT, and XR.[7]

PFPS is considered as an overuse injury with risk factors that include: : (1) patellar mal-alignment / maltracking, (2) increased Q-angle, (3) quadriceps weakness, (4) decreased flexibility, (5) muscle imbalance[8] (6) onset of timing of vasti muscle (7) genu valgum (8) pes planus[9]. There's also has been evidence that those patients with patellofemoral pain syndrome present decreased in the strength of the gluteus medius and maximus that resulted in an increased knee valgus in patients with PFPS.[10] This decrease in the lower extremity strength can also affect the stability of the core and further predisposes an athlete to injury.[11] Core stability should also be considered as it can also be affected being the foundation of the kinetic chain[12] and responsible for the transfer of forces between the upper and lower extremity. This is why neuromuscular control of the trunk and hip muscles are important in reducing the knee adduction moment.[13] Although many articles mention the relationship between lower extremity strength and PFPS, there is no published literature on the core stability levels of individuals with PFPS. Available literature only presented the impact of core stability in developing lower extremity injuries.[11] Thus, this study aims to determine the difference between hip strength and core strength and stability between PFPS and non-PFPS groups.

METHODS

Ethical Approval. The study was conducted in compliance with the guidelines set by the declaration of Helsinki and the good clinical practice guidelines of the Philippine Health Research Ethics Board (PHREB). Ethical approval was obtained from the University of Santo Tomas-College of Rehabilitation Sciences Ethical Review Committee (UST-CRS-ERC).

Study Design. The study utilized a cross-sectional comparative study that determined the differences of core stability and hip muscular strength of athletes with and without PFPS.

Sampling Procedure. A purposive sampling design was utilized based on the inclusion and exclusion criteria below:

Inclusion criteria:

- Male football athletes in the official roster of a collegiate football team
- Age 18 to 25 years old

Exclusion criteria:

- With any fractures & dislocations that would hinder the outcome of the study
- Who have other physical complications in the lower extremity such as patellar tendinopathy, ACL/MCL/PCL tear, meniscal tear, etc.
- Who had surgical conditions in the hip, knee or ankle for the past year from the day of the implementation

10 participants with PFPS and 15 without PFPS met the sampling criteria and were included in the study.

Outcome Measures

1. Victorian Institute of Sport Assessment (VISA-P scale) questionnaire – assesses (i) symptoms, (ii) simple tests of function and (iii) ability to undertake physical activity. Six of the eight questions are scored on a visual analog scale from 0-10 with 10 representing optimal health except Items 7 and 8. Item 7 has four possible rating levels (0, 4, 7, and 10). Item 8 is divided into three assumptions (A, B, and C), from which only one is chosen according to the impact of pain on engagement in sport. The maximal VISA score for an asymptomatic, fully performing individual is 100 points and the theoretical minimum is 0. The questionnaire has a high test-retest reliability (ICC = 0.74).[14]
2. Manual Muscle test using handheld dynamometer - Muscle strength was measured utilizing an economically accessible Jamar Hand-held dynamometer (HDD). Jamar hand-held dynamometer has good test-retest reliability (ICC >97%) and great concurrent validity with functional tests in the assessment of isometric strength.[15]

This method of assessing muscle strength has been shown to have high test-retest reliability (ICC = 0.91- 0.99).[16]

3. Core Stability
    a. Mcgill Core Stability Test - The protocol assesses core stability with a reliability coefficient of 0.98 for extensor, 0.97 for flexor and 0.99 for lateral core muscles.[17] This method of assessing core stability has been shown to have a high test-retest reliability of ICC 0.97-0.99.[17]
    b. The 8-Stage Core Stability Test was used to assess the global core muscle function of the participants. This assessment protocol has been proven to be a valid and reliable (ICC = 0.97) tool to assess the strength and endurance of the core musculature.[18]

Data Gathering Procedure. Participants underwent several assessment protocols that include PFPS diagnosis and Strength assessment. PFPS was diagnosed through Physical Examination by a rehabilitation doctor and the VISA-P Questionnaire. For the hip strength and core stability assessment, a physical therapist and a sports scientist conducted the assessment with the proper order of testing (non-fatiguing to fatiguing). Proper rest intervals were also followed to ensure the reliability of the assessment. The order of assessment protocols and specific procedures is listed in the following sections.

