

Diet Diversity and Food Consumption Patterns Among High School Adolescents in Machakel District, Amhara region, Ethiopia: A Cross-Sequential Study.

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Abstract

Background: Globally, adolescents face significant challenges in achieving food and nutrition security, particularly in Sub-Saharan Africa. This study focused on assessing diet diversity and food consumption patterns of adolescent students in Machakel district during pre-harvest and post-harvest seasons, comparing food and nutrition security between the two seasons.

Method: The study used a cross-sequential design to assess diet diversity and food consumption patterns. Dietary Diversity Score (DDS) and Food Consumption Score (FCS) were used to measure food and nutrition security status. Using a simple random sampling technique, 410 students were selected from four high schools. Data were collected in the pre-harvest (Mid november-December) and post-harvest (April-May) seasons. Data analysis was conducted using descriptive statistics, chi-square tests, and Wilcoxon matched-pairs signed-rank tests. STATA 17 was utilized for analysis.

Result: Dietary diversity and food consumption scores among high school students in Machakel district varied by season and socio-economic status. The study found that food and nutrition security significantly improved in the post-harvest season compared to the pre-harvest season. At pre-harvest, 55%, 41%, and 4% had little, acceptable, and suitable dietary diversity scores (DDS), respectively, compared to 19%, 55%, and 26% post-harvest. Similarly, the percentage of poor, borderline, and acceptable food consumption scores shifted from 55%, 41%, and 4% to 2%, 30%, and 68%, respectively. School location, parental education, and household wealth were among the key factors influencing food and nutrition security.

Conclusion: These findings highlight the need for public awareness and targeted interventions, such as school feeding programs, nutrition education, and social support programs, to address the seasonal and socioeconomic disparities in adolescent nutrition and improve their overall well-being.

Key words: Adolescent students, High school, Diet diversity score, Food consumption score, pre-harvest, post-harvest

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Introduction

Adolescents, comprising over 16% of the global population and 23% in Sub-Saharan Africa, are often overlooked in nutrition programs that primarily target children and mothers. In Ethiopia, adolescents face significant nutritional challenges, with 49.1% suffering from stunting and 49.7% experiencing anemia⁽¹⁾. As the second-fastest growth phase after infancy, adolescence demands increased nutrients for healthy development. This transitional stage comes with unique dietary needs influenced by various factors, making healthy eating essential to support their rapid growth and prevent nutritional deficiencies that can hinder their physical, cognitive, and emotional development ⁽²⁻⁴⁾.

The Dietary Diversity Score (DDS) introduced in 2006, measures dietary variety at household and individual levels, reflecting food security, socioeconomic status, and access to nutrition. Similarly, the Food Consumption Score (FCS), developed by the World Food Programme in 1996, evaluates household dietary diversity and frequency, weighted by nutritional value ^(5, 6). In food-scarce areas, reliance on energy-dense but nutrient-poor diets leads to malnutrition. Promoting dietary diversity with nutrient-rich foods addresses micronutrient deficiencies, improves nutritional outcomes, and enhances food availability, particularly for adolescents ^(5, 7, 8).

Globally, adolescents face a triple burden of malnutrition, including stunting, thinness, obesity, and anemia, often exacerbated by food insecurity and poor dietary diversification. In Lebanon, over half of adolescents were food insecure(9), while in Ghana, factors like family income, gender, residence, and meal frequency significantly influenced food diversity and food consumption pattern(10). Similarly, in Kenya, Nigeria, and Uganda, less than half of young farmers achieved acceptable FCS despite their role in food production, highlighting widespread food insecurity among adolescents(11).

Inadequate dietary diversity in adolescents contributes to malnutrition and physical, emotional, and psychological challenges, yet many interventions fail to address their specific needs(12). Empowering communities and considering adolescents' real-life experiences are essential to overcoming barriers, improving global food security, and promoting proper nutrition, which can reduce malnutrition, obesity, and noncommunicable diseases in this critical population of 1.2 billion (13-15).

From mini-EDHS conducted in Ethiopia in 2019, only 11% children consumed minimum acceptable diet (16), Similarly, Ethiopian adolescents experience limited dietary diversity with factors like household size, wealth, geography, and maternal education. Food and nutrition security studies for urban adolescents in Ethiopia, further highlighted poor dietary diversity and the need for policies promoting nutrition awareness and access to diverse foods (17, 18). This study aimed to evaluate the food and nutrition security of adolescent high school students by analyzing their diet diversity and food consumption scores during the pre-harvest (Mid November-December) and post-harvest (April-May) seasons. Specifically, it focused on assessing and comparing diet diversity and food consumption scores across both seasons and identifying associated factors.

Methods

Description of the study area

Machakel district is located in East Gojjam, Amhara region of Ethiopia, approximately 328 km from Addis Ababa and 228 km from Bahir Dar. The district's capital is Amanuel town. Machakel has a diverse agro-ecological landscape, with 88% of the area classified as Woyina Dega (mid-altitude) and Dega (highlands) zones. The district is known for its high agricultural productivity, with most farmers practicing mixed agriculture, combining crop production and livestock grazing (19, 20).

