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Original article

Dietary patterns, nutritional status and agricultural work performance of small-scale farmers in North West Pakistan

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Summary. Dietary patterns examined to assess the overall dietary intake in relation to various health outcomes that may influence physical work capacity of small scale farmers. This follow up study was limited to the farming community of District Mardan, North West Pakistan. Initially, a primary cohort of 1200 farmers was randomly selected using two-stage cluster sampling method; the whole cohort was screened for nutritional status including body weight, height, blood hemoglobin level (Hb) and blood pressure. A sub-cohort of 452 farmers was extracted randomly from the primary sample for follow up; these farmers were followed to gather detailed information on relevant parameters i.e. routine daily working hours in the farm, agricultural, socio-demographic and health characteristics, and dietary intake. Data on nutritional status of the sub-cohort was extracted from the project record; all data was analyzed accordingly using appropriate statistical tests such as Analysis of variance (ANOVA) and logistic regression analysis. Three major dietary patterns were identified: 'energy rich', 'mixed', and 'red meat'. Energy rich pattern was found strongly associated with farmers' body mass index (BMI) and moderately associated with systolic (SBP) and diastolic blood pressures (DBP). Red meat pattern was associated with the risk of high blood pressure among the farmers. Among the nutritional indicators, only Hb had strong correlation with 'mixed dietary pattern' score. Working hours in the farm (farmers' physical work capacity) had significantly strong correlation with the 'mixed dietary pattern' score; this association was further confirmed in logistic regression after adjusting for potential confounding factors. Compared to farmers in lowest quartile of 'mixed dietary pattern', those in the highest quartile had higher work performance after adjusting for covariates (adjusted OR: 0.81, 95% CI: 0.2 – 1.9). Findings of the current research study explained the key role of dietary patterns in farmers' nutritional status and working potential. These results are important, particularly considering the fact that agricultural practices in developing countries are mostly physically demanding, especially in small scale farming. Poor nutritional status adversely affects farmers' health that results in decreasing physical working capacity.

Key words: dietary patterns, nutritional status, physical work performance, farmers, Pakistan

Introduction

An individual's diet plays a key central role in determining nutritional status and inequalities in health outcomes (1, 2). Diet has two significant features related to health outcomes of general population: *insufficient quantity* that leads to majorly energy malnutrition and lesser intake of macronutrients; and *limited quality* or diet with low nutrients density being characterized by inadequate number and variety of food items that results in failing to achieve the essential nutrients specifically the micronutrients. The consequence is the occurrence of malnutrition, which generally represents all deviations from adequate nutrition, affects quality of life through its negative impact on overall health and wellbeing. Several studies have demonstrated a casual effect of poor nutrition on reduced work capacity of the workers (3, 4) indicating functional significance of malnutrition. Health and optimal nutritional status, being a fundamental part of human capital (5), has been documented as sources of economic development and growth in previous literature (6-8).

Dietary intake is under the influence of multifactors including socio-demographic, economical, cultural, religious, professional, physiological, and psychological ones (9). All or some of these factors result in the development of unique dietary practice and habitual dietary intake. Dietary pattern represents the distribution of food items by frequency and / or amount in an individual's habitual diet (10), thus it mainly examines to assess overall dietary intake in relation to various health outcomes, physical work outputs and capacity, and nutritional adequacy (11-14). Dietary patterns also allow to account for total dietary intake of energy and nutrients and thus can be labelled accordingly such as either *energy dense or nutrient rich or whatever particular nutrients they majorly supply*. It has therefore been suggested to measure and use dietary patterns *in nutrition epidemiological research* to investigate and understand diet-disease relations (15).

Pakistan, being a developing agricultural country, is highly dependent on agriculture for its economic development and food security. Association of farmers' nutritional status and dietary diversification with work performance at farm and agricultural productivity has been reported previously from developing world (16, 17). Farm work, particularly small scaled farming in developing world mostly involves physical exertion, therefore poor health results in loss of work days and decreases farmers' working capacity as well as farm productivity (18).

