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ORIGINAL ARTICLE

# MEDITERRANEAN DIET ADHERENCE AND RURAL-URBAN DISPARITY AMONG MOROCCAN ADOLESCENTS: A NATIONALLY REPRESENTATIVE CROSS-SECTIONAL STUDY

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## ABSTRACT

**Background.** Mediterranean diet adherence (MDA) is declining globally, yet comprehensive national data on Moroccan adolescent dietary patterns remain scarce.

**Objective.** The present study aimed to assess MDA and analyze urban-rural disparities among Moroccan adolescents.

**Material and Methods.** This cross-sectional national study recruited 3600 adolescents aged 10-18 years (2160 urban and 1440 rural) across Morocco's 12 administrative regions. The Mediterranean Diet Quality Index for children and adolescents (KIDMED) was used to assess MDA; a structured questionnaire was additionally administered to collect sociodemographic and anthropometric data. The nutritional status was assessed using body mass index-for-age z-scores according to World Health Organization (WHO) standards. Multiple logistic regression identified factors associated with poor adherence. *Chi*-square tests were conducted to examine differences in Mediterranean diet dietary behaviour classes by location and sex.

**Results.** Mean KIDMED score was 4.55 ± 3.51. Poor adherence (≤ 3) was found in 38.66%, medium adherence (4-7) in 38.80%, and optimal adherence (≥ 8) in 22.50%. Urban adolescents showed significantly higher adherence than rural counterparts (5.36 ± 3.54 vs. 3.33 ± 3.08; $p < 0.001$). Rural residence was associated with a 3.12-fold higher odds of poor adherence (adjusted OR = 3.12, 95% CI: 2.69-3.62; $p < 0.001$). Urban-rural disparities were more pronounced among females (2.24 points) than males (1.67 points). Fish consumption demonstrated the largest geographical disparity (41.30% vs. 27.40%; $p < 0.001$).

**Conclusions.** The present study reveals a critical urban-rural inequality in MDA: optimal adherence was achieved by only 22.50% of adolescents nationally, and was more than three times lower in rural (9.65%) than urban (31.10%) settings. Rural residence was the strongest independent determinant of poor adherence. These findings call for geographically targeted, school-based policies integrating both nutritional education and structural improvements in food access infrastructure, particularly in rural Morocco.

**Keywords:** *Mediterranean diet, KIDMED, dietary patterns, adolescents, urban-rural disparities, national study, Morocco*

## INTRODUCTION

The nutrition transition is considered one of the most important public health challenges of the 21st century at the global level [1]. The rapid socioeconomic transformations and urbanization fundamentally alter traditional dietary patterns in developing countries, characterized by the coexistence of undernutrition with increasing prevalence of obesity and chronic disease associated with dietary patterns [2]. This epidemiological transition is particularly evident among adolescent populations who progressively adopt westernized dietary patterns rich in ultra-processed foods. Adolescence represents a sensitive period during which dietary patterns are consolidated and exert lasting influences on long-term health trajectory, making this population particularly vulnerable to suboptimal dietary habits. Paradoxically, Mediterranean countries are currently experiencing a worrying shift away from traditional eating habits, particularly among younger generations [3]. It is known that the Mediterranean diet (MD), defined by

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CIHEAM/FAO [3] and recognized by UNESCO as an Intangible Cultural Heritage of Humanity since 2013 [4], is characterized by moderate dairy consumption, low red meat intake and high consumption of fruits, vegetables, legumes, nuts, olive oil, and fish. Despite that the MD can achieve all nutritional requirements, it presents multidimensional benefits documented by previous studies, including maintaining optimal body weight [5], increased longevity [6], and protective effects against cardiovascular diseases [7, 8], diabetes [9, 10], obesity [11, 12], metabolic syndrome [13], certain cancers, and cognitive impairment [14].

A significant geographic heterogeneity in the level of MDA has been demonstrated, with overall adherence estimated at 21.00% and optimal adherence varying between 7.00% and 30.00% [15, 16]. Geographical and socio-economic factors appear to influence these trends, with significant disparities between urban and rural areas as observed in Spain [17] and other Mediterranean regions. Rural environments tend to maintain traditional food patterns but may face restrictions that limit access to a diverse diet, while urban populations generally have access to greater food diversity, including processed foods, which may paradoxically undermine nutritional quality [17, 18].

Morocco has a rich culinary heritage deeply rooted in Mediterranean principles, situated at the crossroads of Mediterranean and African cultures. Yet MDA patterns among Moroccan adolescents remain insufficiently characterized at the national level. The majority of research on MDA has focused on European Mediterranean populations, leaving a significant knowledge gap with regard to North African countries. Existing Moroccan studies on MD have been geographically fragmented to specific regions such as the Drâa-Tafilalet region [19], the Rif Mountains [20], or the city of Casablanca [21]. To the best of authors' knowledge, no study has yet assessed MDA patterns among Moroccan adolescents using a nationally representative sample, significantly limiting the generalizability of current findings and impeding evidence-based national nutrition policy. Understanding urban-rural disparities carries considerable public health relevance, as these differences directly inform the design of targeted interventions and policy frameworks. Urbanization may generate divergent dietary trajectories between urban and rural contexts, warranting particular attention in countries undergoing rapid nutritional transition [17, 21]. In this context, the present study aimed to evaluate the prevalence of MDA at the national level among Moroccan adolescents aged 10 to 18 years, using the validated Mediterranean Diet Quality Index for children and adolescents (KIDMED). The primary objective was to estimate the overall prevalence of adherence and to characterize urban-rural divergence. Secondary objectives included analyzing consumption patterns of specific MD components and exploring variation by age and sex.

