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The Association of Diet and Physical Activity in Nairobian Pre-Adolescents

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Abstract

Background: Majority of studies on the association of diet and physical activity are conducted in high-income countries and to date, none have been conducted in Kenya although unhealthy lifestyle behaviours are on the rise and may pose more severe risk in low-to-middle-income than in high-income countries.

Methods: Study consists of 9-14-year old pre-adolescents (N=104) living in a middle- or low-income area in Nairobi. Dietary data was collected using 7-day FFQ and physical activity data by accelerometer. Dietary patterns were formed through principal component analysis and Dietary Diversity Score created by counting the number of food groups that were used daily. Statistical analysis was conducted using linear regression analysis with wealth index, area, age, gender and BMI as confounding variables.

Results: Time spent in moderate-to-vigorous physical activity (MVPA) was weakly and negatively associated with the Snacks, fast food and meat dietary pattern alone and in combination with age and gender and significantly in combination with BMI (p=0.041), while time spent in sedentary behaviour showed no relation. Time spent in MVPA could not explain the variation in adherence to the Traditional Kenyan pattern while time spent in sedentary behaviour showed weak, negative association with adherence to this diet pattern, although it did not reach significance. Neither time spent in sedentary behaviour nor time spent in MVPA could explain variation in Dietary Diversity Score or adherence to the Dairy and plant protein pattern.

Conclusions: Physical activity showed some association with diet, but the connections were mostly weak, and the socio-economic position and environment are possibly stronger determinants of lifestyle behaviour in urban Kenya.

Keywords

diet, physical activity, Nairobi, pre-adolescents, nutrition transition, physical activity transition

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Tiivistelmä

Tausta: Ruokavalion ja fyysisen aktiivisuuden yhteyttä on pääosin tutkittu korkeatuloisissa maissa ja toistaiseksi yhtään tutkimusta ei ole tehty Keniassa, vaikka epäterveelliset elintavat ovat nousussa ja voivat aiheuttaa suuremman riskin matala- ja keskituloisissa maissa kuin korkeatuloisissa.

Menetelmät: Otanta koostuu 9-14-vuotiaasta lapsesta (N=104), jotka asuvat joko keski- tai matalatuloisella alueella Nairobissa. Ruokavaliodata kerättiin 7 päivän ruokavaliokyselyllä ja fyysinen aktiivisuus mitattiin kiihdytinanturilla. Ruokavaliomallit muodostettiin pääkomponenttianalyysillä ja ruokavalion monipuolisuusarvo laskemalla ruokaryhmät, joita käytettiin päivittäin. Tilastomenetelmänä käytettiin lineaarista regressioanalyysiä, jossa varallisuusindeksi, ikä, sukupuoli, asuinalue ja painoindeksi olivat sekoittavina tekijöinä.

Tulokset: Keskiraskaan ja raskaan liikunnan (MVPA) määrä oli heikosti ja negatiivisesti yhteydessä Välipalat, pikaruoka ja liha -ruokavaliomalliin itsenäisesti sekä yhdessä iän ja sukupuolen kanssa ja merkitsevästi yhdessä painoindeksin kanssa (p=0.041), kun taas paikallaanolo ei ollut yhteydessä tähän ruokavaliomalliin. MVPA:n määrä ei pystynyt selittämään vaihtelua Perinteisen kenialaisen ruokavaliomallin noudattamisessa, kun taas paikallaanolo oli heikosti ja negatiivisesti yhteydessä tähän ruokavaliomalliin. MVPA:n määrä tai paikallaanolo eivät pystyneet selittämään vaihtelua ruokavalioon monipuolisuudessa tai vaihtelua Maitotuotteet ja kasviproteiini -ruokavaliomallin noudattamisessa.

Päätelmät: Fyysinen aktiivisuus oli yhteydessä ruokavalioon, mutta nämä yhteydet olivat pääosin heikkoja. Sosioekonominen asema ja elinympäristö saattavat olla vahvempia elintapojen määrittäjiä Kenian kaupunkialueella.

Avainsanat

ruokavalio, fyysinen aktiivisuus, Nairobi, varhaisnuoret, ravitsemuksen siirtymä, fyysisen aktiivisuuden siirtymä

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Abbreviations

DDS = Diet Diversity Score

FFQ = Food Frequency Questionnaire

KENFIN-EDURA = Kenya-Finland Research Alliance

LMIC = low-to-middle-income country

MVPA = moderate-to-vigorous physical activity

SED = sedentary behaviour

SES = socio-economic status

1 Introduction

Lifestyles around the world are constantly evolving as a result of economic, educational, cultural and technological developments that are occurring the fastest in lower-income countries. One aspect of this is the nutrition transition which is characterized by lower-income countries adapting the dietary patterns of higher-income countries, which leads to higher intake of fat and sugar and lower intake of dietary fibre (Popkin 1993). This view also includes the changes occurring in the physical activity; however, physical activity transition has since evolved to a concept of its own. Physical activity transition is characterized by lowering levels of occupational, domestic and transportation activity but in certain populations, increases in leisure-time physical activity are also reported (Ng and Popkin 2012, Borodulin et al 2016). Together these changes often lead to higher energy intake and lower energy expenditure placing individuals at risk of obesity and chronic, non-communicable diseases (Popkin 1993). The most vulnerable group are children, since lifestyle adopted in childhood tracks into adulthood (Mikkilä et al. 2005): during a longer period of exposure these diseases have time to develop and heavily affect the health (Weichrauch-Blüher et al. 2019). This results in burden on both the individual and the society as the economic cost can be great (Popkin et al. 2006)

The transitions in nutrition and physical activity are driven by multiple factors, such as urbanization; development of food processing technologies; investment and trade by transnational food companies; mechanization and increased access to information and communications technology (Popkin 1993, Drewnowski and Popkin 1997, Hawkes 2005, Pratt et al. 2012). Additionally, lifestyle transitions are highly associated with socioeconomic status (Jaacks et al. 2019). This association depends on the stage of transition and thus varies from one population to other.

Partly same factors are driving both nutrition and physical activity transitions and thus it is reasonable to ask whether there is association between these two changes. Majority of research on the association of nutrition and physical activity has been conducted in high-income countries and knowledge of this in the low- and middle-income countries is lacking. Yet, the burden of nutrition and physical activity transitions is growing across the developing world. In these settings the transitions have been noted to be much faster in comparison to high-income countries (Popkin 2002). Thus, lower-resource settings are expected to have difficulties in adapting their health care and governance to this new set of issues arising while simultaneously facing the longstanding problems of undernourishment (Min et al. 2018).

Therefore, it is important to gain more understanding of the presentation and the stage of nutrition and physical activity transitions in low- to middle-income countries to find ways to address these problems. Through focus on Nairobi, the capital city of Kenya, the present study, as a part of the KENFIN-EDURA project, aims to do this by exploring the association of diet and physical activity in pre-adolescents. In Kenya, where previous studies have already found lifestyle transitions occurring especially in the urban areas, studies like these are still lacking.

2 Literature review

2.1 Lifestyle transitions

Since 1975 the global obesity prevalence has nearly tripled (WHO 2018a). In 2016, more than 1.9 billion adults aged 18 years and older (39% of men and 40% of women) were overweight or obese. At the same time, over 340 million children and adolescents aged 5-19 (18% of girls and 19% of boys overweight) and 41 million children under the age of five were overweight or obese. Overweight and obesity were once seen as the problem of high-income countries, but they are now on the rise in low- and middle-income countries as well, particularly in urban settings (WHO 2018a). For example, in Africa, the number of overweight children under the age of five has increased by nearly 50 per cent since 2000. Globally more people are obese than underweight, except for some parts of sub-Saharan Africa and Asia. More deaths are caused by overweight and obesity than being underweight as being overweight or obese may lead to chronic diseases such as cardiovascular diseases, diabetes, musculoskeletal disorders, and cancers (WHO 2018a).

Increase in obesity and overweight prevalence is ultimately caused by an increased intake of energy and decreased physical activity (WHO 2018). These lifestyle factors are highly linked to the environment and the possibilities of the individual to make choices: the socioeconomic status (SES) determines where people live, what they eat and how they move.

The association of SES and lifestyle across economic development stages is illustrated in Figure 1 (adapted from Jaacks et al. 2019). The figure describes the changes in obesity prevalence in the 30 most populous countries. At the first stage, obesity prevalence is low and the effect of high-SES on obesity is mainly seen in women although the authors found signs of similar effect in men as well. The rate of childhood obesity is low. In the second stage the obesity prevalence increases especially among adults but also among children. The gender difference remains but in the second stage, the SES-obesity association is found also in men. In the third stage the obesity prevalence remains on the same level, but the burden slowly shifts to the group with low SES where obesity prevalence increases in both men and women. The obesity prevalence in children continues to increase. The fourth stage of declining obesity is mainly a prediction as there are not yet many countries that would have entered this stage. It is unclear how this stage will be achieved but it is thought that the decline in obesity and gender disparity could be achieved mostly by leaner children entering adulthood, than the obese and overweight adults losing weight. This would make children the prime focus of health promotion projects, especially as it is known that the risk factors of chronic diseases persist from childhood to adulthood (Adams et al. 2005, Mikkilä et al. 2005, Chen & Wang 2008, Singh et al. 2008, Telama 2009, Nguyen et al. 2010).

