American Journal of Public Health Research, 2015, Vol. 3, No. 4, 167-173
Available online at http://pubs.sciepub.com/ajphr/3/4/7

DOI:10.12691/ajphr-3-4-7

Association of Cost and Quality of Diets with Risk of Non-Communicable Diseases: A Review

Kanika Agarwal[1,*], Ravinder Chadha[1], Nikhil Tandon[2]

[1]Department of Food and Nutrition, Lady Irwin College, Sikandra Road, New Delhi, University of Delhi, India
[2]Department of Endocrinology and Metabolism, All India Institute of Medical Sciences, Ansari Nagar, New Delhi, India
*Corresponding author: kanika.agarwal@gmail.com

Received April 20, 2015; Revised June 25, 2015; Accepted July 08, 2015

Abstract This review aims to examine evidence on whether dietary costs explain variations in diet quality; and that diet cost is an indicia of risk of non communicable diseases such as obesity, diabetes etc. A thorough review of scientific literature available on PubMed and Google Scholar on diet cost and diet quality was undertaken. Research shows that the energy dense-nutrient poor diets are cheaper and have a lower diet quality compared to nutrition rich diets. One reason behind this may be that since energy dense foods are dry and have a stable shelf life and give more energy per unit cost while foods with lower energy density like fruits and vegetables are perishable. Education is shown to be related to high diet quality in some studies. Few studies have shown that the diet cost and body mass index as well as waist circumference are inversely related; however no association was seen between diet cost and risk of developing cardiovascular disease.

Keywords: *diet cost, energy density, energy cost, diet quality, non-communicable disease*

Cite This Article: Kanika Agarwal, Ravinder Chadha, and Nikhil Tandon, "Association of Cost and Quality of Diets with Risk of Non-Communicable Diseases: A Review." *American Journal of Public Health Research*, vol. 3, no. 4 (2015): 167-173. doi: 10.12691/ajphr-3-4-7.

1. Introduction

The Engel's law states that as income rises, the proportion of income spent on food falls, even if actual expenditure on food rises, resulting in increasing share of non-food spending [1]. In other words, as income rises, the marginal propensity to consume declines and share of non-food spending increases.

The incremental spending on food usually takes effect by way of increased quantities and/or improved quality. Thereby, affecting food demanded, purchased, and consumed [2]. At a household level, food quantities and quality are determined by the socio-economic factors such as household income, cost of food (prices), family size, ethnicity, literacy level, occupation, tastes and preferences. It is noted that the household income plays a crucial role in determining share of expenditure on food and composition of the food basket. Composition of food basket determines the quality of diet consumed by the individuals.

A diet comprising of higher intakes of whole grains, lean meats, fresh fruits and vegetables, and by lower intakes of added fats and sugars, and refined grains is said to be of a good quality [3,4]. Diet quality can be measured by using various indices like micronutrient level [5,6,7] dietary energy density (dietary energy per unit weight) [8,9,10,11], Healthy Eating Index (HEI) [10,12], Healthy Diet Indicator (HDI) [13], Mediterranean Diet Score (MDS) [12] and Mean Adequacy Ratio (MAR) [11,14]. Higher quality diets, in turn, tend to be associated with higher diet costs.

The primary objective of this review are to assess whether (a) dietary costs explain variations in diet quality; and (b) diet cost is an indicia of risk of chronic diseases such as obesity, diabetes etc.

2. Association of Diet Cost and Diet Quality

The relationship between food cost and diet quality has been studied extensively in developed countries. The two commonly used indicators to measure food cost are [8]:

1. Diet cost (*i.e.*, cost of food per day); and
2. Energy cost of a diet (*i.e.*, cost of food per unit of energy)

Also, researchers have explored the relationship between diet/energy cost with diet quality by using different measures of diet quality. In the subsequent sections, we discuss the effect of diet cost and energy cost on diet quality.

2.1. Effect of Diet Costs on Diet Quality

Diet cost is defined as the cost of food per day or week [13,14,15,16]. A number of observational studies as well as intervention studies have explored the relationship between diet cost and diet quality. One such intervention study done on 18-65yrs centrally obese Danish adults found that a healthy, palatable Nordic diet was 25% more

expensive than the average Danish diet [9]. However, in another intervention study conducted on 4-10year children at risk of elevated plasma total cholesterol received nutrition education for a year on consumption of low fat diets while the control group consisted of children who were not at risk and did not receive nutrition education. At the end of 12 months, it was found that the consumption of low fat diets did not increase the food cost as the mean food cost per day was $3.45 and $3.2 for control and intervention group respectively [17]. Similar finding was seen by Raynor *et al.*, 2002 who conducted a 20 week behaviour modification intervention program focusing on increasing the nutrient density in the diet on 24 families with an obese child aged between 8-12years. They found that there was no significant change in the diet cost after 6 months of intervention, though the cost decreased a year after the intervention was started suggesting that a healthy diet is not expensive than the average diet [18]. The diet costs for the participants of the Finnish Diabetes Prevention Study were analyzed both at baseline and after first year of the intervention. It was noted that diet cost did not significantly increase in obese subjects with impaired glucose tolerance even as the quality improved. When both the intervention and control groups were pooled for analysis, the results revealed that diet costs vary according to sex, age, body mass index (BMI), and education [19].

