

Original Article

Effects of Dietary Patterns on Hand Grip Strength in Undergraduate Medical Students

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ABSTRACT

Background: Handgrip strength is a practical indicator of muscular performance and general health, and may be influenced by habitual dietary intake. Undergraduate medical students are vulnerable to irregular eating behaviors, academic stress, and variable physical activity, but local evidence on the relationship between dietary patterns and grip strength remains limited. **Objective:** To determine the association between dietary patterns and dominant and non-dominant handgrip strength among undergraduate medical students. **Methods:** This analytical cross-sectional study included 115 undergraduate medical students aged 18–25 years from Akhtar Saeed Medical and Dental College, Lahore. Participants with systemic, neuromuscular, musculoskeletal, or hand-related conditions affecting grip performance were excluded. Dietary intake was assessed using a self-administered dietary pattern and food frequency questionnaire, and handgrip strength was measured using a hand-held dynamometer. Data were analyzed using SPSS version 25, and linear regression was used to assess associations between dietary variables and grip strength. **Results:** Mean dominant-hand and non-dominant-hand grip strength were 33.32 ± 16.01 kg and 24.53 ± 16.12 kg, respectively. Meat consumption was positively associated with grip strength in both dominant ($B = 3.940$, $p = .002$) and non-dominant hands ($B = 3.672$, $p = .003$), while fruit consumption showed negative associations in both dominant ($B = -2.977$, $p = .006$) and non-dominant hands ($B = -3.265$, $p = .002$). No snack consumption and energy-dense snack intake were also positively associated with grip strength in both models, whereas breakfast frequency and milk and dairy consumption were not statistically significant. **Conclusion:** Selected dietary patterns were associated with handgrip strength among undergraduate medical students, particularly meat intake, fruit intake, and snack-related categories. Because of the cross-sectional design, findings should be interpreted as associations rather than causal effects. **Keywords:** Handgrip strength; dietary patterns; food frequency questionnaire; undergraduate medical students; muscle strength; cross-sectional study.

INTRODUCTION

Handgrip strength is a simple, non-invasive, and clinically meaningful indicator of overall muscular strength and functional capacity. It is increasingly used in clinical and epidemiological research because it reflects not only localized upper-limb performance but also broader physical health, nutritional status, and functional reserve. Reduced grip strength has been associated with impaired daily functioning, frailty, cardiometabolic risk, respiratory disease, cancer-related outcomes, and all-cause mortality, making it a valuable marker for early identification of individuals at risk of poor health trajectories (1–3). Emerging evidence also suggests that lower grip strength may be associated with cognitive decline

and incident dementia, further supporting its role as a practical measure of general health and physiological resilience (4).

Grip strength is influenced by multiple biological, behavioral, and lifestyle-related factors, including age, sex, body composition, hand dominance, posture during assessment, physical activity, and nutritional intake. Population-based studies have established reference values and identified demographic and lifestyle determinants of grip strength in different adult groups, while other studies have demonstrated variation in grip strength according to gender, posture, depressive symptoms, fall risk, and secular trends across populations (5–9). These findings indicate that grip strength is not a fixed characteristic but a measurable functional outcome shaped by individual and environmental exposures. Among young adults, particularly university students, dietary behaviors and physical activity patterns may be important contributors because this period is often marked by irregular meals, frequent snacking, variable protein intake, academic stress, and reduced structured physical activity.

Dietary patterns are of particular relevance because adequate energy intake, protein consumption, micronutrient balance, and meal regularity contribute to muscle maintenance and performance. Previous research has shown that diets rich in protein-containing foods, fruits, vegetables, and overall healthier dietary patterns may be associated with better grip strength in the general population (10). Studies among Chinese adults have reported associations between eating behaviors and handgrip strength, while evidence from the Healthy Eating Index-2015 in U.S. adults suggests that overall diet quality may be positively related to muscular strength (11, 12). Similarly, analysis of Korean National Health and Nutrition Examination Survey data demonstrated significant associations between dietary patterns and handgrip strength, emphasizing the potential role of habitual diet in preserving muscle function (13). Meal frequency and timing may also be relevant, as breakfast consumption has been associated with grip strength in healthy Japanese adults (14). Evidence from children and adolescents further suggests that dietary choices may influence muscular and cardiorespiratory fitness from an early age, highlighting the long-term relevance of nutritional behaviors for physical performance (15).