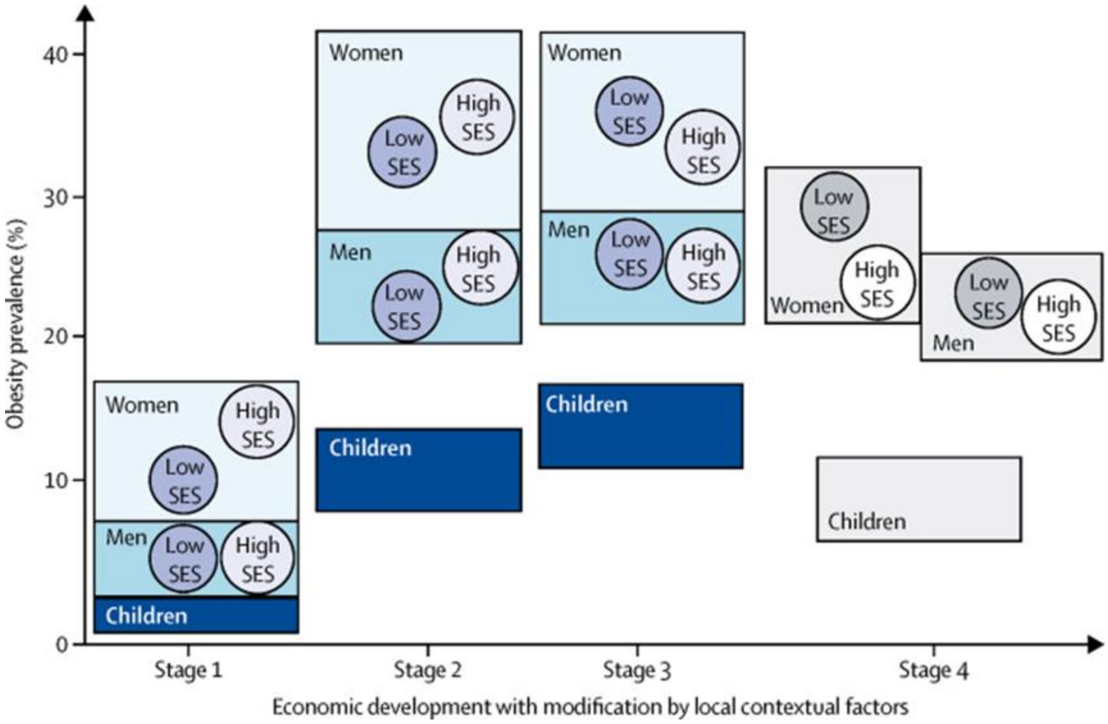

Figure 1. Association of SES and obesity prevalence across economic development stages (Jaacks et al. 2019).

Regarding obesity and chronic diseases, lifestyle transition is often divided into nutrition and physical activity transitions. These transitions, although presented in a different manner, are linked to the same changes in the society, environment and SES. In the next chapters, they are explored more deeply.

2.1.1 Nutrition transition

Barry Popkin (1993) constructed the concept of nutrition transition almost 30 years ago. Popkin identified five dietary patterns that are both occurring today but also those occurred before. The first pattern is the hunter-gatherer -phase where the diet consists of a varied range of plants and wild animal and people have only few nutritional deficiencies although both birth rate and life expectancy are low. In the second phase settling down turns the diet into less varied, consisting mainly of cereals. This results in many nutritional deficiencies along with widespread infectious diseases. High fertility makes especially women and children vulnerable to these problems. The third phase of receding famine is characterized by incorporation of slightly more animal products, fruits and vegetables into the diet as the proportion of energy from cereals decreases. Even though mortality declines at this stage and the population grows, women and children continue to face nutritional problems. Income disparity is increased, dividing the population more clearly into classes. In the fourth phase of degenerative diseases, the development of food processing technology and income growth leads to increased intake of fats especially from animal products, sugar, and processed foods and decreased intake of dietary fibre. At this phase, obesity and the non-communicable diseases following it become the main nutritional and health problems. As life expectancy increases, these kinds of diseases are allowed the time to degenerate and cause problems. In the fifth phase, the occurrence and high prevalence of these diseases leads to behavioural change in which the intake of carbohydrates, fruits and vegetables is increased and fat intake and food processing is decreased. People become healthier, life expectancy increases, and the population proportion of elderly is increased.

Although these changes are presented here as separate phases, the different patterns may be practised simultaneously even within the same countries, areas, communities and household (Popkin 2002, Popkin 2006). Often high-income countries are characterized mostly by the fourth pattern of unhealthy lifestyle and degenerative diseases but there are also signs of the behavioural change described in the fifth pattern as they have already passed the earlier stages of nutrition transition (Popkin 1993). Low-to-middle-income countries (LMICs) then again are characterized mostly by the third and the fourth patterns as their economies continue to grow. As the transition from the third to the fourth pattern is the most common globally, often when talked about nutrition transition, this change of pattern is the one focused on.

Table 1. The nutrition transition phases (Popkin 2006).

	Pattern 1: collecting food	**Pattern 2: famine**	**Pattern 3: receding famine**	**Pattern 4: degenerative disease**	**Pattern 5: behavioral change**
Diet	Plants, low-fat wild animals, varied diet	Cereals predominant, diet less varied	Fewer starchy staples; more fruit, vegetables, animal protein; low variety continues	More fat (especially from animal products), sugar, processed foods; less fibre	Higher-quality fats, reduced refined carbohydrates, more whole grains, fruits and vegetables
Nutritional status	Robust, lean population; few nutritional deficiencies	MCH[1] suffer most from low fat intake, nutritional-deficiency diseases emerge, stature declines	Continued MCH[1] nutrition problems, many deficiencies disappear, weaning diseases emerge, stature grows	Obesity, problems for elderly (bone health, etc), many disabling conditions	Reduction in body fat and obesity, improvement in bone health
Economy	Hunter-gatherers	Agriculture, animal husbandry, homemaking begins; shift to monocultures	Second agricultural revolution (crop rotation, fertilizer), industrial revolution, women join the labor force	Fewer jobs with heavy PA[2], service sector and mechanization, household technology revolution	Service sector mechanization and industrial robotization dominate, increase in leisure time exercise
Morbidity	Much infectious disease, no epidemics	Epidemics, Infectious diseases, deficiency diseases, starving common	Infectious diseases, parasitic disease, weaning diseases (diarrhea, stunting) expand, later decline	Chronic disease related to diet and pollution (heart disease, cancer), decline in infectious disease	Increases in health promotion (preventive and therapeutic), rapid decline in CVD[3], slower change in age-specific cancers

[1] Maternal and child health
[2] Physical activity
[3] Cardiovascular disease

These transitions are promoted by a variety of changes in the society (Popkin 1993). For example, shifts in population growth and migration can lead to changes in lifestyle. In the urban areas, the diets include more processed foods such as polished or milled cereals, sugar and fat and less home-cooked meals (Popkin 1993). The hypothesis of poor diet resulting from urbanization was tested by Drewnowski and Popkin (1997) and it was found that a rise in proportion of urban residents from 25% to 75% was associated with a four-percentage-point increase in total energy intake from fat and 12 percentage point increase in energy intake from sweeteners. Previous studies have found that rural-to-urban migration changes the eating habits. The conducted studies in Tanzania, India and Guatemala found increased intake of red meat, sugar, dairy, sweetened beverages, total energy and saturated fats (Torun et al. 2002, Unwin et al. 2010, Bowen et al. 2011). Although two of these studies found that the intake of fruits and vegetables was also increased, the overall result of these changes seemed to be adverse (Unwin et al. 2010, Bowen et al. 2011). These results suggest that the migration to urban areas changes the diet and thus, urbanization can be major threat to public health.

Development of food processing technologies promotes these changes too, as it has widened the variety of foods available (Popkin 1993). The processing of foods provides new sensory qualities but may also affect the price of the food, since an improvement in preservation techniques allows the price of the product to be lowered. This may lead to easily spoilt food to have proportionally higher price than those that can be preserved for longer time. In the Figure 2, it is shown that for example fats and sweets, which are low in nutrients but high in energy, are easily affordable whereas vegetables and fruits are not. The availability of edible oils has increased to concern a wider population during the second half of 20th century (Popkin & Ng 2007). This has high importance especially to the poorer population as income is known to be associated with diet (Hoffman et al. 2008). The price reductions are coupled in low-to-middle-income countries (LMIC) with the view that “Western” diets are more preferable as they have so far been linked with higher level of income and education (Noack & Pouw 2015).

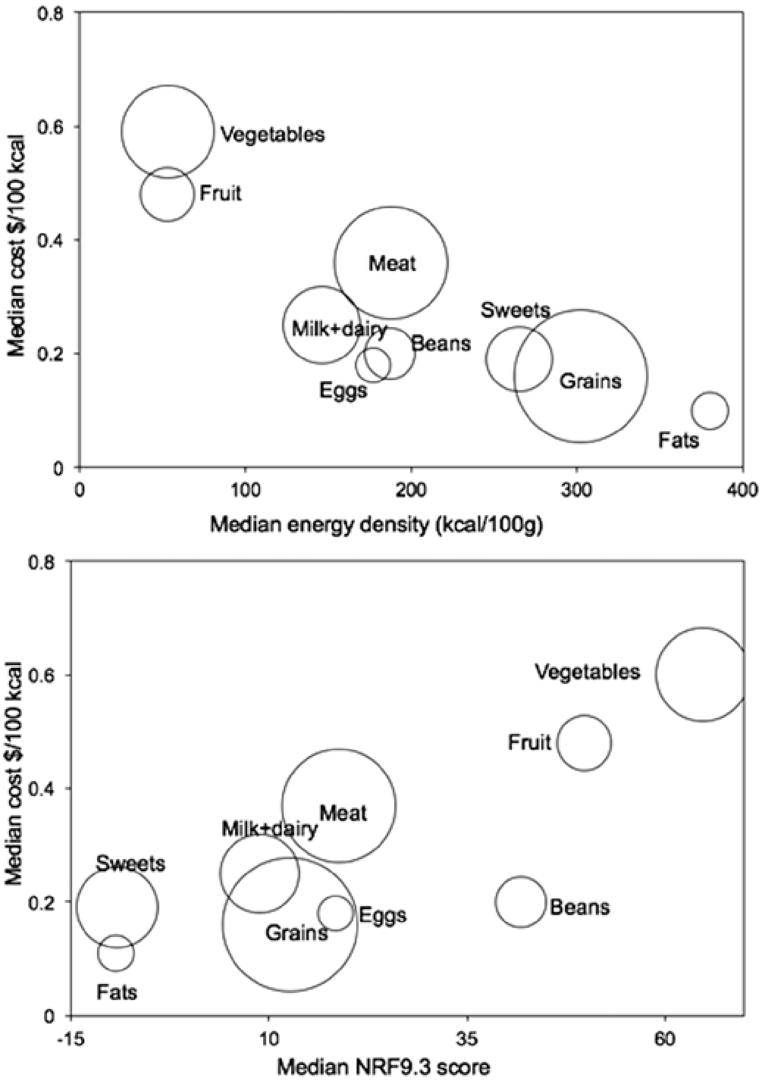

Figure 2. The price ($) of food per energy (100kcal) and the price ($) of food per nutrient density, measured by the NRF9.3 score (Drewnowski 2018).