This study was designed to examine prospectively the relationship among dietary patterns, nutritional status, and farm work performance among small scale farmers participating in a longitudinal research project. Objective of the study was to elucidate and explore the complex relationship of farmers' dietary patterns and nutritional status with their routine physical involvement in agricultural activities which is one of the major predictor of farm productivity in developing countries.

Methods

Study location and participants

The current research project was carried out for three years (2013 - 2016) and was limited to the farming community of District Mardan, North West Pakistan. The study location is basically an agricultural area where more than half of population is directly or indirectly related to agriculture. Major objective of the research project was to investigate the influential role of various socio-demographic, health and nutritional factors in the farm outputs. Initially, 1200 farmers (age > 20 years), free from any infectious / chronic disease and dynamically involved in farming, were randomly selected using two stage cluster sampling method. Formal consent of the farmers to participate the study was sought. The study was ethically approved according to the university (Ethical approval reference No. FNS-ECHSRB-2013-091) regulation. The whole cohort was screened systematically for nutritional status.

Baseline Nutritional Status assessment of the primary cohort

Nutritional status of the primary cohort (n=1200) was assessed after enrolment, measuring relevant parameters, such as body weight, height, blood Hb level and blood pressure. These parameters were measured with standardized equipments and methods. Height and weight were measured without shoes and in lightweight clothing to the nearest 0.1 cm and 0.1 kg, respectively. Body mass indexes (BMI) were calculated using weight and height measurements. Whole - blood Hb concentration was determined with HemoCue method (19). Farmers were asked to have a comfortable seated position on a supportive surface for measuring blood pressure on the fully exposed right arm with sphygmomanometer. Two readings of both systolic and diastolic blood pressure were taken with at least 10 minutes interval and the mean values were recorded on the screening proforma.

Data Collection at follow-up

Detailed data on relevant parameters others than baseline characteristics, were collected from a representative sub-cohort of the screened farmers. The subcohort of 452 farmers was extracted randomly from the primary sample using the simple random sampling technique; these farmers were followed to gather detailed information on relevant parameters including agricultural and socio-demographic characteristics, current health status, medical history, and dietary status. These information were collected by trained research associates. Screening data including body weight, height, BMI, blood pressure and hemoglobin of the sub-sample was extracted from the project record, merged with the current data and analyzed accordingly.

Following data was collected in detail at follow-up:

Agricultural, socio-demographic and general health characteristics:

Farmers were interviewed in detail to collect information on basic agricultural and socio-demographic characteristics including farm holding size, farm ownership status, physical involvement (in term of working *hours)* of the farmers on daily basis in different agricultural activities, family support in agricultural practices, literacy level, and income sources other than agriculture. These information were attained through pretested questionnaires. Farmers' working performance in the farm was assessed using data on 'working hours' which was dichotomized by median value. Farmers above the median value were likely to have higher work performance and those below had lower working capacity.

The general health status of farmers was investigated interviewing them in detail. Pretested standardized questionnaire and observational check-list were used. Farmers were enquired about medical history, recent visit to doctor or health facility and current use of medicine for any acute health problem. Similarly, they were asked to self-rate their current health status either as *healthy or unhealthy*

Dietary intake and patterns

A pretested Food frequency questionnaires (FFQ) including all locally consumed foods and beverages, was used to assess farmers' dietary status. FFQ method is a relatively low-cost and easily administer tool in nutritional and epidemiological studies. It is the most frequently used method to evaluate the frequency of habitual and routine dietary intake over a reference time period (20). Farmers were asked to recall the frequency of each food and beverage items that was consumed per day, week and month. A food and beverage item being consumed less than 4 days a month was considered as taken 'rare/never' by the respondent.

Food items listed in the FFQ were grouped into thirty one food groups based on culinary usage or similar nutrients profile. Factor analysis was run to identify interpretable dietary patterns based on the consumption frequency of each amongst the 31 food groups using the Statistical Package for Social Sciences (SPSS) (21). A factor analysis approach used to derive dietary patterns reduces the diets complexity to a few essential foods and beverages and has the capability to integrate complex and subtle interactive effects of many dietary exposures (22). Before factor analysis performance, data adequacy was evaluated using the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) (23) and Bartlett Test of Sphericity (BTS) (24). The factor analysis model was suitable based on KMO and BTS (KMO= 0.81, and $p<0.001$ for BTS). Factor analysis was run to identify dietary factors or combinations of food / beverage consumed by the farmers. Principal component analysis (PCA) was run to extract the factors. The factors were rotated by an orthogonal (Varimax) transformation to minimize the number of indicators that have high loading on one factor (23). The number of factors retained was based on components with an eigenvalue > 1, the interpretability of the factors and scree plot test (25). Food groups / items with absolute factor loadings ≥0.30 were considered as significantly contributing to the pattern.