Linear programming models are used to study the impact of diet cost on other variables such as food composition and nutrient density. In a study on French adults, iso-energetic diets were modelled by linear programming. It was seen that strengthening the cost constraint in these diet models led to a lower proportion of energy provided by fruits and vegetables, meat, and dairy products, while there was increase in the proportion of energy from cereals, sweets and fats. The nutritional quality of the diet reduced with lower vitamin C and β carotene [16]. Another study done on a representative adult French population showed that low energy dense diets had a higher nutritional quality but cost more. They calculated the MAR and saw that the highest tertile of MARs had low energy density and higher diet costs when calculated per day and per 10MJ. They observed a positive relationship between MAR and diet cost after adjusting for age and energy intake [11]. A research on French men showed that as the quintile of energy density increased, the cost decreased from $65.86 per 7 days to $60.66 per 7 days from the lowest to the highest quintile respectively, similar finding was observed in women [20].

A study conducted in UK used HDI to measure the diet quality and found that high adherence to healthy diet was associated with higher dietary cost and women who followed the healthy diet pattern had a higher education level [13]. Another study showed that increase in 1 Euro ($1.25) of diet cost per day was associated with a change of 046 units ($p<0.001$) and 2.3 units ($p<0.001$) in the MDS and HEI respectively. Also, people who adhered to the MDS and HEI paid 1.2 Euros ($1.5) and 1.4 Euros ($1.75) per day respectively than those who had a low adherence to these diet patterns [12].

A lot of research has taken place in the US, examining the association between diet cost and diet quality. In the Seattle Obesity Study (SOS) done on adults, the mean diet cost ($/day), based on foods and caloric beverages, was $9.45±4.07 for men and $8.75±3.60 for women. It was found that people in the highest quintile of diet cost were significantly more likely to have a higher income and education background [14]. Assessment of nutrient density of diet showed that as the quintile of diet cost per day increased the level of nutrient intake also increased. The nutrient density based on vitamins A, C, E, calcium, magnesium, dietary fibre, and potassium was 99.4 in the highest cost quintile ($13.43/day) while it was 68.5 in the lowest quintile ($5.7/day) [21].

Evidence from Nurses' Health study shows that the median amount spent on food per day was $3.72 in the lowest quintile of Alternate Healthy Eating Index (AHEI) score while that in the highest quintile was $4.62 ($p<0001$) [15]. The dietary data of National Health and Nutrition Examination Survey (NHANES) was analysed and diet costs and HEI were calculated and it was seen that the daily diet costs were lower for women as compared to men and decreased with increasing age. It was also observed that higher educational level resulted in an increase in diet cost as well HEI score [10]. Table 1 below shows studies that have assessed this relation between diet cost and quality of diet.

2.2. Effect of Energy Costs on Diet Quality

The energy cost refers to the cost of per unit of energy (*e.g.*, Euros/1000 kcal or dollars per mega-joule) [27]. To a large extent, the energy density depends on the water content of food. Energy dense foods like cereals, grains, pulses are usually dry with a stable shelf life. These provide more energy per unit cost than energy dilute foods such as fruits, vegetables and meat which provide fewer calories per unit cost [28]. High moisture content of energy dilute foods usually makes them perishable [28,29]. It has been well documented that the energy dense diets are often found to be economical but low in quality [20,26,27,30,32]. Linear programming model using the French diet showed that cost constraint led to the consumption of an energy dense diet [22]. A large cross sectional study involving 7,500 participants classified them into low, medium and high energy density diets using tertile cut offs saw that low energy diets consisted of lower energy intake and higher diet quality [4].

An intervention study conducted on centrally obese Danish individuals saw that the New Nordic Diet inspired by the Mediterranean diet was 25% more expensive than the average Danish diet. After adjusting for energy, it was seen that the cost reduced to 16-17% but even then it was costlier than the average diet consumed [9]. Another intervention study involving a behaviour modification program in 8-12 year old children showed that there was no change in diet cost even after adjusting for energy per 1000 kcal [18] . While contrasting results were shown by a study done on Danish children where low fat diets cost more. They found that a reduction of energy from dietary fat from 35% to 25% may increase food costs by 10-20% [31].