A profile sheet containing the age, gender, height, weight, and questions that would determine the presence of knee pain as well as those that would eliminate other conditions stated in the exclusion criteria were answered by the participants.

The participants were then examined by a rehabilitation doctor and asked them to perform a squat. The presence of pain in the knee area without any of the findings in the exclusion criteria made them eligible for the study. The participants also completed the Victorian Institute of Sport Assessment-Patella Scale (VISA-P scale) before undergoing lower extremity and core musculature tests.

After completing the questionnaire, hip strength was assessed using a manual muscle test with a Jamar hand-held dynamometer. All trials were evaluated by a registered Physical Therapist. Participants were instructed to push maximally against the plate and the piston of the HHD for 5 seconds. All HDD appraisals were performed with the test limb segment in a position that was not influenced by gravity. Furthermore, the therapist manually stabilized the proximal body parts of the test limb segment. Specific positions are illustrated in Table 1.

The core stability of the participants was then measured using the McGill Core Stability test. Four separate tests measure the isometric endurance of the trunk flexors, trunk extensors, and left and right trunk lateral flexors.

For the trunk flexor, the participant was in a hook lying position with the back resting in a wooden surface-angled 60 degrees off the floor. Hip and knees were both flexed 90 degrees, arms across the chest with hands on top of the opposite shoulder and feet were held in position by an assessor. Once the participant was in place, the wooden surface was pulled 10 cm away. The timer started in this position and ended until when the participant was not able to hold the position or any part of the body touched the wooden surface.

For the trunk extensor, the participant is in prone on a table with the trunk hung and only the pelvis, hip, knee, and ankle were secured on top of the table. Both upper extremities were held across the shoulders. The timer started once this position was assumed and stopped once the participant failed to hold this position or the trunk dropped below the horizontal position.

For the trunk lateral flexors, the participant was in a side-lying position on top of a 2-inch mat with the shoulders abducted and elbows flexed to 90 degrees. Both legs were extended with the top foot placed in front of the other foot for added support. Participants were instructed to raise the hip off the mat with only the elbow, forearm and feet supporting the weight of the body. The non-supporting arm was held across the chest with the body aligned in a straight position in the frontal plane. The timer started once this position was assumed and stopped once the participant's hip sagged or failed to maintain the said position. Both right and left lateral trunk flexors were tested. During the four tests, participants were reminded that these tests require maximal effort and should maintain the different testing positions for as long as possible.

The 8-stage core stability test was then used to further assess the core stability of the participants. The participant was instructed to assume a plank position on top of a treatment table only supported by the elbow, forearm, and feet. Shoulders and elbows should remain in one vertical line with the forearm and hand both pointing forward. The spine should remain neutral throughout the test with the head and heel forming a straight horizontal line. Participants then underwent different variations of the plank with no rest in between, while maintaining the following position during the assessment: (1) Front plank for 30 seconds, (2) lift the right arm off the ground for 15 seconds, (3) lift the left arm off the ground for 15 seconds, (4) Lift right leg off ground for 15 seconds, (5) Lift left leg off ground for 15 seconds, (6) Lift right arm and left leg off ground for 15 seconds, (7) Lift left arm and right leg off ground for 15 seconds and (8) front plank for 30 seconds.

A familiarization trial for the front plank was also conducted to serve as the reference position, during the assessment. The distances between the medial epicondyle of the left and right elbow, first metatarsal of the right and left foot, and the elbow and feet on the left and right sides of the body were measured during the familiarization trial. In addition, an 80 cm string that was attached to two vertical scales was placed horizontally beside the participant. The distance between the two strings was kept at 10 cm and the height was adjusted at the level of the participant's hip (iliac crest evenly in between the two strings). This setting served as the reference for the objective monitoring of hip movement during the test. All measurements taken should also remain constant throughout the test.