## METHODS

### Study design and participants

This is a nationally representative cross-sectional study conducted from 20 September 2022 to 10 June 2023 among 3600 adolescents aged 10 to 18 years (urban and rural) across Morocco's 12 administrative regions. The age range of 10-18 years was selected in accordance with the World Health Organization's definition of adolescence (10-19 years). The lower limit of 10 years corresponds to the earliest age of enrolment in Moroccan secondary education (middle school); the upper limit of 18 years aligns with the legal age of majority in Morocco and the upper age of the secondary school system (high school), ensuring ecological validity within a school-based sampling design. The sampling frame included public and private secondary schools (middle school and high school) as listed in the official registry provided by the Ministry of National Education. Schools were stratified by: administrative region (n = 12), settlement type (urban: > 10,000 inhabitants; rural: ≤ 10,000 inhabitants), and ownership (public vs. private). The 12 administrative regions were: Tanger-Tétouan-Al Hoceima, Oriental, Fès-Meknès, Rabat-Salé-Kénitra, Béni Mellal-Khénifra, Casablanca-Settat, Marrakech-Safi, Drâa-Tafilalet, Souss-Massa, Guelmim-Oued Noun, Laâyoune-Sakia El Hamra, and Dakhla-Oued Ed-Dahab.

A systematic sampling approach was used within each region: two urban schools (one public, one private) and one rural school (public, given negligible coverage of private institutions in rural settings) were selected, totaling 36 schools nationwide. Within each school, three classes were randomly selected from available grade levels to ensure age diversity. Eligible participants were adolescents aged 10-18 years present on the survey day with parental consent. Exclusion criteria: chronic medical conditions requiring therapeutic diets (diabetes, coeliac disease, food allergies); clinically diagnosed eating disorders; and inability to complete questionnaires independently due to cognitive impairment. The recruitment process and final sample composition are presented in Figure 1.

### Sample size justification

The sample size was calculated using standard methods for prevalence estimation in cluster-sampled populations. Based on published estimates, the prevalence of MDA among Moroccan school-age children is 39.98% [19] with a 95.00% confidence level and desired precision of ± 2.40%. To account for clustered sampling, a design effect (DEFF) of 1.80,

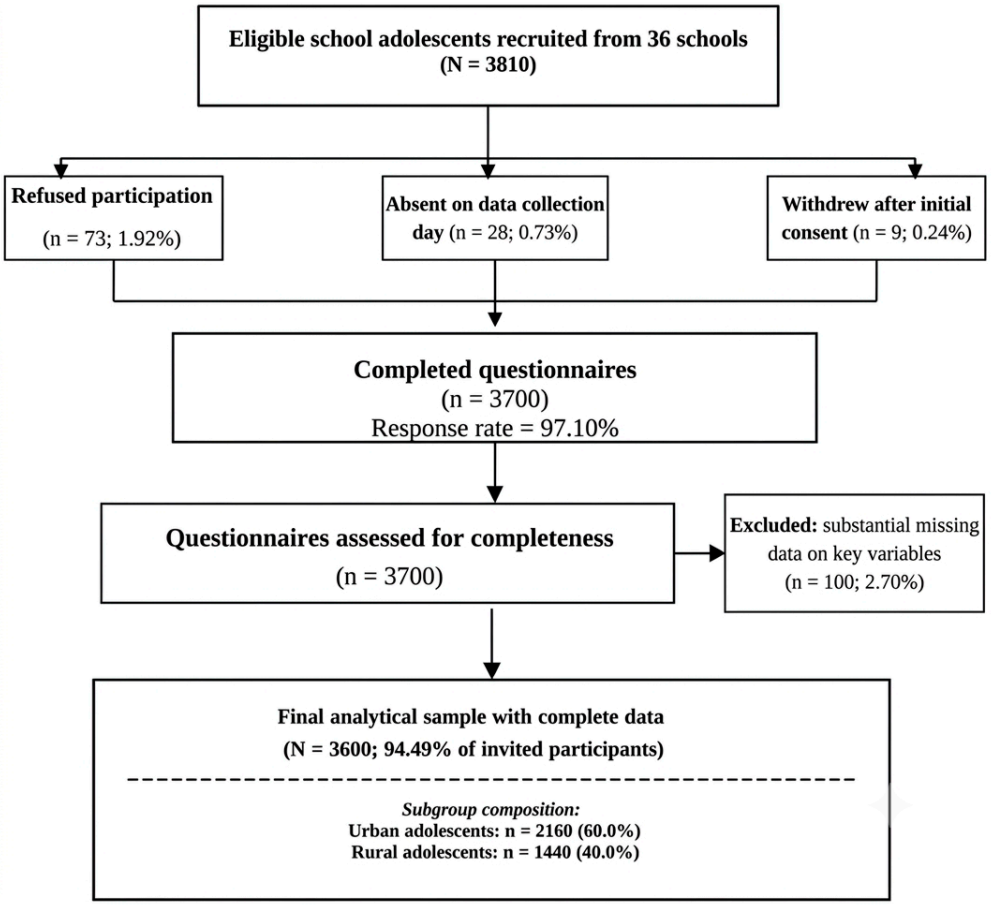


Figure 1. Flow diagram of participant recruitment and final analytical sample

was applied corresponding to an estimated intra-cluster correlation coefficient (ICC) of approximately 0.05, consistent with published ICC values for dietary behaviour outcomes in school-based surveys [22]. Using the formula:

$$N = Z^2pq/d^2 \times DEFF/(1 - r)$$

where Z = 1.96, p = 0.3998, q = 0.6002, r = non-response rate, d = 0.024: basic sample size $n_0$ = 1600; adjusted for DEFF: $n_1$ = 2880; adjusted for 19.00% non-response: N final = 3556. The final sample of 3600 exceeded this minimum, providing adequate statistical power for planned subgroup analyses.

## Anthropometric parameters

All anthropometric measures were taken following WHO standardized protocols for adolescent populations [23]. Weight was measured to the nearest 0.1 kg (SECA 803, Germany), with participants barefoot and wearing light indoor clothing. Height was measured to the nearest 0.1 cm (SECA 213, Germany) in the Frankfurt horizontal plane [24]. Each measurement was performed twice, with the mean value recorded. Nutritional status was assessed using age- and sex-specific BMI z-scores derived with WHO AnthroPlus software (version 1.0.4), based on the WHO 2007 growth reference standards [25, 26]. Four categories were defined: underweight (BMI z-score < −2SD), normal weight (−2SD ≤ BMI z-score ≤ +1SD), overweight (+1SD < BMI z-score ≤ +2SD), and obesity (BMI z-score > +2SD) [27].

