International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Correlation Study of Knee and Ankle Proprioception and Strength with Squat Performance

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ABSTRACT

BACKGROUND: Knee injuries are common in both athletic and non-athletic populations, often resulting from impaired neuromuscular control, proprioception deficits, and muscle weakness. Proprioception, defined as the ability to sense joint position and movement, is crucial for maintaining stability and reducing injury risk. The knee and ankle joints function synergistically in weight-bearing activities, making it essential to assess their proprioception and strength in relation to injury risk. While muscular strength provides stability, proprioception enables precise movement control and reflexive joint stabilization. The purpose of this study is to investigate the relationship between knee and ankle proprioception, strength, and knee injury risk as determined by a squat test.

OBJECTIVE: The study aimed to investigate the correlation of knee and ankle proprioception and strength with squat performance.

MATERIALS AND METHODS: A total of 30 participants were assessed for knee proprioception and ankle proprioception (joint position sense). Strength was measured using a push-pull dynamometer for knee extension and ankle plantar flexion. Squat performance was evaluated using a squat test.

STASTISTICAL ANALYSIS: Proprioception, strength, and squat test scores were compared by employing Spearman's rank correlation coefficient. Statistical importance had been assessed at $p < 0.05$ (significance level).

RESULTS: The findings demonstrated a negative relationship between squat performance and knee and ankle proprioception, suggesting that a decrease in proprioception (a drop in the proprioception value) was associated with a decrease in squat efficiency. In contrast, knee strength and ankle strength were positively correlated with squat performance, suggesting that greater strength improves squat ability.

CONCLUSION: These findings suggest that while proprioception is essential for joint control, excessive reliance on it may reduce squat efficiency. On the other hand, greater lower limb strength enhances squat performance. This study provides useful insights for training and rehabilitation programs focused on improving lower limb function.

Keywords: Ankle Proprioception, Correlation Study, Joint Position Sense, Knee Proprioception, Muscle Strength, Push-Pull Dynamometer, Squat Performance.

INTRODUCTION

For both healthy adults and athletes, knee function is important to maintaining mobility, stability, and overall performance. Knee function is affected by a number of elements, such as proprioception and muscular strength. Maintaining knee stability requires strength in the lower limbs, particularly in the hamstrings and quadriceps. In addition to enhancing athletic performance by promoting explosive movements as well as endurance, a balanced strength between different muscle groups also reduces the prevalence of knee injuries in both athletes and healthy people. The capability of the body to perceive movement and joint position, or knee proprioception, is crucial for balance, coordination, and effective movement. It is also important for daily activities and sporting performance. Nevertheless, it is presently uncertain how exactly these characteristics contribute to functional knee tasks.[1]

Since Charles Sherrington introduced proprioception in 1906, extensive research has explored its sensory receptors, neural pathways, testing, training, and influencing factors.[2] Sports performance, injury prevention, and recovery all depend heavily on proprioception. Motion threshold measurement, joint angle reset, and force sense reproduction are common methods of assessment, though usually only one is employed. In active individuals, proprioception and lower limb strength, especially in the knee and ankle, are essential for optimal function and injury prevention.[3]

Knee proprioception integrates sensory inputs from mechanoreceptors like “Ruffini endings”, “Pacinian corpuscles”, and “Golgi tendon organ-like receptors” in ACL. These receptors convert mechanical loads into neural signals, aiding joint stability and injury prevention. Joint position sense (JPS) and motion detection are key components of proprioception. Recent research highlights its role in maintaining functional knee stability[4].

Rehab programs can benefit from quantifying strength since it gives valuable information about target values, suitable exercise loads, and therapy effectiveness and progress. Strength testing is a common procedure used by medical professionals to evaluate healthy people and to treat patients with various upper or lower limb conditions, such as osteoarthritis in the knee. Hand-held dynamometers (HHDs) are the most used tool for measuring strength in clinical settings because of their affordability, portability, and ease of use in comparison to other, less flexible, and more costly techniques (such as the isokinetic dynamometer). HHDs can generally be divided into two categories: push and pull[5].

In the majority of sports, the squat is an essential movement. Most of the power activities that include the lower extremities require this ready position. When performed properly, the deep squat is a test of total body mechanics, assessing i) bilateral, ii) symmetrical, iii) functional hip, iv) knee, and v) ankle mobility. The dowel held above determines the bilateral, symmetrical mobility of shoulders and thoracic spine and also the stability as well as motor control of the core muscles[6].

The study goal was to determine the extent to which knee and ankle proprioception and strength contribute to squat performance, with a particular focus on the potential interactions between these variables. With implications for both sports performance as well as injury prevention, our goal is to better understand the mechanics underlying efficient squat execution through this research.