During testing, the assessor was instructed to sit one meter away from the table. The participant was warned, once the hip went beyond either the reference lines. The test was terminated if the participant failed to maintain proper hip position after two consecutive warnings. The stage and measured time to exhaustion were recorded.

Data Analysis. Data in this study were treated as individual lower extremity instead of per participant when comparing the strength of the hip muscles. A total of 20 knees with PFPS and 30 knees without PFPS were compared with their corresponding hip muscles. For the comparison of core stability, data were treated per participant with and without PFPS.

Shapiro-Wilks test revealed that the height, weight, and age of all the participants don't fall on a normal curve. Therefore, the Mann-Whitney U test was used to assess the homogeneity of the participants based on the demographic data. A two-sample t-test was used to compare the hip and core muscular strength of knees with PFPS and without PFPS. Fisher-Exact test of association was also used to determine the association between core stability and PFPS. All statistical analysis was done with a 95% confidence interval.

RESULTS

Demographic information of the participants is presented in Table 2. There are no significant statistical differences in height, weight, and age between the PFPS group and the non-PFPS group. Therefore, parametric tests can be utilized to compare the hip and core strength levels of knees with and without PFPS.

Hip strength. Table 3 summarizes the findings on the mean difference of the hip flexors, abductors, adductors, and extensors of both groups. There were 20 lower extremities tested on those with PFPS and 30 on those without PFPS. Among the variables tested, the hip adductors showed to be significantly weaker in those with PFPS as compared to those without PFPS, $t(48)$ 2.10, $p=0.04$. No differences were found in the hip flexors ($p=0.8$), hip extensors ($p=0.5$) and abductors ($p=0.1$) strength. However, the mean force produced by the hip extensors and hip abductors is lower on those with PFPS compared to those without PFPS.

Core strength. Table 4 summarizes the result of the McGill Core Endurance Test. Results showed that there is a statistically significant difference in the endurance of the lateral core musculature (p=0.00) and trunk flexors (p=0.02) between the two groups. Those with PFPS have lesser core endurance compared to those without PFPS. No significant difference was noted on the trunk extensors' endurance on both groups; however, the mean time of those with PFPS is lower than those without PFPS.

Figure 1 illustrates that more participants from the PFPS group were in stage 0. There is also a statistically significant association found in the 8-stage core stability test results between those with and without PFPS (p=0.031).

Table 1. Muscle strength testing position

Muscle Group	Patient Position	Limb Position	Manually Stabilized Limb	Dynamometer Placement
Hip Extensor	Supine	Hip flexed to 90°, knee relaxed	Trunk	5 cm proximal to knee on extensor surface of thigh
Hip Flexor	Supine	Hip flexed to 90°, knee relaxed	Trunk	5 cm proximal to knee on flexor surface of thigh
Hip Abduction	Supine	Knee extended, hip in neutral abduction	Contralateral lower extremity	5 cm proximal to knee on lateral surface of thigh
Hip Adduction	Supine	Knee extended, hip in neutral abduction	Contralateral lower extremity	5 cm proximal to knee on medial surface of thigh

Table 2. Demographic data of participants

Demographics	Mean ± SD		P-value
	With PFPS (n=10)	Without PFPS (n=15)	
Height (cm)	162.8 ±10.34	164.7 ± 7.4	0.59
Weight (kg)	72.64 ± 19.88	68.85 ± 12.75	0.57
Age (yrs)	19.2 ± 1.14	20.6 ± 1.99	0.091*

*Data non-normal; P-value based on Mann-Whitney U Test

Table 3. Mean values of hip muscle strength

	Mean ± SD (kg)		t	P-value
	With PFPS (n=20)	Without PFPS (n=30)		
Hip Flexion	14.5 ± 2.5	14.6 ± 2.4	0.239	0.812
Hip Extension	21.7 ± 7.2	23.2 ± 6.4	0.745	0.460
Hip Abduction	16.6 ± 3.8	18.2 ± 3.4	1.557	0.126
Hip Adduction	16.3 ± 3.3	18.1 ± 2.8	2.039	0.040*