Three interpretable dietary patterns were retained and labeled based on interpretability and characteristics of the items retained in each pattern (Table 1). Together, the dietary patterns identified accounted for 41% of total variance in the sample. The first dietary pattern was labelled *energy-rich* because it was loaded heavily on fats, sweets and cereals based food groups; the second pattern was labelled as *mixed pattern* because of the predominantly high loadings of wide variety of foods such as dairy products, eggs, vegetables, fruit, nuts, commercially available cereal products and pulses while the third pattern was labelled as *red meat* because of the high factor loadings of red meat and its products. Standardized factor score coefficients (mean ± standard deviation, SD: 0±1) were estimated by re-

Table 1. Factor loading matrixes for the dietary patterns

Food groups	Food items	Energy rich pattern	Mixed Pattern	Red Meat Pattern
Fats	Butter, desi ghee, cheese, solid fat	**0.71**	--	0.22
Starchy vegetables	Potato, yam, pumpkin, green peas	**0.65**	0.26	--
Rice with dairy fats/yogurt	Rice with dairy fats/butter/desi ghee or yogurt	**0.59**	--	0.25
Cereals products	Homemade wheat flour products such as semolina paste, starch paste, corn flour products (cooked in oil/ghee and sugar/or Jaggery)	**0.51**	--	--
Simple Rice	Simple rice (no added pulses, meat or yogurt)	**0.47**	-0.22	--
Added sugar/jiggery	Sugar/ Jaggery, added to food items	**0.41**	0.21	0.29
Homemade bread	Bread (naan, chapatti, pan-cake) prepared at home from whole/refined wheat flour; homemade corn cake	**0.37**	0.27	0.28
Sweets & confectionery	All sweets and confectionery products	**0.33**	--	--
Deeply fried foods	Deeply fried potato, or cereals*	**0.32**	--	--
Fresh dairy products	Milk (fresh), homemade yogurt, buttermilk	0.22	**0.66**	0.26
Pulses	All pulses cooked without added meat/mince meat	--	**0.61**	--
Green leafy vegetables	All green leafy vegetables with no added meat	--	**0.54**	--
Other Vegetables	All vegetables other than green and starchy	--	**0.46**	0.27
Egg	Fried egg, egg cooked in oil and spices, omelet	--	**0.42**	0.22
Fresh fruits	All fresh fruits	-0.21	**0.38**	--
Cereals commercial products	Vermicelli, macaroni, spaghetti, noodles	--	**0.35**	--
All Nuts	Dry fruits and nuts	--	**0.32**	--
Fish	Fish	--	**0.30**	--
Beef	Beef (Cow & Buffalo), veal & meat (grilled & curries)	--	--	**0.56**
Ground beef	Minced meat and its curries	0.22	--	**0.51**
Lamb	Lamb, mutton	--	--	**0.43**
Red meat broth	Broth and soup	--	--	**0.36**
Kebab	Kebab prepared from red meat			**0.32**
Home based Meat products	Meat balls & sausages (prepared from red meat)	--	--	**0.31**
Rice with other meat/pulses	Rice cooked with white meat (chicken) /pulses	--	--	--
Chicken / organ meat	Chicken, other birds, liver, kidney, brain, intestine	--	--	--
Salads	All salads	--	0.27	-0.22
Bakery products	All bakery items, biscuits, cakes	--	--	--
Hot drinks	Black tea (with/without milk and/or sugar), green tea (with /without sugar)	--	--	--
Vegetables with meat/mince-meat	All vegetables with added meat or mince-meat	--	--	--
Condiments	Ketchup, pickles, sauces	-0.23	-0.26	--

*E.g. deeply fried food items such as chapatti (locally known as *paratha* and is traditionally consumed in the breakfast) **Note:** factor loadings between -0.20 and 0.20 are not shown for simplicity; those >0.30 are bold

gression after PCA and saved for each dietary pattern. These scores were also categorized into quartiles, with the highest quartile representing greater dietary pattern adherence and used in the subsequent analysis. Each quartile contains similar number of farmers.