Medical students represent an important population for examining this relationship because their academic schedules, workload, stress exposure, and lifestyle routines may predispose them to unhealthy eating patterns and inadequate physical activity. Previous studies have reported that breakfast consumption, saturated fat intake, and body mass index differ between medical and non-medical students, while healthier eating habits and prudent dietary patterns have been associated with better health-related quality of life among international medical students (16, 17). Evidence from Pakistani medical and dental students has also shown poor dietary habits and low levels of physical activity, which may increase the risk of obesity, metabolic disorders, and reduced physical fitness (18). However, most available evidence on dietary patterns and handgrip strength has been generated from adult populations in countries such as China, Korea, Japan, the United States, and European settings, and findings may not be directly generalizable to Pakistani undergraduate medical students because of differences in food culture, socioeconomic context, physical activity patterns, body composition, and student lifestyle (11, 13, 19).

Despite the clinical and public health relevance of handgrip strength, limited local evidence is available on how dietary patterns are associated with grip strength among Pakistani undergraduate medical students. Understanding this relationship may help identify modifiable lifestyle factors that can be targeted through nutrition education, student wellness programs, and preventive health strategies. Therefore, this study aimed to determine the association between dietary patterns and handgrip strength of the dominant and non-dominant hands among undergraduate medical students. The study specifically examined whether breakfast consumption, snack intake, milk and dairy intake, meat consumption, and fruit consumption were associated with measured handgrip strength in this population.

MATERIAL AND METHODS

This analytical cross-sectional study was conducted at Akhtar Saeed Medical and Dental College, Lahore, over a six-month period to evaluate the association between dietary patterns and handgrip strength among undergraduate medical students. The study design was selected because the objective was to examine the relationship between habitual dietary intake and measured grip strength at a single point in time rather than to establish temporal or causal effects. The target population consisted of undergraduate medical students aged 18 to 25 years. A minimum sample size of 110 participants was determined using SampSize, and 115 eligible participants were included in the final analysis through non-probability convenience sampling.

Male and female undergraduate students were considered eligible if they were within the specified age range and provided written informed consent. Students were excluded if they had diabetes mellitus, cardiac disease, myasthenia gravis, myopathy, Duchenne muscular dystrophy, poliomyelitis, recent fracture of the hand or forearm, deformity of the arm or hand, or any condition that could directly affect handgrip performance. Students who were involved in hand-dominant sports or regular gym-based activities were also excluded to reduce the influence of training-related grip adaptation on the outcome measurement. Eligible participants were briefed about the purpose and procedures of the study before enrollment, and written informed consent was obtained before data collection.

Data were collected using a self-administered questionnaire that included demographic characteristics, hand dominance, body mass index, physical activity information, and dietary intake patterns. Dietary exposure was assessed using a dietary pattern and food frequency questionnaire adapted from previously used instruments (21, 22). The dietary variables included frequency of breakfast consumption, type of breakfast consumed, snack consumption, type of snack consumed, milk and dairy intake, meat consumption, and fruit consumption. Weekly frequency categories were recorded for major dietary groups, including breakfast, milk and dairy, meat, and fruits. Breakfast type and snack type were treated as categorical dietary pattern variables, with categories including no breakfast consumption, tea with bread, tea with bread and curry, milk/juice/fruits/cereals, no snack consumption, bread or homemade paratha, and energy-dense snacks such as soft drinks, ice cream, pizza, and chocolates. The primary outcome variable was handgrip strength, measured separately for the dominant and non-dominant hands.

Handgrip strength was measured using a hand-held dynamometer, which is a commonly used instrument for assessing grip strength in clinical and epidemiological studies (20). Hand dominance was recorded before measurement, and grip strength values were documented separately for the dominant and non-dominant hands. The dependent variables were dominant-hand and non-dominant-hand grip strength, while the independent variables were dietary pattern indicators. Potential confounding variables considered during analysis included age, sex, body mass index, hand dominance, and physical activity characteristics, because these factors may influence grip strength independently of dietary intake.

Data were entered and analyzed using SPSS version 25. Continuous variables, including age, body mass index, and handgrip strength, were summarized using means, standard deviations, and ranges. Categorical variables, including gender, hand dominance, breakfast consumption, snack consumption, milk and dairy consumption, meat consumption, and fruit consumption, were summarized as frequencies and percentages. Data were screened for completeness, coding consistency, and implausible values before analysis. Linear regression analysis was used to examine the association between dietary pattern variables and handgrip strength. Separate regression models were used for dominant-hand and non-dominant-hand grip strength. Unstandardized coefficients, standardized beta coefficients, and p-values were used to describe the direction, relative strength, and statistical significance of associations. Categorical dietary variables were entered using indicator coding, and interpretation of coefficients was

based on comparison with the relevant reference category. A p-value of less than 0.05 was considered statistically significant.