## Mediterranean diet adherence assessment

To assess the MDA, the present study used the validated KIDMED index questionnaire, developed by Serra-Majem et al. (2004) [28]. The KIDMED index is composed of a 16-item questionnaire) assigning positive scores (+1) to beneficial Mediterranean behaviours and negative scores (−1) to detrimental habits, yielding total scores ranging from −4 to +12, with higher scores indicating greater adherence. Previous studies have extensively validated the KIDMED and confirmed its reliability and applicability across diverse populations, including non-European settings [29-31], providing the basis for its adoption in the present study.

To meet the objective, the KIDMED questionnaire was translated into the Arabic language following cross-cultural adaptation procedures [32, 33]. To the best of the authors' knowledge, no formally published psychometric validation study of the KIDMED index conducted specifically among Moroccan adolescents exists in the peer-reviewed literature. Accordingly, a pilot study was conducted to assess comprehension,

internal consistency, face validity, and feasibility, with the recruitment of 51 Moroccan adolescents aged 12 to 18 years (mean = 16.84 ± 1.58 years), including 33 females (64.70%) and 18 males (35.30%). The results revealed high acceptability, as all items were understood without ambiguity by at least 94.00% of participants, and the mean completion time was 13.20 minutes (range: 10-18 minutes). The internal consistency of the KIDMED questionnaire was evaluated using Cronbach's alpha coefficient, yielding $\alpha = 0.75$ (95% CI: 0.65-0.85), indicating acceptable internal consistency ($\alpha \geq 0.70$). Minor linguistic adjustments were made based on pilot feedback to enhance clarity while maintaining semantic equivalence with the original instrument.

These items are categorized into two groups:

Positive items (+1 point each):

- Takes a fruit or fruit juice every day;
- Has a second fruit every day;
- Has fresh or cooked vegetables regularly once a day;
- Has fresh or cooked vegetables more than once a day;
- Consumes fish regularly (at least 2-3 times per week);
- Likes pulses and eats them more than once a week;
- Consumes pasta or rice almost every day (5+ times per week);
- Has cereals or grains for breakfast;
- Consumes nuts regularly (at least 2-3 times per week);
- Uses olive oil at home;
- Has a dairy product for breakfast;
- Takes two yoghurts and/or cheese (40 g) daily.

Negative items (−1 point each):

- Goes more than once a week to a fast-food restaurant;
- Skips breakfast;
- Has commercially baked goods or pastries for breakfast;
- Takes sweets and candy several times every day.

KIDMED scores were categorised as ≤ 3 (poor adherence), 4-7 (medium adherence), and ≥ 8 (optimal adherence) [26].

**Data collection procedures**

The training session was delivered online through Google Meet and led by two registered dietitians. Life and Earth Sciences teachers attended a full-day workshop on KIDMED administration and standardized anthropometric measurement procedures. The structured electronic Arabic-version questionnaires (Google Forms) comprised three main components (demographic, anthropometric, and KIDMED) administered in fixed sequence. After a structured briefing session, participants completed the questionnaire independently within a standardized 15-minute timeframe, followed by systematic response verification to minimize missing data. Anthropometric data were entered directly into Google Forms, eliminating transcription errors. Demographic variables assessed included participant's age, sex, educational level, family composition, and household location (urban/rural).

**Statistical analysis**

Statistical analyses were performed using R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were expressed as means ± standard deviations (SD). Normality was assessed using the Kolmogorov-Smirnov (K-S) test: all continuous variables (KIDMED score, age, BMI z-score, family size) showed significant K-S results (all $p < 0.05$), reflecting minor departures from normality; however, given the large sample (N = 3600), the central limit theorem supports the robustness of parametric comparisons (independent t-test) for group-level inference. Age and BMI z-score were used exclusively as categorical variables in regression analyses. Group comparisons for continuous variables were performed using the independent t-test; categorical variables were expressed as absolute frequencies and percentages (standardized to 2 decimal places) and compared using Pearson's *Chi*-square test.

To examine urban-rural disparities across demographic subgroups, separate analyses were performed by sex (females vs. males) and age group (≤ 16 years vs. > 16 years) using independent t-tests. Multiple logistic regression analysis identified independent factors associated with poor MDA (KIDMED score ≤ 3). Variables included in the model were rural residence, age group (≤ 16 vs. > 16 years), educational level (middle school vs. high school), sex, large family size (≥ 7 members), and WHO nutritional status (underweight, overweight, and obesity, each vs. normal weight as reference), entered simultaneously as dummy variables in a single multivariable model, with all N = 3600 participants included in all estimates (no exclusions for any BMI z-score comparison). Crude (unadjusted) odds ratio (ORs) were estimated from separate univariable logistic regression models for each predictor individually; adjusted ORs were estimated from a single multivariable model including all variables simultaneously, allowing quantification of confounding and magnitude of change after adjustment. Model fit was assessed using Nagelkerke $R^2$ and the Hosmer-Lemeshow goodness-of-fit test. Individual KIDMED components were compared by *Chi*-square tests (Tables 3 and 4). Effect sizes were calculated using Cohen's d for mean differences and Cramér's V for categorical associations. All statistical tests were two-tailed. For sociodemographic variables

with three or more categories (family size: 3 groups; nutritional status: 4 groups), pairwise post-hoc comparisons of MDA category distributions were conducted using *Chi*-square tests with Bonferroni correction (adjusted significance level: $\alpha = 0.05/k$, where k denotes the number of pairwise comparisons: $k = 3$ for family size, $k = 6$ for nutritional status). For the mean KIDMED score, pairwise Welch's t-tests with Bonferroni correction were applied to the same groups. Post-hoc superscript letters (a, b) in Table 2 denote statistically distinct subgroups after correction; groups sharing the same letter are not significantly different. Statistical significance was set at $p < 0.05$ for all primary analyses.