Data Analysis

All data was entered into SPSS (SPSS Inc. 2007); to minimize entry errors, different files (such as for nutritional status, health characteristics, dietary intake and agricultural- socio-demographic characteristics) were generated. All files had a common ID (Identification number) variable which was used to merge data files for further analysis and investigations. Descriptive statistics was initially carried out to check data for entry errors and to determine suitable and appropriate statistical tests for data manipulation and analysis. Histograms were used to check distribution of numerical data (26). Significance level was set as p<0.05.

Pearson product-moment correlation coefficient (27) was used to assess association among the factor scores for the dietary patterns and farmers' nutritional indicators and working hours. Correlations between the variables were considered as statistically s*trong, moderate and fair* if the associated p-values were <0.001, <0.01 and <0.05 respectively. Statistical differences in continuous measures among the quartiles of factor scores were tested by running one-way analysis of variance (ANOVA) with post hoc multiple comparisons test of Tukey's honest significant difference (HSD) (28).

Farmers with lower work performance (< median of working hours) were compared with the rest of subcohort for age, agricultural and general health characteristics, nutritional indicators, and dietary patterns using logistic regression. Logistic regression models estimated odds ratio and their corresponding 95% confidence intervals (95% CI) to assess relationship between farmers' work outputs and its determinants. The unadjusted relationship between each factor and the risk of lower work output was first explored running univariate logistic regression. Multivariate logistic regression was then executed by putting all variables into the models to get the adjusted odds ratios.

Results

The study population consisted of 452 small scale farmers, actively involved in farming. General socio-demographic, agricultural and health characteristics of the farmers are summarized in table 2. The mean age was 40 years (range: 20 – 58 years). Majority of the farmers had no formal education (77%) and other income resources except agriculture (81%). Total of 53% farmers were farm owners and the remaining were tenants. Mean farm holding size of the cohort was 4±1.3 acre. Overall the respondents were actively involved in farm activities with average daily working hours of 6±1.6. Most of the cohort (76%) had no family support or assistance in routine daily farm related activities such as in ploughing, sowing, irrigation, crop protection and harvesting.

Table3 depicts results on nutritional status and work performance of the farmers by score quartiles of dietary patterns. The table shows mean values of the lowest in comparison to the highest quartiles (Q 1 & Q4). Farmers in the lowest quartile of 'energy rich dietary pattern' had significantly lower mean weight, BMI, SBP and DBP than those in the highest quartile (p<0.001). Compared with farmers in the lowest quartile in the 'mixed pattern' those in the highest quartile had higher mean Hb level and working hours (p<0.0001); no statistical differences were evident in means anthropometric measurements and blood pressures of the groups (p>0.05). Statistical differences were evident in means SBP, DBP and blood Hb level between the 'red meat' groups; no significant differences were found in means age and working hours. Among the anthropometric measurements, farmers in the highest quartile of 'red meat' pattern had slightly higher means weight and BMI (p<0.05).

Strengths of associations of factor scores of the three dietary patterns with farmers' nutritional indi-

Table 2. General socio-demographic, agricultural and health characteristics of the farmers (n=452)

Characteristics		**Mean±SD / N (%)**
Farmers' age (year)		40.6±7.6 (**Range:** 20 – 58 years)
Literacy level	Illiterate	348 (77%)
	Primary or below	86 (19%)
	Secondary school or below	18 (4%)
Income sources *(other than agriculture)*	No	367 (81%)
Family support in farming	No	343 (76%)
Working hours		6±1.6
Farm holding size (Acre)		4±1.3
Farm ownership status	Owners	239 (53%)
Medical history	No	393 (87%)
Current use of medicine	Yes	122 (27%)
Self-reported health status	Healthy	357 (79%)

