

EXPLORING THE RELATIONSHIP BETWEEN HANDGRIP STRENGTH, BODY FAT MASS, AND FAT-FREE MASS IN MALE AND FEMALE HANDBALL ATHLETES

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Abstract: This research endeavors to examine the correlation among handgrip strength (HGS), body fat mass (BFM), and fat-free mass (FFM) within the population of handball athletes.

This was a cross-sectional study involving 81 handball athletes consisting of 44 males (Age 17.4±1.5 years, height 1.73±0.06 m, body weight 64.7±10.5 kg, BMI 21.6±2.9 kg/m²) and 37 females (Age 17.0±1.4 years, height 1.61±0.06 m, body mass 55.9±10.2 kg, BMI 21.7±3.7 kg/m²).

There was a correlation in male handball athletes where the right HGS was correlated with the right BFM ($r=0.231$; $p=0.022$), the right HGS with the right FFM ($r=0.302$; $p=0.003$), the left HGS with the left FFM ($r=0.297$; $p=0.003$). Meanwhile, in female handball athletes, the right HGS was correlated with the right FFM ($r=0.466$; $p=0.004$), and the left HGS with the left FFM ($r=0.448$; $p=0.005$). This research elucidates that substantial correlations exist between Fat-Free Mass (FFM) and both right and left handgrip strength (HGS) in male and female handball athletes. In contrast, BFM only correlates with the right HGS, but not with the left HGS. This is likely influenced by the dominant side of the muscle. Thus, strength training programs should be focused on improving FFM as a whole, while also considering the potential for muscle imbalances due to the dominance of one side of the body to enhance the overall efficiency of physical capabilities.

Keywords: Handball, handgrip strength, body fat mass, fat free mass

INTRODUCTION

Handball is an example of a competitive sport that requires high physical strength, especially in the hands (HGS) when passing (Wagner et al., 2014), shooting, and defending (Karcher & Buchheit, 2014). HGS measurement is one of the most simple yet useful parameters for measuring hand grip strength (S. H. Lee & Gong, 2020). The force exerted by the hand grip serves not only as an indicator of the strength of a specific muscle group, but it also demonstrates a significant correlation with the overall muscular strength of the entire body. (Szaflik et al., 2025). In contrast, BFM and FFM are thought to affect muscle performance (Ardha et al., 2024). Higher FFM is usually associated with greater muscle strength, while high BFM tends to inhibit performance because it is a non-functional load (Nonaka et al., 2018). However, this is not always true; some athletes with higher FFM have a disproportionate HGS, and vice versa, some athletes with higher BFM but yet have good HGS (Patnaik et al., 2021). This indicates that the relationship between HGS and BFM and FFM is not always linear and consistent because it can be swayed by various additional variables including gender differences, muscle mass distribution, team playing position, and neuromuscular adaptation of each individual (Feuerbacher et al., 2025). In addition, injuries are also an important variable that can interfere with the function of the hand. Differences in hamstring eccentric in handball athletes with a documented history of physical injuries can also affect muscle stability and the risk of re-injury, especially in areas of the hands and wrists that are vulnerable in play (Isna et al., 2024). In a six-year survey, 13% of injuries in young handball players in Japan occurred on the wrist and hand, with sprains being the the predominant category of physical injury (37.9%), followed by contusion (30%) and injuries (20.7%) (Asai et al., 2020). There remains a deficiency in

empirical data that elucidates the precise correlation between handgrip strength (HGS) and both body fat mass (BFM) and fat-free mass (FFM) (Tavares Junior et al., 2023a).

Competitive sports demand optimal muscle strength and body composition because both play a direct role in determining the performance of athletes, especially in the game of handball (Lasković, 2022). Adequate muscle mass also contributes directly to the performance of jumps, which are used when making shots or blocks (Solikah et al., 2025). HGS not only indicates the strength of the upper arm muscles, but can also be used as a general way to assess the fitness level of the entire muscle (Vaishya et al., 2024). Body compositions such as BFM and FFM exhibit fat proportions and fat-free mass which are both essential for speeding up movement, speed, and physical endurance (Hernandez-Martinez et al., 2024). Numerous studies have been conducted on the relationship between muscle strength and body composition in the general population and athletes from various sports (Cataldi et al., 2023). However, there are not many studies that specifically investigate the relationship between HGS and BFM and FFM in male and female handball athletes.

