JOURNAL OF HEALTH AND SOCIAL SCIENCES

Journal of Health and Social Sciences (JHSS)
The Italian Journal for Interdisciplinary Health and Social Development **EDIZIONI FS Publishers**
Original Article in Psychology

Associations between Hand Grip Strength, Physical Activity, Cognitive Function, and Quality of Sleep in Healthy Adult Individuals: A cross-sectional study

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Abstract

Introduction: Hand grip strength is a simple and reliable measure of overall muscular strength and has been associated with various health outcomes. This study aimed to investigate the relationships among hand grip strength, physical activity, cognitive function, and sleep quality in healthy adults.
Methods: This cross-sectional study included 160 normal adult participants, comprising 80 males and 80 females, with an average age of 25 (SD 9.69) years and a BMI of 24.58 (SD 5.99). Handgrip strength, physical activity, cognitive function, and quality of sleep were measured using a hydraulic hand dynamometer, the International Physical Activity Questionnaire (IPAQ), the Cognitive Failures Questionnaire (CFQ), and the Pittsburgh Sleep Quality Index (PSQI), respectively. The collected data were statistically analyzed using descriptive statistics, and Spearman's correlation tests were used to assess the association between the measured outcomes.
Results: Right-hand grip strength demonstrated positive correlations with BMI ($r=0.24$, $p=0.003$), IPAQ scores ($r=0.71$, $p=0.001$), IPAQ level ($r=0.62$, $p=0.000$), while showing negative correlations with poor sleep quality ($r=-0.42$, $p=0.001$) and cognitive failures ($r=-0.23$, $p=0.001$). Physical activity displayed a weak, non-significant correlation.
Discussion: This study demonstrates that higher hand grip strength is associated with increased physical activity, improved cognitive function, and enhanced sleep quality in healthy adult individuals. These findings suggest that assessing hand grip strength may provide valuable insights into an individual's overall health and well-being. Longitudinal studies are warranted to elucidate the causal relationships among these variables further.

Take-home message: This study found that stronger hand grip, a simple measure of overall strength, is positively associated with physical activity level and BMI, while negatively associated with poor sleep quality and cognitive failures in healthy adults. This is important because it shows that building and maintaining muscle strength is not just about physical health. Clinicians can use grip strength as a quick, easy screening tool to identify patients at risk for cognitive decline or sleep issues, enabling earlier lifestyle interventions, such as exercise programs.

Keywords: hand grip strength, physical activity, cognitive function, body mass index, sleep quality, healthy adults.

Cite this paper as: Shanb AA, Ahsan M. Associations between Hand Grip Strength, Physical Activity, Cognitive Function, and Quality of Sleep in Healthy Adult Individuals: A cross-sectional study. J Health Soc Sci. 2025;10;4:375-389. Doi: 10.19204/2025/SSCT9

Received: 30 August 2025; Accepted: 29 October 2025; Published: 15 December 2025

INTRODUCTION

Hand grip strength is widely used as an indicator of overall muscle strength and functions in adults. Hand grip strength declines naturally with age due to loss of muscle mass and function [1]. Hand grip strength is also influenced by the coordination of intrinsic and extrinsic hand muscles during object manipulation. Studies investigating fine motor tasks, such as chopstick use or precision grasping, reveal that grip force control is a complex process that involves both muscle strength and neuromuscular coordination [2,3]. The ability to anticipate and adjust grip strength in response to object weight and movement is essential for effective hand functions and daily activities [4,5]. These motor control aspects highlight that hand grip strength is not solely about raw force but also about the fine regulation of muscle activity.

Physical activity is widely recognized as a fundamental component of health and well-being for adults. The evidence consistently demonstrates that engaging in regular physical activity confers multiple benefits across various domains of adult health [6-9]. For example, resistance training is a potent stimulus for increasing muscle mass, strength, and physical function in healthy adults, with prescription variables such as load, frequency, and volume influencing outcomes [6]. Physical activity plays a critical role in mitigating age-related physiological decline. Exercise programs incorporating aerobic, resistance, flexibility, and balance training improve functional capacity, reduce the risk of falls, and enhance quality of life [7-9].