Table 3. Nutritional status and work performance (mean ± SD) by quartiles of factor scores of dietary patterns

Characteristics	**Energy rich pattern**		**Mixed Pattern**		**Red Meat Pattern**	
	Q1	**Q4**	**Q1**	**Q4**	**Q1**	**Q4**
Age (year)	39.0±8	41±7	39.5±8	39.7±8	40.2±7	41±8
Weight (kg)	60.91±12.63**	68.35±12.80**	64.28±13.09	65.82±13.0	62.41±11.68*	64.70±12.91*
Height (cm)	168.8±7.0	167.9±5.6	168.0±7.1	168.3±6.8	169.2±6.6	168.1±6.3
BMI	21.0±2.1**	24.6±3.8**	22.9±4.3	23.2±3.3	22.8±3.5*	23.7±4.1*
SBP (mmHg)	114±13**	120±15**	117±13	117±13	112±11**	121±15**
DBP (mmHg)	73±12**	80±13**	76±12	77±12	74±10**	80±14**
Hemoglobin (g/dl)	12.6±2.0	13.0±1.8	12.2±2**	14.1±1.4**	12.6±1.9**	13.6±1.8**
Working Hours	5.5±1.3	5.9±1.2	5.1±0.8**	6.3±1.1**	5.8±1.3	6.2±1.5

BMI=Body mass index; SBP & DBP=Systolic & Diastolic blood pressure; Q=Quartiles of the factor score. *p<0.05 **p<0.01

Table 4. Correlation of factor scores of dietary patterns with characteristics of nutritional status and work performance

	Age (year)	**Weight**	**Height**	**BMI**	**SBP**	**DBP**	**Hb**	**WH**
Energy rich pattern	0.079	0.237**	-0.068	0.346***	0.212*	0.230*	0.097	-0.004
Mixed Pattern	0.117*	0.032	0.013	0.019	0.009	0.037	0.487***	0.367***
Red Meat Pattern	0.007	0.180*	-.067	0.192*	0.332***	0.315***	0.206**	0.048

BMI=Body mass index; SBP & DBP=Systolic & Diastolic blood pressure (mmHg); Hb=Blood hemoglobin level (g/dl) WH= Working Hours. * p<0.05; **p<0.01; ***p<0.001

cators and working hours were investigated and expressed as Pearson's correlation coefficients (r - values) (Table 4). 'Energy pattern' had strong association with BMI, moderate association with weight, SBP and DBP, and no correlations with other variables (age, height, Hb and working hour). Mixed dietary pattern was found in strong correlations with farmers' Hb level and working hours. No significant associations between the 'mixed pattern' score and other variables were evident except for age where it was fairly positive (p<0.05). Correlations of 'red meat pattern' score with farmers' blood pressure measurements were strong and those with weight, BMI and Hb were fair to moderate.

Indicators with strong correlations with the dietary patterns were further explored by the quartiles of their respective factor scores (figures I – III). These figures show mean values (95% confidence intervals) of different parameters and the *coefficients of determination (R^2).*As shown in figure 1, overall, 12% variation in farmers' BMI (R^2=0.121) was explained by the 'energy rich' dietary pattern score. Farmers in the 1st and 2nd quartiles 'energy rich pattern' had significantly lower mean BMI in comparison to those in 3rd and 4th quartiles. Similarly, 23% variations in farmers' blood Hb level (R^2=0.229) were explained by 'mixed dietary pattern' score (figure 2). Farmers in the 1st quartile (lowest) of factor scores for 'mixed pattern' had significantly lower mean blood Hb level in comparison to other quartile groups. As shown in figure 3, about 10% and 9% variation in farmers' systolic and diastolic blood pressures (associated R^2 values are 0.098 and 0.086 respectively) were explained by 'red meat pattern' score. Farmers in the lower quartiles (1st & 2nd) had both means blood pressures in the normal range comparing to the rest. These findings suggest that