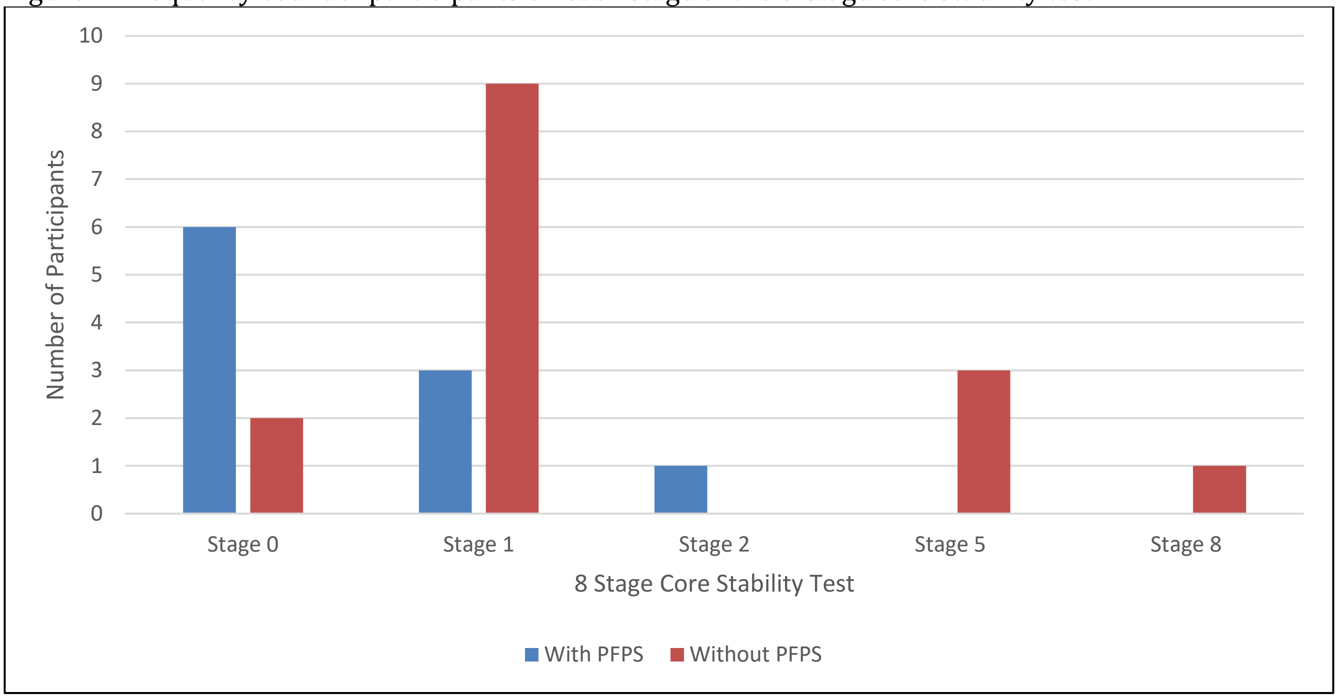
*significant difference

Table 4. Mean values of McGill Core Endurance Test

	Mean ± SD (in seconds)		t	P-value
	With PFPS (n=10)	Without PFPS (n=15)		
Trunk Flexor	44.6 ± 28.2	92.5 ± 69.9	2.382	0.027*
Trunk extensor	51.7 ± 35.2	62.6 ± 33.5	0.774	0.442
Lateral musc.	36.22 ± 22.65	73.62 ± 27.17	5.085	<0.001*

*significant difference

Figure 1. Frequency count of participants on each stage of the 8-stage core stability test



DISCUSSION

This study was able to compare the hip strength and core strength and stability between PFPS and non-PFPS groups. One of the significant findings of this study was there was a difference between the hip adductor strength between PFPS and non-PFPS group. There were also differences in core strength levels specifically the lateral core muscles between the groups. Similarly, an association was also found in the performance of the 8-stage core stability test, with the non-PFPS group reaching higher stages compared to the PFPS group.