Cognitive functions are essential for daily functioning, decision-making, and maintaining quality of life. Cognitive function is influenced by a variety of factors, including age, physical health, mental health, lifestyle behaviors, and neurological conditions [10-12]. Research consistently shows that a complex interplay of biological, psychological, and environmental factors influencing cognitive function [11,13]. Physical activity during childhood, for example, is positively associated with cognitive development, particularly in attention, memory, and learning. Engaging in sports appears to enhance cognitive and emotional functions in children, although specific cognitive benefits may vary by type of physical activity and age group [13]. Similarly, in adults, especially those with depression, physical exercise interventions have demonstrated improvements in executive functions like working memory, albeit with small effect sizes and some uncertainty due to limited high-quality studies [11].

A good night's sleep is essential for maintaining physical health, mental well-being, cognitive function, and overall quality of life. Poor sleep quality is common among adults and is associated with various adverse outcomes [15-20]. For example, inadequate or disturbed sleep negatively affects cognitive performance, emotional regulation, and physical health, and it is associated with increased risks of depression, anxiety, and chronic diseases [14,15]. Sleep quality is often measured using validated tools such as the Pittsburgh Sleep Quality Index (PSQI), which assesses multiple dimensions of sleep over a month-long period [16]. Several lifestyles and behavioral factors influence sleep quality. Physical activity has been shown to improve sleep parameters, including sleep latency (the time it takes to fall asleep) and overall sleep quality. However, the strength of evidence varies, and more comprehensive meta-analyses are needed to confirm these effects [17,18].

Understanding the relationships between hand grip strength, physical activity, cognitive function, and sleep quality is crucial for comprehending how these factors influence overall adult health. The evidence suggests a strong interrelationship among these variables [19,20]. Physical activity, particularly exercises that involve movement and physical exertion, has been shown to enhance hand grip strength and cognitive function. For example, in elderly patients with cardiovascular disease undergoing cardiac rehabilitation, locomotive physical activity was positively associated with improved sleep latency (the time it takes to fall asleep). It enhanced cognitive function, as measured by standard tests [19]. This suggests that engaging in regular physical activity can improve both sleep quality and mental acuity. A community-based study involving adults aged 40 to 75 found that reduced physical activity was associated with multiple health deficits, including declines in cognition and grip strength [20]. A randomized controlled trial demonstrated that nocturnal melatonin ingestion improved subjective sleep quality and, importantly, enhanced hand-grip strength, reaction time, and short-term maximal physical performance in the following days [21]. This suggests that sleep quality directly influences both cognitive and physical performance, possibly by facilitating recovery and optimizing neuromuscular functions. Intervention strategies, such as home-based, mobile-guided exercise programs tailored for older adults with cardiovascular conditions, enhance physical function, increase handgrip strength, and improve cognitive and sleep outcomes [22]. Although the full results of such interventions are pending, their design reflects the growing recognition that integrated approaches addressing physical activity, cognitive health, and sleep quality can yield comprehensive benefits [22].

The studies mentioned above have examined the independent associations among hand grip strength, sleep quality, and cognitive function [20-22]. Few have integrated these parameters with levels of physical activity to assess their combined effects [19,20]. Most studies have focused on older adults and the patient population, with varied results [9,12,19,20], leaving a gap in understanding these relationships among younger and middle-aged adults. Therefore, this study aimed to investigate the associations among hand grip strength, physical activity, cognitive function, and sleep quality in healthy adults. Investigating these associations could provide valuable insights into early interventions that preserve mental health and improve sleep quality through targeted physical activity interventions, such as strength training.

Research Hypothesis

- Hypothesis 1: Higher hand grip strength will be positively associated with greater physical activity levels.
- Hypothesis 2: Higher hand grip strength will be positively associated with better cognitive function.
- Hypothesis 3: Higher hand grip strength will be positively associated with improved sleep quality.

Significance and advantages of our work

This cross-sectional study provides a more comprehensive understanding of the role of hand grip strength in overall health and well-being. The study population consisted of healthy adult individuals, allowing the researchers to explore the associations between hand grip strength and various health outcomes in a non-clinical setting. The study's findings underscore the importance of assessing hand grip strength as a straightforward, accessible measure that can provide valuable insights into an individual's overall health status and well-being. This information can inform the development of targeted interventions and guide healthcare professionals in promoting healthy aging and improving patient outcomes.

METHODS

Study Design and Settings:

To achieve objectives, this study employed a cross-sectional correlational design, conducted in the physical therapy laboratory at Imam Abdulrahman bin Faisal University in Dammam. Data were collected between January 2025 and April 2025.

Ethical Consideration:

Ethical approval was obtained from the Deanship of Scientific Research at Imam Abdulrahman bin Faisal University (IRB-2025-03-0361). This study was conducted in accordance with the Declaration of Helsinki at the Department of Physical Therapy.

