

Research Article



Differences in Limb Muscle Strength Affecting Vertical Jump Heights in Soccer Players after Chronic Ankle Injury

Anggara Dwi Samudra¹ , Bambang Purwanto^{2*} , Dwikora Novembri Utomo³

1. Program of Sport Health Science, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia.

2. Department of Medical Physiology, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia.

3. Department of Orthopedic and Traumatology, Faculty of Medicine, Regional General Hospital Dr. Soetomo, Universitas Airlangga, Surabaya, Indonesia.



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ABSTRACT

Introduction: Muscle strength strongly affects soccer players' activities, but chronic ankle injuries can reduce the ability of athletes to achieve their best performance. No report exists in the literature about the role of certain muscles in affecting the vertical jump height of soccer players. Therefore, this study aimed to analyze the differences in leg muscle strength that affect the vertical jump height of soccer players after chronic ankle injury.

Materials and Methods: To achieve the aim of this study, a cross-sectional design was employed by involving one team consisting of 25 Surabaya Football Association (PERSEBAYA) players. They were divided into injury and noninjury groups, according to the questionnaire. The participants were determined based on their normal body mass index (BMI), age (17-40 years), male gender, and PERSEBAYA players. The collected data included vertical jump, ankle muscle construction, and hamstring muscle data. The data were statistically analyzed using the t test and Pearson correlation ($P < 0.05$).

Results: There was no significant difference in leg muscle strength between the injured and uninjured players. Only the hamstring muscle significantly affected soccer players' vertical jump after chronic ankle injury ($r = 0.422$, $P = 0.035$ with moderate influence) and was not affected by the gastrocnemius, plantar, adductor, and abductor muscles.

Conclusion: There was a correlation between eccentric contraction of the hamstring muscle and vertical jump height in soccer players after a chronic ankle injury. These findings benefit soccer practitioners and medical teams in designing injury management and recovery strategies for players with ankle injuries.

* Corresponding Author:

Bambang Purwanto, MD.

Address: Department of Medical Physiology, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia.

Tel: +62 (81) 217772995

E-mail: bpaifo@gmail.com



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Introduction

Football is categorized as a sport with a very high injury rate [1, 2]. This high rate is due to the unpredictability of complex field situations, the intensity of the game, and the inherent nature of physical contact [3]. Jones et al. reported that athletes are susceptible to a wide range of injuries, including contusions (or bruises), cramps, sprains, strains and fractures of the bones, most of which transpire in the ankle [4]. Walls et al. revealed that throughout the 2019 Indonesian League, the Surabaya Football Association's (PERSEBAYA) medical team documented a 55% incidence of ankle injuries, whereas the number of ankle injuries increased to 50% of the total incidence during the FIFA World Cup [5, 6-8]. Ankle injuries are a challenge for athletes, doctors, physiotherapists, and related stakeholders because they can affect the performance of soccer players on the field [9, 10].

Proper and comprehensive recovery is a key factor in improving the performance of players with ankle injuries [11, 12]. Li et al. reported that leg muscle strength can be restored in individuals who have suffered ankle injuries through proper and holistic rehabilitation until it reaches a level equivalent to that of individuals who have not experienced dere [13]. These findings follow the initial preliminary study of the PERSEBAYA team, in which players with a history of chronic ankle injuries and who had undergone a rehabilitation process did not perform differently than players who did not experience injuries. The severity of the injury [14-16], the effectiveness of the rehabilitation program, and individual compliance with the provided rehabilitation protocol [11, 17] significantly influence the success rate of restoring muscle strength to the equivalent of an uninjured individual.