MATERIALS AND METHODS

Study Design and Participants

The current study included 30 participants selected through convenience sampling. Eligible participants were aged 18-25, had a normal BMI, no recent knee or ankle injuries, and no neurological or musculoskeletal impairments[7]. For the previous six months, they participated in moderate physical exercise at least three days a week. Individuals with major lower limb surgeries in the past two years were included only if medically cleared. Knee and ankle proprioception were assessed using a joint position sense test[7], while isometric knee extension and ankle plantar flexion strength were measured with a push-pull dynamometer. Squat performance was evaluated through a squat test, analyzing knee valgus, instability, and asymmetrical weight distribution[6].

OUTCOME MEASURES

Assessment of knee and ankle proprioception:

One researcher evaluated the dominant leg's knee joint position sense using an inclinometer[7]. The participants sat with their hips as well as knees bent at 90°. The individual was blindfolded during the exercise, and the examiner moved the leg to a goal position of 25° or 40° knee flexion for five seconds before returning it to the starting position. The test was done three times, and the subject actively moved their knee to the goal and indicated when they considered they had reached it. “Joint position error (JPE)” was measured in degrees. The mean absolute error across trials was calculated[10].

Assessment of knee and ankle strength:

Every position was evaluated three times, and participants had three seconds to repeat the target after the examiner controlled foot to a target angle and then returned it to neutral[5]. The mean error angle was calculated. A shin pad was placed 2 cm above the malleoli, with the instrument aligned to the tibia and calf. Participants exerted maximum effort by pushing or pulling against the dynamometer, with all tests conducted in a gravity-eliminated position and 30-second rest intervals between trials.

The same examiner used standardized commands to complete each assessment[11].

Assessment of Squat Performance

The standard FMS Deep Squat Test (DST) protocol was followed without visual demonstration. Participants received verbal instructions, with a maximum of three trials allowed. A score of 3 was given if the torso was parallel to the tibia or vertical, knees aligned over feet, and the dowel aligned over feet. If criteria were unmet, a 2-inch platform was used; meeting the criteria then resulted in a score of 2, otherwise a 1. For DSTO, participants held hands at chest level without grasping. For DSTF, they positioned their feet comfortably[6].

STATISTICAL ANALYSIS

TEST FOR NORMALITY:

After determining that the data was not regularly distributed, the “Shapiro-Wilk” test was employed to test for normality. For the correlations listed below, a non-parametric test called the Spearman coefficient of correlation was employed.

DESCRPITIVE STATISTICS:

TABLE 1.1

PARAMETERS	Total number of participants	MIN	MAX	MEAN	STANDARD DEVIATION
Knee proprioception	30	1	8	4.7	2.36
Ankle proprioception	30	1	9	5.0	2.51
Knee strength	30	30	59	43.03	8.36
Ankle strength	30	20	50	33.4	9.54
Squat test	30	1	3	1.8	0.87
Age	30	19	24	21.4	1.583

SPEARMAN CO EFFICIENT OF CORRELATION ANALYSIS:

Data were analyzed by employing "Spearman's rank correlation coefficient" to determine relationships between proprioception, strength, and squat test performance. A p-value <0.05 was considered statistically significant.

TABLE 1.2

	Squat test	
	r value	p value
Knee proprioception	-0.55	0.0018
Ankle proprioception	-0.595	0.0007
Knee strength	0.804	0.001
Ankle strength	0.832	0.0001

SCATTERED PLOTS:

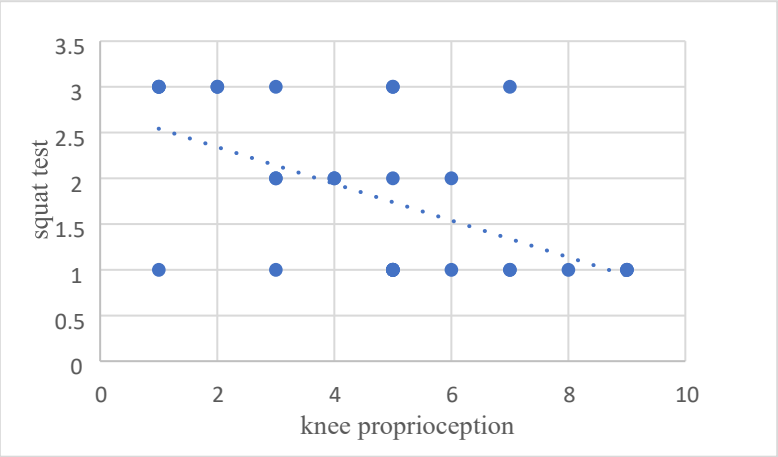

Fig 1.1 Correlation Between Knee Proprioception and Squat Test.