Study sample:

A total of 160 participants were enrolled in this study, with an age range of 18 to 50 years. Participants were recruited from the Eastern Province of KSA, particularly from the cities of Dammam and Al-Khobar, via WhatsApp invitations. All participants were selected using a random sampling approach. All individuals maintaining a normal lifestyle and aged between 18 and 50 were chosen to participate in this study, while those with either strong or weak strength of the hand grip due to all affecting pathological conditions e.g. muscle diseases, motors neuron disease, neuropathy or those who participate in sports activities or have specific nature of their work that affects strength of hand grip, also those receiving any drinking or medications can affect cognitive functions or quality of sleeping were excluded.

Assessment instruments

a) ***Global Pittsburgh Sleep Quality Index (PSQI):***

The PSQI is a widely used self-report questionnaire for assessing sleep quality over a one-month interval. The PSQI is commonly used in both clinical and research settings to evaluate various aspects of sleep [16]. The validity of the Pittsburgh Sleep Quality Index (PSQI) was rigorously examined. Nineteen individual items generate 7 "component" scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction [16]. The sum of the scores for these seven components yields a single global score. A global PSQI score, ranging from 0 to 21, can be obtained by summation of the seven components, each weighted on a scale of 0 to 3 [α = 0.74]. For each element and the global PSQI score, higher sleep scores indicated worse sleep status [16].

b) ***Hand grip strength measurement:***
Hand grip strength (HGS) has been recognized as a reliable proxy indicator of an individual's overall physical function. It is a powerful predictor of morbidity, disability, and mortality, and it is a major diagnostic component of frailty and sarcopenia in adulthood [23]. A weak HGS is an early indicator of age-related functional decline, as grip strength is closely linked to physical function and independence among community-dwelling older adults [24]. Hand grip strength was measured using the Jamar (hydraulic hand dynamometer). Participants were asked to take their seats comfortably, with their elbows flexed to 90 degrees, forearms in a neutral position, and wrists slightly extended (15-30 degrees). They were instructed to grip the dynamometer as forcefully as possible for 3-5 seconds. The measurement was repeated three times for each hand, with a 15-second rest between trials to prevent fatigue. The maximum grip strength value (measured in kilograms) from three trials was recorded for each hand. Both dominant and non-dominant hand grip strengths were measured, and the highest value was used for analysis. A qualified physical therapist conducted handgrip strength tests using a dynamometer.

c) ***Cognitive Failures Questionnaire (CFQ):***
CFQ was used to assess participants' self-reported cognitive lapses in everyday life. The CFQ has predictive validity and evidence of criterion validity regarding safety [25]. The CFQ is a widely used tool for evaluating the frequency of cognitive errors in memory, attention, perception, and action during routine tasks. It is particularly suitable for assessing subjective cognitive functioning in normal adult populations. The CFQ consists of 25 items that measure everyday cognitive errors. Participants rate how often they experience specific cognitive lapses on a 5-point Likert scale (0: "Never", 1: "Very rarely", 2: "Occasionally", 3: "Quite often", 4: "Very often"). The total CFQ score was calculated by summation of the responses to all items, with a possible range of 0 to 100. Higher scores indicate a greater frequency of cognitive failures [25]. During the study, all participants were asked to respond to all CFQ questions with their actual responses, reflecting their typical cognitive experiences over the past month. Completion time was approximately 5-10 minutes.

d) ***The International Physical Activity Questionnaire (IPAQ):***
The IPAQ comprises seven questions with a self-administered method. The questions asked about the time spent being physically active in the last 7 days. The purpose of the questionnaires is to provide common instruments for obtaining internationally comparable data on health-related physical activity [26].

Procedure of assessment

Before recruitment, participants are selected through convenience sampling from the Eastern Province of KSA, including the cities of Dammam and Al-Khobar. Participants were briefed about the study objectives, procedures, and their rights. Written informed consent was obtained from all participants before their participation. Personal data of all participants and general information were recorded between January 2025 and May 2025, using the following tools and procedures:

a) ***Hand grip strength*** was measured using a hydraulic hand dynamometer (Jamar). Participants were asked to comfortably sit with their elbows flexed to 90 degrees, forearms in a neutral position, and wrists slightly extended (15-30 degrees). They were instructed to grip the dynamometer as forcefully as possible for 3-5 seconds. The measurement was repeated three times for each hand, with a 15-second rest between trials to prevent fatigue. The maximum grip strength value (measured in kilograms) from three trials was recorded for each hand. Both dominant and non-dominant hand grip strengths were measured, with three trials per hand and a 15-second rest between trials. The highest value for each hand was used for analysis. The hand grip strength tests were conducted by a qualified physical therapist using a dynamometer to ensure reliable measurements [27].