The preservation of an optimal body composition is critically significant for athletes engaged in handball, as the attainment of ideal body fat percentages and sufficient muscle mass substantially enhances physical performance attributes such as strength, velocity, and stamina (Martínez-Rodríguez et al., 2023). Therefore, regular monitoring of body composition, including body fat, muscle mass, and weight, is highly recommended so that trainers can adjust their training program in a timely manner (Giovannelli et al., 2024). One solution that can be implemented is to develop a personalized exercise program based on the results of these measurements (Lukaski & Raymond-Pope, 2021). For example, players with low muscle mass can be given more intensive strength training to improve their performance (Fyfe et al., 2022). In addition, by knowing the correlation between HGS versus BFM and FFM, coaches and medical teams can develop more efficient evaluation methods without having to constantly rely on expensive or invasive measuring devices (Di Vincenzo et al., 2020). Understanding this relationship can also be used to design more specific training programs, such as handgrip enhancement exercises to optimize FFM or reduce BFM to support athlete performance (Nara et al., 2022). Gender differences also need to be considered because men and women may have different correlation patterns, so the approach to physical exercise and evaluation cannot be equalized (Pérez et al., 2024). In the context of periodic monitoring, a handgrip dynamometer can be a practical measuring tool because it is cheap, fast, and non-invasive (Sartorio et al., 2025). If proven to have a strong correlation with BFM or FFM, this tool can be used as an initial screening method or a routine monitoring tool in handball teams (Szaflik et al., 2025).

This research endeavor seeks to systematically examine the correlation between hand grip strength (HGS) and body composition, with a particular emphasis on body fat mass (BFM) and fat-free mass (FFM) among handball athletes. This relationship is important to understand because hand grip strength is an easily measured indicator of muscular strength and is related to overall physical performance (S. Y. Lee, 2021). While BFM and FFM play a role in supporting or inhibiting muscle performance and physical performance (Merchant et al., 2021). By knowing the correlation between these variables, this study is expected to provide more in-depth information about the factors that affect the physical strength of handball athletes, especially in the aspect of handgrip.

MATERIALS AND METHODS

Study Participants

Across-sectional study method was used, with subjects classified based on demographic characteristics (age and sex) and anthropometric/physical characteristics (body mass, height, and BMI) as shown in Table 1 (Mayorga-Vega et al., 2014). Prior to testing, all participants were screened for injuries by a physiotherapist. The inclusion criteria were: 1) handball athletes registered as participants in provincial championships 2) in good health and have good physical endurance to conduct tests (Riebe et al., 2015)? Specifically no upper-limb injury within the past 6 months 3) Not experiencing any health problems or muscle injuries that may affect physical abilities during data collection. This research has obtained ethical clearance 008/UN38.10/EC.KEPK/HK.01.02/2025 from Universitas Negeri Surabaya, Indonesia.

Study Organization

Data acquisition in the present investigation commenced with an evaluation of stature and an assessment of body composition to ascertain body mass, body fat mass (BFM), and fat-free mass (FFM). Subsequently, a handgrip

strength test was administered on both the dominant and non-dominant arms to evaluate the maximum grip strength. The raw data, encompassing variables such as age, height, weight, body mass index (BMI), BFM, and FFM, along with the peak handgrip strength values, were systematically gathered and organized in accordance with the criteria established in Microsoft Excel. Limitations of the study: This research constituted a cross-sectional analysis involving of 81 handball athletes, comprising 44 males and 37 females which means one time collecting data.