There are currently four high schools in Machakel district: Amanuel, Dega Segnin, Gira Kidamin, and Shetel. Amanuel High School is located in the district capital, while the other three are situated in semi-urban areas. As of the 2022/2023 academic year, the total student enrollment in these four high schools was 7,561, with 3,811 female students and 3,750 male students.

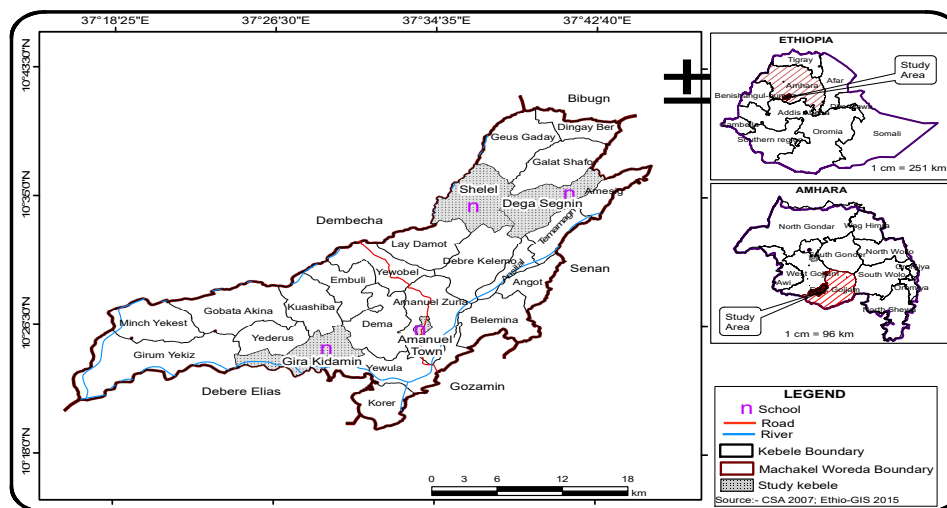


Figure 1: Map of study area (Machakel District)

Study design and sampling procedure

A cross-sequential study design was employed to assess dietary diversity and food consumption patterns among high school students in Machakel district. This design combines elements of both longitudinal and cross-sectional methods, allowing for data collection at two different time points (pre-harvest and post-harvest seasons) from the same cohort of students. This approach enables the examination of both within-individual changes and between-group differences in dietary patterns over time.

A proportional simple random sampling technique was used to select 410 students from a sampling frame of all 7,561 high school (Grades 9-12) students enrolled in the four high schools in the district. The sample size was determined using the following formula for known population size:

$$SS_{kp} = \frac{S}{1 + \frac{S-1}{Pk}}$$

Where SS_{kp} is the sample size for the known population size and S is the sample size for an unknown population, PK is the known population size from which the sample size is calculated (21), cross-checked with the creative research system software for sample size calculation (CRS-2012). The final sample size of 410 was then allocated proportionally to each high school based on the number of students enrolled in each school (see Table 1).

The given formula for sample size adjustment when the population is known incorporates finite population correction (FPC) to refine the sample size estimate. It ensures that the sample remains representative while accounting for the limited population size. The formula relies on key statistical assumptions, including a confidence level at 95%, with a significant level of 0.05, a margin of error 5%, and a standard normal Z-score 1.96 based on the chosen confidence level 95%. Since the population proportion is unknown, it is assumed to be 50% (0.5) to account for maximum variability.

A randomized selection process was undertaken to identify a total of 410 students from four high schools, spanning across Grades 9 to 12. The procedure commenced with a comprehensive listing of all sections within each of the four high schools, ensuring that every section was properly documented along with its respective school name. This step was crucial in maintaining accuracy and transparency in the selection process.

To ensure representativeness and eliminate any potential bias, a lottery-based selection method was employed. Under this approach, sections were randomly drawn from each grade level, ensuring equal representation across different schools and grade levels. This method provided every section with an equal opportunity to be selected, thus upholding the principles of randomness and impartiality. Once the sections were chosen through the lottery process, the corresponding students within those sections were identified as part of the final group of 410 students from all four high schools.

Data collection Procedure

Data was collected during two distinct periods: the pre-harvest season (August-December 2022), which typically represents a time of food shortage and reliance on stored crops, and the post-harvest season (January-May 2023), when food availability is generally higher due to the recent harvest. These seasons were chosen to capture the potential variation in dietary diversity and food consumption patterns across periods of relative food scarcity and abundance. Structured questionnaires were used to collect data on various aspects of the students' lives, including their socio-demographic characteristics (age, gender, grade level, household size, parental education and occupation, household wealth, dependency ratios), diet diversity and food consumption habits.