b) ***Quality of sleep*** was evaluated by using the Pittsburgh Sleep Quality Index (PSQI). All participants were asked to respond to all questions of the PSQI as a self-reported questionnaire, providing answers that accurately reflected their actual conditions, and to report on their sleep patterns, disturbances, and overall quality over the past month. The scores were collected and recorded.

c) ***Cognitive function*** *and lapses* were assessed using the Cognitive Failures Questionnaire (CFQ). All participants rated their cognitive errors over the past month. The CFQ was completed in a quiet, distraction-free environment.

d) ***Physical activity*** of each participant, including both scores and levels of physical activity, was assessed using IPAQ. Every participant was asked to respond to all IPAQ questions with the appropriate answers for their condition. IPAQ asks about the time spent being physically active in the last 7 days. Collected data were anonymized and stored securely to maintain participant confidentiality.

Statistical analysis

The data were analyzed statistically using descriptive methods. The Shapiro-Wilk test was used to test its normality. The Spearman correlation test was used to assess the relationships among the measured outcomes. The level of significance was determined at $p < 0.05$, with a 95% confidence interval.

RESULTS

The study included 160 male and female healthy adult participants (124 males, 77.5% and 36 females, 22.5%), Mean and range values of demographic data of recruited participants, including age, BMI, right and left-hand grip strength, blood pressure, physical activities, quality of sleeping, and cognitive function, are included in Table 1. The results show that all recruited participants within the adult category of age, the range of age is 43years, body weight within overweight, range of body index is 27.4 Kg/m2, hand grip strength within the average around 42 & 46 kg, they are ranged between moderate and highly physical active (1888.41±1400.46) METs in minutes/ week, mean values of quality of sleeping (6.63±2.40) is good, in addition good mean values of cognitive function (36.88±11.92), (Table 1).

Table 1. Mean values of demographic data of recruited participants.

Variables	**Mean ±SD**	**Range**
Age *(years)*	27.94±10.1	43
BMI *(kg/m²)*	24.21±5.67	27.40
SBP *(mmHg)*	116.87± 13.06	67
DBP *(mmHg)*	73.61 ± 8.59	41
MABP *(mmHg)*	88.03± 8.44	45
Right-hand grip strength *(Kg)*	33.26±10.25	42
Left-hand grip strength *(Kg)*	31.12±9.83	40
IPAQ score (METs minute /week)	1888.41±1400.46	6300
IPAQ Levels	1.98 ± 0.69	2
PSQI Scores	6.63±2.40	11
CFQ	36.88±11.92	56

Note: BMI: body mass index equals weight in kilograms divided by height in meters squared. SBP in mmHg is the upper number in a blood pressure reading, measured in millimeters of mercury (mmHg). DBP in mmHg is typically considered to be less than 80 mmHg. MABP in mmHg equals from 70-100 mm Hg, and a MAP of at least 60 mm Hg is necessary for adequate cerebral perfusion; IPAQ score in METs minute /week: International Physical Activity Questionnaire IPAQ) Scores are measured in METs (minutes per week); IPAQ Levels are categorized into low, moderate, and high; PSQI: the Pittsburgh Sleep Quality Index (PSQI) was administered to evaluate sleep quality; CFQ: the Cognitive Failures Questionnaire was used to assess cognitive function.

Table 2. Correlations between hand grip strength and other outcome measures in adult healthy individuals.

Variables	**Right-hand grip strength**		**Left-hand grip strength**	
	r- values	**p-values**	**r- values**	**p-values**
Age in years	0.285	0.001**	0.272	0.001**
BMI in kg/m²	0.237	.003**	0.252	0.001**
SBP in mmHg	0.405	0.001*	0.346	0.001**
DBP in mmHg	.028	0.728	0.006	0.945
MABP in mmHg	0.230	0.003*	0.184	0.020*
IPAQ scores	0.708	0.001**	0.703	0.001**
IPAQ levels	0.617	0.001**	0.629	0.001*
PSQI	-0.420	0.001**	-0.462	0.001**
CFQ	-0.231	0.001**	-0.312	0.001**

Note: BMI: body mass index; SBP in mmHg is systolic blood pressure measured in millimeters of mercury (mmHg); DBP: Diastolic blood pressure; Mean arterial blood pressure; IPAQ score in METs/week: international physical activity questionnaire; IPAQ Levels: as it is categorized into low, moderate, and high; PSQI: The Pittsburgh Sleep Quality Index (PSQI); CFQ: the Cognitive Failures Questionnaire.