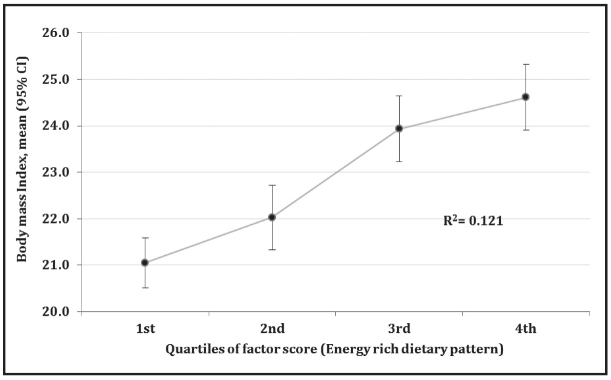

Figure 1: Mean (95% CI) Body mass index by quartiles of 'energy rich dietary pattern' factor score.
CI= Confidence Interval; R^2= the coefficients of determination
Means with similar letters are statistically not different (p>0.05)

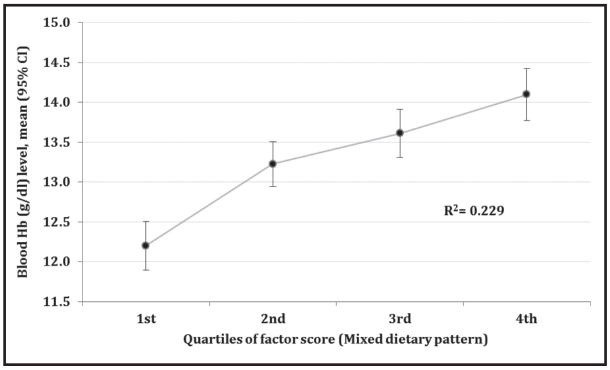

Figure 2: Mean (95% CI) blood hemoglobin level by quartiles of 'mixed dietary pattern' factor score.
CI= Confidence Interval; R^2= the coefficients of determination
Means with similar letters are statistically not different ($p>0.05$)

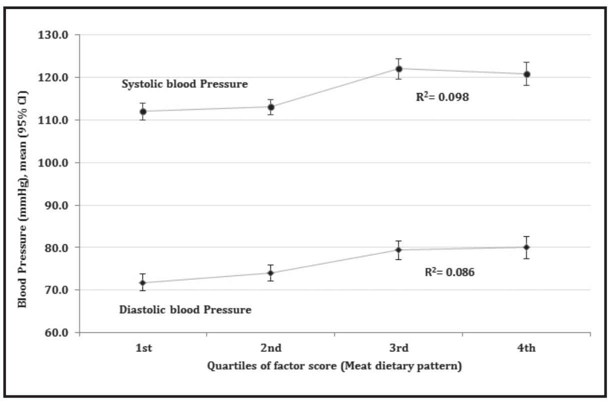

Figure 3: Mean (95% CI) systolic & diastolic blood pressure by quartiles of 'red meat dietary pattern' factor score.
CI= Confidence Interval; R^2= the coefficients of determination
Means with similar letters are statistically not different ($p>0.05$)

farmers in the higher quartiles (3rd & 4th) of 'red meat dietary pattern' score had a tendency of having high systolic and diastolic blood pressures in comparison to the rest.

We thoroughly investigated independent effects of socio-demographic and nutritional determinants on working capacity of the farmers using logistic regression models. Working hours in the farm (farmers' physical performance) had significantly strong correlation with only one dietary pattern, i.e. the mixed pattern ($r=0.367$, $p<0.001$, table 3). This association was further confirmed in logistic regression after adjusting for potential confounding factors. Figure 4 depicts findings on factors associated with work performance.