Ethical approval for the study was obtained from the Institutional Review Board of Akhtar Saeed Medical and Dental College. Participation was voluntary, written informed consent was obtained from all participants, and confidentiality of participant information was maintained throughout data collection, analysis, and reporting. The study involved no external funding, and the authors declared no conflict of interest.

RESULTS

A total of 115 undergraduate medical students were included in the final analysis. The mean age of participants was 21.90 ± 1.84 years, with an age range of 18–25 years. The mean BMI was 22.51 ± 3.55 kg/m². Mean grip strength was higher in the dominant hand than in the non-dominant hand, with values of 33.32 ± 16.01 kg and 24.53 ± 16.12 kg, respectively.

Table 1. Descriptive Statistics of Continuous Variables Among Undergraduate Medical Students

Variable	Mean \pm SD	Range
Age, years	21.90 \pm 1.84	18–25
BMI, kg/m ²	22.51 \pm 3.55	15.1–33.6
Dominant-hand grip strength, kg	33.32 \pm 16.01	6–71.6
Non-dominant-hand grip strength, kg	24.53 \pm 16.12	3–68

SD, standard deviation; BMI, body mass index.

The participants were young adults with a mean BMI within the normal range. Dominant-hand grip strength exceeded non-dominant-hand grip strength by 8.79 kg, indicating a clear functional difference between hands in this sample. The wide ranges for both dominant-hand and non-dominant-hand grip strength suggest substantial variability in muscular performance across participants.

Table 2. Distribution of Demographic and Dietary Characteristics

Variable	Category	n (%)
Gender	Male	54 (47.0)
	Female	61 (53.0)
Dominant hand	Right	108 (93.9)
	Left	7 (6.1)
Breakfast consumption	0 days/week	23 (20.0)
	1–2 days/week	31 (27.0)
	3–4 days/week	10 (8.7)
	5–6 days/week	6 (5.2)
	Daily	45 (39.1)
Snack consumption	No	16 (13.9)
	Yes	99 (86.1)
Milk and dairy consumption	0 days/week	27 (23.5)
	1–2 days/week	28 (24.3)
	3–4 days/week	21 (18.3)
	5–6 days/week	8 (7.0)
	Daily	31 (27.0)
Meat consumption	0 days/week	8 (7.0)
	1–2 days/week	25 (21.7)
	3–4 days/week	37 (32.2)
	5–6 days/week	28 (24.3)
	Daily	17 (14.8)
Fruit consumption	0 days/week	15 (13.0)
	1–2 days/week	33 (28.7)
	3–4 days/week	31 (27.0)
	5–6 days/week	9 (7.8)
	Daily	27 (23.5)

Percentages are based on n = 115.

The sample included slightly more females than males, with females comprising 61 participants and males comprising 54 participants. Most participants were right-hand dominant. Daily breakfast consumption was reported by 45 participants, while 23 participants reported no breakfast consumption. Snack consumption was common, with 99 participants reporting snack intake. Daily milk and dairy consumption was reported by 31 participants, while meat consumption was most frequently reported at 3–4 days per week. Fruit consumption was most reported at 1–2 days per week and 3–4 days per week.

Table 3. Linear Regression Analysis of Dietary Patterns with Dominant-Hand Grip Strength

Predictor	B	β	p-value
Constant	19.547		.000
Breakfast consumption, per week	0.018	0.002	.987
TOBC: no breakfast consumption	-1.924	-0.048	.693
TOBC: tea with bread	-5.472	-0.133	.148
TOBC: tea with bread and curry	4.734	0.066	.445
TOBC: milk, juice, fruits, cereals	3.233	0.054	.541
TOSC: no snack consumption	17.187	0.373	.001
TOSC: bread, homemade paratha	6.330	0.117	.248
TOSC: soft drinks, ice cream, pizza, chocolates	11.449	0.354	.002
Milk and dairy consumption, per week	1.217	0.116	.223
Meat consumption, per week	3.940	0.281	.002
Fruit consumption, per week	-2.977	-0.252	.006

B, unstandardized regression coefficient; β , standardized regression coefficient; TOBC, type of breakfast consumption; TOSC, type of snack consumption. Reference categories were not specified in the supplied regression output and should be reported in the final manuscript.

