Research Article

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

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Abstract

Introduction: Muscle strength strongly affects the activities of soccer players, but the presence of chronic ankle injuries can reduce the ability of athletes to achieve their best performance. Existing literatures related to the role of certain muscles in affecting the vertical jump height of soccer players has not been reported; therefore, this study was aimed at analyzing 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, who were grouped into injury and non-injury groups according to the questionnaire. The participants were determined based on their normal 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's 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 the vertical jump of soccer players 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 chronic ankle injury. These findings are beneficial for soccer practitioners and medical teams in designing injury management and recovery strategies for players with ankle injuries.

Keywords: Leg muscles, hamstring muscles, muscle strength, vertical jump, chronic ankle, soccer.

Introduction

Football is categorized as a sport with a very high injury rate [1,2]. This 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. [4] explained that Athletes are susceptible to a wide range of injuries, including contusions (or bruises), cramps, sprains, strains, and fractures of the bones, the majority of which transpire in the ankle. Walls et al. [5] 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 [6-8]. Ankle injuries are a challenge for athletes, doctors, physiotherapists, and related stakeholders because they can affect the performance of soccer players in 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. [13] explained 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. These findings are in accordance with the initial preliminary study of the PERSEBAYA team, in which players who had a history of chronic ankle injuries and 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]. As such, the measurement of 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 in detail the role of specific muscles in recovery after a chronic ankle injury, particularly with regard to 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 located 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) groups 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 inclusion of research participants in this study included coming from PERSEBAYA players, being male, having a normal BMI (18.5–22.9) and being aged 17–40 years. The exclusion criteria for this study were currently experiencing injuries that required further action and were not willing 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

To measure the variables that were the focus of the research, three instruments were used, namely: the force frame; force deck; and NordBord. The force frame was used as a tool 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, and 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 stage. 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, 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 main groups: injured and uninjured. The vertical jump was measured in each group using a force deck (N/kg). This was followed by examination of the adductor, abductor, gastrocnemius, and plantar flexor muscles using a force frame.

The participant in the hamstring muscle examination was positioning the Nordic hamstring exercise, and 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 hamstring muscle examination. During the examination of the gastrocnemius muscle, the position of the foot was in full extension, the position of the plate force deck was under the sole of the foot, after which the plate was pushed with a plantar flexion movement. Then, the examination of the flexor platar muscle was carried out by positioning the plate force deck on the instep, after which the plate was pushed with a dorsoflexation movement. The adductor muscle was examined by positioning the knee at 90° of flexion. The plate was positioned on the outside of the knee, after which the plate was pushed outward, and the knee remained in a 90° position. Finally, the adductor muscle examination was carried out by positioning the knee at 90° of flexion, the position of the plate was on the inside of the knee, and the plate was pushed toward the inside while still ensuring that the knee is 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 physical status and muscle condition of the study subjects. The methods used to measure ankle muscle contraction with a force frame and a NordBord are presented in Figure 1.