The vertical jump test [18] can measure muscle recovery from ankle injuries. The assessment of vertical jump height can reflect the progress of recovery from an ankle injury, as it includes an evaluation of the ability of the leg muscles to produce the explosive force, strength, and coordination required in the jumping motion [19, 20]. When recovering from an ankle injury, the muscles around the ankle, such as the hamstring, gastrocnemius, plantar flexor, adductor group and abductor group, undergo adaptation [9, 21, 22]. Measuring vertical jump height can provide a holistic view of an athlete's ability to perform jumping activities effectively and safely following an ankle injury. However, to date, no study has sought to analyze the role of specific muscles in recovery after a chronic ankle injury, particularly concerning improving the function of vertical jumping movements.

Therefore, this study aimed to analyze the differences in leg muscle strength influencing the vertical jump height of soccer players after a chronic ankle injury. Understanding the role of leg muscles can provide practical and clinical information regarding the design of injury management and recovery strategies for soccer players with ankle injuries.

Materials and Methods

Study design

This study used a cross-sectional design and was retrospective [23]. This study was conducted at the PERSEBAYA team dormitory in Jalan Doho, Number 15, Surabaya, in December 2021. All the PERSEBAYA soccer players were included in the study population (n=25) and then grouped into injured (n=11) and uninjured (n=14) based on questionnaire assessment. If the player had experienced an ankle injury, he was included in the injury group; if he had never experienced an ankle injury, he was included in the uninjured group. The inclusion criteria for the research participants included coming from PERSEBAYA players, being male, having a normal body mass index (BMI) (18.5–22.9 kg/m²) and 17–40 years old. The exclusion criteria were experiencing injuries requiring further care and were unwilling to provide informed consent. The criteria for dropping out of the participants included injury occurring during the examination and resigning from the subject. Therefore, purposive sampling was used in this study [24].

Measurement tools

Three instruments were used to measure the variables that were the focus of the research: the force frame, force deck and NordBord. The force frame was used to measure the strength of muscle contractions that move the ankle joint; the force deck was used to assess the vertical jumping ability of the individuals included in the study; the NordBord was used to measure hamstring muscle strength. Measurements were made by testing each participant's muscle strength and recorded on the data collection sheet.

Study procedure

The research procedures consisted of an initial examination and an examination management. During the initial examination stage, researchers evaluated anthropometric and physiological parameters such as body weight (kg), height (cm), body temperature (°C), and structural parameters such as the hamstring muscle,



Figure 1. Measurement of ankle muscle contraction with the force frame and nordbord

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gastrocnemius muscle, plantar flexor muscle, adductor group muscle and abductor group muscle. They used a NordBoard for the hamstring muscles and a force deck for other muscles. Furthermore, during the examination management stage, the research subjects were classified into two groups: Injured and uninjured. The vertical jump was measured in each group using a force deck (N/kg). This measurement was followed by using a force frame to examine the adductor, abductor, gastrocnemius and plantar flexor muscles.

The participant in the hamstring muscle examination was positioning the Nordic hamstring exercise. When doing the Nordic hamstring to produce maximum strength, the participant must hold the body as slowly as possible when dropping the body so it could produce a strong eccentric contraction in the hamstring. The participant was in the Nordic hamstring exercise position for the muscle examination. During the gastrocnemius muscle examination, the foot's position was in full extension, and the plate force deck was under the sole, after which the plate was pushed with a plantar flexion movement. Then, the flexor plantar muscle was examined by positioning the plate force deck on the instep, after which the plate was pushed with a dorsiflexion movement. The adductor muscle was examined by position-

ing the knee at 90° flexion. The plate was positioned on the outside of the knee, after which the plate was pushed outward and the knee remained at a 90° position. Finally, the adductor muscle examination was conducted by positioning the knee at 90° of flexion. The plate's position was on the inside of the knee, which was pushed toward the inside while ensuring the knee was in a 90° position. The final stage of the assessment involved evaluating the hamstring muscles using a NordBord. This methodological approach was carefully designed to provide a holistic picture of the study subjects' physical status and muscle condition. The methods used to measure ankle muscle contraction with a force frame and a NordBord are presented in Figure 1.