In the dominant-hand regression model, weekly breakfast frequency was not associated with grip strength. Among breakfast type categories, none of the reported categories showed a statistically significant association with dominant-hand grip strength. No snack consumption was positively associated with dominant-hand grip strength, with an unstandardized coefficient of 17.187 and standardized coefficient of 0.373. Consumption of soft drinks, ice cream, pizza, and chocolates was also positively associated with dominant-hand grip strength, with an unstandardized coefficient of 11.449 and standardized coefficient of 0.354. Meat consumption showed a positive association with dominant-hand grip strength, while fruit consumption showed a negative association. Milk and dairy consumption showed a positive but statistically non-significant coefficient.

Table 4. Linear Regression Analysis of Dietary Patterns with Non-Dominant-Hand Grip Strength

Predictor	B	β	p-value
Constant	7.215		.161
Breakfast consumption, per week	1.533	0.156	.171
TOBC: no breakfast consumption	3.078	0.077	.514
TOBC: tea with bread	-5.251	-0.126	.151
TOBC: tea with bread and curry	9.081	0.126	.132
TOBC: milk, juice, fruits, cereals	3.776	0.063	.460
TOSC: no snack consumption	19.547	0.422	.000
TOSC: bread, homemade paratha	6.332	0.116	.233
TOSC: soft drinks, ice cream, pizza, chocolates	11.870	0.365	.001
Milk and dairy consumption, per week	0.974	0.092	.313
Meat consumption, per week	3.672	0.261	.003
Fruit consumption, per week	-3.265	-0.275	.002

B, unstandardized regression coefficient; β , standardized regression coefficient; TOBC, type of breakfast consumption; TOSC, type of snack consumption. Reference categories were not specified in the supplied regression output and should be reported in the final manuscript.

In the non-dominant-hand regression model, weekly breakfast frequency and breakfast type categories were not statistically significant predictors of grip strength. No snack consumption showed the largest standardized positive association with non-dominant-hand grip strength, followed by consumption of

soft drinks, ice cream, pizza, and chocolates. Meat consumption was positively associated with non-dominant-hand grip strength, whereas fruit consumption was negatively associated. Milk and dairy consumption showed a positive but statistically non-significant coefficient.

Overall, the regression findings showed a broadly similar pattern across dominant and non-dominant hands. Meat consumption was positively associated with grip strength in both hands, while fruit consumption was negatively associated with grip strength in both hands. Snack-related categories also showed positive coefficients in both models, particularly no snack consumption and consumption of energy-dense snacks. Breakfast frequency, breakfast type categories, and milk and dairy consumption did not show statistically significant associations in the reported regression models. Because the study used a cross-sectional design, these findings should be interpreted as associations rather than causal effects.