The coefficient of Correlation between knee proprioception and squat test is -0.55. Since the p-value =0.0018, i.e., <0.05, we can "reject H_0" and "accept H_1". This indicates a negative correlation between knee proprioception error (inclinometer reading, i.e., absolute error) and the squat score. Since the decrease in the inclinometer value indicates better proprioception. Therefore indicating a positive correlation between knee proprioception and squat performance. (Fig 1.1)

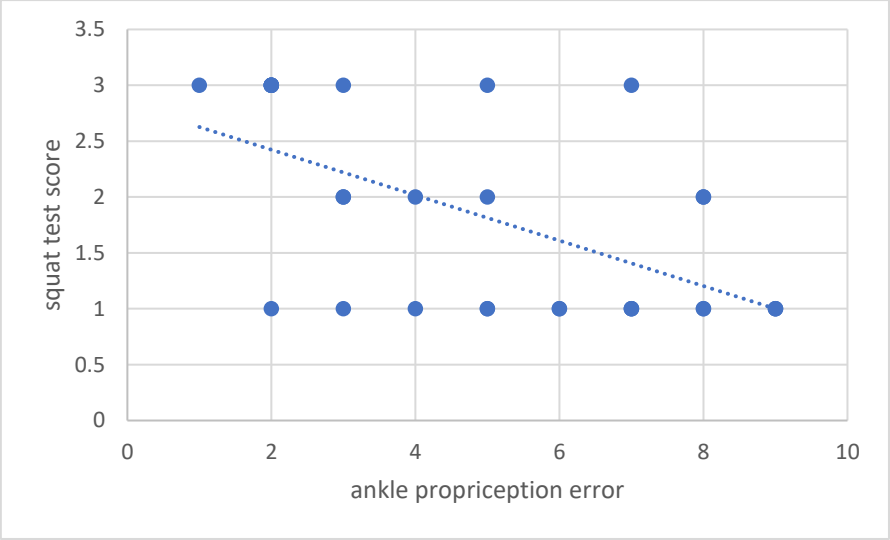

Fig 1.2 Correlation Between Ankle Proprioception and Squat Test.

The coefficient of Correlation between ankle proprioception and squat test is -0.595 since the p-value =0.0007 <0.05; hence, we can "reject H_0" and "accept H_1". This indicates a negative correlation between ankle proprioception error (inclinometer reading, i.e., absolute error) and the squat score. Since the decrease in the inclinometer value indicates better proprioception. Therefore indicating a positive correlation between ankle proprioception and squat performance. (Fig 1.1)

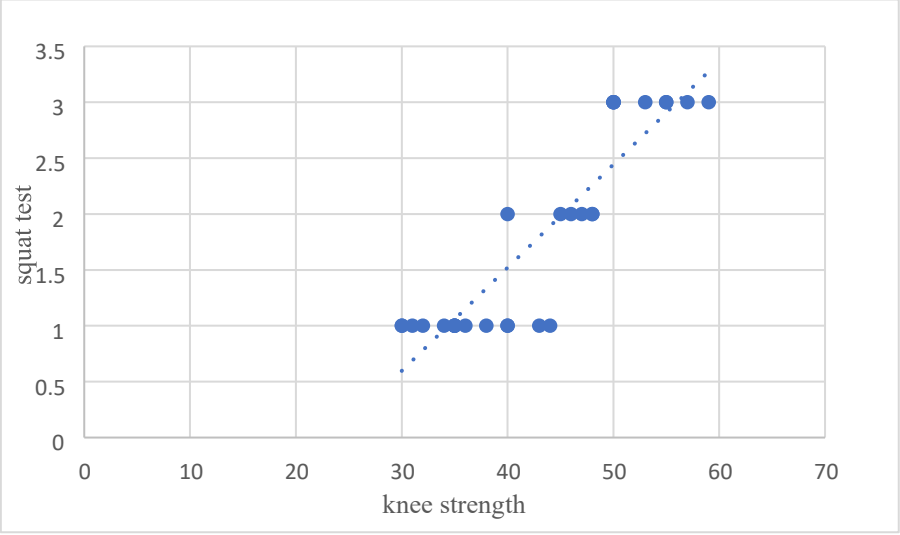

Fig 1.3 Correlation Between knee Strength and Squat Test.