Like intervention studies, the observational studies show contrasting results. A cross sectional study done in France on a nationally representative sample of 1,332 adults found that participants in the highest tertile of MARs had the lowest dietary energy density per 10MJ but the highest diet cost. It was seen that a 10% increase in MAR values at constant energy density and intake levels

adjusted for age and gender lead to an increase in diet costs of about 0.7€/10MJ and 0.72€/10MJ in men and women respectively [25]. Regression analysis of freely chosen diets of 837 French adults showed that at each quintile of energy intake (MJ/d), the energy dense diets cost less than the energy dilute diets. This relationship strengthened after adjusting for age and gender [32]. In another cross-sectional study, dietary intakes of 1,474 French adults (672 men and 802 women), aged 15 to 92 years, were assessed using 7-day diet records. Within each quintile of energy intakes, the more energy-dense diets were associated with lower diet quality and with lower diet costs (r^2 ranged between 0.38-0.44). In a regression model, after adjusting for energy intake, sex and age, the more energy-dense diets cost less, whereas low-energy-density diets cost substantially more. They also saw that vitamin C level was associated with higher diet costs [20]. Another study obtained similar results where participants in the lowest quartile of energy cost had highest dietary energy density and energy intakes but lowest daily intakes of vitamins C, D, and E, β-carotene, folates and iron. The participants having low energy dense diets had a 165% higher dietary cost [24]. Research showed that energy dense foods like refined grains, sweets and fats were cheaper sources of energy as compared to lean meat, fruits and vegetables [23]. A study done in Spain found that participants with the highest scores on the western dietary pattern spent less money (-$0.80) per 1000 kcal on their daily food costs, whereas the opposite was true for the Mediterranean dietary pattern (+$0.90) per 1000kcal [33].

Table 1. Literature Review of Studies Assessing Relationship Between Diet Cost And Diet Quality

Reference	Study design	Setting and Population	Instrument used	Diet cost	Results
[13]	Cross sectional	UK, n= 15191, 35-69yr women	FFQ + telephonic interview; HDI calculated	Retail food prices	Healthy diet (HDI=8) was £1.48 more than the unhealthy diet (HDI=0). Fruits & vegetables increase diet cost
[16,22]	Linear programming	France; 837 adults (361 men and 476 women); ≥18yr, Val-de-Marne dietary survey	Diet history	Retail food prices	Stronger cost constraint results in energy dense diets
[23]	Diet model	France; 837 adults (361 men and 476 women), 18-76 yrs	Diet history (6 months)	Retail food prices	Energy dense diets cost less than energy dilute diets
[24]	Cross sectional	France; 1474 adults (672 men, 802 women), ≥15yr	7 day food record	Retail food prices	Nutrient dense diets had a higher diet cost
[20]	Cross sectional	France; 1474 adults (672 men, 802 women), 15-92yrs	7 day food record	Retail food prices	Energy dense diets were associated with low diet costs. High diet costs were associated with vitamin C, fiber and folate
[12]	Cross sectional	Spain; 1547 men and 1615 women; 25-74 yrs	FFQ; MDS, HEI calculated	Average food prices	High MDS and HEI scores related with high diet cost. Fruits &vegetables comprise 35% of the total expenditure in healthy diet
[25]	Cross sectional	France; 1985 adults, 15-92 yr (INCA study)	7 day record, food group, nutrient profiling	Retail food prices	Fruits, vegetables (17% of the total cost) and meats were costly but had a high nutritional quality. Low nutritional foods like sweets and salted snacks less expensive
[26]	Cross sectional	USA; 164 men and women aged 25-65yrs	FFQ	Retail food prices	Lower energy diets have a higher nutrient intakes and higher costs
[17]	Cross sectional	USA,; 112 low income women aged 18–45 y	FFQ , 3 months	Local market prices	Lower dietary energy density and higher diet cost were associated with higher intakes of dietary fibre, vitamin A and vitamin C and with lower intakes of total fat and saturated fat.
[21]	Cross sectional	USA;1295 adults	FFQ, nutrient density score	Local supermarket price	Nutrient dense diets had a higher diet cost and positively associated with income and education
[10]	Cross sectional	USA; 4744 NHANES (2001-2002) participants ≥20yrs age	Single 24 hr recall, HEI	National food price database	Higher diet costs were associated with higher HEI scores in both the sex and consuming more of fruits and vegetables and fewer calories from sugars, fats and alcohol
[14]	Cross sectional	USA;1266 adults, Seattle Obesity Study,	FFQ, MAR	Retail food prices	Lower energy diets and high MAR are associated with higher income and education. High diet quality has higher diet cost

In the US, AHEI was assessed on 78,191 participants of the Nurses' Health Study and it was found that the energy adjusted spending was 24% more in the highest quintile of AHEI than the lowest quintile [15]. Another study conducted on 118 women aged 18-45 years living in California showed that high diet cost was significantly associated with lower dietary energy and high intake of vitamins A and C [7]. Aggarwal *et al*., [14] showed that income and education were associated with lower energy dense diets and higher MAR scores. They also saw highest income and education were associated with higher energy adjusted diet costs. Similar finding was observed in a study conducted on 1,295 adults where energy adjusted diet costs were significantly higher in overall nutrient density [21]. Research conducted on 164 men and women aged 25-65 years found that lower energy density diets were associated with higher nutrient intakes but with higher diet costs. Education and household income had a positive relationship with the energy adjusted cost of the diet [26].