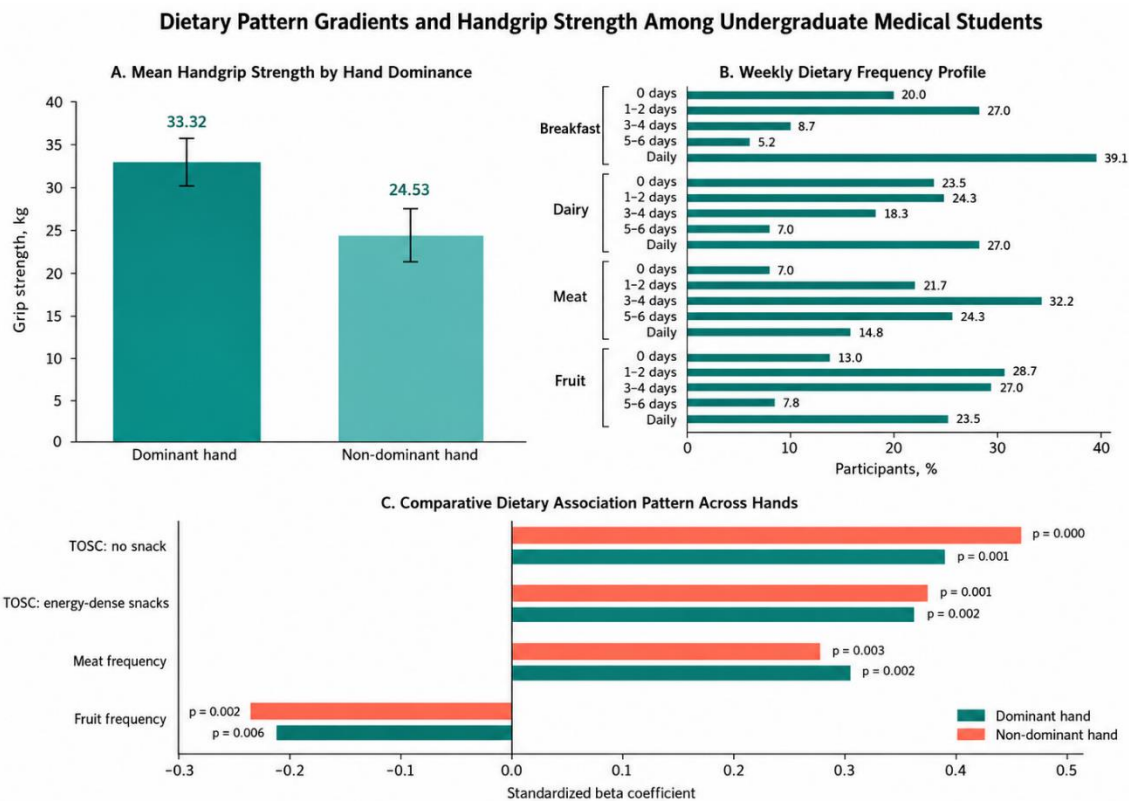


Figure 1 Dietary Pattern Gradients and Handgrip Strength Among Undergraduate Medical Students

The panelled figure demonstrates that mean dominant-hand grip strength was higher than non-dominant-hand grip strength, with values of 33.32 kg and 24.53 kg, respectively. Dietary frequency profiling showed that daily breakfast consumption was reported by 39.1% of participants, while daily milk and dairy, meat, and fruit consumption were reported by 27.0%, 14.8%, and 23.5%, respectively. Regression-based dietary gradients showed consistent positive standardized associations for no snack consumption, energy-dense snack intake, and meat consumption across both hands, with the strongest standardized coefficient observed for no snack consumption in the non-dominant hand ($\beta = 0.422$, $p < 0.001$). Fruit consumption showed a consistent negative association with grip strength in both dominant ($\beta = -0.252$, $p = 0.006$) and non-dominant hands ($\beta = -0.275$, $p = 0.002$), suggesting that the dietary predictors followed a similar direction of association across both functional outcomes. Regression confidence intervals were not displayed because they were not available in the supplied manuscript output.

DISCUSSION

This analytical cross-sectional study examined the association between dietary patterns and handgrip strength among undergraduate medical students. The findings showed that dominant-hand grip strength was higher than non-dominant-hand grip strength, with mean values of 33.32 ± 16.01 kg and 24.53 ± 16.12 kg, respectively. This pattern is consistent with the expected functional advantage of the dominant hand and agrees with previous evidence showing that hand dominance, testing position, and upper-limb use may influence measured grip performance in healthy young adults (23, 24). The wide range of grip strength values observed in both hands also suggests considerable variability in muscular performance within this student population, which may reflect differences in sex distribution, body composition, habitual activity, nutritional intake, and individual physical conditioning.

Meat consumption demonstrated a positive association with grip strength in both dominant and non-dominant hands. In the dominant-hand model, each weekly increase in meat consumption frequency was associated with a higher grip strength coefficient of 3.940, while the corresponding coefficient in the non-dominant-hand model was 3.672. These findings are biologically plausible because meat is a major source of high-quality protein and essential amino acids that contribute to muscle protein synthesis, maintenance of lean tissue, and preservation of neuromuscular function. Previous studies have similarly suggested that meat consumption and overall protein intake may be associated with muscle strength, partly through their relationship with total protein intake and lean mass percentage (25, 26). However, because the present study was cross-sectional and did not measure total protein intake, lean body mass, or dietary energy intake, the observed association should be interpreted as a relationship rather than evidence that meat consumption directly improves grip strength.

Fruit consumption showed a negative association with grip strength in both hands, with coefficients of -2.977 for the dominant hand and -3.265 for the non-dominant hand. This finding differs from some studies in older adults, where higher fruit and vegetable consumption has been associated with better physical function and muscle strength, potentially because of antioxidant, anti-inflammatory, and micronutrient benefits (20). Evidence from adolescents has also explored fruit and vegetable intake in relation to muscle strength and power, although associations may vary according to age group, overall diet quality, physical activity, and body composition (27). In the present student sample, the negative coefficient should not be interpreted as evidence that fruit intake reduces muscle strength. A more cautious interpretation is that fruit consumption may be acting as a marker of broader dietary pattern differences, substitution effects, lower total energy or protein intake, reporting bias, or residual confounding that could not be fully addressed using the available aggregate regression output.