The age cut-off of ≤ 16 vs. > 16 years was selected because age 16 represents a developmental threshold in the Moroccan educational system, corresponding to the transition from middle school (collège) to high school (lycée), consistent with the dichotomization used in comparable Mediterranean adolescent studies [34]. The family size threshold of ≥ 7 members was selected based on the distribution of the study data (19.39% of participants; see Table 1) and is supported by national data on household food insecurity in Morocco indicating that larger Moroccan households face disproportionately higher food access constraints [35], while ensuring adequate cell sizes for logistic regression.

**Ethical approval**

Written informed consent was obtained from parents of all participating adolescents before data collection. Participation was voluntary, confidential, and participants could withdraw at any time. No incentives were provided. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki as revised in 2024 [36]. The study protocol was approved by the Bioethical Commission (No. Adol-H-83/2022).

## RESULTS

**Study participants**

The overall mean age was 16.81 years, with urban participants significantly older than rural counterparts ($p < 0.001$) (Table 1). Urban-rural differences were significant across all demographic and anthropometric characteristics (all $p < 0.001$), as detailed in Table 1.

Table 1. Characteristics of study participants (N = 3600) and comparison between urban and rural adolescents

| Characteristic | Urban (n = 2160) | Rural (n = 1440) | Total (N = 3600) | p-value |
|---|---|---|---|---|
| Demographics | | | | |
| Age, mean ± SD (years) | 17.09 ± 1.39 | 16.39 ± 1.92 | 16.81 ± 1.66 | < 0.001 |
| Age groups, n (%) | | | | |
| ≤ 16 years | 953 (44.12%) | 789 (54.79%) | 1742 (48.39%) | < 0.001 |
| > 16 years | 1207 (55.88%) | 651 (45.21%) | 1858 (51.61%) | |
| Sex, n (%) | | | | |
| Female | 1361 (63.01%) | 744 (51.67%) | 2105 (58.47%) | < 0.001 |
| Male | 799 (36.99%) | 696 (48.33%) | 1495 (41.53%) | < 0.001 |
| Educational level, n (%) | | | | |
| Middle school | 281 (13.01%) | 409 (28.40%) | 690 (19.17%) | < 0.001 |
| High school | 1879 (86.99%) | 1031 (71.60%) | 2910 (80.83%) | |
| Anthropometric data | | | | |
| BMI z-score, mean ± SD | 0.51 ± 0.98 | 0.42 ± 0.95 | 0.48 ± 0.97 | 0.021 |
| Nutritional status, n (%) | | | | |
| Underweight | 43 (1.99%) | 14 (0.97%) | 57 (1.58%) | 0.041 |
| Normal weight | 1648 (76.30%) | 1129 (78.40%) | 2777 (77.14%) | |
| Overweight | 427 (19.77%) | 278 (19.31%) | 705 (19.58%) | |
| Obesity | 42 (1.94%) | 19 (1.32%) | 61 (1.69%) | |
| Family characteristics | | | | |
| Family size, mean ± SD | 5.75 ± 1.58 | 6.16 ± 1.74 | 5.92 ± 1.66 | < 0.001 |
| Family size categories, n (%) | | | | |
| 2-3 members | 85 (3.94%) | 40 (2.78%) | 125 (3.47%) | < 0.001 |
| 4-6 members | 1697 (78.56%) | 1080 (75.00%) | 2777 (77.14%) | |
| ≥ 7 members | 378 (17.50%) | 320 (22.22%) | 698 (19.39%) | |

SD – standard deviation; BMI z-score derived using WHO AnthroPlus v1.0.4 (WHO 2007 growth reference); Statistical tests: independent t-tests for continuous variables; Pearson *Chi*-square ($\chi^2$) for categorical variables.

**Mediterranean diet adherence**

The MDA categories differed significantly by geographical location, educational level, and age group (all $p < 0.001$), with urban adolescents, high school students, and older adolescents (> 16 years) showing better adherence, respectively (Table 2). We have found no significant sex-based differences were observed ($p = 0.44$). The post-hoc pairwise comparisons revealed a significant gradient in adherence across family size categories: large families (≥ 7 members) showed significantly poorer adherence compared with both smaller family groups (all $P_{Bonf} \leq 0.004$), while no significant difference was found between small and medium-sized families ($P_{Bonf} = 0.745$). In addition,

Table 2. KIDMED scores and adherence categories by sociodemographic and anthropometric variables

| Variable | n | KIDMED Mean ± SD | Poor ≤ 3 n (%) | Medium 4-7 n (%) | Optimal ≥ 8 n (%) | p overall | P Bonferroni |
|---|---|---|---|---|---|---|---|
| Overall | 3600 | 4.55 ± 3.51 | 1392 (38.66%) | 1398 (38.83%) | 810 (22.50%) | - | - |
| Geographical location | | | | | | | |
| Urban area | 2160 | 5.36 ± 3.54 | 651 (30.13%) | 838 (38.79%) | 671 (31.06%) | < 0.001 | - |
| Rural area | 1440 | 3.33 ± 3.08 | 741 (51.45%) | 560 (38.88%) | 139 (9.65%) | | - |
| Sex | | | | | | | |
| Female | 2105 | 4.61 ± 3.49 | 792 (37.62%) | 832 (39.52%) | 481 (22.85%) | 0.442 | - |
| Male | 1495 | 4.46 ± 3.52 | 600 (40.13%) | 566 (37.85%) | 329 (22.00%) | | |
| Educational level | | | | | | | |
| Middle school | 690 | 3.89 ± 3.21 | 312 (45.21%) | 267 (38.69%) | 111 (16.08%) | < 0.001 | - |
| High school | 2910 | 4.73 ± 3.58 | 1080 (37.11%) | 1131 (38.86%) | 699 (24.02%) | | |
| Age group | | | | | | | |
| ≤ 16 years | 1742 | 4.27 ± 3.40 | 733 (42.08%) | 684 (39.26%) | 325 (18.66%) | < 0.001 | - |
| > 16 years | 1858 | 4.74 ± 3.60 | 659 (35.46%) | 714 (38.42%) | 485 (26.10%) | | |
| Family size | | | | | | | |
| 2-3 members[a] | 125 | 5.21 ± 3.67[a] | 38 (30.40%)[a] | 52 (41.60%)[a] | 35 (28.00%)[a] | < 0.001* | vs. 4-6: p = 0.745 vs. ≥ 7: p = 0.004 |
| 4-6 members[a] | 2777 | 4.60 ± 3.52[a] | 1043 (37.60%)[a] | 1072 (38.60%)[a] | 662 (23.80%)[a] | | vs. ≥ 7: p < 0.001 |
| ≥ 7 members[b] | 698 | 4.31 ± 3.46[b] | 311 (44.60%)[b] | 274 (39.30%)[b] | 113 (16.20%)[b] | | Reference |
| Nutritional status | | | | | | | |
| Underweight | 57 | 4.21 ± 3.28 | 24 (42.10%) | 22 (38.60%) | 11 (19.30%) | 0.973* | vs. NW: p = 1.000 vs. OW: p = 1.000 vs. Ob: p = 1.000 |
| Normal weight | 2777 | 4.57 ± 3.50 | 1071 (38.60%) | 1077 (38.80%) | 629 (22.70%) | | vs. OW: p = 1.000 vs. Ob: p = 1.000 |
| Overweight | 705 | 4.57 ± 3.55 | 271 (38.40%) | 275 (39.00%) | 159 (22.60%) | | vs. Ob: p = 1.000 |
| Obesity | 61 | 4.41 ± 3.58 | 26 (42.60%) | 24 (39.30%) | 11 (18.00%) | | Reference |