Hip strength. Results showed that those with PFPS have significantly weaker adductor muscle strength compared to those without PFPS. This contradicts the results of other studies where-in participants with PFPS had weaker hip abductors and lateral rotators.[19,20] One possible reason for this discrepancy in results may lie in the role of the hip adductor during movement. A study investigated the effect of hip adduction on the activity of the Vastus Medialis and Vastus Lateralis muscles during a semi-squat exercise. The result of the study shows that isometric contraction of the hip adductors during a squat produced a balanced activity of the quadriceps during the activity.[21] This would explain the difference in hip adductor strength among the PFPS and non-PFPS groups in this study.

Core strength. This study showed that those with PFPS have significantly lower core stability and endurance of the lateral musculature compared to those without. These lateral musculatures include the quadratus lumborum, external oblique, internal oblique, iliocostalis, longissimus, and intertransversalis.[22] These muscles serve as the key dynamic stabilizers of the spine and lumbopelvic region especially during a reaction-based task such as running. This task is a common skill needed in football. One study mentioned that the lateral musculature deficits can lead to lower extremity injury. Any deficit in the core musculature could cause muscle imbalance in the hip area as compensation. The weakness of the hip external rotators is proposed to cause an increase in hip internal rotation and knee valgus angles during dynamic tasks, therefore leading to lateral compressive forces at the patellofemoral joint.[23] In addition to this, a study by Cowan, et al. found that there was an association between decreased trunk side flexion strength and PFPS.[24] This could be the reason why those with PFPS had lower mean scores for both lateral musculatures.

In the 8-stage core stability test, frequency count shows that there are more participants from the PFPS group who had lower results as compared to those without PFPS. Recent studies have mentioned that deficits in core musculature capacity can increase the risk of lower extremity injuries. Since core musculature activity precedes lower extremity activity in the majority of athletic tasks[22] it could be deduced that during movements of any particular task involving the lower extremity in sports, neuromuscular coordination is required to produce an efficient action, therefore, motor control of the trunk plays a huge role in the incidence of lower extremity injuries. A study by Cholewicki and Van Vilet, has also stated that all of the core musculatures contributes to core stability. The activity of the specific core musculature only changes depending on the task.[25] In a study by Leetun, et. al it was mentioned that core stability is the product of motor control and muscular capacity.[11] As such, apart from having a strong core, the ability to generate sufficient force and efficiently recruit the trunk musculature is important. A study investigated the association between core stability and dynamic stability of the lower extremity. They concluded that decreased neuromuscular control of the trunk can increase the valgus positioning of the knee. Therefore, a strong core is needed to control hip adduction and internal rotation of the knee.[23]

CONCLUSION

The study compared the core stability and hip strength of football athletes with and without PFPS. Football athletes without PFPS in this study demonstrated greater core stability and hip adductor muscle strength compared to those without PFPS. However, due to the small sample size, the results of this study may only apply to those who participated in the study.

Implications. Training for core stability and hip muscle strength should be an integral part of the rehabilitative intervention on patients with patellofemoral pain syndrome and should be part of the strength and conditioning program of athletes or clients as a preventive measure.

Limitations. This study has potential limitations. First, due to the limited number of participants, the results of this study may not be generalizable to the whole population. Second, the researchers were not able to factor in limb dominance that may be a confounding factor in the result of the study. Also, chronicity of the injury was not taken into consideration in this study which may affect the outcome.

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Individual Author's Contributions

G.S., K.S., K.A., M.K.; Designed and performed experiments, analyzed data and co-wrote the paper. G.S., K.S., K.A., M.K.,E.A, J.T., J.B., J.P., W.A, M.U.; Performed experiments. G.S., K.S., K.A., M.K.; Supervised the research. G.S., K.S., K.A., M.K.; Designed the experiments and co-wrote the paper.

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Conflicts of Interest

The authors of this paper declare no conflicting interest.

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