The snack-related findings require particularly careful interpretation. No snack consumption was positively associated with grip strength in both the dominant hand and non-dominant hand, while consumption of energy-dense snacks such as soft drinks, ice cream, pizza, and chocolates also showed positive associations in both models. In the dominant hand, no snack consumption had a standardized beta of 0.373, and energy-dense snack consumption had a standardized beta of 0.354. In the non-dominant hand, the corresponding standardized beta values were 0.422 and 0.365. This apparently paradoxical pattern suggests that snack-type coefficients may be strongly influenced by the unspecified reference category, subgroup distribution, total energy intake, physical activity, or unmeasured lifestyle factors. Previous research has suggested that eating behaviors, including snack intake patterns, may be associated with handgrip strength, but the direction and interpretation of these relationships depend heavily on dietary classification, population characteristics, and adjustment for confounders (11, 28). Therefore, the present snack-related results should be reported cautiously and should not be used to imply that energy-dense snack consumption is beneficial for muscular strength.

Breakfast frequency and breakfast type categories were not significantly associated with grip strength in the reported regression models. This contrasts with some evidence suggesting that breakfast

consumption may be associated with grip strength or physical fitness in selected populations (14, 35). The absence of a significant association in the present study may be related to limited sample size, broad dietary categories, lack of nutrient-level assessment, or insufficient adjustment for energy intake and physical activity. Similarly, milk and dairy consumption showed positive but statistically non-significant coefficients for both dominant and non-dominant hand grip strength. Although dairy products provide protein, calcium, and other nutrients relevant to muscle and bone health, the current findings do not provide sufficient evidence to conclude that dairy intake was independently associated with grip strength in this sample (13).

The overall pattern of findings indicates that dietary factors may be related to grip strength among undergraduate medical students, but the associations were not uniform across all dietary domains. Meat consumption showed consistent positive associations, fruit consumption showed consistent negative associations, and selected snack-related categories showed positive coefficients across both hands. These findings support the broader hypothesis that habitual dietary patterns may be linked with muscular performance, but they also highlight the complexity of interpreting food-frequency data without detailed nutrient quantification, body composition assessment, and fully adjusted regression models. Previous studies have shown that physical activity, cardiorespiratory fitness, and muscular strength are interrelated, and grip strength may also modify broader associations between physical activity and health outcomes (29–32). However, the present Results tables do not provide complete regression outputs for physical activity, BMI, gender, or walking; therefore, these variables should not be emphasized as independent findings unless the corresponding statistical models are added to the Results section.

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design prevents determination of temporal sequence or causality between dietary patterns and grip strength. Second, participants were recruited from a single institution using non-probability convenience sampling, which may limit generalizability to other student populations. Third, dietary intake was assessed using a self-reported food frequency questionnaire, which may be affected by recall bias, social desirability bias, and misclassification of intake frequency. Fourth, the available regression output did not include standard errors, 95% confidence intervals, reference categories, model-fit indices, or assumption diagnostics, limiting assessment of estimate precision and model robustness. Fifth, important determinants of grip strength, including lean mass, fat mass, total calorie intake, total protein intake, sleep, stress, and objectively measured physical activity, were not reported in the supplied analysis. Future studies should use larger multicenter samples, validated dietary assessment tools, standardized grip strength protocols, body composition measurements, and multivariable models with clearly reported confidence intervals to better clarify the relationship between diet and muscular strength in young adults.

CONCLUSION

This study found that selected dietary patterns were associated with handgrip strength among undergraduate medical students, with broadly similar patterns observed for dominant and non-dominant hands. Meat consumption was positively associated with grip strength in both hands, while fruit consumption showed a negative association. No snack consumption and energy-dense snack consumption also showed positive coefficients in both regression models, although these findings should be interpreted cautiously because of possible reference-category effects, residual confounding, and the cross-sectional nature of the analysis. Breakfast frequency, breakfast type categories, and milk and dairy consumption were not significantly associated with grip strength in the reported models. Overall, the findings suggest that dietary behaviors may be linked with muscular performance in young medical students, but causal conclusions cannot be drawn, and further studies with stronger dietary measurement, body composition assessment, and fully adjusted statistical models are needed.