The coefficient of Correlation between knee strength and squat test is 0.804 since the p-value =0.0007,

i.e., <0.05; hence, we can reject H_0. This indicates a positive correlation between knee strength and the squat test. (Fig 1.3)

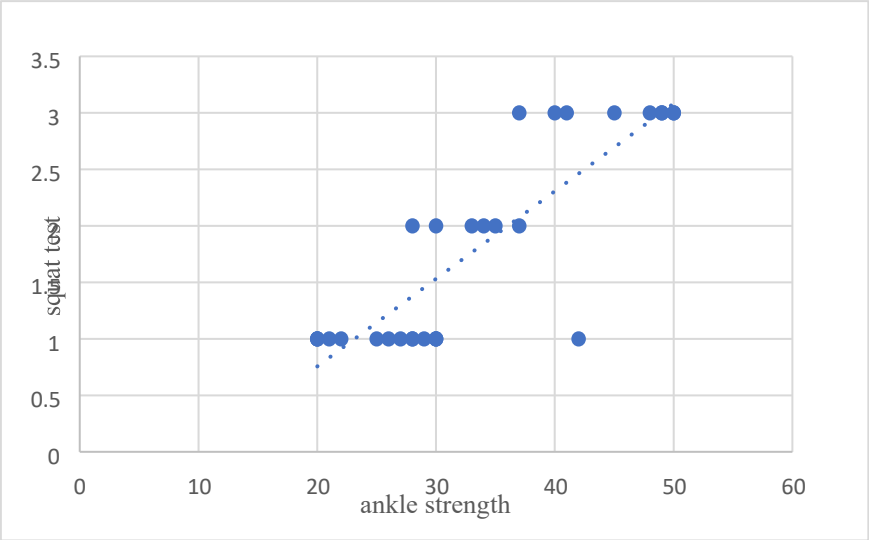

Fig 1.4 Correlation Between Ankle Strength and Squat Test.

The coefficient of Correlation between ankle strength and squat test is 0.832 since the p-value =0.0001, i.e. <0.05; hence, we can "reject H_0". This indicates a positive correlation between ankle strength and the squat test (fig1.4).

DISCUSSION

This study provides insight into how proprioception and strength influence squat performance. The observed negative correlation between knee and ankle proprioception error (inclinometer reading) with squat test score suggests that heightened proprioceptive awareness enhances squat efficiency. So, the study shows a positive correlation between proprioception and squat performance. One possible explanation is that individuals with greater proprioceptive sensitivity may show better squat performance. According to one study that looked at the variables affecting one's capacity to execute a deep squat, ankle dorsiflexion flexibility is strongly related to the posture's successful completion. Ankle dorsiflexion flexibility was lower in those who couldn't complete the deep squat, indicating that poor ankle mobility may make it difficult to do a correct squat[13].

Another study examined the relationships between muscular strength, ankle, knee, and hip "range of motion (ROM)", and maximal squat depth. The results showed a strong positive correlation between the knee and hip flexion angles during squat and the ROM of the ankle dorsiflexion and knee flexion[14]. This suggests that greater flexibility in ankle and knee joints contributes to achieving a deeper squat position.

While these studies highlight the importance of ankle and knee mobility in deep squat performance, the direct relationship between proprioception, specifically the body's capability to sense joint position and movement and deep squat performance, is less clearly established. However, it is reasonable to infer that improved proprioception could enhance movement coordination and stability, potentially leading to better performance in movements like the deep squat.

Conversely, the strong positive correlation between knee and ankle strength with squat performance reinforces the idea that muscular strength is a key determinant of squat efficiency. Greater strength

enhances force generation, stability, and movement control, all of which contribute to improved squat performance. Strength is crucial for squat performance, ensuring muscle activation, control, and stability, especially in the legs, core, and joints. Strong muscles help maintain proper form, prevent injury, and contribute to power, endurance, and squat depth[15]. These findings align with previous research suggesting that lower limb strength is a fundamental factor in athletic and functional movements.

From a practical perspective, these results emphasize the importance of balanced training. While proprioception training is valuable for injury prevention and joint control, it should not come at the expense of strength development. Integrating strength training with proprioceptive exercises may provide a more comprehensive approach to optimizing squat performance. Future research could further explore how different training interventions influence these relationships across various populations, including athletes, rehabilitation patients, and older adults.

Limitation and future scope

The included studies used diverse techniques to measure knee and ankle proprioception and strength, and the sample size was very modest, whereas a greater sample size would have improved the study's statistical power. Biases may be introduced by the utilization of particular instruments and approaches to evaluate knee and ankle proprioception and muscle strength. Using more sophisticated equipment and a variety of measurement techniques could improve the accuracy of the outcome.

CONCLUSION

This study discovered a strong relationship between squat performance, strength, and proprioception. Knee and ankle proprioception errors were negatively correlated with squat test scores, indicating a positive correlation between proprioception and squat performance. Therefore, suggesting that higher proprioception may improve the squat ability. In contrast, knee and ankle strength showed a strong positive correlation with squat performance, indicating that greater muscular strength improves squat ability.

DECLARATION OF CONSENT

The authors attest that each participant gave their informed consent prior to taking part in the research. Data confidentiality was maintained, and personal details were anonymized.

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