Dietary Diversity Score (DDS):

The DDS was assessed based on FAO guidelines (22) and the IDDEX project (5). It was calculated based on the consumption of 12 food groups within the past 24 hours (see Table 2). A score between 0 and 12 was assigned, with higher scores indicating greater dietary diversity. While there is no universally accepted cut-off for DDS, this study adopted the following thresholds: Little diversity: $DDS < 5$; Acceptable diversity: $DDS 5 - 8$; Suitable diversity: $DDS > 8$. These cut-offs were based on recommendations from previous

research and guidelines (23). However, it is important to acknowledge that these thresholds are somewhat arbitrary and may not fully capture the complexity of dietary diversity in the specific context of this study.

Food Consumption Score (FCS):

The Food Consumption Score (FCS) measures both the variety and frequency of different food groups consumed by an individual over the past 7 days. This score is calculated by following these steps: (1) Data on the frequency of consumption of 18 standard food items over the past 7 days are collected; (2) These food items are then grouped into specific food groups, with the consumption frequencies within each group summed up. Any sum exceeding 7 is capped at 7 to prevent overemphasis on any single food group; (3) Each group's sum is then multiplied by its respective weight to create weighted food group scores; and (4) These scores are added together to generate the overall Food Consumption Score (FCS). By applying a suitable threshold, the continuous FCS is converted into a categorical variable for easier interpretation. Based on World Food Programme thresholds and the IDDEX project, the FCS is categorized into 'poor (0-21),' 'borderline (21.5-35),' or 'acceptable (>35)' (5, 24).

Data collection was conducted by four trained BSc nurses. These nurses underwent rigorous training to ensure they had a clear understanding of the study objectives, standardized data collection procedures, and ethical considerations, such as obtaining informed consent from participants. Training covered the proper use of structured questionnaires, standardized dietary recall methods, and techniques to minimize recall bias when collecting data on food consumption. To ensure high-quality data, the principal investigator was present for supervision throughout the data collection process. The investigator monitored the nurses' adherence to protocols, provided immediate clarification on any doubts, and ensured that data were recorded consistently and accurately. Spot-checks and random verifications were conducted to identify potential errors or inconsistencies. In cases where discrepancies were noted, immediate feedback was provided to ensure corrective actions were taken. In addition, Pre-testing and piloting of survey tools were conducted to refine questions and minimize respondent bias.

Data analysis

Data processing and management were conducted using STATA version 17. To address the research questions, descriptive and inferential analyses were performed.

Descriptive Statistics: Frequency tables were used to describe the characteristics of the respondents, including their socio-demographic information, school-related factors, and household characteristics.

Chi-Square Test: The Chi-square test was used to explore the relationships between the outcome variables (DDS and FCS) and various independent variables, including age, gender, grade level, school location, parental education and occupation, household wealth. This test allowed for the identification of significant associations between dietary diversity, food consumption, and the influencing factors under investigation. A p-value of <0.05 was considered statistically significant.

Wilcoxon Matched-Pairs Signed-Rank Test: To analyze seasonal variations in food and nutrition security, the Wilcoxon matched-pairs signed-rank test was used to compare changes in DDS and FCS between the pre-harvest and post-harvest seasons. This non-parametric test was chosen due to its robustness in handling non-normally distributed data and its ability to assess paired differences. A statistically significant difference indicated a significant median shift in DDS or FCS between the two seasons, suggesting a change in food and nutrition security. The Wilcoxon test showed a statistically significant increase in median DDS and FCS from the pre-harvest to the post-harvest season ($p < 0.05$), indicating a substantial improvement in dietary diversity.

Results and Discussions

Characteristics of the respondents

The study sample consisted of 410 high school students, with 44% attending Amanuel High School. The remaining participants were distributed across the other three high schools in the district (Table 1). Approximately 30% of the students were 18 years old, and 32% were 19 years old. All 15-year-old students

were enrolled in 9th grade, which is the typical age for this grade level in the district. The sample included 29% of students in 9th grade, and 19% in 12th grade. The gender distribution was balanced, with females comprising 50% of the participants.

A notable finding was that most of the students (63%) lived alone, away from their families, in low-cost rented rooms. The remaining 37% resided with their families. This high proportion of students living independently is common in the district due to the distance between schools and students' homes. This living arrangement may have implications for food and nutrition security, as students living alone might have limited access to home-cooked meals and rely on less nutritious and affordable food options.

For students living alone, the cost of low-cost rented rooms constituted the primary expense, while food was the main expenditure for about one-third of this group. This highlights the financial challenges faced by students living independently and the potential trade-offs they might make between food and other expenditures. Over 60% of the students lived more than six kilometers from school, with 12% residing more than 20 kilometers away (Table 1). This considerable distance may affect students' access to food and nutrition, particularly if they rely on school meals or have limited time to prepare meals at home (table).