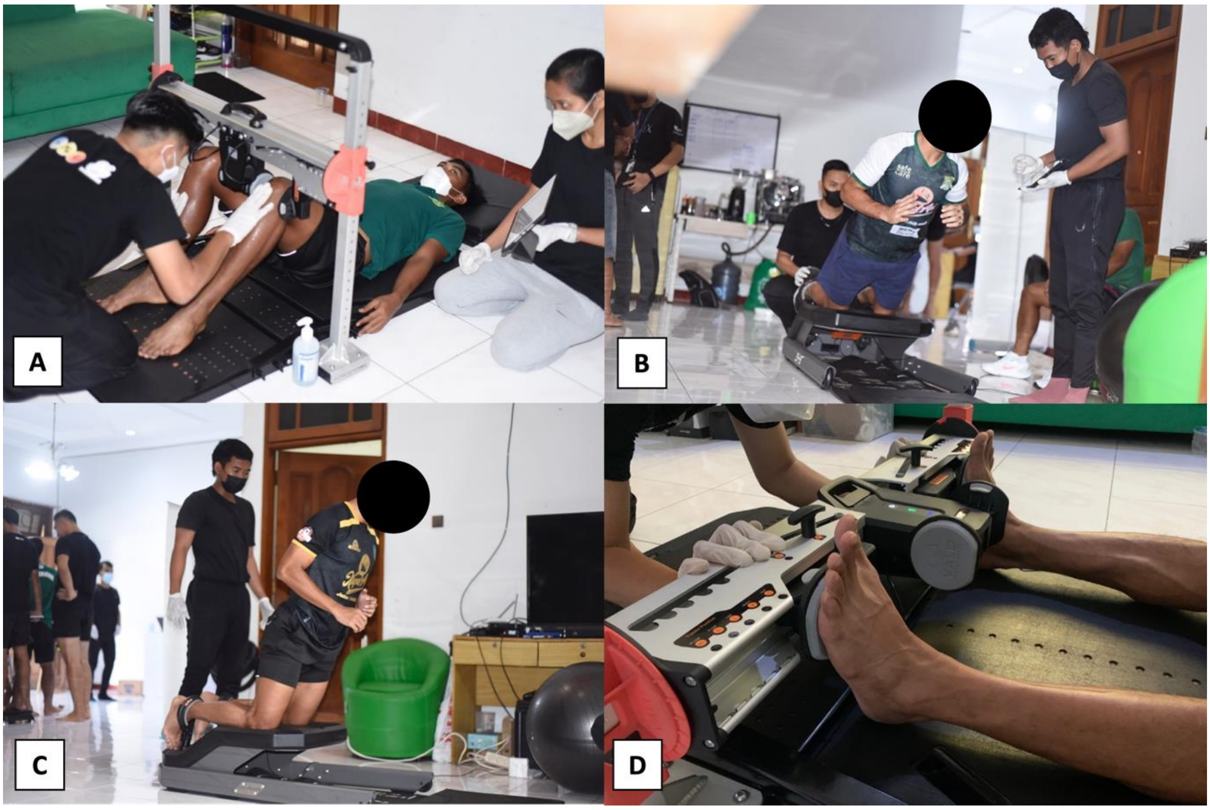

Figure 1. Measurement of ankle muscle contraction with the force frame and NordBord. Remarks: Force plate to check isometric contraction of the adductor group muscle (A),

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, parts B and C both measure the hamstring muscles using the NordBord tool, but there are differences in position or movement in the ankle; in the figure, B shows plantar flexion, and C shows dorsiflexion; however, these differences are not evident because only the hamstring works in the pure Nordic hamstring.

Ethical approval

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

Statistical analysis

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

Results

Descriptive analysis

Descriptive analysis of the research data involved measuring various physical parameters, including body mass index (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.

Table 1. Descriptive analysis

Variables	Group	Mean ± SD
BMI (kg/m²)	**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

Remarks: BMI: body mass index; cm: centimeter; kg: kilogram; m^2: square meter; SD: standard deviation.

Classical assumption testing and hypothesis evaluation

The results of the normality test using the Shapiro–Wilk test (n ≤ 50) revealed that all the groups, both injured and uninjured, 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 variance or was homogeneous. The results showed that there was 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≥ 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 results of the Pearson correlation test showed that ankle muscle contractions affected by the hamstring, gastrocnemius, plantar, adductor, and abductor muscles were moderately correlated. The results of classical assumption testing and hypothesis evaluation (independent t-test and Pearson's 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 value
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				

Remarks: r: 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 in soccer players without injury

This study confirmed the strength of the hamstring muscles, gastrocnemius muscles, plantar muscles, adductor muscles, 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 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. [28] explained that injured muscles generally perform several healing mechanisms, including inflammation, proliferation, and remodeling. First, during the inflammatory stage, white blood cells clean up damaged tissue. 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. [33] revealed that the recovery of muscle strength due to an ankle injury is influenced by proper rehabilitation and physical exercise. 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 plays an important role in restoring movement control and preventing reinjury [35,36].

Research by Li et al. [13] revealed 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. The rehabilitation process prioritizes the restoration of muscle dysfunction resulting from reduced movement and atrophy of inactive tendons, along with the restoration of articular tendon weakness due to ankle injuries [28]. Adequate rehabilitation can also reduce pain and swelling, as well as the risk of re-injury, by improving muscle function and increasing ankle joint stability [37].

Furthermore, McKeown et al. [33] explained that the recovery of muscle strength in individuals with ankle injuries after rehabilitation may vary depending on several factors. Rehabilitation generally aims to restore muscle strength and other functions that the injury may have affected. However, the success rate of restoring muscle strength to the equivalent of an uninjured individual depends largely on the severity of the injury, the effectiveness of the rehabilitation programme, 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 influence 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 Gallego-Izquierdo et al.'s [41] and Ueno et al.'s [21] studies revealed 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 revealed that the involvement of hamstring muscles significantly influences 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 through which hamstring muscles 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 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, influencing ACL load more significantly than ground reaction force (GRF) and quadriceps muscle activation [21]. Coordination between quadriceps and hamstring muscles is crucial for achieving maximum jump height safely [40,44]. The jumping phase, involving hip, knee, and ankle joints, is comprised of 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], and 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 is essential for enhancing 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 aimed at improving vertical jump performance and mitigating 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 that there is no significant difference in leg muscle strength between players with and without chronic ankle injuries. This is because muscles that have been injured in the ankle exhibit healing potential through regenerative mechanisms and reparative processes through proper and comprehensive rehabilitation. Only the hamstring muscles affect vertical jumping in soccer players after chronic ankle injury. This is because the hamstring muscles involve the muscles at the back of the thigh, which play an important role in controlling ankle movement, helping to maintain balance and body stability, and having a direct effect on 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 fully. 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, Faculty of Medicine, Universitas Airlangga (protocol number 254/EC/KEPK/FKUA/2022). Informed consent was obtained from each participant prior to data collection.

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Authors' contribution

A.D.S.: Concepts, Literature search, Experimental studies, Data acquisition, Data analysis, Manuscript preparation; B.P.: Design, supervisor, Data acquisition, Guarantor, Manuscript editing, review and Finalization; D.N.U: Experimental studies, Data acquisition, Data analysis, Manuscript editing, review and Finalization. All the authors contributed equally to this article.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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