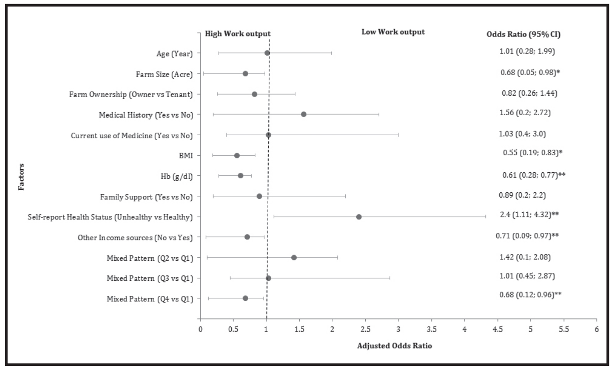

Figure 4: Adjusted OR (95% CI) of the association between 'agricultural work performance' and selected variables in small scale farmers.
BMI= Body mass index; Hb= Blood hemoglobin level
* $p<0.05$ ** $p<0.01$**

The results are reported as adjusted odds ratios (ORs) and corresponding 95% confidence intervals associated with low work output. After adjustment, farm size, BMI, blood Hb level, self-reported health status, income sources (other than agriculture) and 'mixed dietary patterns were significantly associated with work performance and output. There was an increasing trend in lower work output per unit decrease in farm size, BMI and blood Hb level. Respondents with self-reported unhealthy status and those had 'income sources other than agriculture', were more likely to have lower work performance comparing to the rest. Compared to farmers in 1st quartile of mixed dietary pattern, those in the 4th quartile had higher work performance after adjusting for covariates. There was no statistical significant association of work performance with farmers' age, farm ownership status, medical history, current medicine use, and family support in agricultural practices ($p>0.05$).

Discussion

This study aimed to identify major dietary patterns in the farming community of North West Pakistan and to investigate their relationship with farmers' nutritional status and working hours. Compared to eastern and southern regions, farmers in the north-western Pakistan are mostly small scaled because major part of this region is mountainous and occupied for residential and business purposes. However, the study farmers, though on average small scaled, but were majorly dependent on agriculture for their livelihood. The cohort was actively involved in farming and had agriculture as main source of income.

Three major dietary patterns were extracted using PCA: 'energy rich', 'mixed', and 'red meat'. Energy rich items included predominately deeply fried foods, starchy vegetables, refined cereals, rice, sugar and sugary substances, sweets and beverages. Mixed dietary pattern included green and other non-starchy vegetables, fruit, milk and milk products, pulses, nuts, chicken egg and fish, while red meat pattern was majorly composed of fried and grilled red meat (beef and mutton) and their curries, sausages, and other meat products such as minced meat. The three patterns were significantly associated with some of the nutritional status indicators; mixed pattern had strong association with blood Hb level; associations of energy-rich and meat patterns were evident with BMI and blood pressures respectively. Similarly, farmers in the mixed pattern were more physically involved in agricultural activities comparing to those in other patterns. These results are important especially in context of their impact on the overall health status of farmers who makes a significant portion of Pakistani population and play a major role in country's economy.

Energy rich pattern was found strongly associated with farmers' BMI and moderately associated with SBP and DBP. These findings suggest an imbalance status in energy intake and expenditure. Exceeding energy intake over expenditure, results in an increase in body mass which is usually body fat (29). This unhealthy weight gain may lead to other health consequences such as hypertension (30). Though mean BMI of the farmers in the highest quartile of energy rich factor score was below the WHO criteria for overweight i.e. 25 (Table 3); however increasing trend in BMI was observed with increasing factor score for energy rich dietary pattern. Our results on association between energy dense dietary pattern and BMI suggest that, though farmers are physically involved in the farms and physical activity is related with reduced risk of overweight, still farmers with high adherence to energy rich pattern were at the risk of overweight and associated health consequences such as high blood pressure.