Force plate to check isometric contraction of the adductor group muscle (A), eccentric contraction check of the hamstring muscle using a NordBord (B and C), and force plate to check isometric contraction of the gastrocnemius muscle (D). In the Figure 1B and C measure the hamstring muscles using the NordBord tool, but there are differences in position or movement in the ankle. Figure 1B shows plantar flexion and Figure 1C shows dorsiflexion; however, these differences are not evident because only the hamstring works in the pure Nordic hamstring.

Table 1. Descriptive analysis

Variables	Groups	Mean±SD
BMI (kg/m ²)	Injured	22.13±1.55
	Uninjured	23.04±1.81
Vertical jump (cm)	Injured	42.51±4.71
	Uninjured	46.36±4.67
Hamstring muscle strength (N/kg)	Injured	273.35±66.67
	Uninjured	290.09±52.81
Gastrocnemius muscle strength (N/kg)	Injured	192.71±39.26
	Uninjured	226.90±56.62
Plantar muscle strength (N/kg)	Injured	388.85±100.5
	Uninjured	496.90±150.5
Adductor muscle strength (N/kg)	Injured	294.42±71.68
	Uninjured	322.36±37.96
Abductor muscle strength (N/kg)	Injured	370.35±42.07
	Uninjured	388.72±63.84

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Statistical analysis

All ankle muscle contraction measurement data were subjected to difference and correlation tests. The study employed the independent t-test to examine variations in leg muscle strength, encompassing the hamstring, gastrocnemius, plantar, adductor and abductor muscles, among soccer players following a chronic ankle injury. At the same time, the Pearson correlation test was used to analyze differences in leg muscles influencing vertical jumps. The statistical analysis was performed using SPSS software, version 21, with a 95% confidence level ($P < 0.05$) [25].

Results

Descriptive analysis

Descriptive research data analysis involved measuring various physical parameters, including BMI, vertical jumping ability, and muscle strength in the hamstring, gastrocnemius, plantar, adductor and abductor areas. The data collected from the injured and noninjured respondent groups are presented in [Table 1](#).

Classical assumption testing and hypothesis evaluation

The results of the normality test using the Shapiro-Wilk test ($n \leq 50$) revealed that injured and uninjured groups were normally distributed, as indicated by a probability value greater than the standard ($P > 0.05$). Furthermore, testing the data's homogeneity using Levene's test revealed that each variable came from the same or homogeneous variance. The results showed no significant difference in leg muscle strength between injured and uninjured players. Only the hamstring muscle significantly affected the vertical jump of soccer players after a chronic ankle injury ($r = 0.422$, $P = 0.035$ with moderate influence) and was not affected by the gastrocnemius, plantar, adductor, or abductor muscles ($P \geq 0.05$). Consequently, there is a significant correlation between hamstring muscle strength and the vertical jumping capability of soccer players post-chronic ankle injury. Furthermore, the Pearson correlation test results showed moderately correlated ankle muscle contractions affected by the hamstring, gastrocnemius, plantar, adductor, and abductor muscles. The results of classical assumption testing and hypothesis evaluation (independent t-test and Pearson correlation) are presented in [Table 2](#).

Table 2. Classical assumption testing and hypothesis evaluation (t-test and Pearson correlation)

Variables	Group	Shapiro–Wilk	Levene’s Test	Independent t-test	Pearson Correlation	P
Hamstring muscle	Injured	0.718	0.246	0.500	0.422	0.035*
	Uninjured	0.438				
Gastrocnemius muscle	Injured	0.852	0.263	0.088	0.395	0.051
	Uninjured	0.932				
Plantar muscle	Injured	0.323	0.099	0.042	0.333	0.104
	Uninjured	0.342				
Adductor muscle	Injured	0.238	0.210	0.255	0.323	0.323
	Uninjured	0.127				
Abductor muscle	Injured	0.207	0.348	0.396	0.319	0.319
	Uninjured	0.797				

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Note: Pearson correlation; r=0.90–1.00: Very high; r=0.70–0.89: High; r=0.50–0.69: Moderate; r=0.30–0.49: Low; 0.00–0.29=Negligible.