A study conducted in Japan on female dietetic graduates is one of the few studies done in Asia to understand the relationship between energy cost and diet quality. They found that monetary costs of dietary energy were positively associated with intake of fruits, vegetables, fish, shellfish and pulses, while a higher cost was associated with consumption of fat and oil, meat and energy containing beverages and lower consumption of cereals like rice. They also found a positive association between energy cost and intake of fibre, vitamins, fat, cholesterol, sodium and a negative association with carbohydrate intake. Therefore it can be said that increase in diet cost was associated with healthy as well unfavourable diet patterns [34]. The authors also found a positive relationship between energy adjusted diet costs and nutritional biomarkers like sodium, potassium and protein [6].

A research on Swedish children aged 4, 8 or 10 years showed that higher scores on HEI resulted in higher diet costs. The energy adjusted costs showed that the diets of those in high HEI groups were more expensive [35]. A cross sectional study examined the data from two Dutch cohorts found significant inverse associations between energy density and energy costs in single food items and composed diets. They also saw that individuals in higher energy density quartiles consumed significantly more energy per day, less fruits and vegetables, and had lower diet costs. They did not find any relationship between income and energy density and energy costs [36]. Similar finding was observed in a Spanish study where high dietary energy costs were associated with higher intake of micronutrients and fibre [33]. A study did nutrient profiling of foods consumed by 1,332 French adults and found that meats, fruits and vegetables had the highest nutritional quality as well as the highest diet cost, while sweets and salted snacks were the least expensive sources of dietary energy. They also found that, starches and grains provide dietary energy at a relatively low cost, having a better nutritional quality to price ratio [25]. The literature on this topic is summarised in Table 2.

Table 2. Literature Review of Studies Assessing Relationship Between Energy Costs And Diet Quality

Reference	Study design	Setting and Population	Instrument used	Cost	Results
[34]	Cross sectional	Japan; 3931 female dietetic students,18-20yrs	Self administered diet history questionnaire	Retail food prices	Dietary energy cost positively associated with intakes of fruits, vegetables, fish, shellfish, pulses, fats and oils, meats and lower consumption of cereals
[6]	Cross sectional	Japan; 1046 female dietetic students; 18-20yrs	Diet history questionnaire, 24 hr urine collection	Retail food prices	Increased diet costs related with biomarker based protein, sodium and potassium as well as fruits & vegetables
[25]	Cross sectional	France; 1332 adults, 15-92 yr, INCA study	7 day record, mean adequacy ratio (MAR)	Retail food prices	Diets with low energy density had low energy cost and good nutritional quality
[30]	Cross sectional	France; 837 adults (361 men and 476 women); ≥18yr, Val-de-Marne dietary survey	Diet history(6 months)	Retail food prices	Fruits & vegetables raise diet costs adjusted for energy . Fats, sugars & grains are associated with lower diet costs
[37]	Cross sectional	Australia; 1700 aboriginal population	Food outlets, electronic food transactions, 3 months		Diets high in refined carbohydrates and low in fruits and vegetables. High energy density associated with lower cost
[33]	Cross sectional	Spain; 17197 university graduates, SUN study	Semi quantitative FFQ, nutritional recommendations	Average food prices	Higher dietary costs resulted in an increase in micronutrient levels, while in low cost diets atleast 3 nutritional recommendations were not met
[36]	Cross sectional	Netherlands; 373 young adults + 200 elderly community setting	Face to face interviews (young adults)+ booklets with coloured pictures (elderly)	National food prices	Dietary energy density is inversely related to energy cost. No difference in diets with income levels.

It is well established that the energy dense diets are high on fats, sugars and cereals, and have poor nutritional quality as compared to diets containing more of fruits and vegetables. These diets cost less, and thereby make affordable option for the lower sections of the population [38]. A French study showed that fruits and vegetables had a lower energy density but higher contributed to a higher diet cost, where 100g of additional fruits and vegetables was associated with a €0.18–0.29 per day increase in diet costs, while fats and sweets resulted in €0.05–0.40 per day reduction [30]. The decrease in food expenditure by consuming more energy dense foods can result in an increase in the rate of obesity, a risk factor for other chronic diseases [39]. Analysis of food expenditure can give an insight into the possible causes of obesity [40]. The relationship between diet costs, diet quality, and subsequent non-communicable disease risks will be discussed in the following section.

3. Relationship of Diet Cost and Quality with Non-Communicable Disease

The diet cost or energy cost of a diet is a major factor behind food purchasing pattern of an individual. Lower income group spends more on energy dense diets since they are affordable [41]. The possible associations of dietary cost and metabolic risk factors have not been investigated in developing countries [6]. Monetary expenditure on foods may explain the link between income and body weight which is caused by nutrition transition because food expenditures reveal choices and access to different food baskets [41]. However, this research has largely been conducted in the developed industrialised world barring a few recent studies conducted elsewhere.