Table 1: Socio-demographic characteristics of adolescent high school students in Machakel district in 2022/2023 academic year, (n=410)

Variables	Frequency (%)	Variables	Frequency (%)
School location		Grade Level	
Amanuel	182(44.4)	Grade-9	120(29.3)
Dega Segnin	95(23.2)	Grade-10	96(23.4)
Gira Kidamin	90(21.9)	Grade-11	115(28.1)
Shelel	43(10.5)	Grade-12	79(19.3)
Sex of respondents		Living arrangement	
Male	205(50)	Living alone	260(63.4)
Female	205(50)	Living with family	150(36.6)
Main expense for adolescents		Main source of money for adolescents	
Food	137(33.4)	Family only	182(44.4)
Health	12(2.9)	Part-time only	41(10)
Transport	9(2.2)	Part-time and family	173(42.2)
Leisure	71(17.3)	Others	14(3.4)

Dormitory rent	181(44.2)		
Distance from school		Age of the respondent (adolescents)	
<1 KM	30(7.3)	15-17 Years	19(4.6)
1-5 KM	133(32.4)	16 Years	74(18.1)
6-10 KM	77(18.9)	17 Years	62(15.1)
11-15 KM	57(13.9)	18 Years	122(29.8)
16-20 KM	64(15.6)	19 Years	133(32.4)
>20 KM	49(11.9)		

Male-headed households were predominant (82%), with 65% of these household heads being married, 17% divorced, and 15% widowed. This information provides insights into the family structures of the students and may be relevant for understanding the dynamics of food decision-making within households.

More than half of the mothers (51%) were unable to read and write, and none had completed higher education. Similarly, over one-third (37%) of fathers were unable to read and write, and only 2% had attained higher education. Farming was the primary occupation for both parents, with 54% of mothers and 78% of fathers engaged in agriculture. These findings suggest that most students come from households with limited educational attainment and predominantly agricultural livelihoods (Table-2).

Table 2: Parental socio-demographic characteristics of adolescent high school students in Machakel district, (N=410)

Age of household head		Marital status of household head	
30-40 Years	81(19.8)	Single	12(2.9)
41-50 Years	166(40.5)	Married	266(64.9)
51-60 Years	75(18.3)	Divorced	69(16.8)
61-70 Years	50(12.2)	Widowed	63(15.4)
>70 Years	38(9.3)		
Fathers' level of education		Mothers' level of education	
Can't read & write	95(23.2)	Can't read & write	210(51.2)
Can read & write	156(38.1)	Can read & write	73(17.8)

Grade 1-4	96(23.4)	Grade 1-4	98(23.9)
Grade 5-8	55(13.4)	Grade 5-8	26(6.3)
Grade 9-12	4(0.98)	Grade 9-12	3(0.73)
College/University	4(0.98)		
Mothers' occupation		Fathers' occupation	
Housewife	126(30.70)	Farmer	319(77.8)
Farmer	207(50.5)	Merchant	57(13.9)
Merchant	45(10.9)	Daily labor	6(1.5)
Daily labor	7(1.7)	Employee	8(1.9)
Employee	6(1.5)	Mixed	20(4.9)
Mixed	19(4.6)		

About 46% of households owned one hectare of land, and livestock ownership varied, with 46% owning one to three animals. This information provides further context on the socioeconomic status of the households and their potential access to food resources.

The distribution of respondents by household wealth status revealed that a significant proportion (38%) belonged to the poorest or lower-middle wealth quintiles. The middle quintile comprised 26% of the respondents, while the upper-middle and richest quintiles accounted for 36.3%. This distribution highlights the socioeconomic diversity within the sample study, with a substantial proportion of students coming from economically disadvantaged backgrounds. Wealth disparities may have potential implications for food security and dietary diversity to students from poorer households.

The study also examined the dependency ratio within households, which is the ratio of dependents (individuals not of working age) to working-age individuals. A considerable proportion of households (39%) had at least one dependent, indicating that many families had to support non-working members. Households with higher dependency ratios may face greater challenges in ensuring adequate food for all members (Table-3).

Table 3: Household wealth and family structure of adolescent high school students in Machakel District, (N=410)

Numbers of Livestock for household		Household farmland size	
None	8(1.9)	None	44(10.7)
1-3 Livestock	188(45.9)	One Hectare	188(45.9)

4-6 Livestock	162(39.5)	Two Hectare	154(37.6)
7-9 Livestock	27(6.6)	Three Hectare	24(5.9)
>9 Livestock	25(6.1)		
Dependency ratio		Household Wealth Index	
None	133(32.4)	Poor	77 (18.8)
One	158(38.5)	Lower middle	79(19.3)
Two	35(8.5)	Middle	105(25.6)
Three	32(7.8)	Upper middle	61(14.9)
Four	45(10.9)	Rich	88(21.5)
Five	7(1.7)		

Diet Diversity Score (DDS)

This study examined the dietary diversity of adolescent high school students in Machakel district during the pre-harvest and post-harvest seasons. During the pre-harvest season, all students reported consuming some form of carbohydrates within the 24 hours preceding the survey. However, the consumption of other food groups was limited, with only 15% consuming flesh foods and 13% consuming nuts and seeds. A total of 409 (nearly 100%) students reported eating beans and peas, indicating a reliance on a limited range of food groups during this period of relative food scarcity (Table-4).