The results of Spearman correlations show a significant positive correlation between the strength of the right- & left-hand grip and age, BMI, Blood pressure, and physical activity, $p < 0.05$

(Table 2), suggesting that any increase in hand grip strength is associated with increases in age, BMI, blood pressure, and physical activity. In contrast, the results show significant negative correlations between the strength of the right- & left-hand grip with sleep quality (PSQI) and cognitive function (CFQ), $p < 0.05$ (Table 2), suggesting that lower sleep quality (higher PSQI scores) and failure of cognitive function are associated with weakness of the hand grip strength and vice versa.

The results of Spearman correlations show existing significant positive correlations between mean values of physical activity scores, cognitive function, and age, BMI, and Blood pressure, $p < 0.05$ (Table 3), suggesting that any increases in mean values of physical activity scores and cognitive function are associated with increases in age, BMI, and blood pressure. In contrast, the results show existing significant negative correlations between mean values of physical activity scores, PSQI and cognitive function (CFQ) $p < 0.05$ (Table 3), suggesting that lower mean values of physical activity scores are associated with increases or higher PSQI scores (low quality of sleeping) and failure of cognitive function are related to weakness of the hand grip strength. Vice versa (Table 3). While any increases in physical activity scores are associated with reductions in cognitive function scores, indicating good cognitive function (Table 3).

Table 3. Correlations between physical activity, cognitive function, and other outcome measures in adult healthy individuals.

Variables	Physical activity scores		Cognitive function	
	r- values	**P-values**	**r- values**	**P-values**
Age	0.183	0.021*	0.336	0.001**
BMI	0.183	0.021*	0.040	0.614
SBP	0.284	0.002**	-0.156	0.048*
DBP	0.111	0.161	0.093	0.242
MABP	0.054	0.50	-0.147	0.064
PSQI	-0.310	0.001**	0.290	0.001**
Cognitive function	-0.282	0.001**	-	-

Note: BMI: body mass index; SBP in mmHg is systolic blood pressure measured in millimeters of mercury (mmHg); DBP: Diastolic blood pressure; Mean arterial blood pressure; IPAQ score in METs/week: international physical activity questionnaire; IPAQ Levels: as it is categorized into low, moderate, and high; PSQI: The Pittsburgh Sleep Quality Index (PSQI).

While sub-grouping the current sample of participants into males and females. The included male participants constituted 126 (77.5%) and female 36 (22.5%) the findings of male sub-group found significant positive correlations between strength of the right & left-hand grip and age, BMI, and physical activity $p < 0.05$ (Table 4) suggesting any increases (linear association) in the strength of hand grip strength is associated with increases in age, BMI, and physical activity. In contrast, significant negative correlations existed between strength of the right- & left-hand grip diastolic blood pressure, sleep quality score (PSQI) and cognitive function (CFQ) $p < 0.05$ (Table 4), suggesting that any reduction in DBP, low sleep quality (higher PSQI scores) and failure of cognitive function are associated with weakness of the hand grip strength and vice versa.

Table 4. Correlations between hand grip and other outcome measures in adult healthy males.

Variables	**Right-hand grip**		**Left-hand grip**	
	r- values	**P-values**	**r- values**	**P-values**
Age	0.249	0.005**	0.232	0.010**
BMI	0.227	.011*	0.244	0.006**
SBP	0.140	0.120	0.076	0.404
DBP	-0.274	0.002**	-0.280	0.002**
IPAQ scores	0.668	0.001*	0.672	0.001**
IPAQ levels	0.655	0.001**	0.664	0.001**
PSQ	-0.353	0.001**	-0.426	0.001**
CFQ	-0.234	0.009*	-0.300	0.001**

Note: BMI: body mass index; SBP in mmHg is systolic blood pressure measured in millimeters of mercury (mmHg); DBP: Diastolic blood pressure; Mean arterial blood pressure; IPAQ score in METs/week: international physical activity questionnaire; IPAQ Levels: as it is categorized into low, moderate, and high; PSQI: The Pittsburgh Sleep Quality Index (PSQI).