Supporting these notions, Sievert et al. (2019) found that in the Pacific, the trend of sale of processed foods was rising in both lower- and upper-middle-income countries steadily across nations between 2004 to 2018, with the fastest increase seen in the lower-middle-income countries. In high-income countries, both increases and declines were noted during the same period. Currently, the overall volumes are bigger in high-income countries but continuing these trends the middle-income countries are catching up. Transnational food and beverage corporations are likely to be significant players in the retail, manufacturing and food service sectors although they also face competition from emerging domestic companies that offer similar processed options (Baker & Friel 2016). The investments of these companies in the lower-income countries have increased and food processing is the most important recipient of investment in the food system (Hawkes 2005).

Alongside the Pacific region, changes in consumption patterns are observed across other LMICs. In sub-Saharan Africa availability of energy, fat, protein and sugar has increased; in Asia consumption of sugar, salt and fat from processed foods has increased; as well as in Latin America intake of total energy, fat and refined carbohydrates has increased (Rivera et al. 2004, Baker & Friel 2014, Steyn & Mchiza 2014). These changes are not limited to adults. Aurino et al. (2017) found that while adolescents' dietary diversity generally has increased, intake of animal-based products and sugar has also increased in India, Vietnam and Ethiopia. Additionally, almost half of children in Kuwait have greater energy intake than recommended; fat intake has increased while carbohydrate intake has declined in Chinese children; and Westernization of diet was found in Tunisian adolescents (Aounallah-Skhiri et al. 2011, Cui & Dibley 2012, Zaghloul et al. 2013)

2.1.2 Physical activity trends

Physical activity transitions are linked to several changes in the society. Popkin (1993) identified increased mechanization, fewer jobs with high physical activity, and household technology revolution as the reasons for decreasing energy expenditure, as illustrated in Table 1. Additionally, information and communication technology has seen an enormous leap in accessibility: from 1997 to 2009 access to internet has increased from 0.01% to 4.3% of the population in low-income countries; from 0.21% to 23.8% in middle-income countries; and from 11.2% to 51.9% in high-income countries (Pratt et al. 2012). At the same time mobile phone ownership has increased even more: from 0.05% to 28.9% in low-income countries; from 1% to 71% in middle-income countries; and from 17.9% to 96.3% in high-income countries (Pratt et al. 2012). Pratt et al. (2012) also argued that motorized transportation, at least when privately owned, contribute to decreasing physical activity.

Similarly, urbanization is associated with less physical activity in LMICs (Monda et al. 2007, Creber at al 2010, Assah et al. 2011). In fact, it has been estimated in China that every one-unit increase in urbanization translates to 7% and 6%, for men and women respectively, higher odds of light occupational activity instead of heavy occupational activity (Monda et al. 2007). It could be argued that in an urban setting motorized transportation and technology are present alongside with less active occupations, combining all the factors mentioned before. Additionally, in an urban setting, environmental factors, such as fear of violence and crime in outdoor areas; high-density traffic; low air quality; and lack of parks sidewalks and sports facilities contribute to physical inactivity (WHO 2018b).

World Health Organization (WHO) has identified physical activity to be the fourth biggest risk factor for global mortality (WHO 2009). Adequate activity has been previously associated with an increase in perceived health, bone health, cognitive function, weight management, cardiovascular health and sleep quality and a decrease in some forms of cancers and depression (Abu-Omar & Rütten 2008, Hills et al. 2015). Low physical activity levels often correspond with a high gross national product (WHO 2018b). However, according to WHO, physical inactivity is the cause of higher morbidity in both low- and middle-income countries than in high-income countries (WHO 2009). Also, more disability-adjusted life years are caused by physical inactivity in middle-income countries than in the high-income countries, emphasizing the need for more focus in the developing countries.

There are differences in physical activity between high- and low-to-middle-income countries. The review of studies from 122 countries found that the proportion of physically inactive adult population was 27.5% in Africa, 43.3% in the Americas, 43.2% in the eastern Mediterranean, 34.8% in Europe, 17.0% in southeast Asia, and 33.7% in the western Pacific (Hallal et al. 2012). Out of 105 countries, the proportion of 13-15-year-old adolescents not meeting the required 60 minutes of MVPA equalled 80% or greater in 56 countries for boys and 100 countries for girls. The distribution of results per country are presented in Figure 3.

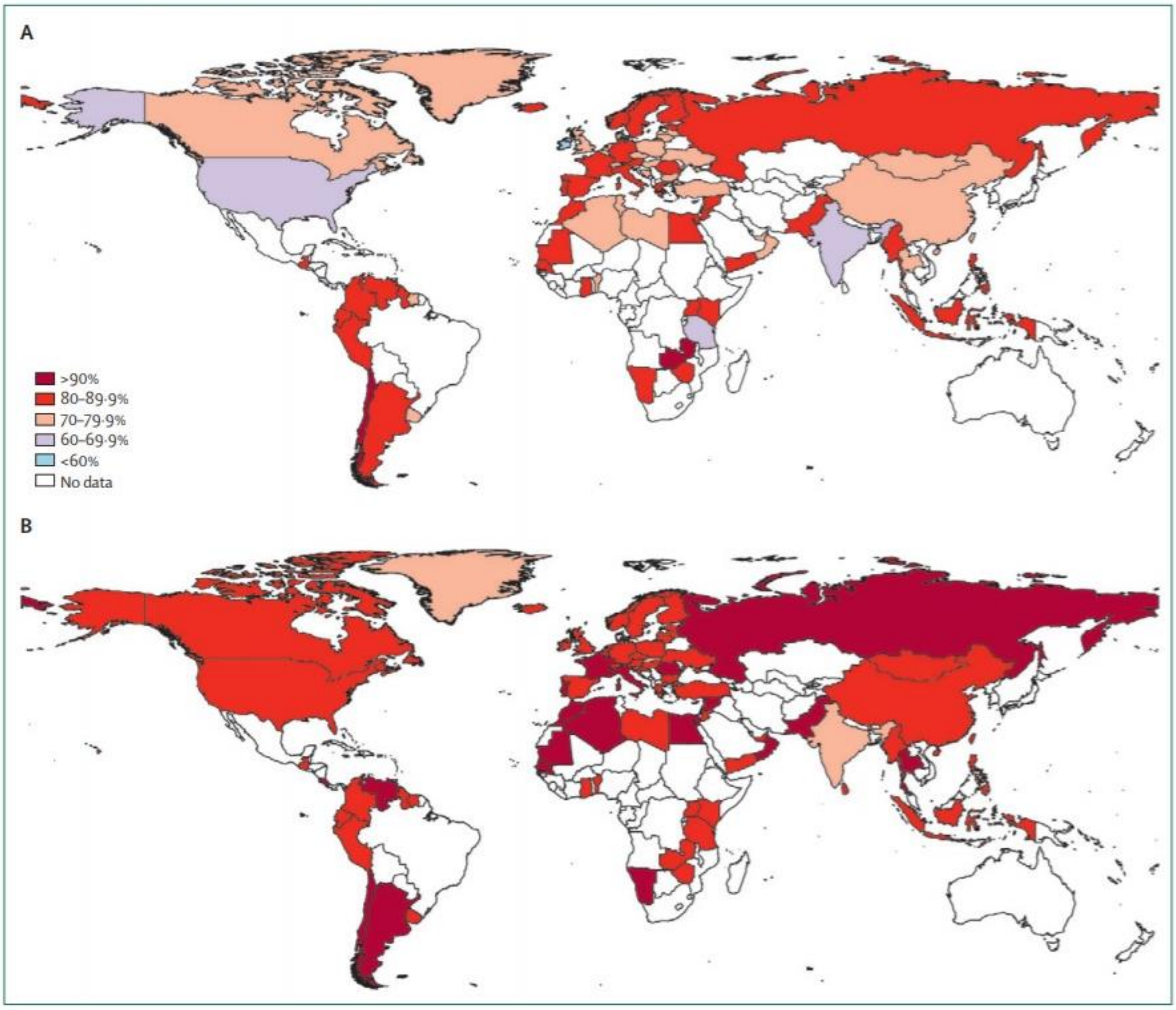

Figure 3. The proportion of boys (A) and girls (B) not achieving the recommended 60 minutes of MVPA per day (Hallal et al. 2012)

When looking at the trends in physical activity the overall result seems to be a downward trend. Ng and Popkin (2012) examined physical activity levels in US (1965-2009), UK (1961-2005), Brazil (2002-2007), China (1991-2009) and India (2000-2005) and found that total physical activity decreased in all five countries. In the US and UK, reductions were seen in occupational and domestic physical activity whereas sedentary time and leisure time physical activity increased. Interestingly, while travel physical activity also decreased in the US, in the UK it increased over two-fold. Similar results were found in other studies conducted in these countries although Stamatakis et al. (2007) found also a total increase in physical activity in the UK (Church et al. 2011).