SD – standard deviation; Statistical tests: independent t-tests for continuous variables (KIDMED score); Pearson *Chi*-square ($\chi^2$) for adherence category distributions; * Corrected overall p-values: family size $\chi^2 = 25.92$ (df = 4, $p < 0.001$); nutritional status $\chi^2 = 1.28$ (df = 6, $p = 0.973$); Bonferroni post-hoc correction, Family size (k = 3 pairs, adjusted $\alpha = 0.0167$): 2-3 vs. 4-6 members: $\chi^2 = 2.785$, $p = 0.745$ (ns); 2-3 vs. ≥ 7 members: $\chi^2 = 13.381$, $p = 0.004$; 4-6 vs. ≥ 7 members: $\chi^2 = 21.706$, $p < 0.001$; KIDMED mean Welch t-test (Bonferroni, k = 3): 2-3 vs. 4-6: $p = 0.213$; 2-3 vs. ≥ 7: $t = 2.547$, $p = 0.035$; 4-6 vs. ≥ 7: $p = 0.146$; Nutritional status (k = 6 pairs, adjusted $\alpha = 0.0083$): UW vs. NW: $p = 1.000$; UW vs. OW: $p = 1.000$; UW vs. Ob: $p = 1.000$; NW vs. OW: $p = 1.000$; NW vs. Ob: $p = 1.000$; OW vs. Ob: $p = 1.000$ (all ns); [a], [b]: groups sharing the same letter are not significantly different after Bonferroni correction; Abbreviations: UW – underweight; NW – normal weight; OW – overweight; Ob – obesity.

no significant differences in MDA distribution were observed across nutritional status categories after Bonferroni correction (all $P_{Bonf} > 0.05$). Detailed results are presented in Table 2.

**Individual KIDMED components by geographical location**

The urban-rural disparities were significant across all positive Mediterranean diet behaviours (all $p < 0.05$), while no significant geographical differences emerged for any negative behaviour (all $p > 0.05$) (Table 3). Moreover, among positive behaviours, fish consumption showed the largest urban-rural gap, followed by olive oil usage, breakfast cereals, and daily fruit intake.

**Sex-specific patterns in individual KIDMED components**

The sex-based differences in individual KIDMED components were no significant for most dietary behaviours, except for pasta/rice consumption, nut consumption, fast-food frequency, yoghurt/cheese intake, and sweets consumption (Table 4). The olive oil usage at home showed the highest adoption rate overall, while daily yoghurt/cheese intake showed the lowest.

**Urban-rural differences by age and sex**

Substantial urban-rural differences in MDA were observed across all demographic subgroups, with all comparisons reaching statistical significance ($p < 0.001$) (Table 5). The urban-rural mean difference was more pronounced among females (2.24 points) than among males (1.67 points; $d = 0.49$). Combined stratification identified rural females aged ≤ 16 years as the most vulnerable subgroup, with the lowest mean KIDMED score (2.89) and the largest urban-rural difference (2.34 points; 95% CI: 1.90-2.78). All effect sizes ranged from medium to large (Cohen's d: 0.49-0.75), confirming substantial public health significance.

**Factors associated with poor Mediterranean diet adherence**

Multiple logistic regression identified rural residence as the strongest independent factor associated with poor MDA ($p < 0.001$) (Table 6), representing more than three-fold higher odds among rural compared to urban adolescents after controlling for all other variables. Notably, the adjusted OR (3.12) was substantially higher than the crude OR (2.46), indicating the presence of negative confounding. Younger age (≤ 16 years) was the second strongest