The post-harvest season showed a significant improvement in dietary diversity across various food groups. The consumption of nuts and seeds increased dramatically from 52 (13%) to 380 (93%) students, dairy from 60 (14%) to 340 (83%), and flesh foods from 62 (15%) to 308 (75%). Eggs and Vitamin A-rich foods also saw moderate increases. This suggests that the post-harvest season brings greater access to a wider variety of foods, potentially leading to improved diet quality and micronutrient intake among the students.

The Wilcoxon matched-pairs signed-rank test confirmed a statistically significant change in dietary diversity from pre-harvest to post-harvest ($p=0.000$), indicating a clear shift in food consumption patterns between the two seasons. This variation likely reflects the seasonal changes in food availability and access, with the post-harvest season offering greater abundance and diversity of food options. The increased consumption of certain food groups after harvest could be attributed to their increased availability, affordability, or cultural preferences associated with the post-harvest period. It is important to note that the study relied on self-reported food consumption data, which might be subject to recall bias or social desirability bias. However, the observed changes in dietary diversity across the two seasons provide valuable insights into the food and nutrition security situation of adolescent students in the district.

Table 4: Consumption of twelve food groups among adolescent high school students in the two seasons (pre-harvest and post-harvest seasons), n=410

S · N	Type of Food Group	% of participants (Yes)		Wilcoxon test
		Pre-harvest	Post-harvest	
1	All starchy staples	100%	100%	0.000*
2	Beans and peas	100%	100%	
3	Nuts and seeds	13%	93%	
4	All dairy	15%	83%	
5	Flesh foods and fish	15%	75%	
6	Eggs	21%	62%	
7	Vitamin A rich dark vegetables	22%	32%	
8	Other Vitamin A rich vegetables	21%	52%	
9	Other fruits	28%	58%	
10	Other vegetables	30%	60%	
11	Oils and fats	49%	96%	
12	Nonalcoholic beverages	48%	70%	

Analysis of dietary diversity scores (DDS) revealed concerning low levels of dietary diversity among students during the pre-harvest season. Over half of the students (55%) had "Little Variety" in their diets, consuming less than four food groups within the 24-hour recall period. This suggests a high risk of micronutrient deficiencies, which can negatively impact health, growth, and development, particularly during adolescence. Another 41% of students reached an "Acceptable" level of diversity, consuming five to eight food groups, while only a mere 4% achieved a "Suitable" level, consuming nine to twelve food groups (Table 3).

These findings highlight the challenges faced by adolescents in achieving adequate dietary diversity during the pre-harvest season, a period often characterized by limited food availability and affordability. This reflects broader food insecurity concerns, as households struggle to access a variety of nutritious foods during the lean season.

Table 5: DDS status of adolescent high school students in the pre-harvest and post-harvest season in Machakel district, (n=410)

DDS in pre- and post-harvest season	Pre-harvest season		Post-harvest season	
	Frequency	Percentage	Frequency	Percentage
Little Variety	227	55.37%	78	19.02%
Acceptable	169	41.22%	224	54.63%
Suitable	14	3.41%	108	26.34%

These findings underscore the need for interventions to improve dietary diversity and address food insecurity during the pre-harvest season. Potential strategies include promoting home gardens to increase access to fresh produce, encouraging diversification of crop production to ensure a wider range of available foods, and providing nutrition education to empower adolescents and their families to make healthier food choices. Addressing these challenges can contribute to better nutritional outcomes and overall well-being for adolescents in Machakel district.

These findings highlight the challenges faced by adolescents in achieving adequate dietary diversity during the pre-harvest season, a period often characterized by limited food availability and affordability. This reflects broader food insecurity concerns, as households struggle to access a variety of nutritious foods during the lean season. This aligns with findings from other studies conducted in Europe, Africa, and Ethiopia, which also observed significant seasonal variations in dietary diversity, with lower DDS scores reported during pre-harvest periods (25-27).

The post-harvest season brought a notable improvement in dietary diversity among the students. A larger proportion (26%) achieved a "Suitable" DDS, indicating a more balanced intake of essential food groups, while 45% had an "Acceptable" DDS. However, 19% of students still exhibited "Little Variety" in their diets, suggesting persistent challenges in accessing a diversity of foods, even during the post-harvest season. This could be due to factors such as dietary habits, food preferences, or continued limitations in food access for certain groups.

The observed improvement in DDS post-harvest aligns with the concept of seasonal food availability and affordability. Increased agricultural production and lower food prices after harvest are likely to contribute to greater dietary diversity. This finding is consistent with research in Ghana and Ethiopia, where similar improvements in dietary diversity were observed during post-harvest periods (28, 29).

The observed improvement in food security and dietary diversity after the harvest season is consistent with previous research. A study conducted in Nigeria by Ayenew and colleagues in 2018 found a positive correlation between post-harvest production diversification and increased dietary diversity among rural households(29). Similarly, systematic reviews and studies in Africa have linked improvements in DDS to harvest seasons and agricultural cycles (30, 31). These findings collectively highlight the influence of seasonal food availability on dietary patterns and nutritional outcomes.