The findings of various studies on this topic are fairly consistent. These studies provide evidence that dietary cost and BMI are negatively associated. The diet quality indices also showed a negative relationship with BMI [6,12,41,42,43]. One of the studies even showed that the diet costs were inversely related with waist circumference [42]. These findings indicate that higher diet costs reduce the risk of overweight or obesity.

A longitudinal study showed that the diet costs were not associated with incidence of cardiovascular risk in a 5 years follow up, while the adherence to the traditional Mediterranean diet resulted in lowering the development of disease [44]. Another study based on pooled data from two Japanese nationally representative surveys found that the household food expenditure was significantly associated with obesity, hypertension, diabetes, and presence of multiple risk factors [43].

Two studies focussed on the food expenditure patterns and risk of chronic diseases in indigenous populations of Australia and Canadian Artic. They found that the larger share of food expenditure was being spent on refined grains, fats and sugars as compared to fresh produce such as fruits and vegetables [40,45]. Table 3 shows the studies where dietary cost, quality of diets has been associated with BMI status, weight gain or the risk of cardiovascular disease.

Table 3. Literature Review of Studies Assessing Influence Of Diet Cost And Quality On The Risk of Non-Communicable Disease

Reference	Study design	Population (Age, sample size)	Instrument used	Results
[12]	Cross sectional	Spain; 1547 men and 1615 women; 25-74 yr\s	FFQ; MDS, HEI calculated	Dietary cost negatively associated with BMI. Risk of obesity decreased across MDS quartiles
[34]	Cross sectional	Japan; 3931 female dietetic students, 18-20yrs	Self administered diet history questionnaire	Weak negative association between dietary energy cost and BMI
[46]	Cross sectional	Brazil; 346 children, 3-4yrs from a nested cohort of randomised field study	2 days 24 hr recall	No relationship between expenditure and risk of being overweight
[6]	Cross sectional	Japan; 1136 female students 18-20yrs	Self administered diet history questionnaire	Significant negative association between diet cost and BMI as well as diet cost and waist circumference.
[33]	Cohort	Spain; university graduates, n=17 197 for the cross-sectional baseline assessment and n=11 195 for the prospective follow-up analyses (SUN study)	Semi quantitative FFQ	Higher daily food costs associated with greater weight gain
[44]	Cross sectional	USA, 1514 men, 1518 women >18yrs without CVD, followed for 5 yrs, ATTICA study	Semi quantitative FFQ, modified Mediterranean Dietary Score(MDS)	Diet cost marginally related with MDS. No significant relationship between diet cost and 5yr incidence of CVD
[43]	Cross sectional	Japan; 6326 adults(2664 men & 3662 women aged 40-64yrs	Two nationally representative surveys	Lower household expenditure was significantly associated with obesity, hypertension, diabetes
[45]	Cross sectional	Australia,2644 Aboriginal population	12 month assessment of community diet	25% of the total food expenditure spent on beverages including soft drinks. High intake of refined cereals and low intake of fruits and vegetables.
[41]	Cross sectional	Bolivia, 1199 Tsimane' population,≥ 16yrs	Expenditure on market foods	61% purchased market foods, men buying these foods had a relatively higher BMI
[40]	Cross sectional	Canadian Artic, 441 adults	Quantitative FFQ	Non nutrient dense foods consisted of 34% of the total food expenditure followed by non traditional meats (chicken, pork, meats) and traditional meats.

However, some studies do not show a relationship between diet cost and the risk of overweight or obesity. Food expenditure and the risk of being overweight were not associated in a study conducted on children in Brazil [46]. Lopez *et al*. [5], found that higher dietary costs are associated with a Mediterranean diet resulted in greater weight gain. A probable explanation behind this could be that the participants who spent more on food had a higher baseline BMI. These participants being overweight/ obese were conscious of their weight status and incurred higher dietary costs in an attempt to lose weight [33].

4. Discussion

One of the key findings of this review is that diets having a high nutritional quality have higher diet and energy costs. Consequently, the lower and middle income group resort to low cost diets to maintain their energy requirements within budgetary constraints. This may result in obesity, a common cause for other diseases in lower and middle income segment. This finding corroborates with an increasing obesity trend among lower income groups in western/developed countries. However, similar phenomenon is yet to be seen in developing countries.

Another finding is that the diet costs are associated with non-communicable chronic diseases such as obesity, diabetes, and hypertension. However, there is a need for more robust researches using different methodologies to establish a conclusive causal relationship.

One of the limitations of the studies reviewed is that most of them estimate costs of diets by using prices of foods at grocery stores, local retail stores or supermarkets [11,14,20,34] rather than using actual expenditure details [41,43]. This may impact estimation of diet costs due to seasonal variation in the prices, stores picked for survey of food prices may underestimate or overestimate the diet costs, discounts or the brand of foods consumed. Therefore, collection of expenditure data from individuals may be done to get better results.