Body composition test

Proper assessment was valid assessment through multifrequency analytical impedance bioelectric and bioelectric devices using InBody 270. The InBody 270 device can be used as a DXA alternative (Dual-energy X-ray Absorptiometry) because the results are quite accurate, especially in active individuals (Czartoryski et al., 2020). The InBody 270 uses multifrequency bioimpedance technology to accurately measure body composition based on the ability of the body's tissues to conduct electrical currents, so that it can assess muscle mass, fat, and body fluids in detail (Bukowska et al., 2021). In weight measurement, BMI, BFM, and FFM were carried out using InBody 270 (Seoul, South Korea). During the measurement, the subject was instructed to remove the footwear and also metal or iron accessories. Then the subject adjusts the position of the foot with an electrode or sensor and takes a weight measurement. Once the weight data has been inputted, the participant is required to authenticate their identity by utilizing their user ID, which facilitates the generation of body composition results. Subsequently, at the commencement of the body composition assessment, the participant is instructed to grasp the handle and position their thumb upon the electrode or sensor. It is imperative that the participant maintains straight elbows, refrains from bringing them close to the body, and keeps their gaze directed forward, remaining immobile until the conclusion of the testing procedure. Each participant engages in a singular experimental trial until the body composition results are displayed on the designated screen; the output from the InBody device will be automatically printed thereafter.

Handgrip strength test

The assessment of hand grip strength was conducted utilizing the Omron Handgrip apparatus (Tokyo, Japan). Prior to the execution of the evaluation, the participants engaged in a series of gymnastic stretches to adequately prepare their muscles. During the assessment, the participant is instructed to adopt a standing position facing forward with their elbows fully extended. Subsequently, the participant exerts maximal force on the handgrip for a duration of three seconds. Each subject performs on both the right and left hands. With a rest time of 30-60 seconds between reps, thus avoiding a large drop in average HGS (Fernandes et al., 2014). Each subject took three measurements and calculated the average strength in (kg). However, hand dominance was not assessed in this study because handedness data was not used to categorize or analyze the handgrip strength results.

Statistical analysis

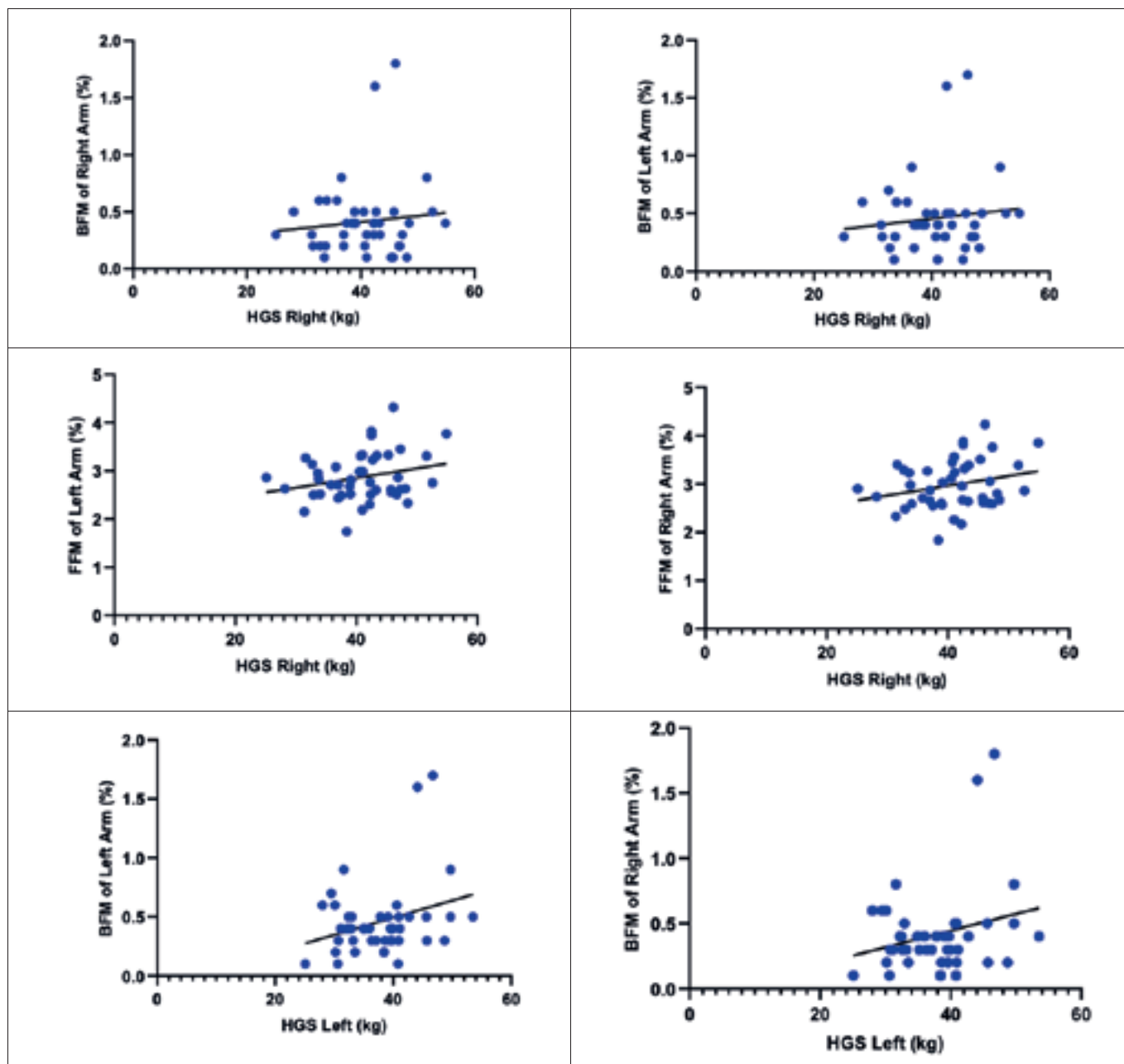
The test outcomes and subject measurement data were meticulously examined utilizing Minitab Version 26 software. Following the selection of data that aligns with the research objectives, a normality assessment was conducted employing the Kolmogorov–Smirnov one-sample method with a significance threshold (p -value < 0.05 indicating normally distributed data). The Pearson Correlation test was employed to evaluate the interrelationships among variables within each cohort (p -value < 0.05 indicating a significant relationship), and the r -value served as the correlation coefficient to ascertain the magnitude of the relationship between variables.