*Statistically significant associations at P<0.05.

Discussion

Leg muscle strength in players after chronic ankle injury and soccer players without injury

This study confirmed the strength of the hamstring, gastrocnemius, plantar, adductor and abductor muscles in soccer players with and without chronic ankle injuries. The results revealed no significant difference in leg muscle strength between players with chronic ankle injuries and those without injuries. This condition is because injured muscles in the ankle can heal through regenerative mechanisms and reparative processes that are part of the regenerative capacity of the human body [26, 27].

Ju et al. reported that injured muscles perform several healing mechanisms, including inflammation, proliferation, and remodeling [28]. First, white blood cells clean up damaged tissue during the inflammatory stage. In the subsequent phase of proliferation, fresh cells emerge to replenish those that have been impaired. Ultimately, during the remodeling phase, recently generated cells undergo maturation to facilitate the restoration of muscle functionality [29–32]. Furthermore, McKeown et al. revealed that the recovery of muscle strength due to an ankle injury is influenced by proper rehabilitation and physical exercise [33]. The rehabilitation process is specifically designed to strengthen muscles and improve

proprioceptive sensation, which can help speed up the recovery of injured muscles [34]. This exercise aims to improve muscle strength, joint stability, and proprioceptive abilities and is essential in restoring movement control and preventing reinjury [35, 36].

Research by Li et al. reveals that applying proper and holistic rehabilitation can generally generate the ability to restore limb muscle strength in individuals who have sustained ankle injuries until it reaches a level equivalent to that of uninjured individuals [13]. The rehabilitation process prioritizes the restoration of muscle dysfunction resulting from reduced movement and atrophy of inactive tendons, along with restoring articular tendon weakness due to ankle injuries [28]. Adequate rehabilitation can also reduce pain and swelling and the risk of reinjury, improving muscle function and increasing ankle joint stability [37].

Furthermore, McKeown et al. reported that the recovery of muscle strength in individuals with ankle injuries after rehabilitation may vary depending on several factors [33]. Rehabilitation generally aims to restore muscle strength and other functions the injury may have affected. However, the success rate of restoring muscle strength to the equivalent of an uninjured individual depends largely on the injury’s severity, the rehabilitation program’s effectiveness, and the individual’s adherence

to the rehabilitation protocol [11, 17]. Therefore, correct and consistent performance of rehabilitation and muscle strength training can restore the injured limb's muscle strength to the level of an uninjured limb.

Mechanisms of leg muscle strength on vertical jump height post-chronic ankle injury

The analysis revealed a significant impact of the hamstring muscle on vertical jump height. However, no significant correlations were observed between vertical jump performance and the activity of the gastrocnemius, tibialis anterior, adductor, or abductor muscles. These findings are consistent with prior research that has underscored the pivotal role of the hamstring muscles in vertical jump performance. Studies by Ueno et al. [21] studies reveal that activating the hamstring muscles is important for controlling ankle movement, keeping the body stable and controlling the amount and timing of load on the anterior cruciate ligament during vertical jump landings. Furthermore, our results align with the work of Gulu et al. [22], who highlighted the multifaceted mechanisms through which the hamstring muscles contribute to vertical jump performance, including their involvement in hip extension, knee joint stability, and explosive power generation. Our study provides empirical evidence supporting the association between hamstring muscle activity and vertical jump performance in soccer players with chronic ankle injuries.