Red meat pattern was associated with the risk of high blood pressure among the farmers. Our findings are in consistent with some previous studies reporting that a dietary pattern characterized by high meat content, particularly red meat, is associated with increased rates of elevated blood pressure, atherosclerosis and other heart diseases (31, 32). The Western diet, characterized by frequent consumption of red meat, was previously reported to be associated with increased risk of heart problems (33 - 34). In another cross sectional epidemiological study, association of red meat intake with blood pressure was investigated using 17 population samples (n=4680, age > 40 years) from China, Japan, the United Kingdom, and the United States participating in the international collaborative study on macro-/micronutrients and blood pressure (INTERMAP). The study concluded that red meat intake was directly associated with blood pressure; this association persisted after adjustment for multiple confounders (35). Red meat contains high biological value protein, a wide range of fats including essential omega-3 polyunsaturated fats, and important micronutrients. However, nutritional composition varies depending on breed of animal, season, meat cuts as well as trimming status of the cuts. Reports on meat quality status from advanced countries have shown that meat with 80% less external fat is commonly available in the market for the consumers, indicating that trimming excess fat from meat is being widely practiced. Furthermore, dietary guidance being developed in recent decades instructing the increased consumption of lean meats, have resulted an increasing trend in consumers' preferences for leaner cuts of red meat (36, 37). In Pakistan, common consumers have particularly low nutritional awareness level, which may have an impact on dietary preferences and choices. In the current study, the cohort was majorly composed of illiterate or low educated farmers who were though sufficiently trained in the conventional farm techniques but have insignificant health and nutrition related knowledge. As shown previously that particularly nutrition knowledge is a distal predictor for diet quality and therefore has a strong impact on overall health at community level (38, 39). In trimmed lean meat, it is usually the external fat only that is removed. Association of red meat pattern and blood pressure suggest consumption of untrimmed or partially trimmed red meat by the cohort which indirectly increase dietary fat intake. Previously high dietary fat intake has been linked with the likelihood of raised blood pressure in different age groups (40, 41) as well as in male workers (42).

In the current study, mixed pattern was predominantly composed of plant- and milk- based foods as well as chicken egg, and fish; these food items enabled the consumers to achieve a variety of macro and micronutrients. Mixed pattern reflects dietary diversification. Positive associations of factor scores of mixed pattern with farmer's Hb level and working hours were evident. These findings suggest substantial effect of dietary diversification on blood Hb level that has been shown to enhance physiological potential and physical performance in different previous studies. Dietary diversification as represented by mixed patterns is important to improve the intake of micronutrients (43, 44). Though the minerals content such as iron and zinc are either low in most vegetables and fruits or biologically less available, however, inclusion of legumes, fish and milk could improve minerals contents of mixed pattern. Similarly, vitamin C rich fruits enhance iron absorption as well from the plant-based dietary sources. As integral part of blood Hb, iron plays a significant role in reducing the prevalence of anemia at community level, which in-turn improves work capacity of the workers. Strong causal associations between iron deficiency and voluntary physical activity have been thoroughly investigated and reported in both human and animal based researches (45, 46). Negative associations between poor nutritional status and work output have frequently been reported previously in workers related to agricultural and other different professions (4, 47). In an econometric study, it was concluded that current nutritional status of farmers was associated with increased farm outputs, holding other inputs constants (8). In developing countries, farmers, particularly those related to small scale farming, are physically involved in all agricultural activities such as ploughing, sowing, irrigation, harvesting. 'Working hours' of the farmers is thus indirectly an inevitable predictor of presenteeism and physical involvement in agricultural activities, and farm productivity. In current study, mixed dietary pattern was found an independent determinant of higher work performance in the study cohort.

Our study does have few minor limitations including reliance on self-reported data dietary intake and physical involvement in farm activities. Farmers were, however, thoroughly interviewed by trained research associates to collect data on dietary intake and work output using relevant standardized questionnaires. Our study has certain strengths. This is the first large fully-funded longitudinal study in Pakistan to explore association between nutritional characteristics and agricultural work performance. Nutritional status assessment of the cohort was carried out using both anthropometric and biochemical measurements; these measurements have frequently been used previously in studies on health and work capacity in different settings. Data on relevant possible confounding factors were collected; adjustments were made for potential confounders affecting association between farmers' nutritional characteristics and farm work capability.

Recent findings suggest that specific nutritional awareness programs may be designed and planned for the farming community at national level. Such programs will not only be beneficial in improving the nutritional status of the farmers but will also have long term impact on both agricultural work performance and productivity.

Conclusions

In conclusion, the current findings explained the important role of dietary patterns in farmers' nutritional status. Mixed dietary pattern had significant association with both farmers' nutritional status and physical work capacity. Farmers with the highest adherence to the 'mixed dietary' pattern were more physically involved in farming activities comparing to those in other dietary patterns. The adherence to red meat and energy dense patterns were associated with the risk of unhealthy outcomes such is elevated blood pressure and raised BMI among the farmers.

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