Results of a study conducted in Japan involves dietetic graduates may be affected since their nutrition knowledge may affect the results and the results of the study cannot be generalised to the general Japanese population [6]. Similarly, the low fat diet intervention study comprised of

children belonging to white families in the middle and high income groups [17], while, SOS comprised of adults which were not representative of the population in the US since they have relatively higher median income than the national figures [14]. Therefore, a representative sample of the population should be used to increase the generalisability of the results.

Dietary energy density is mainly driven by the water content of foods and beverages [29]. These energy density values can vary depending on whether water as well calorie and non calories containing beverages and alcohol were excluded or included in the analysis. It has been observed that energy density based on foods is a better indicator of diet quality than that based on foods and non calorie beverages [47]. Also, there is variability of prices in beverages [28]. Therefore, majority of the studies have excluded water, tea, coffee and alcohol from their analysis [11,12,25,34] while, some studies have done analysis excluding as well as including these caloric and non caloric beverages [7,14]. The exclusion of beverages especially alcohol affect the results since they form a component of money spent on food.

Another major limitation is that majority of the research has been conducted in the developed countries, largely in Spain, France, and the USA. The results from studies conducted in developed countries may not be useful in extrapolating to the population living in developing countries. The developing countries like India and China are in a phase of nutrition transition resulting in dual burden of under-nutrition and over-nutrition in these countries [48]. Until recently, overweight and obesity were a disease of affluent in developing countries. However, the recent research showed that there is a trickling of these diseases in lower income groups as well, especially among women [49]. This calls for focused and thorough researches in developing countries.

This review has collated the studies which were mainly cross sectional in nature or involved linear programming to make diet models to show that poor diet quality results in lower diet costs and increases the risk of chronic disease. The longitudinal studies should be conducted to establish robust causal relationships among variables of interest, for example relationship among diet cost, diet quality, and the risk factors of chronic disease.

In the view of foregoing, it is noted that there is a need to broaden the geographical base and expand scope by including all sections of society in future researches in this area. Broad based researches would not only be helpful in making policy decisions at macro level, but also strengthen counselling of households to better allocate their limited economic resources.

5. Conclusion

Researches show that the diet costs are associated with diet quality: low energy dense diets (commonly indicate good diet quality) have high diet cost. These diets are comprise of cereals, sweets and fats and give more energy per unit weight as compared to energy dilute foods like fruits and vegetables. Diet cost is found to be inversely related with body mass index and waist circumference. It is important to remember that these studies have estimated cost using retail prices after dietary data collection was done which may have caused bias in the study. Therefore, expenditure data may help us in ascertaining the relationship between diet cost and quality.

Most of the studies conducted are in the developed countries therefore, similar studies should be done in the developing countries to examine the diet cost-quality relationship. Also, relationship between diet cost and the risk of non communicable diseases needs to be explored since there are limited studies addressing this issue.

Conflict of Interest

The authors have no conflict of interest.

List of Abbreviations

AHEI- Alternate Healthy Eating Index
BMI- Body Mass Index
HDI- Healthy Diet Indicator
HEI- Healthy Eating Index
MAR- Mean Adequacy Ratio
MDS- Mediterranean Diet Score
NHANES- National Health and Nutrition Examination Survey
MJ- Mega Joules
SOS- Seattle Obesity Study

References

[1] Banovic, M., Barreiram, M.M. and Fontes, M.A, "Portuguese household expenditure: 1990, 1995 and 2000," *New Medit N*, 2, 25-31. 2006.

[2] Drewnowski, A. "Fat and sugar: an economic analysis," *J Nutr*, 133(3). 838S-840S. 2003.

[3] Darmon, N., Darmon, M., Maillot, M. and Drewnowski, A. "A Nutrient Density Standard for Vegetables and Fruits: Nutrients per Calorie and Nutrients per Unit Cost," *J Am Diet Assoc*,105(12), 1881-7. 2005.

[4] Ledikwe, J.H., Blanck, H.M., Khan, L.K., Serdula, M.K., Seymour, J.D., Tohill, B.C. and et al. "Low-Energy-Density Diets Are Associated with High Diet Quality in Adults in the United States," *J Am Diet Assoc*, 106(8), 1172-80. 2006.

[5] Lopez, C.N., Martinez-Gonzalez, M.A., Alonso, A., Sanchez-Villegas, A., de la Fuente, C. and Bes-Rastrollo, M. "Cost of compliance with daily recommended values of micronutrients among a cohort of Spanish university graduates: the SUN (Seguimiento Universidad de Navarra) Study," *Public Health Nutr*, 12(11), 2092-6. 2009.

[6] Murakami, K., Sasaki, S., Takahashi, Y., Uenishi, K. and the Japan Dietetic Students' Study for Nutrition and Biomarkers Group. "Monetary cost of self-reported diet in relation to biomarker-based estimates of nutrient intake in young Japanese women," *Public Health Nutr*, 12(08), 1290-7. 2009.