This investigation reveals that the involvement of hamstring muscles significantly affects the vertical jump performance of soccer players who have sustained chronic ankle injuries. Hamstring muscles contribute to the stability and strength of the posterior thigh [38–40], playing a crucial role in ankle control, balance maintenance, and ultimately impacting vertical jump height [41]. Previous research has identified three primary mechanisms in hamstring muscles that affect vertical jumps. Firstly, they are vital for hip extension, facilitating upward and forward body movement, thus increasing jump height [18, 40]. Secondly, cooperation between the hamstring and quadriceps muscles enhances knee joint stability during take-off, facilitating efficient force transfer and enhancing jump height [42, 43]. Thirdly, specialized exercises targeting hamstring muscles, such as the Nordic hamstring exercise, improve muscle length-tension relationship and explosive power, resulting in increased vertical jump performance [43, 44].

Additionally, hamstring muscle contraction regulates the magnitude and timing of peak load on the anterior cruciate ligament (ACL) during vertical jump landings,

affecting ACL load more significantly than ground reaction force and quadriceps muscle activation [21]. Coordination between the quadriceps and hamstring muscles is crucial for achieving maximum jump height safely [40, 44]. The jumping phase, involving hip, knee and ankle joints, comprises four stages: Starting position, quiet phase, propulsive phase, and flight phase [18, 42]. During preparation, muscles contract eccentrically, setting the stage for optimal concentric contractions during take-off [45–48]. In squat jumps, prime movers include the gluteus, quadriceps and hamstring muscles, while secondary movers involve various other lower extremity muscles. The hamstring muscle's involvement in the jumping phase is delineated into eccentric, amortization, and concentric phases [49]. Each phase is critical for jump quality; the eccentric phase stores elastic energy, the amortization phase rapidly transitions to the concentric phase to avoid energy waste [50], the concentric phase generates movement with strength and speed [50], and the concentric phase generating movement with strength and speed [51]. Effective hamstring muscle strength training enhances vertical jump performance in soccer players recovering from chronic ankle injuries. By elucidating the specific muscles involved in vertical jump performance and their respective contributions, our findings offer valuable insights for designing targeted rehabilitation programs to improve vertical jump performance and mitigate the risk of injury recurrence in athletes.

Conclusion

Soccer players' muscle strength is crucial, but persistent ankle issues may hinder performance. There is no literature on how certain muscles affect soccer players' vertical jump height, so this study examined how leg muscle strength affects vertical jump height after chronic ankle injury. The findings of this study indicate no significant difference in leg muscle strength between players with and without chronic ankle injuries. The reason is that muscles injured in the ankle exhibit healing potential through regenerative mechanisms and reparative processes through proper and comprehensive rehabilitation. After chronic ankle injury, only the hamstring muscles affect vertical jumping in soccer players. This is because the hamstring muscles involve the muscles at the back of the thigh, which are important in controlling ankle movement, helping maintain balance and body stability, and directly affecting vertical jump height. Strong and well-trained hamstring muscles can increase neuromuscular activation to produce the explosive power needed for vertical jumps. The results of this study can serve as

a scientific reference for sports health practitioners and soccer medical teams to design injury management and recovery strategies for players with ankle injuries.

Study limitations

The participants' involvement in a football club limits this study, making it impossible to generalize the results. This study lacked follow-up control, making it impossible to fully control the subjects' nutritional status and physical activity, potentially impacting their condition. In addition, before and after the study, the researcher did not include respondents' ownership of pain, so the results only focused on muscle strength. Therefore, this study did not measure the quadriceps muscle, necessitating additional measurements in the future to compare postinjury and noninjury muscle strength, power, or endurance at a more precise level.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Health Research Ethics Committee of Universitas Airlangga (Code: 254/EC/KEPK/FKUA/2022). Informed consent was obtained from each participant prior to data collection.

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Authors' contributions

Conceptualization, investigation, Writing the original draft and methodology: Anggara Dwi Samudra; Study design and supervision: Bambang Purwanto; Data analysis: Anggara Dwi Samudra and Dwikora Novembri Utomo; Review & editing: Bambang Purwanto and Dwikora Novembri Utomo; Data collection: All authors.

Conflict of interest

The authors declared no conflict of interest.

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