Table 3. Individual KIDMED components by geographical location

| KIDMED component | Urban (n = 2160) n (%) | Rural (n = 1440) n (%) | Total (N = 3600) n (%) | p-value* |
|---|---|---|---|---|
| Positive behaviours (% adopting behaviour) | | | | |
| Takes a fruit or fruit juice every day | 834 (38.61%) | 421 (29.23%) | 1255 (34.86%) | < 0.001 |
| Has a second fruit every day | 869 (40.23%) | 476 (33.05%) | 1345 (37.36%) | < 0.001 |
| Has fresh/cooked vegetables once a day | 985 (45.60%) | 530 (36.80%) | 1515 (42.08%) | < 0.001 |
| Has fresh/cooked vegetables > once a day | 956 (44.26%) | 523 (36.32%) | 1479 (41.08%) | < 0.001 |
| Consumes fish regularly (≥ 2-3 times/ week) | 892 (41.29%) | 395 (27.43%) | 1287 (35.75%) | < 0.001 |
| Likes pulses and eats them > 1/week | 1354 (62.68%) | 791 (54.93%) | 2145 (59.58%) | < 0.001 |
| Consumes pasta or rice ≥ 5 times/week | 1012 (46.85%) | 545 (37.84%) | 1557 (43.25%) | < 0.001 |
| Has cereals/grains for breakfast | 1698 (78.61%) | 984 (68.33%) | 2682 (74.50%) | < 0.001 |
| Consumes nuts regularly (≥ 2-3 times/ week) | 1378 (63.79%) | 865 (60.07%) | 2243 (62.30%) | 0.029 |
| Uses olive oil at home | 1934 (89.53%) | 1145 (79.51%) | 3079 (85.52%) | < 0.001 |
| Has a dairy product for breakfast | 1054 (48.79%) | 587 (40.76%) | 1641 (45.58%) | < 0.001 |
| Takes 2 yoghurts and/or cheese (40 g) daily | 512 (23.70%) | 254 (17.63%) | 766 (21.27%) | < 0.001 |
| Negative behaviours (% engaging in behaviour) | | | | |
| Goes > 1/week to a fast-food restaurant | 482 (22.31%) | 353 (24.51%) | 835 (23.19%) | 0.152 |
| Skips breakfast | 675 (31.25%) | 472 (32.77%) | 1147 (31.86%) | 0.347 |
| Has commercially baked goods for breakfast | 426 (19.72%) | 298 (20.69%) | 724 (20.11%) | 0.494 |
| Takes sweets and candy several times/day | 488 (22.59%) | 354 (24.58%) | 842 (23.38%) | 0.208 |

* $\chi^2$: *Chi*-square tests.

Table 4. Individual KIDMED components by sex

| KIDMED component | Female (n = 2105) n (%) | Male (n = 1495) n (%) | p-value* |
|---|---|---|---|
| Positive behaviours (% adopting behaviour) | | | |
| Takes a fruit or fruit juice every day | 743 (35.29%) | 512 (34.24%) | 0.512 |
| Has a second fruit every day | 796 (37.81%) | 549 (36.72%) | 0.504 |
| Has fresh/cooked vegetables once a day | 894 (42.47%) | 621 (41.53%) | 0.584 |
| Has fresh/cooked vegetables > once a day | 881 (41.85%) | 598 (40.00%) | 0.274 |
| Consumes fish regularly (≥ 2-3 times/week) | 751 (35.70%) | 536 (35.90%) | 0.916 |
| Likes pulses and eats them > 1/week | 1247 (59.23%) | 898 (60.06%) | 0.618 |
| Consumes pasta or rice ≥ 5 times/week | 832 (39.52%) | 725 (48.49%) | < 0.001 |
| Has cereals/grains for breakfast | 1574 (74.77%) | 1108 (74.08%) | 0.662 |
| Consumes nuts regularly (≥ 2-3 times/week) | 1247 (59.23%) | 996 (66.62%) | < 0.001 |
| Uses olive oil at home | 1787 (84.89%) | 1292 (86.42%) | 0.238 |
| Has a dairy product for breakfast | 965 (45.84%) | 676 (45.22%) | 0.717 |
| Takes 2 yoghurts and/or cheese (40 g) daily | 410 (19.48%) | 356 (23.81%) | 0.003 |
| Negative behaviours (% engaging in behaviour) | | | |
| Goes > 1/week to a fast-food restaurant | 372 (17.67%) | 463 (30.97%) | < 0.001 |
| Skips breakfast | 657 (31.21%) | 490 (32.78%) | 0.365 |
| Has commercially baked goods for breakfast | 408 (19.38%) | 316 (21.14%) | 0.237 |
| Takes sweets and candy several times/day | 445 (21.14%) | 397 (26.56%) | < 0.001 |

* $\chi^2$: *Chi*-square tests.

Table 5. Urban-rural KIDMED score differences by age and sex

| Subgroup | Urban KIDMED mean (SD) | Rural KIDMED mean (SD) | Mean difference (95% CI) | Cohen's d | p-value* |
|---|---|---|---|---|---|
| By sex | | | | | |
| Urban n: (Female = 1361, Male =799); Rural n: (Female = 744, Male = 696) | | | | | |
| Female (n = 2105) | 5.48 ± 3.52 | 3.24 ± 3.01 | 2.24 (1.95-2.53) | 0.71 | < 0.001 |
| Male (n = 1495) | 5.19 ± 3.57 | 3.52 ± 3.18 | 1.67 (1.37-1.97) | 0.49 | < 0.001 |
| By age group | | | | | |
| Urban n: (≤ 16 years = 953, > 16 years = 1207); Rural n: (≤ 16 years = 789, > 16 years = 651) | | | | | |
| ≤ 16 yrs (n = 1742) | 5.12 ± 3.41 | 3.08 ± 2.95 | 2.04 (1.67-2.41) | 0.64 | < 0.001 |
| > 16 yrs (n = 1858) | 5.56 ± 3.64 | 3.52 ± 3.18 | 2.04 (1.74-2.34) | 0.60 | < 0.001 |
| Combined stratification (exploratory) | | | | | |
| Urban n: (F ≤ 16 yrs = 660, F > 16 yrs = 701); (M ≤ 16 yrs = 385, M > 16 yrs = 414); Rural n: (F ≤ 16 yrs = 361, F > 16 yrs = 383): (M ≤ 16 yrs = 336, M > 16 yrs = 360) | | | | | |
| Female ≤ 16 yrs (n = 1021) | 5.23 ± 3.46 | 2.89 ± 2.84 | 2.34 (1.90-2.78) | 0.75 | < 0.001 |
| Female > 16 yrs (n = 1084) | 5.71 ± 3.56 | 3.54 ± 3.12 | 2.17 (1.74-2.60) | 0.65 | < 0.001 |
| Male ≤ 16 yrs (n = 721) | 4.95 ± 3.34 | 3.32 ± 3.08 | 1.63 (1.08-2.18) | 0.51 | < 0.001 |
| Male > 16 yrs (n = 774) | 5.38 ± 3.75 | 3.49 ± 3.27 | 1.89 (1.46-2.32) | 0.53 | < 0.001 |

Comparisons: independent t-tests; SD – standard deviation; CI – confidence interval; n: Urban and Rural n added explicitly per subgroup; yrs – years; F – Female; M – Male.

factor ($p < 0.001$), followed by middle school education ($p = 0.014$) and large family size (≥ 7 members; $p = 0.042$). Male sex ($p = 0.42$) and all nutritional status categories showed no independent association with poor adherence after adjustment. The model explained 18.70% of variance in poor adherence (Nagelkerke $R^2 = 0.187$). Model fit was confirmed by the Hosmer-Lemeshow test ($p = 0.39$).