Furthermore, this study examined the factors associated with dietary diversity among the students. A chi-square test revealed significant associations between DDS and several factors, including school location, grade level, living arrangements, number of siblings, main sources of income, main expenses of students, and distance from high school. Students living alone had significantly lower DDS scores compared to those living with their families. These findings suggest that both individual and household-level factors influence adolescent dietary diversity. This study's findings align with research from Bangladesh, which also demonstrated the influence of adolescent and parental factors on adolescent food security status (32). Similarly, systematic reviews and studies in Ethiopia have identified parental factors, residence, and gender as key determinants of adolescent dietary diversity (Annex 1).

The analysis revealed a significant association between school location and dietary diversity score ($p = 0.037$), with students attending rural schools have significantly lower DDS scores compared to those in urban schools. This finding suggests that school location plays a role in shaping adolescent dietary patterns, potentially due to a combination of factors related to food access, socioeconomic conditions, and school environment.

In Machakel district, from four high schools, Amanuel High School is located in the district capital with a larger proportion of students from wealthier families, while the other three schools are situated in more rural areas with a higher proportion of students from poorer agricultural backgrounds. The lower DDS scores observed in rural schools could be attributed to several factors, such as limited access to diverse food groups due to remoteness and lower household incomes, a lack of school feeding programs, and challenges in procuring and storing fresh produce.

This finding aligns with a study conducted in Lokossa, Benin, in 2023, which found that 25.8% of schoolchildren and adolescents had inadequate dietary diversity, with rural residence, low socioeconomic status, and lack of school meals being significant factors (33). Similarly, research in Ethiopia has highlighted the compounded challenges faced by rural schools due to socio-economic disparities and environmental constraints (34). This reinforces the critical role of targeted interventions like community gardening projects and school lunch programs in improving dietary diversity and addressing the disparities linked to school location and socio-economic background.

These findings underscore the importance of targeted interventions to address the disparities in dietary diversity linked to school location and socio-economic background. Community gardening projects can empower schools and communities to produce a variety of nutritious foods, increasing their availability and accessibility. School lunch programs can provide students with regular access to balanced meals, ensuring they receive essential nutrients even during periods of food scarcity. By implementing such interventions, we can contribute to improving adolescent nutrition and reducing health inequalities.

Grade level ($p = 0.025$) shows a significant correlation with dietary diversity, as older students, benefiting from greater autonomy, nutritional awareness, and economic factors, tend to adopt more varied diets, whereas younger students remain constrained by household dietary patterns. A study in central China similarly found that dietary diversity increases with grade level, reinforcing the notion that independence in food choices plays a crucial role in shaping dietary habits (35).

While those living with family were more likely to consume better food variety compared to those living alone away from families which had similarities with a systematic review conducted in 2015 and studies in Sub-Saharan countries stated that living alone affects DDS negatively and adolescents living with family had better dietary diversity due to access to shared resources and home-cooked meals (36, 37). The importance of the living with or away from family is emphasized by studies who found that living with family positively influences adolescents' nutrition through better meal planning and diverse food access (38, 39).

Financial constraints play a significant role in shaping dietary diversity among students. Those prioritizing non-food expenses, such as rent, transportation, and school fees, tend to exhibit lower DDS scores, highlighting the impact of financial limitations on adolescent nutrition. This finding aligns with research on U.S. college students, which revealed that rising tuition and housing costs hinder dietary balance and contribute to food insecurity (40). Similarly, recent studies have demonstrated that financial stability, often linked to higher socioeconomic status, enables greater dietary diversity (41-43).

In this study, students from poorer households were more likely to prioritize non-food expenses and consequently have lower DDS scores. This is likely because limited financial resources restrict their ability to purchase a variety of foods, particularly more expensive nutrient-rich options like fruits, vegetables, and animal-source foods. These findings underscore the need for interventions that address financial constraints and support access to nutritious foods for adolescents, especially those from low-income households. Such interventions could include providing financial assistance for food purchases, promoting affordable and nutritious food options, and implementing school feeding programs that offer balanced meals.

Furthermore, the study found a significant association between the number of siblings and dietary diversity ($p = 0.000$). Households with fewer siblings tend to have better resource allocation per child, contributing to higher dietary diversity. Conversely, larger families often face greater economic constraints that limit access to a diverse diet, particularly in resource-limited settings. This finding is supported by various studies and systematic reviews in Ethiopia, which have demonstrated the link between family size, resource allocation, and dietary diversity (18, 44-46). Addressing the challenges faced by larger families requires a multi-faceted approach that includes social support programs, economic empowerment initiatives, and nutrition education to promote healthy dietary practices even with limited resources.