In addition, the findings of female sub-group found only significant positive correlations between strength of the right & left-hand grip and BMI, systolic blood pressure, and physical activity $p < 0.05$ (Table 4) suggesting any increases (linear association) in the strength of hand grip strength is associated with increases in BMI, systolic blood pressure and physical activity (Table 5) and vice versa.

Table 5. Correlations between hand grip and other outcome measures in adult healthy female individuals.

Variables	**Right-hand grip**		**Left-hand grip**	
	r- values	**P-values**	**r- values**	**P-values**
Age	0.194	0.257	0.264	0.120
BMI	0.244	.152	0.342	0.041*
SBP	0.408	0.013*	0.436	0.008**
DBP	-0.100	0.564	-0.270	0.111
MABP	0.057	0.743	-0.019	0.912
IPAQ scores	0.451	0.006**	0.510	0.001**
IPAQ levels	0.139	0.420	0.261	0.124
PSQ	-0.121	0.482	-0.119	0.488
CFQ	-0.126	0.464	-0.232	0.173

Note: BMI: body mass index; SBP in mmHg is systolic blood pressure measured in millimeters of mercury (mmHg); DBP: Diastolic blood pressure; Mean arterial blood pressure; IPAQ score in METs/week: international physical activity questionnaire; IPAQ Levels: as it is categorized into low, moderate, and high; PSQI: The Pittsburgh Sleep Quality Index (PSQI).

DISCUSSION

This study aimed to investigate the association between hand grip strength, physical activity, cognitive function, and sleep quality in healthy adults. The current findings reveal significant associations. The current findings support the role of hand grip strength (HGS) as a useful tool or indicator of physiological and lifestyle factors in healthy adults. Significant positive correlations were observed between BMI and the right HGS. The left HGS aligns with previous literature, suggesting that higher body mass may contribute to greater muscle strength, possibly through increased mechanical loading [28]. The evidence consistently shows that HGS and BMI are related. Still, the nature of this relationship is complex and influenced by several factors, including age, sex, adiposity, and health conditions. Generally, higher BMI is associated with greater absolute grip strength because increases in body mass often results in greater muscle mass. However, this relationship is not straightforward. For example, in obesity, excess fat mass may mask reduced muscle quality or strength, leading to conditions such as sarcopenic obesity, in which muscle strength is low despite a high BMI [29], [30]. Porto et al. [31] conducted a direct cross-sectional analysis of 150 community-dwelling older adults, revealing a strong positive correlation between grip strength and global muscle strength ($r = 0.690$, $p < 0.001$), even after adjusting for BMI and other confounders. This supports the validity of HGS as a proxy for overall muscle function independent of BMI. However, the relatively small sample size and cross-sectional design limit the ability to draw causal inferences. Studies indicate that relative hand grip strength adjusted for body weight or BMI is a more accurate indicator of muscle function and health risk than absolute strength alone. Lower relative HGS is linked to higher risks of metabolic syndrome, cardiovascular disease, and mortality, independent of BMI [32], [33]. This suggests that simply having a higher BMI does not guarantee better muscle strength or health outcomes.

The current results show positive correlations between hand grip strength, physical activity, age and systolic blood pressure, these associations meet as main physiological requirements because good muscle strength and physical activities require good systolic blood pressure particular with non-trained or athletes as case in our study in addition existing positive correlations with age may be different than in case of older adults or geriatrics existing negative association with advancing age but in the current survey existing positive correlations because mean age of the current sample within the age of adult category of populations. Hand grip strength is a simple yet powerful indicator of overall muscle strength and physical function. It tends to decline with age, reflecting general muscle weakening, which is linked to health outcomes including cardiovascular risk [34]. Physical activity, especially aerobic and resistance training, is widely recognized for its beneficial effects on cardiovascular health, including regulation of blood pressure and arterial function [35], [36]. Age, as a non-modifiable factor, naturally influences blood pressure and vascular stiffness, often leading to increased systolic blood pressure (SBP) as arteries lose elasticity over time (40,37). The evidence suggests a complex but interconnected relationship among these variables. Age is positively correlated with systolic blood pressure, meaning SBP tends to rise with age [34], [37]. This increase in SBP is a key risk factor for cardiovascular diseases. Physical activity, particularly when regular and of moderate to high intensity, can mitigate age-related increases in SBP by improving vascular function and reducing arterial stiffness [35], [36]. For example, structured exercise programs in older adults have demonstrated reductions in SBP and improvements in physical fitness, including increases in hand grip strength [36], [38]. Hand grip strength itself shows a nuanced relationship with SBP and physical activity. While hand grip strength declines with age, it is often positively associated with physical activity levels and overall muscle function [34], [38]. However, in the current study, a positive association between age and hand grip strength was found, as the sample consisted of adults. However, some studies indicate that hand grip strength alone may not directly correlate with arterial stiffness or SBP in older populations, suggesting that muscle strength is one of several factors influencing cardiovascular health [39]. Notably, interventions combining aerobic and resistance exercises improve both SBP and hand grip strength, indicating that enhanced muscle strength through physical activity may contribute indirectly to better blood pressure control [36], [38].