## DISCUSSION

This first nationally representative cross-sectional study of 3600 Moroccan adolescents reveals substantial deviation from Mediterranean dietary patterns, with pronounced geographical disparities warranting public health attention. The present findings demonstrate that 38.66% of participants exhibited poor adherence, with a mean KIDMED score of 4.55, indicating that 77.50% of Moroccan adolescents did not achieve optimal MDA. Notably, rural adolescents showed significantly lower adherence (KIDMED score = 3.33) compared to their urban counterparts (5.36). In addition, the present study showed that rural residence emerged as the strongest independent factor associated with poor adherence. Moreover, when compared with previous research conducted in different Moroccan regions, the present study revealed an important variation. The study of El Mokhtari et al. [20] reported a higher

Table 6. Multiple logistic regression analysis for poor MDA (KIDMED ≤ 3)

| Variable | n | Crude OR (95% CI) | p | Adjusted OR (95% CI) | p |
|---|---|---|---|---|---|
| Geographical location | | | | | |
| Urban residence (reference) | 2160 | 1.00 (reference) | - | 1.00 (reference) | - |
| Rural residence | 1440 | 2.46 (2.14-2.82) | < 0.001 | 3.12 (2.69-3.62) | < 0.001 |
| Age group | | | | | |
| > 16 years (reference, n = 1858) | | | | | |
| > 16 years (reference) | 1858 | 1.00 (reference) | - | 1.00 (reference) | - |
| ≤ 16 years | 1742 | 1.14 (0.98-1.32) | ≥ 0.05 | 1.15 (1.08-1.22) | < 0.001 |
| Educational level | | | | | |
| High school (reference, n = 2910) | | | | | |
| High school (reference) | 2910 | 1.00 (reference) | - | 1.00 (reference) | - |
| Middle school | 690 | 1.05 (0.88-1.24) | ≥ 0.05 | 1.28 (1.05-1.56) | 0.014 |
| Sex | | | | | |
| Female (reference, n = 2105) | | | | | |
| Female (reference) | 2105 | 1.00 (reference) | - | 1.00 (reference) | - |
| Male | 1495 | 1.11 (0.97-1.27) | ≥ 0.05 | 1.06 (0.92-1.22) | 0.418 |
| Family size | | | | | |
| < 7 members (reference, n = 2902) | | | | | |
| < 7 members (reference) | 2902 | 1.00 (reference) | - | 1.00 (reference) | - |
| Large family size (≥ 7 members) | 698 | 1.03 (0.89-1.20) | ≥ 0.05 | 1.19 (1.01-1.41) | 0.042 |
| Nutritional status (BMI z-score) | | | | | |
| Normal weight (reference, n = 2777), all N = 3600 in single model | | | | | |
| Normal weight (reference) | 2777 | 1.00 (reference) | - | 1.00 (reference) | - |
| Underweight | 57 | 0.60 (0.33-1.07) | ≥ 0.05 | 1.05 (0.86-1.29) | 0.637 |
| Overweight | 705 | 0.88 (0.74-1.04) | ≥ 0.05 | 0.92 (0.74-1.15) | 0.467 |
| Obesity | 61 | 1.15 (0.68-1.95) | ≥ 0.05 | 1.08 (0.62-1.89) | 0.787 |

Crude (unadjusted) ORs estimated from separate univariable logistic regression models; adjusted ORs estimated from a single multivariable model including all variables simultaneously; BMI z-score categories modelled as dummy variables within a single multivariable model; normal weight (n = 2777) as reference; all N = 3600 participants included in all estimates; OR – odds ratio; CI – confidence interval. The adjusted OR was controlled for the following confounding variables: geographical location (urban/rural), age group (≤ 16 vs. > 16 years), educational level (middle school vs. high school), sex (female vs. male), family size (< 7 vs. ≥ 7 members), and nutritional status (underweight, overweight, and obesity vs. normal weight).

mean KIDMED score among adolescents from the northern Rif region, where 72.80% achieved medium adherence and 14.90% with optimal adherence, contrasting markedly with the national distribution of 38.83% medium and 22.50% optimal. However, the Rif study had a relatively small sample (n = 302), limiting generalizability. A recent study in school-age adolescents in the Atlantic coastal region revealed lower optimal adherence of 7.70% [37], while a higher rate of optimal adherence (39.90%) was reported in the Tafilalet Oasis [19], which included a younger age group (9-13 years), making direct comparison difficult. The prevalence of optimal adherence of 22.50% in the present sample is comparable to that reported in other Mediterranean populations, including Turkish adolescents (22.90%) [38], Italian schoolchildren from Taranto (24.80%) [39], Greek adolescents (21.00%) [40], and Spanish schoolchildren (27.40%) [41].