[7] Townsend, M.S., Aaron, G.J., Monsivais, P., Keim, N.L. and Drewnowski, A. "Less-energy-dense diets of low-income women in California are associated with higher energy-adjusted diet costs," *Am J Clin Nutr*, 89(4):1220-6. 2009.

[8] Lee, J.H., Ralston, R.A. and Truby, H. "Influence of food cost on diet quality and risk factors for chronic disease: A systematic review: Food cost and diet quality," *Nutr Diet*, 68(4), 248–61. 2011.

[9] Jensen, J.D. and Poulsen, S.K. "The new nordic diet–consumer expenditures and economic incentives estimated from a controlled intervention," *BMC Public Health*, 13(1):1114. 2013.

[10] Rehm, C.D, Monsivais, P., and Drewnowski, A. "The quality and monetary value of diets consumed by adults in the United States," *Am J Clin Nutr*, 94(5), 1333-9. 2011.

[11] Maillot, M., Darmon, N., Vieux, F. and Drewnowski, A. "Low energy density and high nutritional quality are each associated

with higher diet costs in French adults" *Am J Clin Nutr*, 86(3), 690-6. 2007.

[12] Schröder, H., Marrugat, J. and Covas, M.I. "High monetary costs of dietary patterns associated with lower body mass index: a population-based study," *Int J Obes*, 30(10), 1574-9. 2006.

[13] Cade, J., Upmeier, H., Calvert, C. and Greenwood, D. "Costs of a healthy diet: analysis from the UK Women's Cohort Study," *Public Health Nutr*, 2(04), 505-12. 1999.

[14] Aggarwal, A., Monsivais, P., Cook, A.J. and Drewnowski, A. "Does diet cost mediate the relation between socioeconomic position and diet quality," *Eur J Clin Nutr*, 65(9), 1059-66. 2011.

[15] Bernstein, A.M., Bloom, D.E., Rosner, B.A., Franz, M. and Willett, W.C. "Relation of food cost to healthfulness of diet among US women," *Am J Clin Nutr*, 92(5), 1197-203. 2010.

[16] Darmon, N., Ferguson, E.L. and Briend, A. "A cost constraint alone has adverse effects on food selection and nutrient density: an analysis of human diets by linear programming," *J Nutr*, 132(12), 3764-71. 2002.

[17] Mitchell, D.C., Shannon, B.M., McKenzie, J., Smickla-Wright, H., Miller, B.M. and Tershhakovec, AM." Lower fat diets for children did not increase food costs," *JNE*, 32, 100-103. 2000.

[18] Raynor, H., Kilanowski, C., Esterlis, I. and Epstein, L.H. "A cost-analysis of adopting a healthful diet in a family-based obesity treatment program," *J Am Diet Assoc*, 102, 645-50. 2002.

[19] Ottelin, A.M., Lindström, J., Peltonen, M., Martikainen, J., Uusitupa, M., Gylling, H. and et al. "Costs of a self-selected, health-promoting diet among the participants of the Finnish Diabetes Prevention Study," *Diabetes Care*, 30(5), 1275-7. 2007.

[20] Drewnowski, A., Monsivais, P., Maillot, M. and Darmon N. "Low-Energy-Density Diets Are Associated with Higher Diet Quality and Higher Diet Costs in French Adults," *J Am Diet Assoc*, 107(6), 1028-32. 2007.

[21] Monsivais, P., Aggarwal, A. and Drewnowski, A. "Are socio-economic disparities in diet quality explained by diet cost?," *J Epidemiol Community Health*, 66(6), 530-5. 2012.

[22] Darmon, N., Ferguson, E. and Briend, A. "Do economic constraints encourage the selection of energy dense diets?," *Appetite*, 41(3), 315-22. 2003.

[23] Darmon, N., Briend, A. and Drewnowski, A. "Energy-dense diets are associated with lower diet costs: a community study of French adults," *Public Health Nutr*, 7(1), 21-7. 2004.

[24] Andrieu, E., Darmon, N. and Drewnowski, A. "Low-cost diets: more energy, fewer nutrients," *Eur J Clin Nutr*, 60(3), 434-6. 2005.

[25] Maillot, M., Darmon, N., Darmon, M., Lafay, L. and Drewnowski, A. "Nutrient-dense food groups have high energy costs: an econometric approach to nutrient profiling," *J Nutr*, 137(7), 1815-20. 2007.

[26] Monsivais, P. and Drewnowski, A. "Lower-Energy-Density Diets Are Associated with Higher Monetary Costs per Kilocalorie and Are Consumed by Women of Higher Socioeconomic Status," *J Am Diet Assoc*, 109(5),814-22. 2009.

[27] Drewnowski, A. and Darmon, N. "The economics of obesity: dietary energy density and energy cost," *Am J Clin Nutr*, 82(1), 265S-273S. 2005.

[28] Drewnowski, A. "The role of energy density," *Lipids*, 38(2), 109-15. 2003.