Similar results have been obtained in other high-income countries. A retrospective cohort conducted in Swedish men found reductions in physical activity in all age groups (Norman et al. 2003). In Finland, from 1982 to 2012 leisure time physical activity has increased while occupational and commuting physical activity have decreased (Borodulin et al. 2016). However, despite the changes in physical activity domains, total physical activity had remained stable. Additionally, a study conducted in urban Switzerland found increases in physical activity from 1999 to 2009 and a study conducted in Australia found increases in the prevalence of sufficient physical activity from 1989 to 2011 (Guessous et al. 2014, Chau et al. 2017). These results in Finland, Australia and Switzerland give light on emerging transition in high-income countries: through increasing health consciousness, decreases in occupational and transportation activity can be outweighed by leisure-time physical activity, possibly resulting ultimately in lower prevalence of overweight and chronic diseases (Popkin 1993, Jaacks et al. 2019).

Among children and adolescents longer time spans of over 10 years have not been used in many studies. However, a review by Tucker (2008) found that active transportation declined significantly from 42% in 1969 to 16% in 2001 in the US; from 53% in 1986 to 43% in 2006 in Canada; from 78% in 1994 to 71% in 2005 in Switzerland; and from 44% in 1971 to 21% in 2003 in Australia. Although these results seem to be conclusive, the results on total physical activity have more variance. Overall physical activity reduced in Czech Republic from 1998 to 2010 while in Sweden and Denmark on shorter time span, 7-8 years, no difference was detected.

In Russian children both moderate activity and sedentary time was increased while vigorous physical activity was reduced from 1995 to 2002 (Jahns et al. 2012). Additionally, a review by Dollman et al. (2005) reported that the physical activity level remained stable in Canada from 1981 to 1998 while increased in the UK from 1987 to 2003 and in the US from 1991 to 2003. The inconclusive results seem to point that the trend is not similar across the high-income countries but at least in certain populations leisure time physical activity could be increasing. It is possible that factors such as SES and culture play a part in these results.

Much less research has been conducted in LMICs and only few of them have examined physical activity trends. One of them is the five-country study by Ng and Popkin (2012), who reported a decrease in occupational, domestic, travel and total physical activity as well as increase in leisure-time activity and being sedentary in Brazil, India and China. Despite the increase in leisure-time physical activity, total physical activity is projected to continue to decline. Additionally, Sun et al. (2013) found a decrease in physical activity in Brazilian older adults over time.

While the studies on temporal trends are missing, there are differences between rural and urban populations supporting the previously found association between urbanization and decline in physical activity. In West Africa, 18% of urban population was inactive while in the rural population only 9% was inactive and in India, rural-dwellers reported five and seven times, for men and women respectively, more physical activity than urban-dwellers (Yadav & Krishnan 2008, Abubakari et al. 2009). In China the intensity of occupational physical activity was greater in rural than urban areas (Xie et al. 2008). In Ecuador, rural women reported more walking and strenuous work but less leisure-time physical activity than urban women (Melby et al. 2017). Finally, across six middle-income countries urban populations were found to have lower occupational physical activity but greater leisure-time activity (Oyebode 2015).

Few studies on trends in physical activity have been conducted in children in LMICs. Dos Santos et al. (2014) found negative secular trends in physical activity in both Mozambican girls and boys: declines were seen in household chores, walking and games between 1992 to 2012. Additionally, Senegalian girls were found to have a decline in physical activity with age between 1997 to 1999 (Bénéfice et al. 2001). Muthuri et al. (2014 a) attempted to explore trends in Sub-Saharan children and adolescents. Due to lack of consistency in study variables no trends could be detected, highlighting the need for more studies in LMICs. In terms of specific domains, active commuting declined in Brazilian children between 2002 to 2007 but increased later in children entering adolescence and declined in Chinese children and adolescents between 1997 to 2006 (Cui et al. 2011, Costa et al. 2012). Also, sedentary behaviour was found to increase in Chinese children and adolescents (Dearth-Weasley et al. 2017). Overall these studies seem to point to a decline in physical activity in children in LMICs, but more studies are needed to make justified conclusions.

2.1.3 Lifestyle transition in low-to-middle income countries

Although there are similarities between lifestyle patterns globally, they are not observed the same way in all areas. When comparing the lifestyle transition in high-income countries and in LMICs, there are few aspects that should be considered. Firstly, the transition seems to be accelerated in the LMICs as a result of globalization (Popkin 2002). The introduction of modern technology in LMICs has been much more rapid than in high-income countries. Television and mobile phone ownership, and access to internet and mass media has been and still is generalizing quickly. Additionally, technology in manufacturing, food processing, agriculture and other services has been introduced to LMICs rapidly. Opprtunities to use different forms of transportation have been increased just as fast. In addition, high urbanization is driving these changes (Drewnowski & Popkin 1997). Whereas high-income countries had decades to familiarize themselves with these changes, LMICs are experiencing them in 10-20 years.

Secondly, the capacity of LMICs to deal with these nationwide problems are limited (Popkin 2002). As these countries have focused on prevention and treatment of problems occurring with the nutrition pattern of receding famine, such as nutritional deficiencies, hunger and infections, they may not have the required time to adjust the health care and health promotion to deal with the chronic diseases generated by the less active lifestyle and more energy-dense diet. This has been studied for example in Ghana, where diagnosis and treatment of infectious diseases were more accessible than for non-communicable diseases (Kushitor & Boatemaa 2018). Also, a review by Sunguya et al. (2014) found that only around half of LMICs had nutrition policies to address overweight and obesity and only 36% had nutrition policies to address both overnutrition and undernutrition. Yet, from previous studies, we know that the economic cost of poor diet and physical inactivity can be big. A case study in China found that the indirect costs of these obesity-related lifestyle patterns were 3.58% of GNP in 2000 and are estimated to reach 8.73% by 2025 (Popkin et al. 2006).

Thirdly, many of LMICs also face the two problems of under- and overnutrition simultaneously, limiting the possibilities of facing the problems of lifestyle transition (Min et al. 2018). This phenomenon, known as double burden of disease, can be seen at the population level, but also on the household level (WHO a). For example, there can be both underweight and overweight persons in the same household or prenatally undernourished person has increased risk of obesity or other metabolic diseases later on (Doak et al. 2004, Barker et al. 2005). The Food and Agriculture Organization in United Nations has found that whereas the incidences of many chronic diseases are on the rise in many developing countries, there seems to be no decline in the number of cases of infectious diseases demonstrating the problems the healthcare systems of these countries are facing in order to cope with both of these (Kennedy et al. 2006).

2.3 Kenya

2.3.1. Descriptive statistics of Kenya

Kenya is a country in sub-Saharan Africa that lies at the Equator on the east coast of the continent by the Indian Ocean (United Nations). It shares a border with Somalia, Ethiopia, Sudan, Uganda and Tanzania. It covers an area of 582,646 square kilometres and is divided into 47 counties. Nairobi is the capital of Kenya. Figure 4 presents the map of Kenya.

Figure 4. The map of Kenya (United Nations).

Kenya was a British colony from the turn of 20th Century up until 1963 when it gained independence (Embassy of the Republic of Kenya in Japan). In 1964 Kenya became a Republic and is still run by a parliament consisting of a National Assembly and Senate together with the President. In 2011, the gross domestic product (GDP) per capita was $2,961 US dollars, which in relation to, for example, Finland's $41,018 is relatively low (World Bank 2019). The World Bank categorized Kenya as a lower middle-income country but it predicts that the GDP will grow by approximately 6% per year in the near future. At this rate, Kenya is one of the fastest growing economies in Sub-Saharan Africa. Kenya has also seen an increase in its human development index during the last decades, reaching 0.590 in 2017 (UNDP).

In 2018, the population of Kenya was 51,393,010 (World Bank 2019). In 2015, over 16 million habitants lived in urban areas, which is almost 3 million habitants more than in 2006, demonstrating the fast urbanization occurring in Kenya (Otiso & Owusu 2008).

Kenya is ranked as the 66th most unequal country in the world according to the world inequality statistics (KNBS & SID 2013). This can be seen as an unequal access to even the most basic goods and services such as sanitation, safe drinking water, shelter, education and food. The largest inequalities in education are seen in the urban areas, where there are many people with improved level of education but these education possibilities are not accessible for all, whereas in the rural areas, the education levels are lower in general but the gap is much smaller in comparison.

2.3.2 Lifestyle transition in Kenya

Lifestyle transitions occur in numerous ways, in which they have been studied in Kenya as well. Thus, they are explored here in terms of nutrition, physical activity, obesity and non-communicable diseases.

Staple foods form the base of the diet for most Kenyans (Oniang'o, et al. 2003). These include for example sorghum, which can be made into traditional ugali-porridge. Importance of ugali for the diet is great – in a study conducted by Noack and Pouw (2014), interviewees stated that a meal is not a meal without ugali, and they could not feel fulfilled without it. Other staples include maize, cassava and finger millet (Oniang'o et al. 2003). In the urban areas, these products high in dietary fibre are consumed less and non-whole grain products are consumed more. Nowadays it is common to make ugali also out of maize, especially white maize, which is seen as a more modern way even if it is less nutritious (Noack & Pouw 2014). Fruit consumption is more fragmented as income and education level are associated with fruit consumption (Oniang'o et al. 2003). This is true especially in urban areas while in rural areas fruit consumption is more dependent on the seasonality.