RESULTS

This study involving 81 handball athletes consisting of 44 males (Age 17.4 ± 1.5 years, height 1.73 ± 0.06 m, body weight 64.7 ± 10.5 kg, BMI 21.6 ± 2.9 kg/m²) and 37 females (Age 17.0 ± 1.4 years, height 1.61 ± 0.06 m, body weight 55.9 ± 10.2 kg, BMI 21.7 ± 3.7 kg/m²) (Table 1).

Table 1. Demographic Characteristics of Subjects

Characteristics	Male (n=44)	Female (n=37)
Age (yrs)	17.4±1.5	17.0±1.4
Height (m)	1.73±0.06	1.61±0.06
Body weight (kg)	64.7±10.5	55.9±10.2
Body mass index (kg/m ²)	21.6±2.9	21.7±3.7



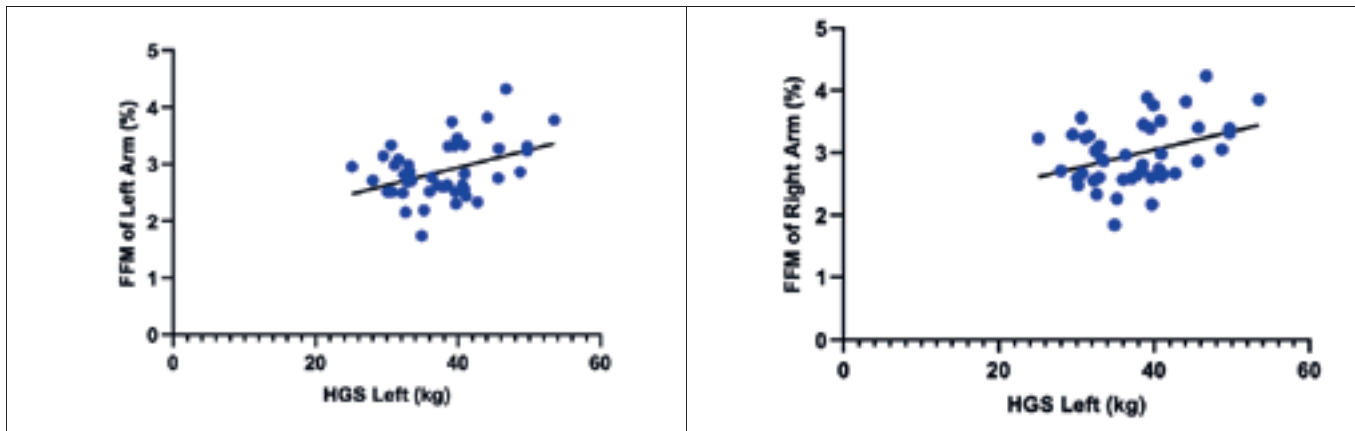
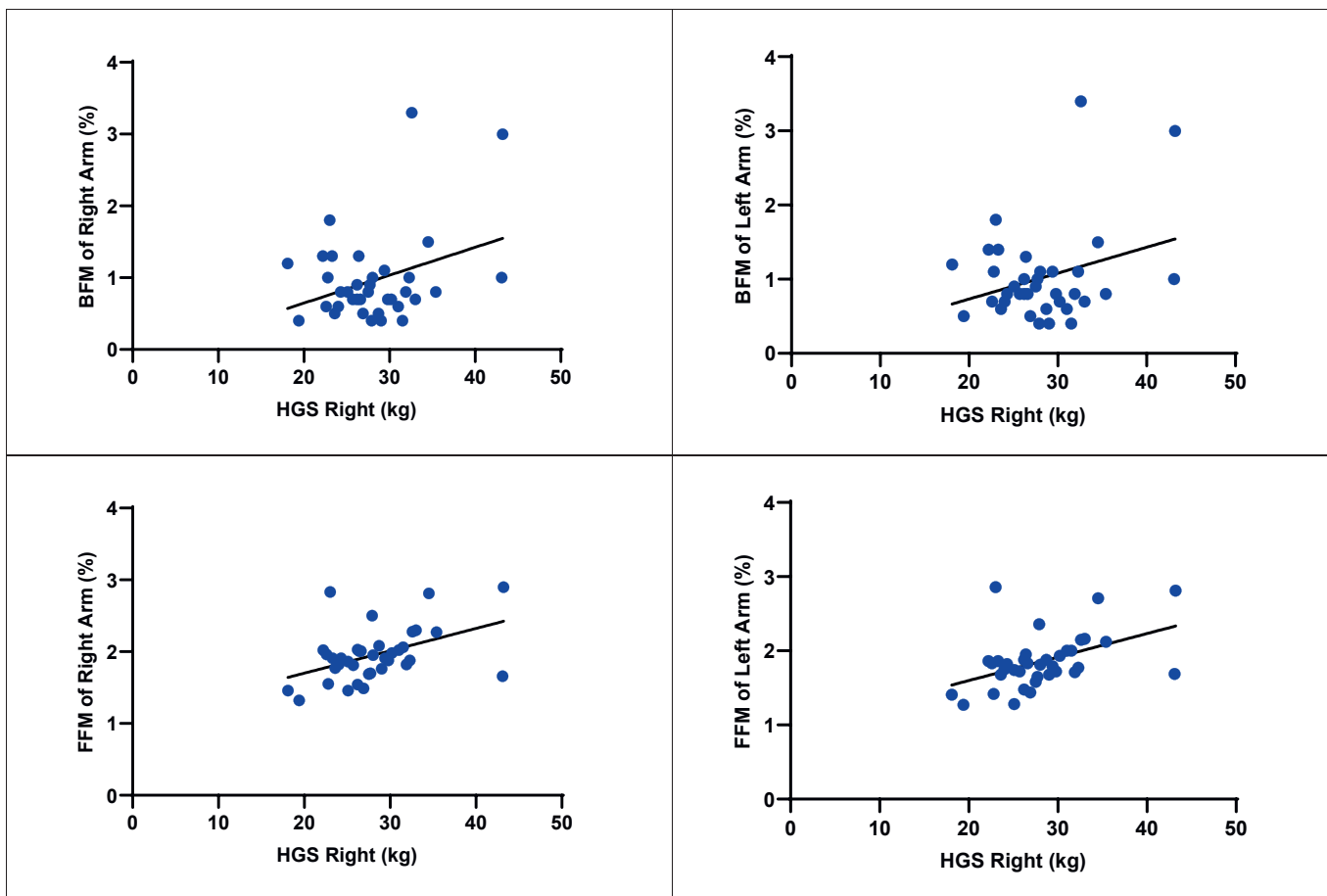