This convergence across countries points to persistent and shared difficulties in sustaining traditional Mediterranean dietary patterns among younger populations. The poor adherence rate observed in the present sample situates Morocco within the intermediate-to-high range of a broad spectrum of poor adherence prevalences documented across Mediterranean adolescent populations. Recent country-specific data confirm the marked geographical heterogeneity of this phenomenon. In Greece, a large school-based cross-sectional study conducted in Attica (n = 2088 adolescents aged 12-18 years) reported poor adherence in 32.90% of participants, with optimal adherence reaching only 9.10% [40], a substantially worse profile than reported by earlier Greek estimates [41]. In Turkey, a recent cluster-sampled study in Izmir (n = 2693 school-aged children, 2022-2023) identified poor adherence in 16.60% in northern regions to 18.80% in southern localities have been documented [39, 42], while the pooled estimate across Italian studies approximates 30.80% [43]. In Cyprus, a prevalence of 37.00% poor adherence has been reported among primary schoolchildren [44]. Within this distribution, Morocco is positioned alongside Cyprus and broadly consistent with southern, European and Eastern Mediterranean context, while exceeding the more recent figures observed in Turkey and Italy. Taken together, these cross-national data confirm that suboptimal MDA among adolescents is not confined to non-Mediterranean settings but represents a shared public health challenge across the Mediterranean basin itself, driven by the progressive convergence of dietary behaviours toward Western patterns regardless of geographical proximity to the diet's region of origin [15, 40, 43].

The present investigation revealed no significant sex differences in the distribution of overall MDA categories, consistent with findings from southern Spain [17] and the general absence of a consistent sex-related pattern in systematic reviews [30, 31]. A sex difference analysis conducted among adults with obesity [45] and a systematic review during the COVID-19 pandemic [46] suggested contextual sex-related differences; however, their generalizability to healthy non-obese adolescents outside a pandemic context is uncertain. The stratified analyses suggested that urban-rural disparities might be more pronounced among females (2.24-point difference) than males (1.67 points), with young rural females showing the lowest KIDMED scores (2.89). These patterns are plausible but were not tested through a formal interaction term in the regression model, representing a hypothesis for future investigation. Younger age (≤ 16 years) was independently associated with significantly higher odds of poor adherence compared to older adolescents (> 16 years), suggesting that dietary adherence tends to improve as adolescents progress toward late adolescence. This pattern is consistent with findings of Patiño-Alonso et al. [47] in a Spanish cross-sectional study, who reported higher MDA among older participants. Previous studies [30, 48] also showed that older age is associated with higher adherence in adolescents. The present study also revealed that middle school education level and large family size (≥ 7 members) were independently associated with poor adherence. The educational effect may reflect the increased awareness of healthy feeding habits associated with longer schooling, driven by early interventions and habit-based programs [49]. Moreover, the post-hoc pairwise analysis further revealed a significant gradient in MDA across family size categories, with adolescents from large family size (≥ 7 members) displaying significantly higher rates of poor adherence and lower optimal adherence compared with smaller family units, independently confirmed after Bonferroni correction. This finding is consistent with the resource dilution hypothesis, whereby increases in family size reduce per-capita food expenditure and dietary diversity [50]. In the Moroccan context, large family size is structurally linked to rural residence and lower socioeconomic status [35]. These findings underscore that family size composition represents a modifiable socioeconomic risk factor that should be integrated into targeted nutritional interventions for Moroccan adolescents. Conversely, no significant differences in MDA were observed across nutritional status categories after Bonferroni correction, indicating that BMI z-score does not independently determine dietary quality in this population. This dissociation between weight status and dietary adherence aligns with evidence from Spanish [34] and Italian [36] adolescent cohorts, and highlights the importance of addressing upstream socioeconomic and environmental determinants

of dietary quality rather than relying exclusively on anthropometric proxies in public health programming.

The present data showed that urban-rural differences were observed exclusively in positive MD components (cereals, legumes, olive oil, fish, vegetables and fruits), with no significant differences in negative dietary behaviours between geographical areas. This finding suggests that disparities may be explained primarily by differential access to key MD foods rather than by differences in awareness of unhealthy dietary practices. Given Morocco's extensive Atlantic and Mediterranean coastline and longstanding fishing tradition, the marked urban-rural gap in regular fish consumption (41.30% vs. 27.43%) is particularly notable, and may be more plausibly explained by limitations in cold-chain logistics and distribution infrastructure than by differences in food preferences. These patterns suggest that familiarity with health-detrimental eating habits is geographically uniform, whereas access to nutritious Mediterranean diet components may represent a primary structural barrier in rural areas. This interpretation aligns with the double burden of malnutrition framework, whereby industrialized ultra-processed foods tend to penetrate both urban and rural markets rapidly and uniformly, while access to fresh and nutrient-dense foods remains structured by infrastructure, market access, and purchasing power. Nevertheless, this study did not include direct measures of the food environment, proximity to markets, household food security, or nutritional knowledge. Consequently, the proposed access-related explanation remains hypothetical and should be examined in future studies incorporating validated food-environment indicators.

The major strengths of this study include being the first nationally representative assessment of MDA among Moroccan adolescents, with a large sample size (N = 3600), multi-stage stratified sampling across 12 regions, and the use of a validated and culturally adapted KIDMED instrument. Limitations include: the cross-sectional design precluding causal inference; omission of physical activity (a recognized correlate of healthy dietary behaviours varying between urban and rural contexts), contributing to the modest explanatory power of the model (Nagelkerke $R^2 = 18.70\%$); absence of direct socioeconomic indicators (parental income, household food expenditure); and the pilot phase not formally pre-testing comprehension among adolescents aged 10-11 years (pilot phase included only ages 12-18 years).

## CONCLUSIONS

This first nationally representative assessment of MDA among Moroccan adolescents reveals a concerning and significant departure from traditional dietary patterns. The study demonstrates a critical public health inequality: optimal adherence was achieved by only 22.50% of adolescents nationally, but the urban-rural divide is particularly alarming, with optimal adherence being more than three times higher in urban (31.10%) than in rural (9.65%) settings. Rural residence independently conferred more than a threefold greater odds of poor adherence, even after adjustment for sociodemographic and anthropometric covariates. The specific finding that geographic disparities were exclusive to positive dietary components, while unhealthy dietary behaviours were uniformly prevalent, points to structural food access barriers rather than differential nutritional awareness as the primary driver of rural disadvantage. These findings call urgently for geographically differentiated public health policies that integrate cold-chain infrastructure improvements, rural food distribution networks, and school-based nutritional programmes. Future research should incorporate socioeconomic indicators, physical activity data, and validated food-environment measures to further characterize the determinants of dietary inequality in this population.

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