The Wilcoxon matched pairs signed-rank test showed a significant difference in dietary diversity scores (DDS) between the pre-harvest and post-harvest seasons, with a (p-value of 0.0000). The effect size, ($r = -0.991$) indicates a very strong effect. The negative sign reflects the direction of change, but the magnitude suggests a substantial difference in DDS between the pre-harvest and post-harvest seasons. Specifically, DDS scores were significantly higher in the post-harvest season compared to the pre-harvest season, indicating that students consumed a greater variety of foods after harvest. This seasonal variation in dietary diversity has implications for students' nutritional status, as the lower DDS during the pre-harvest season may increase their risk of micronutrient deficiencies. These findings highlight the influence of seasonal food availability on adolescent diets, reflecting the challenges in ensuring food security throughout the year. The pre-harvest season, often characterized by limited food stocks and higher prices, restricts access to diverse foods, particularly for vulnerable households. This aligns with other studies in Africa that have documented the impact of seasonal food availability on adolescent diets (27, 28).

While the post-harvest season provides a temporary improvement in dietary diversity, this study underscores the need for interventions to ensure consistent access to nutritious foods throughout the year. This could involve promoting food storage and preservation techniques to extend the availability of seasonal produce, supporting school feeding programs to provide regular access to balanced meals, and encouraging home gardens to diversify food sources. By addressing the seasonal variations in food availability and access, we can contribute to better nutritional outcomes and overall well-being for adolescents in Machakel district.

Food Consumption Score (FCS)

The Food Consumption Score (FCS) for high school students in the district during the pre-harvest season revealed concerning trends in food and nutrition security (Table 5). Among study participants, 19% had a "Poor" FCS, indicating poor dietary diversity and insufficient food intake, which can lead to malnutrition and micronutrient deficiencies, with adverse consequences for health and development. Over half (54%) of the students were in the "Borderline" category, suggesting a risk of food and nutrition insecurity. Only 27% of the students had an "Acceptable" FCS, reflecting a healthier dietary pattern. The pre-harvest season, characterized by food scarcity and limited dietary diversity, showed a higher prevalence of poor and borderline food consumption scores, aligning with the observed low DDS during this period. This trend is consistent with findings in Ethiopia, which emphasized that pre-harvest periods pose the highest risk for household food insecurity(47).

Table 6: FCS level of adolescent high school students in the pre-harvest and post-harvest season in Machakel district, n=410

FCS in pre- and post-harvest	Pre-harvest season		Post-harvest season	
	Frequency	Percentage	Frequency	Percentage
Poor	77	18.78	7	1.71
Borderline	223	54.39	125	30.49
Acceptable	110	26.83	278	67.80

However, the post-harvest season brought significant improvements in FCS, reflecting better food availability and access. The percentage of students with poor FCS decreased from 18.9% pre-harvest to 1.7% post-harvest, while those with acceptable scores rose from 26.8% to 67.8%. These improvements have a positive impact on the students' nutritional status, as they have had greater access to a wider variety of foods after harvest.

Despite this improvement, it is important to note that a small percentage of students (1.7%) still had poor FCS even during the post-harvest season. This highlights the need for continued efforts to address food insecurity and ensure access to nutritious foods for all adolescents, particularly those from vulnerable households. Potential interventions could include school feeding programs to provide regular access to balanced meals, nutrition education to promote healthy eating habits, and support for vulnerable households to improve their food security and access to nutritious foods.

The observed seasonal improvement in FCS is attributed to increased food availability and household food stocks post-harvest. This finding aligns with recent evidence from studies in Ethiopia that linked seasonal

food production surges with improved nutritional outcomes in rural adolescents (48). The clear seasonal shift in FCS reflects changes in food availability tied to agricultural cycles, a pattern well-documented in rural settings globally (10, 49). Furthermore, the significant increase in the percentage of students with an "Acceptable" FCS from the pre-harvest to the post-harvest season underscores the positive impact of the harvest on food security in the district. This observation is supported by other studies that have documented similar improvements in food consumption scores after harvest (28, 50).

In addition to seasonal variations, this study also examined the factors associated with food consumption patterns among the students. A chi-square test (Annex-2) revealed that several factors significantly influenced FCS, including living arrangements, the presence of siblings, the main source of income for students, students' main expenses, distance from high school, age of the head of the household, marital status of the household head, mothers' and fathers' levels of education, size of farmland, number of livestock, wealth index, and dependency ratio .

Students living alone had significantly lower FCS scores compared to those living with their families, and higher parental education levels were associated with better FCS scores. Factors like parental occupation, household wealth, farmland size, and livestock ownership likely affect food availability and dietary diversity. Additionally, the dependency ratio and distance from school may have influenced food accessibility and meal frequency. These associations highlight the complex interplay between socio-economic conditions and adolescent food and nutrition security. These findings emphasize the complex interplay of individual, household, and community-level factors in shaping adolescent food consumption patterns. The influence of family structure and parental factors on adolescent nutritional outcomes is consistent with recent research (10, 51).

The analysis revealed that several factors were significantly associated with FCS. Students living with their families had higher FCS scores compared to those living alone, reflecting the positive influence of parental support, shared resources, and access to home-cooked meals. This finding aligns with research in Ethiopia, which demonstrated that adolescents in stable family environments tend to have better dietary practices (52).