Figure 1. Correlation between Handgrip and BFM and FFM in Male Handball Athletes

The correlation between HGS, BFM, and FFM in male handball athletes presented in Figure 1. There were results that showed a correlation in male handball athletes where the right HGS correlated with the right BFM ($r=0.231$; $p=0.022$), the right HGS with the right FFM ($r=0.302$; $p=0.003$), the left HGS with the left FFM ($r=0.297$; $p=0.003$), while the left HGS did not correlate with the left BFM ($p > 0.05$).



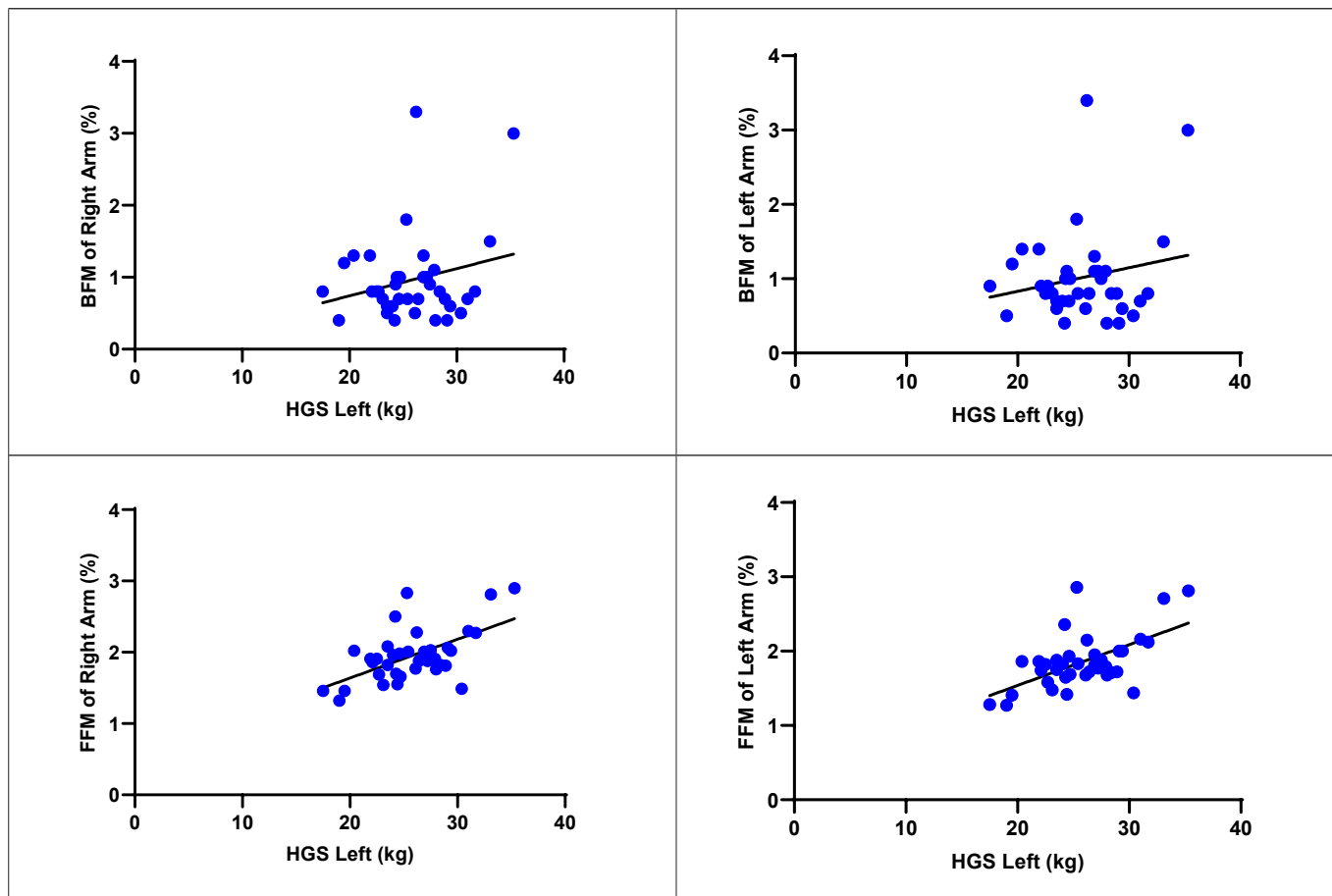


Figure 2. Correlation between Handgrip and BFM and FFM in Female Handball Athletes