In the rural areas, preservation, for example, by drying, is used less than previously, as it is seen somewhat more primitive way by younger generations (Noack and Pouw 2014). This can affect the nutritional intake of vitamins for instance as fruits are not available all year through. Income and education level affect also vegetable consumption but in a contrary manner: since vegetables are regarded as the food of the poor, higher income is negatively associated with vegetable intake (Oniang'o et al. 2003). In the rural areas the access of those with low SES to vegetables is better than that in urban areas demonstrating again how low-income population is more vulnerable in urban than rural settings. Fat, oil and animal product consumption is generally low, although dependent on the income level (Oniang'o et al. 2003). Tea is a widely consumed beverage in Kenya (Noack & Pouw 2014).

Galvin et al. (2015) studied Maasai pastoralists' nutritional status and discovered that little changes had appeared between1989 and 2000, despite great changes in the environment during that time. However, the average weight and BMI was higher in 1931 than in 2000. Malnourishment, especially among males that spent the days herding and thus were not at home to eat, was common. Nutritional deficiencies are common in Kenya: iodine, vitamin A and iron deficiencies burden especially children, which reflects also to a large proportion of under five-year malnourishment and retarded growth (WHO b). Maternal deficiencies are likewise common in Kenya (Shell-Duncan & Yung 2014). Although these are signs associated with the dietary pattern of receding famine, there are signs of nutrition transition also in the rural parts as it has been found that purchase of processed foods and high intake of sugar is now seen alongside traditional food habits (Keding 2016). It has been also reported that access to supermarkets in small towns increases the consumption of processed foods in Kenya (Rischke et al. 2015). In addition, mean BMI and likelihood for overweight and obesity in adults is higher and child undernutrition lower in town with supermarkets, probably due to increased energy intake (Kimenju et al. 2015).

Urbanization drives nutrition transition in Kenya similarly to what Popkin (1993) argued. Kenyan urban women get smaller proportion of energy from carbohydrates but greater proportion from fat than rural women (Steyn et al. 2011). In addition, urban women had greater BMI, mean nutrition adequacy ratio, food variety score and dietary diversity score than their rural counterparts (Steyn et al. 2012). Despite this, intake of certain nutrients, such as calcium and iron, was higher in rural women than urban. Moreover, higher SES was negatively associated with dietary diversity and nutritional adequacy. Another study on urban women found similarly the consumption of protein, cholesterol and alcohol to be higher but the consumption of fibre and carbohydrates lower in urban than rural population (Mbochi et al. 2012). Additionally, rural-to-urban migrants have been found to consume less staples and legumes and more animal products, fruits and vegetables than rural-non-migrants (Peters et al. 2019). Also, migrants consumed less legumes but more vegetables and fruits than urban non-migrants. Studies conducted on children and urban men are still mostly lacking, but these studies on women support the notion of nutrition transition in Kenya.

Similarly, the Kenyan rural-dwelling population was found to have high level of physical activity. In a study by Sayre et al. (2019) Pokot pastoralists achieved on average almost 100 minutes of moderate-to-vigorous physical activity (MVPA) per day. Even though the amount of activity declined by age, older participants still engaged in over 50 minutes of MVPA per day. A study by Groot and Muthuri (2017) also found that urban slum-dwellers had higher physical activity than the national estimates. For this population, physical activity mostly consisted of work and transportation activity and only low levels of leisure time activity, which supports the finding on studies in other LIMCs. Interestingly, the proportion of total physical activity on work, transportation and recreation was the same for urban slum-dwellers as for national estimate even though the total amount of activity differed.

There seems to be more studies conducted for Kenyan children than adults in relation to physical activity. In one study, rural children and adolescents were highly physically active, achieving an average physical activity level of 2.3 (Olijambo et al. 2013). Then again in a study conducted in Nairobi, only 12% of children were found to meet the recommendation of over 60 minutes of MVPA and mean daily time spent on MVPA was 36 minutes (Muthuri et al. 2014 b). In addition, higher SES was associated with lower levels of physical activity. A comparison of physical activity in rural and urban children showed that rural children were more active and engaged significantly less in playing screen games (Onywera et al. 2012). Moreover, 77% of urban parents versus 34% of rural parents reported being more active during childhood than their children. Interestingly, comparing the physical fitness of rural and urban children and adolescents, Castillo et al. (2016) found that even though there were significant differences in body composition, and endurance performance, flexibility or overall strength did not differ between the urban and rural populations.

On the country level, Peltzer (2009) found in his study in four African countries that 36% of Kenyan adolescents were physically active at least 60 minutes on three days per week, almost 25% walked or biked to school daily and 56% sat less than three hours daily. Kenya's 2016 report card on physical activity for children and youth identified some problems related to inactivity (Onywera et al. 2016). Higher parental education; activity-inhibiting built environments; lack of organized sports; lack of appreciation for physical education at schools; and lack of governmental policies and investments that would allow easy access to recreational space for all members of society, were associated with inactivity. Some potential was found in access to active play, engagement in active transportation and relatively low amount of time spent on sedentary behaviour outside of school.

Signs of lifestyle transition can also be seen in the prevalence of obesity with great differences between rural and urban settings. The overall obesity has increased during the last 15 years, as shown in Figure 5. Supporting the previously explained hypothesis by Jaacks et al. (2019), in Kenya, which is still in the beginning of nutrition transition, the rise in obesity is seen for most part in women, although men are experiencing a slight increase as well. The WHO noted that the differentiation in the prevalence of obesity by SES has begun only 25 years ago (WHO b). Additionally, Steyn et al. (2011) found that urbanization along with high income were associated with obesity in Kenyan women. Figure 5 shows solely the prevalence of obesity, but the combined prevalence of obesity and overweight is even higher, reaching 30% in urban slums (Kimani-Murage

2015). In addition, there are differences in children: urban children were found to have greater body mass and higher body fat than rural children (Castillo et al. 2016). Kimani-Murage (2015) found that the prevalence of obesity and overweight was 9% in urban children while 46% of children were stunted. Underweight prevalence was 11% in children and 9% in adults. As stunting was highly prevalent in children with obese or overweight mothers, it is clear that the double burden of malnutrition in evident in poor urban settings at both household and population level.

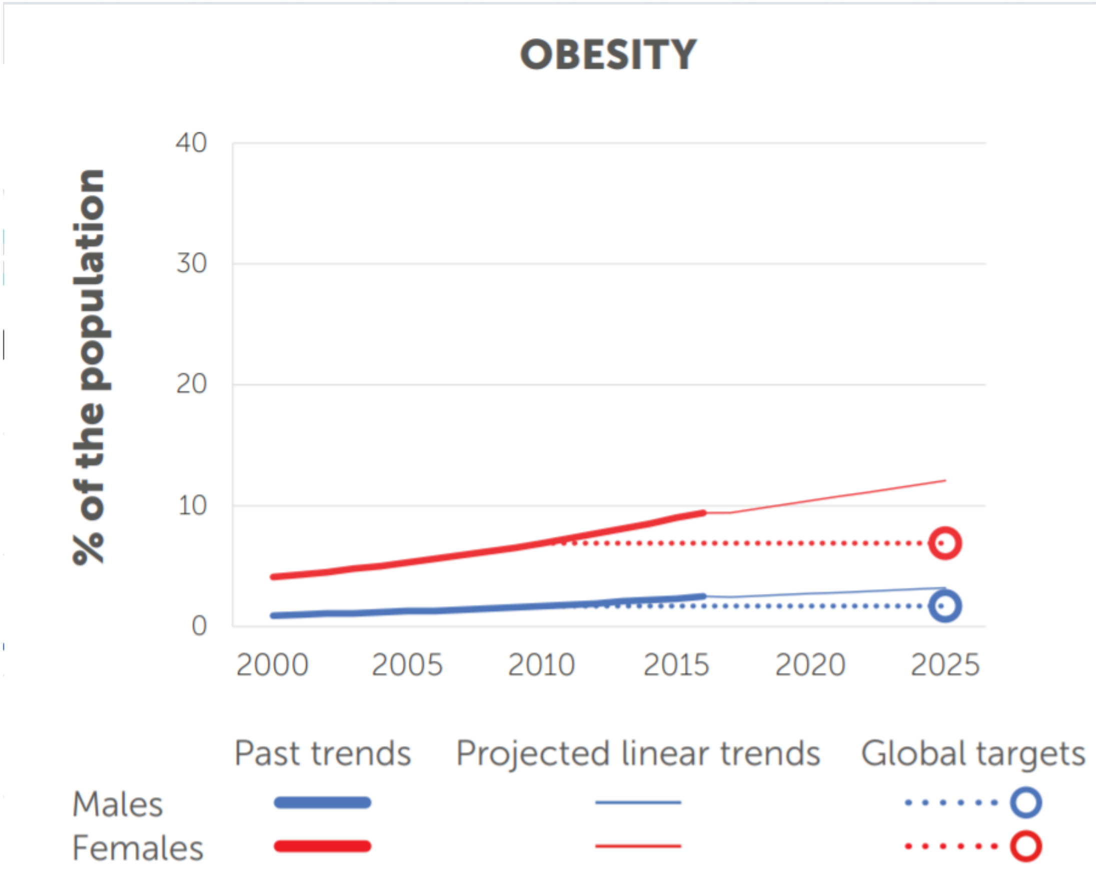

Figure 5. The prevalence of obesity in Kenya from 2000 to 2025 (WHO b).