Our results show significant negative correlations between increases in sleep quality and in HGS, with higher PSQI scores (indicating poorer sleep) associated with lower grip strength. Earlier studies have consistently supported the current results, showing a positive correlation between better sleep quality and higher hand grip strength, as well as greater physical activity levels. In severely obese individuals with poor sleep, a structured exercise program improved both subjective sleep quality and hand grip strength, with a moderate negative correlation between improved sleep scores and increased grip strength [40]. This suggests that interventions enhancing physical fitness can concurrently improve sleep disturbances. Among middle-aged and older adults, poor sleep quality and short sleep duration were associated with obesity and sarcopenic obesity; these conditions are characterized by reduced muscle mass and strength [41]. This relationship underscores the role of sleep disturbances in muscle deterioration and metabolic dysregulation. Physical weakness indicators, such as low grip strength and slow gait speed, were found in males, whereas low physical activity predicted depression in females [42]. This gender-specific association highlights the complex interplay between physical function, mental health, and sleep, as poor sleep quality often accompanies depressive symptoms and reduced physical performance. Adults with metabolic syndrome and non-alcoholic fatty liver disease exhibited lower hand grip strength, aerobic capacity, and sleep efficiency compared to those without liver disease [43]. These results underscore the interconnection between metabolic health, physical fitness, and sleep quality. Objective sleep measures, such as total sleep time and sleep efficiency, were associated with body composition metrics, including lean mass and fat distribution. Importantly, hand grip strength and leg extension strength mediated these relationships, indicating that muscle function plays a critical role in how sleep impacts body composition [44]. Improved physical fitness and activity enhanced sleep quality, whereas poor sleep contributes to muscle weakness, frailty, and metabolic disturbances. These findings advocate for integrated lifestyle interventions targeting both sleep and physical function to promote healthy ageing and disease management [43], [44].

A negative association between HGS and cognitive failure was also observed, with statistical significance for the left hand. This finding is consistent with previous research. The literature consistently suggests that lower hand grip strength is associated with increased cognitive impairment in older adults. Large population-based studies using data from the National Health and Nutrition Examination Survey (NHANES) in the United States have shown a significant inverse relationship between muscle strength and cognitive decline. For example, Nie and Hu analyzed over 2,000 participants. They found a non-linear negative correlation, indicating that as muscle strength decreases, cognitive impairment tends to increase, with a threshold effect suggesting critical points at which this relationship intensifies [45]. Similarly, Huang et al. reported a linear inverse association between HGS and cognitive impairment in adults aged 60 and older, indicating that weaker hand grip strength was associated with a higher risk of cognitive deficits across multiple cognitive tests [46]. This negative association appears robust across different populations and cognitive domains. Stephens-Sarlós et al. found that among older Chinese adults, weakness and asymmetry in hand grip strength were linked to higher risks of cognitive decline and depressive symptoms, especially in women, suggesting that sex differences may modulate this relationship [47]. Pérez-Sousa et al. further elucidated that physical fitness, as measured in part by hand grip strength, mediates the impact of aging on cognitive function, suggesting that maintaining muscle strength could mitigate age-related cognitive deterioration [48]. Stephens-Sarlós et al. reported a weak negative association between hand grip strength and markers of primitive reflexes, often associated with cognitive decline in older adults, reinforcing the potential of grip strength as a marker for cognitive health [47].