Figure 2 shows the correlation between handgrip and BFM and FFM in female handball athletes. There were results that showed a correlation in female handball athletes where the right HGS correlated with the right FFM ($r=0.466$; $p=0.004$), the left handgrip with the left FFM ($r=0.448$; $p=0.005$). While the right HGS has no significant relationship with the right BFM, nor does the left handgrip have a significant relationship with the left BFM.

DISCUSSION

The principal outcomes of the investigation indicate that fat-free mass (FFM) exhibits a significant correlation with both right and left handgrip strength (HGS) among handball athletes of both genders. This finding aligns with numerous prior studies which have posited that FFM serves as a critical determinant of muscular strength. (Zaccagni et al., 2020). According to (Tavares Junior et al., 2023a), FFM reflects a mass of lean tissue that is mostly made up of skeletal muscle, so the increase in FFM describes an increase in muscle mass that plays a role in producing muscle strength, which includes grip strength as well. In contrast, BFM did not show a correlation with HGS in female handball athletes and only correlated with HGS in male athletes. This finding is in line with (Patnaik et al., 2021), which found that increased fat mass does not contribute to increased muscle strength, and in some cases, it can even interfere with performance due to additional non-functional loads. Body fat is generally not involved in the production of strength and in the context of athletics, the accumulation of excess fat can actually reduce movement efficiency and overall physical performance.

Results of a previous recent study (Ardha et al., 2024) showed that there was no significant relationship between FFM and HGS in non-athlete students, both male and female. Athletes exhibit enhanced neuromuscular efficiency, facilitating superior force generation during tasks reliant on grip, as evidenced by grapplers who manifest elevated maximal isometric strength in comparison to untrained subjects (Tavares Junior et al., 2023b). This discrepancy likely arises specifically from sport training adaptations in athletes, where functional muscle development (especially in the forearms) is optimized for grip-dependent tasks, unlike in untrained populations where muscle mass may not

translate directly to specific strength outcomes. Conceptually, FFM that reflects muscle mass without fat content is usually considered to be closely related to muscle strength (Mukti et al., 2024). However, the findings in this study suggest that FFM amounts do not necessarily accurately reflect grip strength levels. Some possible causes of the absence of this relationship include uneven distribution of muscles in the body, differences in neuromuscular activation, and differences in the type of exercises performed by each non-athlete student. The strength of the hand grip itself is more influenced by the strength of specific muscles in the forearm, such as the flexors and extensors, whose growth does not always coincide with the overall increase in FFM (Marques et al., 2023).