The consequences of nutrition and physical activity transitions are not limited to obesity but are also evident in the prevalence of chronic diseases. While communicable, maternal, perinatal and nutritional conditions still account for majority of deaths in Kenya, non-communicable diseases are already the cause for 27% of all deaths (WHO b). Hypertension is observed in 20% of the whole population, but the prevalence can rise up to 50% in older populations, with higher mean blood pressure measured in urban than rural population (WHO b, Mathenge et al. 2010). Whereas majority of the population has normal blood cholesterol, around 20% had high cholesterol in both rural and urban settings (Mathenge et al. 2010). In addition, in a study by Christensen et al. (2009), the prevalence of diabetes was 12% in urban population and 2% in rural population. The overall prevalence was over 4%, which is in line with the prevalence estimated by WHO (Christensen et al. 2009, WHO b). Yet, majority of hypertensive or diabetic persons seem to be unaware of their condition and an even smaller proportion is given treatment (Mathenge et al. 2010, Oti et al. 2013, Chege 2016).

2.4 Associations of diet and physical activity

Studies on the association of diet quality and physical activity have not yet been conducted very widely and a majority of them have been done in high-income countries. A positive association between these two factors seems to be found quite widely in healthy people. In Netherlands, inactive lifestyle was associated with unhealthy diet in the total population in both low and high-educated populations (Fransen et al. 2016). In Croatia, the group with the highest physical activity had also the best adherence to the Mediterranean diet (Zezelj et al. 2019). In Spanish university students, healthy diet was associated with physical activity. However, among those who were physically active the diet quality did not increase by the hours spent on physical activity, indicating that the association was not linear. In the US, Errisurz et al. (2019) studied foreign-born Latino women and found that in those without depressive symptoms meeting physical activity recommendations was associated with higher diet quality although interestingly, in those depressed physical activity and diet quality were inversely associated. Another study in US, looking at Cuban, Haitian and African Americans of whom approximately half were diabetic and half healthy found inverse association between diet quality and physical activity (Huffman et al. 2012). In addition to health factors, it is possible that SES is playing its part as ethnic minorities might more likely be of low SES.

Additionally, Graf et al. (2018) explored the association by using latent class analysis. They reported mixed results across countries in the Americas: in the US, the group with high physical activity was connected to lower diet quality, in Brazil with average diet quality, in Chile with lower diet quality, and in Mexico with better diet quality. In prediabetic Brazilians better diet quality was found in individuals who engaged in over 150 minutes of leisure-time physical activity a week (Monfort-Pires et al. 2014). Looking at the association from the food security point of view, higher physical activity seems to associate with lower dietary diversity although, not energy intake across areas in Nepal (Mathiassen et al. 2014). In Uganda, higher dietary diversity was associated with higher physical activity in urban areas and with both higher and lower physical activity in different rural parts (Mathiassen et al. 2014).

In children, studies on the association of diet quality and physical activity are similarly concentrated to few countries. A few of these were done in Spain: in adolescents, less time spent in sedentary behaviour and greater physical activity were associated with greater adherence to the Mediterranean diet and among 8-12-year olds high level of physical activity together with average level of physical fitness showed better dietary quality (Bibiloni et al. 2012, Grao-Cruces et al. 2012, Guillamon et al. 2017). In Greece, 8-17-year olds with sufficient dietary habits had increased odds of adequate physical activity levels by 38% and among 3-18-year olds greater time spent on sports activities predicted better diet quality (Yannakoulia et al. 2015, Tambalis et al. 2019). In the US, Cusatis et al. (1996) found a gender difference: increased physical exercise was associated with higher pyramid scores in females but not males. In Canadian adolescents physical activity levels increased by levels of dietary quality, from poor to average to superior (Storey et al. 2009).

Some cluster analyses have also been conducted in children. Like those conducted in adults, the results are less conclusive than those explained above. For example: Mayne et al. (2020) found cluster of excess screen time and poor diet quality as well as one with low physical activity and diet quality in 2-19 year old Americans; Sabbe et al. (2008) found clusters of sporty healthy eaters, sporty mixed eaters, moderately active healthy eaters, unsporting unhealthy eaters and sedentary healthy eaters in Belgian 10-year olds; and Cabanas-Sanchez et al. (2018) found clusters of highly active with average diet quality, sedentary with high diet quality and sedentary with low diet quality. Although some of the research in children show conclusive results, cluster analysis shows that in reality there are many different kinds of lifestyles and only some of them combine healthy or unhealthy behaviours. Often unhealthy and healthy behaviours are also observed side by side.

One of the few studies conducted in middle-income countries is a pilot study by McArthur et al. (2008), which explored the association in capitals of Argentina, Guatemala, Cuba, Peru, Panama and Chile. In girls, but not in boys, lower physical activity predicted lower dietary quality. Looking at the cities separately, only in Lima, Peru there was a statistically significant correlation between diet quality and physical activity. Additionally, in Brazilian pre-adolescents, higher dietary quality was associated with maximum of two hours of sedentary activities per day and at least 300 minutes of physical activity per week (Wendpap et al. 2014). Results in Latin America seem to be mixed while studies in other parts of the world are still mostly lacking, hence no understanding of the situation in Asia or Africa can be drawn. Still, it is possible that the variety of lifestyle behaviours presented in the same individuals is even larger in the LMICs than in the high-income countries.

3. Objectives

This study is a part of a larger research project named Kenya-Finland Education and Research Alliance (KENFIN-EDURA), which is a three-year project run by University of Helsinki, Kenyatta University and Haaga-Helia University of Applied Sciences and funded by the Ministry of Foreign Affairs of Finland. The aims of the project are:

1) To enhance the capacity of higher education institutions in societal development in nutrition and physical activity to prevent the rise of non-communicable diseases;
2) To enhance Kenyan research capacity in the field of healthy lifestyles;
3) To improve the quality of higher education and research environment;
4) To build an international team of researches with combined expertise required to address the complex nature of non-communicable diseases in Kenya.

This study aims to explore the association between diet and physical activity in Nairobian pre-adolescents aged 9 to 14 years residing in low-income suburb (Kayole) or a middle-income suburb (Langata) in Nairobi City County. More specifically, it aims to find out whether the healthy diet and sufficient physical activity go hand-in-hand in the target population.

The specific questions the study aims to answer are:

1) Do the adolescents that have a higher level of physical activity have a higher likelihood of a healthy dietary pattern than those with lower physical activity?
2) Do the adolescents that have a higher level of physical activity have larger dietary diversity than those with lower physical activity?
3) How do wealth index, area of residence, age, gender and BMI relate to the association of physical activity and diet?

The hypothesis is that in the middle-SES area, although more sedentary lifestyle and diets similar to those in high-income countries may be more common, healthy diet and physical activity are connected to health consciousness and thus they often are found within the same individuals. In the low-SES area, physical activity is expected to be more strongly associated with transportation and occupation, and diet with factors such as affordability, not health consciousness, hence resulting in physical activity and healthy diet being independent of each other.

Previous data on the association between diet and physical activity in LMICs is scarce and none of the earlier studies were conducted in Kenya. Only few of the earlier studies in LMICs have looked into the association between physical activity and diet pattern or dietary diversity. Information gathered on the whole study population, as well as the sub-populations, provide critical information needed to understand the phenomenon.

By answering the research questions, this study provides

1) more information on how lifestyle transitions occur in urban setting in lower-middle income country;
2) more information on the stage of lifestyle transitions in Kenya;
3) more understanding on the associations between physical activity and diet in pre-adolescents in this setting;
4) view on how to reduce the burden of NCD risk factors on children and adolescents in these settings.

4. Data and methods

4.2. Data collection

The data was collected from two sub-counties in Nairobi county: Kayole, which is characterized by low-SES, and Langata, which is characterized by middle-SES. Prior to the data collection 200 households were mapped with the support of health officers and community health volunteers from Langata Health Center and Kayole II Sub-county hospital. In addition to identifying the eligible households, the households were also introduced to the study and its objectives. The aim was to get 70 households in each area to participate but to account for losses during the study, 80 households were randomly chosen for the study in both areas.

The inclusion criteria was a household with a 9—14-year old child who has lived in either area for at least six months prior to the study and whose parents provided consent to participate in the study. If there was more than one pre-adolescent of this age in the household, the participant was drawn. Since after the data collection it was noticed that a few 8-year-old and 15-year-old pre-adolescents had been included, it was decided that all those over the age of 8.5 years and under 15 at the time of the data collection were included. The exclusion criteria were the documentation of chronic disease conditions with an impact on diet or any significant illnesses preventing participation. The study population consisted of 154 pre-adolescents residing in either of these two sub-counties. However, the full data on diet and physical activity was reported for only 104 pre-adolescents: 57 of them lived in Kayole and 47 in Langata.

To collect the data, groups of three field assistants together with the community health volunteers visited the households twice approximately 8 days apart from each other during spring 2019. These assistants were students at the departments of nutrition, sociology or physical education, exercise and sports science recruited by the co-investigators and each group included at least one nutritionist. The field assistants received one-week training and capacity building exercise to introduce them to the data collection and study protocol. Before the data collection, a pilot period was conducted in April. During the first visit, the guardian completed an informed consent form. This was followed by data collection by background information questionnaire, physical activity questionnaire, food frequency questionnaire (FFQ), 24-hour recall and anthropometric measurements. In addition, the participants received accelerometers. During the second visit, the accelerometers were collected, and a second 24-hour recall was conducted. The questionnaires were available in both English and Swahili. The field assistants collected the data by using a digital mobile data collection platform, Open Data Kit (ODK). The interviewers could clarify questions when needed.