Interestingly, there are positive correlations between Physical activity and HGS in both male & female analyses, as well as in the male sub-group, but not in the female sub-group. This contrasts with findings from other studies, which have demonstrated a strong association between physical activity and HGS [49]. The discrepancy may be due to variations in activity intensity, sample size, or differences in measurement tools. Older adults with hypertension exhibited a negative correlation between comorbidities and grip strength, with higher physical activity levels associated with greater grip strength and reduced mortality risk [50]. These findings highlight that physical activity, as measured by the IPAQ, is a significant predictor of hand grip strength and related health outcomes. Patients undergoing hemodialysis exhibited significantly lower handgrip strength and physical activity levels (as measured by the IPAQ) than healthy controls, indicating that the disease burden adversely affects both muscle strength and physical activity [51]. Likewise, adults with X-linked hypophosphatemia demonstrated markedly reduced physical activity and muscle power, with a significant correlation between total physical activity (as measured by the IPAQ) and muscle power, underscoring the interdependence of physical activity and muscle function [52]. The IPAQ's role as a self-reported measure of physical activity enables practical assessment in clinical and research settings, facilitating monitoring of physical activity levels in relation to muscle strength. However, it is important to note that IPAQ data may be subjected to recall bias and over- or under-reporting, which can affect the precision of associations with hand grip strength [53]. Despite this limitation, consistent evidence suggests that higher physical activity levels, as measured by the IPAQ, correspond with greater hand grip strength across various populations.

Overall, the available evidence supports existing strong associations between hand grip strength, physical activity, cognitive function, BMI, and sleep quality in adults. Each element influences and reinforces the others, contributing to overall health and functional capacity. Encouraging physical activity, healthy bodybuilding practices, and good sleep habits may be vital strategies for preserving both muscle strength and cognitive health throughout adulthood.

***Limitations &* weaknesses**

One of the primary limitations of this study was the relatively small sample size (n = 160), which may have reduced statistical power and limited the generalizability of the findings to the broader population. A larger sample would have strengthened the ability to detect subtle correlations and reduced the analysis's margin of error. Additionally, there was a significant gender imbalance among participants: 124 males and only 36 females were included in the current study. This disparity may have introduced gender bias, particularly in variables such as hand grip strength and physical activity, which are known to differ between genders. As a result, the outcomes may be more reflective of male participants and less representative of the general adult population or female sex. Future studies should aim to include a more balanced gender distribution and a larger sample to allow for proper subgroup analyses and enhance external validity. The study's strength lies on its multidimensional approach to understanding health and wellness. By examining the relationships among hand grip strength, physical activity, cognitive function, and sleep quality, this study provides a comprehensive understanding of how these factors interact in healthy adults. Firstly, the study does not focus solely on one aspect of health, but rather integrates multiple dimensions, providing a broader understanding. Secondly, the hand grip strength is a reliable indicator of physical health, and including this metric strengthens the study's validity. Thirdly, findings could be useful in medical settings, guiding recommendations for maintaining cognitive function and sleep quality through physical activity. Ultimately, by examining these relationships, the study may identify effective strategies for early intervention in cognitive decline or sleep disturbances.

CONCLUSIONS

This study demonstrated positive correlations between hand grip strength and body mass index and physical activity, suggesting a strong connection between hand grip strength and overall physical health. Additionally, significant negative correlations were detected between hand grip strength and both sleep quality and cognitive failures, indicating that poorer sleep and increased cognitive lapses are associated with weaker hand grip strength. These findings highlight the multifactorial nature of hand grip strength and physical activity. The authors emphasize the importance of considering cognitive and sleep-related factors in physical health assessments.

Author Contributions: The authors confirmed contribution to the paper as follows: study conception and design: SS and MA; data collection: SS and MA; analysis and interpretation of results: SS and MA; draft manuscript preparation: SS and MA. All authors reviewed the results and approved the final version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors would like to thank the Dean of Scientific Research at Imam Abdulrahman bin Faisal University, Dr. Belal Elsayed Shanb, cardiology, Helwan university, and the Medical Bachelor

students, Abdullah Alfardan, Mohammed Abualrahi, Mohammed Alkhater, Mohammed Alnuwaisser, and Rawda Alsayed Shanb, for their cooperation and assistance in conducting this research.
Conflicts of Interest: The authors declare no conflict of interest.
Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.
Institutional Review Board Statement: All procedures of this study were approved by the deanship of scientific research at Imam Abdulrahman bin Faisal University (IRB-2025-03-0361). This study was conducted in accordance with the Declaration of Helsinki at the physiological laboratory of the Physical Therapy Department, College of Applied Medical Sciences, Imam Abdualrahman bin Faisal University. Before participating, all participants signed a consent form, and they were informed that the collected data would be submitted for publication.

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