REFERENCES

1. Roberts HC, Denison HJ, Martin HJ, Patel HP, Syddall H, Cooper C, et al. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age Ageing*. 2011;40(4):423-9.
2. Celis-Morales CA, Welsh P, Lyall DM, Steell L, Petermann F, Anderson J, et al. Associations of grip strength with cardiovascular, respiratory, and cancer outcomes and all cause mortality: prospective cohort study of half a million UK Biobank participants. *BMJ*. 2018;361:k1651.
3. Peralta M, Dias CM, Marques A, Henriques-Neto D, Sousa-Uva M. Longitudinal association between grip strength and the risk of heart diseases among European middle-aged and older adults. *Exp Gerontol*. 2023;171:112014.
4. Kuo K, Zhang YR, Chen SD, He XY, Huang SY, Wu BS, et al. Associations of grip strength, walking pace, and the risk of incident dementia: a prospective cohort study of 340212 participants. *Alzheimers Dement*. 2023;19(4):1415-27.
5. Yu R, Ong S, Cheung O, Leung J, Woo J. Reference values of grip strength, prevalence of low grip strength, and factors affecting grip strength values in Chinese adults. *J Am Med Dir Assoc*. 2017;18(6):551.e9-551.e16.
6. Gu Y, Li X, Zhang Q, Liu L, Meng G, Wu H, et al. Grip strength and depressive symptoms in a large-scale adult population: the TCLSIH cohort study. *J Affect Disord*. 2021;279:222-8.
7. Silverman IW. Age as a moderator of the secular trend for grip strength in Canada and the United States. *Ann Hum Biol*. 2015;42(3):199-209.
8. Lee KS, Hwang J. Investigation of grip strength by various body postures and gender in Korean adults. *Work*. 2019;62(1):117-23.
9. Liu H, Hou Y, Li H, Lin J. Influencing factors of weak grip strength and fall: a study based on the China Health and Retirement Longitudinal Study (CHARLS). *BMC Public Health*. 2022;22(1):2337.
10. Zhang X, Gu Y, Cheng J, Meng G, Zhang Q, Liu L, et al. The relationship between dietary patterns and grip strength in the general population: the TCLSIH cohort study. *Eur J Nutr*. 2021;60(5):2409-21.
11. Ding L, Yin J, Zhang W, Wu Z, Chen S. Relationships between eating behaviors and hand grip strength among Chinese adults: a population-based cross-sectional study. *Risk Manag Healthc Policy*. 2020;13:1245-52.
12. Bigman G, Ryan AS. Healthy Eating Index-2015 is associated with grip strength among the US adult population. *Nutrients*. 2021;13(10):3358.
13. Kang Y, Kim J, Kim DY, Kim S, Park S, Lim H, et al. Association between dietary patterns and handgrip strength: analysis of the Korean National Health and Nutrition Examination Survey data between 2014 and 2017. *Nutrients*. 2020;12(10):3048.
14. Huang C, Niu K, Momma H, Kobayashi Y, Guan L, Chujo M, et al. Breakfast consumption frequency is associated with grip strength in a population of healthy Japanese adults. *Nutr Metab Cardiovasc Dis*. 2014;24(6):648-55.
15. Saeedi P, Black KE, Haszard JJ, Skeaff S, Stoner L, Davidson B, et al. Dietary patterns, cardiorespiratory and muscular fitness in 9-11-year-old children from Dunedin, New Zealand. *Nutrients*. 2018;10(7):887.