To determine the SES of the respondent, a researcher-administered structured questionnaire, previously used and validated in Kenyan Demographic Health Survey, was used.

The dietary intake data was collected using a seven-day FFQ. This FFQ will be validated for pre-adolescents within the KENFIN-EDURA project using two 24h recalls as the criterion method. In the FFQ, for each food item the participant is asked to indicate how many times on average they consumed it on a frequency scale that ranges from “Never” to “>6 times per day”. In addition, using a picture booklet made within the KENFIN-EDURA project, portion sizes were specified but this information was not used in this study. The pre-adolescents answered the questions themselves but the guardians were able to help when needed. Upon checking the data, the frequencies that equalled or exceeded 21 were corrected based on the data collected with the 24h recall. However, this procedure excluded tea and water that were likely to be consumed three or more times per day. The dietary intake was analysed on Nutri Survey Software (DE) using the Kenyan food-composition database.

Physical activity was measured by Actigraph GT3X-plus accelerometer (ActiGraph, Pensacola, FL, US). The accelerometer, attached to a flexible belt was worn at waistline for 24h a day on at least eight consecutive days excluding bathing, showering or swimming time. It had a battery that lasts approximately 10 days and thus the participants did not have to charge it. Oral and written instructions to use were given with the accelerometer and the guardians were urged to remind the pre-adolescents to wear the accelerometer. At least four valid days including one weekend day (≥10 h/day of waking wear time) was required for the participant's data to be included in the analysis. For many participants this was not reached, which reduced the study population. Accelerometer measurements have been previously validated among Kenyan children (Barreira et al. 2015). The data was downloaded onto computer using ActiLife analysis software package (Actilife software version 6.13; ActiGraph, Pensacola, FL, US), reviewed for completeness and analysed using Kinesoft. Using an algorithm, nocturnal sleep episodes were removed from the data and non-wear periods were defined as any sequence of at least 20 consecutive minutes of zero activity counts. To assess the intensity of physical activity, the cut points of Evenson (Trost et al 2011) were used to define time spent on sedentary behaviour, light, moderate and vigorous physical activity. Moderate and vigorous activities were summed to obtain moderate-to-vigorous physical activity.

4.2 Statistical analysis

The wealth index was created based on World Food Programme Vulnerability Analysis and Mapping Guidance paper (WFP). Variables with multiple answer options were coded into binary variables, dividing them into improved and unimproved options. Next, the ownership frequencies were checked; the variables with ownership over 95% or less than 5% were excluded, as they do not effectively differentiate between the participants. Additionally, radio and cassette and CD players were removed from the analysis because it was not clear whether these were mostly owned by the wealthy or the poor in this population. The area of agricultural land could not be included in the index as it was not measured numerically. The correlations between variables were checked and drinking water variable and motorcycle were removed as their correlation with other variables was less than 0.1 and their factor loadings were below 0.3. In addition, wallpaper variable had lower factor loading (0.334) compared to others and thus it was removed. The final wealth index had Kaiser-Mayer-Olkin value of 0.871 and it explained 40.4% of the total variation. This index included reclassified sanitation, reclassified floor material, television, refrigerator, chair, cupboard, wall clock, microwave, DVD player, electric or gas stove, kerosene stove, bicycle and car or truck. The wealth index was then ranked into quintiles. The full list of variables used for creation of wealth index can be found in supplement 1.

The FFQ included 174 foods: however, 27 of these were used by none and thus excluded from the following analysis. The full list of foods included in each group are listed in supplement 2. In addition, nine foods that were used by only one participant were excluded from the patterns.

Similarly, intake frequencies of sugar, salt and water were found to be unreliably reported and thus excluded. This left 135 foods included altogether and dietary patterns were formed of 17 food groups: white cereals, wholegrain cereals, porridges, side dishes, root vegetables, legumes, nuts and seeds, fruits, dairy products, meat and eggs, fish and seafood, oil and margarine, spreads and sauces, sweets, savoury snacks, sodas and juices and fast food. Additionally, coffee and tea were included in the analysis as individual factors.

The dietary patterns were formed through principal component analysis with Varimax rotation. Eigenvalues were considered, the break in scree plot was examined and the interpretability of identified patterns were assessed. The correlations between the variables were altogether relatively low, which is why variables with low correlations were kept. Foods with factor loadings of >0.3 were considered for the interpretation and labelling of patterns. Forming four patterns resulted in one pattern with only four factor loadings over the value of 0.3 and additionally two of the patterns were not easily interpreted. Thus, patterns were restricted to three, which resulted in all the patterns having at least five factor loadings >0.3 and better interpreted patterns. This analysis had a coefficient of determination over 1.6 for all patterns and the percentage of total variance in food consumption explained was 36.4%. The Kaiser-Meyer-Olkin test value was 0.662, which is over the required 0.6. The factor loadings of each variable for each pattern can be found in supplement 3.

The dietary diversity score (DDS) was formed using 10 food groups: cereals and grain products, roots and tubers, legumes, nuts and seeds, vegetables, fruits, meat, poultry and organs, eggs, dairy products, fish and seafood and oils and fats. The full list of foods included in each food group are found in supplement 4. The food that were used by at least one person were included in the groups. As the idea of the DDS was to indicate micronutrient adequacy, rather than energy adequacy of the diet, unhealthy foods, such as sweets, sugar sweetened beverages, snacks and fast foods were excluded from the analysis. In addition, sauces, spreads, tea and coffee were excluded as they are often used in small quantities and/or do not greatly contribute to micronutrient adequacy. Water, salt and sugar were also excluded. This left 104 foods in the analysis. Composite dishes were allocated to a food group based on their main ingredient. Following the method by Bellows et al (2019), to be included in the score, the total sum of frequencies of consumption for a food group had to be one or more per day. Thus, in a 7-day record the food groups with frequency of seven or more were counted for each participant.

To explore the associations of diet and physical activity, linear regression analysis was conducted. Wealth index, area, gender, BMI z-score and age were identified as confounding factors with area and gender transformed into dummy variables. Correlations of explaining variables were considered and thus wealth index and area were not included in the same analysis due to the significant correlation between them (0.595, p = <0.001). All the analyses were conducted on SPSS Statistics 25 (IBM, US).

4.3. Ethical considerations

Ethical clearance was received from the Kenyatta University Ethics Review Committee and a research permit obtained from the National Commission for Science, Technology and Innovation. The participants and their guardians were given oral explanation as well as informed consent letter including the purpose of the study, the interviews to be done, the voluntary nature of participation, and the right to refuse to participate in any part of the study. Guardians signed the consent letter, or in the case of illiterate pre-adolescent or guardian, a fingerprint or a signature of a witness was accepted. All participants were asked to read out a short test sentence in English or in Swahili in order to test literacy and ability to read a whole sentence was defined as literacy. Only pseudonymized data was used in the analyses and the personal details are kept on a separate file secured with password. All data are stored in protected files on servers in locked rooms and behind firewalls at the Kenyatta University and University of Helsinki. The research data will not be released outside of the research team.

As a cross-sectional study, this research posed less burden to the participants, as comparison to longitudinal or intervention study. All dietary and background information was gathered through questionnaires divided to two different meeting times in the participants' homes. The visits were mostly scheduled for the evening, but in some cases the children came home from school earlier to attend the meetings, and thus missed out on lessons. Physical activity data was collected by accelerometer, that was not expected to burden the participants. No invasive procedures, such as blood sampling, were conducted. After the data was collected the participating households were given some household supplies, such as rice and oil, but in order to maintain the voluntary nature of the study, this was not informed of beforehand. After the study project is completed, the participants and their guardian will be informed of the results that apply to them. However, there are no other benefits of participating.

5. Results

Out of the 154 adolescents, full data on both diet and physical activity were reported for 104 participants. Forty-five of these were excluded due to inadequate accelerometer data while only five were excluded due to missing data on diet. While mean age, proportion of girls, mean BMI z-score, time spent on sedentary behaviour, mean DDS and adherence to Dairy and plant protein or Traditional Kenyan diet pattern did not differ greatly between the areas, there were significant disparities in mean wealth index, mean time spent on MVPA and adherence to Snacks, fast food and meat diet pattern (Table 2, p = <0.001 for all).

Table 2. Demographics of the participants.

	Langata (N=47)	Kayole (N=57)	p value
Mean age (years)	11.1 (1.6)	11.1 (1.4)	0.940
Gender (% girls)	51.1%	50.9%	0.985
Mean Wealth Index	0.881 (0.630)	-0.336 (0.957)	**<0.001****
Mean BMI z-score	1.76 (2.83)	0.68 (2.54)	0.086*
Mean time spent on MVPA (minutes/day)	61.2 (20.1)	79.7 (30.3)	**<0.001****
Mean time spent on SED (minutes/day)	615.9 (81.3)	601.0 (76.1)	0.338
Mean DDS	3.60 (1.65)	3.19 (1.26)	0.161
Dietary patterns			
Snacks, fast food and meat	0.298 (0.809)	-0.434 (0.775)	**<0.001****
Dairy and plant protein	0.152 (1.175)	-0.117 (0.954)	0.201
Traditional Kenyan	0.231 (1.145)	-0.097 (0.771)	0.085*

MVPA = Moderate to vigorous physical activity
SED = Sedentary behaviour
DDS = Dietary Diversity Score
* p<0.10
**p<0.05

5.1. Dietary pattern and physical activity

In the principal component analysis, three dietary patterns were found (Table 3). The first of these was characterized by many food groups often deemed unhealthy, such as snacks, fast food, sodas and juices and sweets but also fruits and was thus named the ‘Snacks, fast food and meat’ pattern.