Conversely, students living farther away from school had significantly lower FCS scores, likely due to travel burdens that limit their time and resources for meals. This observation is consistent with findings from a systematic review conducted in 2020 (53). These findings highlight the need for community-level interventions, such as school feeding programs, to improve food access and nutrition for students, particularly those in remote areas. Addressing adolescent food insecurity requires a multi-faceted approach that considers socio-economic factors, family structure, and logistical challenges (11).

Furthermore, the analysis revealed that family socio-economic status and parental education are key determinants of nutritional status among the students. Students from wealthier households and those with more educated parents had significantly higher FCS scores, emphasizing the role of economic and educational factors in adolescent nutrition. This finding is consistent with systematic reviews and other studies in Ethiopia, which have established a close link between family socio-economic status and adolescent dietary diversity (54-56). These findings underscore the need for interventions that address socioeconomic disparities and promote educational opportunities to improve adolescent nutrition and well-being.

The analysis revealed that several factors were significantly associated with FCS among the students. The number of siblings was a key factor, with adolescents from larger families having lower FCS scores. This is likely to be due to limited resources being stretched thinner in larger households, resulting in reduced access to adequate food for all members. Additionally, older adolescents in larger families may prioritize the needs of younger siblings, sacrificing their own food intake and potentially compromising their nutritional status. These findings are consistent with research on the impact of family size on adolescent food security (14, 57).

Conversely, adolescents from households with greater access to resources, such as livestock or farmland, tended to have higher FCS scores. These assets provide both food and income, acting as a buffer against food insecurity, particularly in rural areas. This observation echoes findings from studies in Africa that highlight the positive relationship between asset ownership and adolescent nutrition (50, 58).

Furthermore, economic factors, including household income and dependency ratio, significantly influenced adolescents' food consumption patterns. Students from higher-income households with fewer dependents had significantly higher FCS scores, indicating better access to nutritious food. Conversely, those from lower-

income households or those with a higher dependency ratio experienced poorer food consumption. This negative correlation between dependency ratio and FCS underscores the complex link between socioeconomic status and adolescent food security, consistent with findings from studies in Africa and Ethiopia ([42](#), [57](#), [59](#)).

The study also revealed significant seasonal variations in food consumption, with FCS scores being significantly higher in the post-harvest season compared to the pre-harvest season ($p=0.0000$) and effect size ($r=-0.99$). This finding, supported by the Wilcoxon matched-pairs signed-rank test, highlights the influence of seasonal agricultural cycles on adolescent nutrition. The post-harvest period, with its increased food availability and affordability, leads to improved food consumption patterns. This aligns with research in Africa and Ethiopia that has demonstrated the impact of seasonal variations on adolescent nutrition ([27](#), [60](#)).

These findings underscore the need for interventions that address the multi-faceted challenges influencing adolescent food security. This could include social support programs for larger families, economic empowerment initiatives to improve household incomes, and nutrition education to promote healthy dietary practices.

Conclusions and Recommendations

This study highlights the complex interplay of seasonal food availability and socioeconomic factors influencing adolescent food and nutrition security in Machakel district. Pre-harvest food shortages disproportionately affect students from low-income households and those living alone. While post-harvest conditions improve dietary diversity, vulnerability persists, underscoring structural inequalities.

A multi-sectoral approach integrating education, agriculture, and socioeconomic interventions is crucial. Expanding school infrastructure in remote areas can reduce the need for students to live alone, and integrating nutrition education in schools can promote healthy eating habits.

Study limitations

This study has some limitations that should be considered when interpreting the findings. Data was collected during two seasons within one academic year, potentially missing long-term dietary trends. Findings from the Machakel district may not be generalizable to other regions with different contexts. Reliance on one-week recall may introduce recall bias, affecting the accuracy of dietary assessments. Despite these limitations, however, the study provides valuable insights into factors influencing adolescent food and nutrition security in Machakel district, informing interventions and policies to improve adolescent well-being.

Abbreviations and Acronyms

CRS: Creative Research System, **CSA:** Central Statistical Agency, **DDS:** Dietary Diversity Score, **EDHS:** Ethiopia Demographic and Health Survey, **FCS:** Food Consumption Score, **FPC:** Finite Population Correction

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board of the College of Development Studies, Addis Ababa University. Permission to undertake the study was secured from the Amhara Regional State Public Health Institute and the Machakel Woreda Health Office. School directors and Parent-Teacher Associations endorsed the study. Informed consent was obtained from all participants before their involvement in the study. Adolescent students aged 18 years and older provided their own consent, while parents or guardians provided consent for students younger than 18 years. Participants were informed about the study's purpose, procedures, potential risks and benefits, and their right to withdraw at any time without consequences. Verbal consent was obtained from participants. The confidentiality of information obtained from participants and their anonymity were strictly maintained throughout the study.

Availability of data and materials

The datasets used and analyzed during the current study are available upon reasonable request from the corresponding author.

Competing interests

The authors declared that they did not have any form of computing interest

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Author Contributions

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