16. Saintila J, Carranza-Cubas SP, Santamaria-Acosta OFA, Serpa-Barrientos A, Ramos-Vera C, López-López E, et al. Breakfast consumption, saturated fat intake, and body mass index among medical and non-medical students: a cross-sectional analysis. *Sci Rep.* 2024;14(1):12608.
17. Walker AN, Weeto MM, Priddy CB, Yakubu S, Zaitoun M, Chen Q, et al. Healthy eating habits and a prudent dietary pattern improve Nanjing international students' health-related quality of life. *Front Public Health.* 2023;11:1211218.
18. Zuhair HMU, Fatima K, Hussain U, Ayub A. Assessment of eating habits, lifestyle and physical activity among medical and dental students of Faisalabad Medical University. *Pak J Med Sci.* 2024;40(3 Pt 2):473-6.
19. Cuenca-García M, Ruiz JR, Ortega FB, Labayen I, González-Gross M, Moreno LA, et al. Association of breakfast consumption with objectively measured and self-reported physical activity, sedentary time and physical fitness in European adolescents: the HELENA study. *Public Health Nutr.* 2014;17(10):2226-36.
20. Neville CE, Young IS, Gilchrist SE, McKinley MC, Gibson A, Edgar JD, et al. Effect of increased fruit and vegetable consumption on physical function and muscle strength in older adults. *Age (Dordr).* 2013;35(6):2409-22.
21. Ashfaq MM, Jawed N, Safdar NF, Bhutto AA. Breakfast patterns in relation to physical activity among school adolescents in Karachi, Pakistan. *J Health Popul Nutr.* 2023;42(1):116.
22. Paracha P, Bakht S, Paracha S, Vriesekoop F, Alam I, Din Z, et al. Nutritional status, dietary practices and physical activities of adolescents in public and private schools of Karachi, Pakistan. *Obes Res Open J.* 2016;3(2):30-9.
23. El-Gohary TM, Abd Elkader SM, Al-Shenqiti AM, Ibrahim MI. Assessment of hand-grip and key-pinch strength at three arm positions among healthy college students: dominant versus non-dominant hand. *J Taibah Univ Med Sci.* 2019;14(6):566-71.
24. Rostamzadeh S, Saremi M, Tabatabaei S. Normative hand grip strength and prediction models for Iranian office employees. *Work.* 2019;62(2):233-41.
25. Bizzozero-Peroni B, Martínez-Vizcaíno V, Garrido-Miguel M, Fernández-Rodríguez R, Torres-Costoso A, Ferri-Morales A, et al. The association between meat consumption and muscle strength index in young adults: the mediating role of total protein intake and lean mass percentage. *Eur J Nutr.* 2023;62(2):673-83.
26. Lemieux FC, Filion ME, Barbat-Artigas S, Karelis AD, Aubertin-Leheudre M. Relationship between different protein intake recommendations with muscle mass and muscle strength. *Climacteric.* 2014;17(3):294-300.
27. Neville CE, McKinley MC, Murray LJ, Boreham CA, Woodside JV. Fruit and vegetable consumption and muscle strength and power during adolescence: a cross-sectional analysis of the Northern Ireland Young Hearts Project 1999-2001. *J Musculoskelet Neuronal Interact.* 2014;14(3):367-76.
28. Kashima H, Endo MY, Kanda M, Miura A, Fukuba Y, Mizuno M. High-glycemic index meal acutely potentiates blood pressure response to static handgrip exercise in healthy humans. *J Appl Physiol (1985).* 2023;135(3):609-20.
29. Celis-Morales CA, Lyall DM, Anderson J, Iliodromiti S, Fan Y, Ntuk UE, et al. The association between physical activity and risk of mortality is modulated by grip strength and cardiorespiratory fitness: evidence from 498135 UK Biobank participants. *Eur Heart J.* 2017;38(2):116-22.

30. M P, ThamaraiSelvi K, Annamalai N. A cross-sectional study on the effects of physical activity on hand grip strength in type 2 diabetes mellitus patients. *J Basic Clin Physiol Pharmacol*. 2024.
31. Carrasco Poyatos M, Navarro Sánchez MD, Martínez González-Moro I, Reche Orenes D. Daily physical activity impact in old women bone density and grip strength. *Nutr Hosp*. 2016;33(6):1305-11.
32. Berrigan D, Liu A, Belcher BR, Chao A, Fang L, Matthews CE, et al. Physical activity, step counts, and grip strength in the Chinese Children and Families Cohort Study. *Int J Environ Res Public Health*. 2020;17(17):6147.
33. Alqahtani BA, Alenazi AM, Elnaggar RK, Alshehri MM, Alhowimel A, Najmi AA, et al. Normative values for hand grip and pinch strength for 6 to 18 year-olds in Saudi Arabia. *BMC Musculoskeletal Disord*. 2023;24(1):96.
34. Cooper R, Shkolnikov VM, Kudryavtsev AV, Malyutina S, Ryabikov A, Arnesdatter Hopstock L, et al. Between-study differences in grip strength: a comparison of Norwegian and Russian adults aged 40-69 years. *J Cachexia Sarcopenia Muscle*. 2021;12(6):2091-100.
35. Cui Y, Zhang W, Gong Q, Chen Y, Chen S, Wu Z. Frequency of breakfast and physical fitness among Chinese college students. *Am J Health Behav*. 2018;42(1):156-62.