[29] Drewnowski, A. "Energy density, palatability, and satiety: implications for weight control," *Nutr Rev*, 56(12), 347-53. 1998.

[30] Drewnowski, A., Darmon, N. and Briend, A. "Replacing fats and sweets with vegetables and fruits—a question of cost," *Am J Public Health*, 94(9), 1555-9. 2004.

[31] Stender, S., Skovby, F., Haraldsdóttir, J., Andresen, G.R., Michaelsen, K.F., Nielsen, B.S. and et al. "Cholesterol-lowering diets may increase the food costs for Danish children. A cross-sectional study of food costs for Danish children with and without familial hypercholesterolaemia," *Eur J Clin Nutr*, 47(11), 776-786, 1993.

[32] Drewnowski, A. and Darmon, N. "Food choices and diet costs: an economic analysis," *J Nutr*, 135(4):900-4. 2005.

[33] Lopez, C.N., Martinez-Gonzalez, M.A., Sanchez-Villegas, A., Alonso, A., Pimenta, A.M. and Bes-Rastrollo, M. "Costs of Mediterranean and western dietary patterns in a Spanish cohort and their relationship with prospective weight change," *J Epidemiol Community Health*, 63(11), 920-7. 2009.

[34] Murakami, K., Sasaki, S., Okubo, H., Takahashi, Y., Hosoi, Y. and Itabashi, M. "Monetary costs of dietary energy reported by young Japanese women: association with food and nutrient intake and body mass index," *Public Health Nutr*, 10(12), 1430-9. 2007.

[35] Rydén, P.J. and Hagfors, L. "Diet cost, diet quality and socio-economic position: how are they related and what contributes to differences in diet costs?," *Public Health Nutr*, 14(09). 1680-92. 2011.

[36] Waterlander,W.E., de Haas, W.E., van Amstel, I., Schuit, A.J., Twisk, J.W., Visser, M. and et al. "Energy density, energy costs and income – how are they related?," *Public Health Nutr*, 13(10), 1599-608. 2010.

[37] Brimblecombe, J.K. and O'Dea ,K. "The role of energy cost in food choices for an Aboriginal population in northern Australia," *MJA*, 190, 549-51. 2009.

[38] Darmon, N. and Drewnowski, A. "Does social class predict diet quality?," *Am J Clin Nutr*, 87(5), 1107-17. 2008.

[39] Drewnowski, A. and Specter, S.E. "Poverty and obesity: the role of energy density and energy costs," *Am J Clin Nutr*, 79(1):6–16. 2004.

[40] Pakseresht, M., Lang, R., Rittmueller, S., Roache, C., Sheehy, T., Batal, M. and et al. "Food expenditure patterns in the Canadian Arctic show cause for concern for obesity and chronic disease," *Int J Behav Nutr Phys Act*, 11(1), 51. 2014.

[41] Rosinger, A., Tanner, S. and Leonard, W.R. "Precursors to overnutrition: The effects of household market food expenditures on measures of body composition among Tsimane' adults in lowland Bolivia," *Soc Sci Med*, 92, 53–60. 2013.

[42] Murakami, K., Sasaki, S., Takahashi, Y., Uenishi, K. and the Japan Dietetic Students' Study for Nutrition and Biomarkers Group. "Monetary cost of dietary energy is negatively associated with BMI and waist circumference, but not with other metabolic risk factors, in young Japanese women," *Public Health Nutr*, 12(08), 1092-8. 2009.

[43] Fukuda, Y. and Hiyoshi, A. "Associations of Household Expenditure and Marital Status With Cardiovascular Risk Factors in Japanese Adults: Analysis of Nationally Representative Surveys," *J Epidemiol*, 21-7. 2013.

[44] Vlismas, K., Panagiotakos, D.B., Pitsavos, C., Chrysohoou, C., Skoumas, Y., Sitara, M. and et al. "Quality, but not cost, of diet is associated with 5-year incidence of CVD: the ATTICA study," *Public Health Nutr*, 13(11), 1890-7. 2010.

[45] Brimblecombe, J.K., Ferguson, M.M., Liberato, S.C. and O'Dea, K. "Characteristics of the community-level diet of Aboriginal people in remote northern Australia," *Med J Aust*, 198(7), 380-4. 2013.

[46] Rauber, F., Vitolo, M.R. "Nutritional quality and food expenditure in preschool children," *J Pediatr (Rio J)*, 85(6), 536-40. 2009.

[47] Ledikwe, J.H., Blanck, H.M., Khan, L.K., Serdula, M.K., Seymour, J.D., Tohill, B.C. and et al. "Dietary energy density determined by eight calculation methods in a nationally representative United States population," *J Nutr*, 135(2), 273-8. 2005.

[48] Popkin, B.M. "Nutritional patterns and transitions," *Popul Dev Rev*, 138-57. 1993.

[49] Tafreschi, D. "The income body weight gradients in the developing economy of China," *Econ Hum Biol*, 16, 115-134. 2015.