BFM showed a correlation with right HGS in male handball athletes, but not with left HGS or in female athletes. This can be attributed to a stronger hand dominance in male athletes, especially since the right hand is often used in certain activities in sports such as throwing the ball in a handball game. Considering that hand-grip strength is influenced by a plethora of factors (including but not limited to gender, age, and physical fitness), it is essential that normative values for hand-grip strength be determined within large and comprehensively defined populations. (Giancotti et al., 2018). Interactions between the hand and a projectile can be characterized as any engagement in which the hand exerts force upon an object, thereby instigating projectile motion of that object. This encompasses a diverse array of activities, which includes, but is not confined to, the act of throwing (for instance, baseball, cricket, water polo, handball, American football, rugby, soccer, shot put, discus, javelin, and hammer throw), bowling (encompassing both overarm and underarm techniques), shooting (as exemplified in basketball and netball), and striking (as evidenced in volleyball and Australian Rules football) (MacDonald et al., 2018). This gender-specific findings may be explained by physiological differences in fat distribution (e.g., males typically store less subcutaneous fat in extremities) and sport-specific role requiring dominant-side power throws, which are more prevalent in male players also, the selective correlation only in the right hand further supports the role of neuromuscular adaptation due to chronic preferential use of the dominant limb, leading to enhanced strength-specific coordination and motor unit recruitment on that side. The hand constitutes the ultimate nexus (i.e., terminal point of contact) within the kinetic chain wherein the imparted forces and torques are conveyed to the implement or object, thereby underscoring the significance of handgrip functionality and strength in relation to the aforementioned sports-specific maneuvers (MacDonald et al., 2018). This is in line with the findings (Foley et al., 2025), which in its systematic review and metaanalysis states that dominant hands are generally about 10% stronger compared to non-dominant hands. This difference is influenced by several factors such as the type of joint and movement, handedness (dominant skill) (Bryden, 2016; Vingerhoets et al., 2023), as well as environmental factors that cause left-handed individuals to adapt to a life dominated by the use of hands (Vuoksima et al., 2009). Although it does not show a direct relationship with FFM, the strength of HGS's hand grips still plays an important role in supporting the performance of handball athletes. This sport requires a high ball control ability, accuracy in throwing, strength when making passes and shots, and toughness in keeping the ball from the opponent's pressure (ASAN, 2023). All of these aspects depend heavily on the strength and stability of the muscles of the hands and forearms. In addition, HGS can also be used as an indicator of functional strength and upper body ability, which is closely related to technical skills during matches (Omar Lagunes-Carrasco et al., 2025). Therefore, exercises to improve grip strength should be one of the main component in the training program for handball athletes, regardless of the size of the FFM.

In a comprehensive and meticulously conducted study undertaken by esteemed researchers (Acharya et al., 2022), it was determined through empirical investigation that there existed no statistically significant relationship or correlation between body fat mass (BFM) and handgrip strength (HGS) among male medical students, thereby suggesting that variations in body composition do not appear to influence grip strength in this specific demographic group, these findings suggest that individuals with greater muscle mass showed higher muscle strength capacity than individuals with a dominance of adipose tissue in their body composition. Physiologically, fat mass (BFM) has no direct contribution to muscle contraction performance. Body fat tends to be passive and does not help in generating muscle strength. (Cossio-Bolaños et al., 2020) also found no significant correlation between BFM and HGS in children and adolescent boys and women aged ≥ 7.5 years to ≤ 15.49 years. These findings indicate that the amount of fat tissue in the body is not the main determinant of muscle strength in this age group. In contrast, the development of muscle strength is more influenced by the increase in muscle mass that occurs physiologically during the period of growth and puberty.

This investigation is subject to numerous limitations. Firstly, the sample size was comparatively modest, encom-

passing merely 81 participants within the age range of 16 to 18 years, which may constrain the broader applicability of the results. Subsequent research endeavors should strive to incorporate a larger and more heterogeneous sample, which includes a wider array of age demographics, in order to augment external validity. Furthermore, this study employed a cross-sectional design; future inquiries may benefit from adopting longitudinal methodologies to ensure that the data obtained is more robust for analytical purposes.

Furthermore, this research did not differentiate between player positions; it only examined handball players based on gender. Future studies could explore a sport-specific role analysis, investigating positions such as goalkeepers, wingers, and center backs.

CONCLUSION

This study indicates that arm handedness affects muscle mass. As a result, coaches should identify each handball player's dominant arm to enhance their dribbling and shooting training. Additionally, the non-dominant arm can be strengthened using neuromuscular activation techniques and unilateral exercises. This approach can help reduce strength imbalances and lower the risk of injuries. While every player has a dominant arm, training both arms optimally can improve essential skills like ball control and shooting accuracy. This comprehensive training equips handball players with the necessary tools to enhance their overall arm strength. These findings underscore the need for targeted training strategies where coaches should prioritize exercises that increase overall FFM (e.g., compound lifts, plyometrics) while incorporating unilateral techniques such as eccentric wrist curls and sport-specific drills using the non-dominant hand to mitigate strength imbalances and reduce injury risks. Although HGS remains critical for ball control and shooting accuracy, its dependence on FFM highlights the importance of holistic strength development.

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Conflicts of interest - The authors declare no conflicts of interest.

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