The second pattern included many food groups often considered healthy such as legumes, seeds and nuts, dairy, roots and tubers, fish and seafood, wholegrain cereal products and fruits and was named the ‘Dairy and plant protein’ pattern. The third pattern, which was named the ‘Traditional Kenyan’ diet pattern, was less diverse than the other two, characterized by intake of vegetables, white cereal products, oils and tea.

Table 3. Food patterns identified through principal component analysis.

Dietary Pattern	Food groups associated with
Snacks, fast food and meat	Savoury snacks Fast food Meat and eggs Sodas and juices Spreads and sauces Sweets Coffee Fruits White cereal products
Dairy and plant protein	Meat and eggs Spreads and sauces Dairy products Legumes, seeds and nuts Roots and tubers Wholegrain cereal products Side dishes Fish and seafood Fruits Oils and margarines
Traditional Kenyan	Vegetables Tea White cereal products Oils and margarines

Time spent in MVPA explained 3.6% of variation in adherence to the Snacks, fast food and meat diet pattern reaching borderline statistical significance ($p = 0.053$, Table 4). Wealth index and area were associated with this diet pattern ($p = 0.001$ and $p = <0.001$, respectively) while other confounding factors were not. Models combining wealth index or area with time spent in MVPA remained significant ($p = 0.003$ and $p = <0.001$, respectively) however time spent in MVPA was not significant in these models. Combining time spent in MVPA and BMI z-score resulted in 4.8% of variation in adherence to the Snacks, fast food and meat pattern explained with statistical significance ($p = 0.033$). In this model, time spent in MVPA also proved statistically significant ($p = 0.041$). Time spent in MVPA combined with age or gender did not result in statistically significant model although the physical activity variable showed borderline significant, negative association with adherence to this diet pattern ($p =0.059$ and $p = 0.067$, respectively).

Sedentary behaviour alone explained 0.8% of variation (p = 0.370). Combining wealth index or area with time spent in sedentary behaviour resulted in statistical significance (p = 0.001 and p = <0.001, respectively) but time spent in sedentary behaviour did not prove to be significant. Considering sedentary behaviour together with BMI, age or gender did not prove to be significant either.

Table 4. Regression results for Snacks, fast food and meat dietary pattern.

	B coefficient (p value)	Constant	R-square	Model p value
Time spent in MVPA	-0.006	0.323	0.036	0.053*
Time spent in SED	-0.001	0.494	0.008	0.370
Wealth index	0.274	-0.162	0.105	**0.001****
Age	-0.053	0.486	0.008	0.362
Gender (female)	0.141	-0.175	0.007	0.410
Area (Kayole)	-0.732	0.298	0.178	**<0.001****
BMIz	0.052	0.174	0.026	0.106
Model 1.1				
MVPA	-0.002 (0.534)	-0.012	0.090	**0.003****
Wealth Index	0.251 **(0.005**)**			
Model 1.2				
Time spent in MVPA	-0.006 (0.059*)	0.843	0.024	0.110
Age	-0.048 (0.407)			
Model 1.3				
Time spent in MVPA	-0.006 (0.067*)	0.256	0.020	0.133
Gender (female)	0.095 (0.576)			
Model 1.4		0.403	0.164	**<0.001****
Time spent in MVPA	-0.002 (0.567)			
Area (Kayole)	-0.700 **(<0.001**)**			
Model 1.5				
Time spent in MVPA	-0.006 **(0.041**)**	0.272	0.048	**0.033****
BMI z-score	0.059 (0.067*)			
Model 2.1				
Time spent in SED	-0.002 (0.115)	0.842	0.109	**0.001****
Wealth Index	0.297 **(<0.001**)**			
Model 2.2				
Time spent in SED	-0.001 (0.463)	0.891	-0.006	0.505
Age	-0.045 (0.453)			
Model 2.3				
Time spent in SED	-0.001 (0.507)	0.447	-0.004	0.459
Gender (female)	0.149 (0.385)			
Model 2.4				
Time spent in SED	-0.001 (0.150)	-0.323	0.179	**<0.001****
Area (Kayole)	0.753 **(<0.001**)**			
Model 2.5				
Time spent in SED	-0.001 (0.463)	0.320	0.012	0.208
BMI z-score	0.050 (0.120)			

MVPA = moderate-to-vigorous physical activity
SED = sedentary behaviour
* p<0.10
**p<0.05

Time spent in MVPA explained 1.1% of variation in adherence to the Dairy and plant protein diet pattern with no statistical significance (Table 5). None of the confounding factors could alone explain the variation significantly nor could any of the combinations with time spent in MVPA analysed.

Time spent in sedentary behaviour explained 0.1% of the variation in adherence to Dairy and plant protein diet pattern without statistical significance. No combination of factors resulted in a significant explanation of variation.

Table 5. Regression results for Dairy and plant protein dietary pattern.

	B coefficient (p value)	Constant	R-square	Model p value
Time spent in MVPA	-0.004	0.293	0.011	0.288
Time spent in SED	0.000	-0.287	0.001	0.721
Wealth index	0.184	-0.035	0.031	0.073*
Age	-0.071	0.789	0.010	0.322
Gender (female)	0.273	-0.135	0.017	0.191
Area (Kayole)	-0.269	0.152	0.016	0.201
BMI z-score	-0.011	0.038	0.001	0.753
Model 1.1				
Time spent in MVPA	-0.001 (0.734)	0.070	0.013	0.190
Wealth Index	0.167 (0.139)			
Model 1.2				
Time spent in MVPA	-0.004 (0.310)	1.025	<0.001	0.366
Age	-0.067 (0.348)			
Model 1.3				
Time spent in MVPA	-0.003 (0.376)	0.121	0.005	0.288
Gender (female)	0.246 (0.244)			
Model 1.4				
Time spent in MVPA	-0.003 (0.501)	-0.119	0.001	0.352
Area (Kayole)	-0.219 (0.328)			
Model 1.5				
Time spent in MVPA	-0.003 (0.317)	0.200	-0.009	0.575
BMI z-score	-0.008 (0.829)			
Model 2.1				
Time spent in SED	<0.001 (0.963)	-0.072	0.012	0.201
Wealth Index	0.183 (0.080*)			
Model 2.2				
Time spent in SED	0.001 (0.577)	0.411	-0.007	0.526
Age	-0.078 (0.283)			
Model 2.3				
Time spent in SED	<0.001 (0.720)	-0.372	-0.002	0.409
Gender (female)	0.270 (0.199)			
Model 2.4				
Time spent in SED	<0.001 (0.720)	-0.045	-0.003	0.430
Area (Kayole)	-0.264 (0.213)			
Model 2.5				
Time spent in SED	0.001 (0.371)	-0.688	-0.011	0.637
BMI z-score	-0.009 (0.804)			

MVPA = moderate-to-vigorous physical activity
SED = sedentary behaviour
* p<0.10
**p<0.05

Time spent in MVPA explained 1.3% of the variation in adherence to the Traditional Kenyan diet pattern without statistical significance (Table 6). In addition, the confounding variables explained only little of the variation except for area, which contributed to 2.9% of the variation without reaching statistical significance. Combining time spent in MVPA with area resulted in 4.3% of variation explained with significance (p=0.041). In this model time spent in MVPA was weakly associated with the diet pattern but without reaching statistical significance (p = 0.065). Combining time spent in MVPA with gender, age or BMI z-score did not result in statistical significance.

Time spent on sedentary behaviour explained 2.9% of the variation in adherence to the Traditional Kenyan diet pattern but was not significant (p = 0.083). Considering time spent in sedentary behaviour and area resulted in the only significant model (p=0.035). However, in all five models, time spent in sedentary behaviour showed consistent although weak association with adherence to the Traditional Kenyan diet pattern although it did not reach significance (p value varying from 0.054 to 0.093).

Table 6. Regression results for Traditional Kenyan diet pattern.

	B coefficient (p value)	Constant	R-square	Model p value
Time spent in MVPA	0.004	-0.230	0.013	0.255
Time spent in SED	-0.002	1.332	0.029	0.083*
Wealth index	-0.039	0.059	0.002	0.680
Age	-0.014	0.202	0.000	0.835
Gender (female)	0.152	-0.026	0.006	0.426
Area (Kayole)	-0.328	0.231	0.029	0.085*
BMI z-score	-0.025	0.091	0.005	0.474
Model 1.1				
Time spent in MVPA	0.004 (0.289)	-0.241	-0.007	0.523
Wealth index	0.008 (0.939)			
Model 1.2				
Time spent in MVPA	0.004 (0.252)	-0.042	-0.006	0.506
Age	-0.017 (0.791)			
Model 1.3				
Time spent in MVPA	0.004 (0.205)	-0.360	0.003	0.326
Gender (female)	0.187 (0.331)			
Model 1.4				
Time spent in MVPA	0.007 (0.065*)	-0.178	0.043	**0.041****
Area (Kayole)	-0.452 **(0.024**)**			
Model 1.5				
Time spent in MVPA	0.004 (0.206)	-0.216	0.001	0.346
BMI z-score	-0.030 (0.402)			
Model 2.1				
Time spent in SED	-0.002 (0.093*)	1.320	0.010	0.222
Wealth index	-0.011 (0.910)			
Model 2.2				
Time spent in SED	-0.002 (0.085*)	1.258	0.010	0.221
Age	0.008 (0.900)			
Model 2.3				
Time spent in SED	-0.002 (0.076*)	1.279	0.018	0.150
Gender (female)	0.169 (0.372)			

Model 2.4		1.664	0.046	**0.035** **
Time spent in SED	-0.002 (0.054*)			
Area (Kayole)	-0.363 (0.055*)			
Model 2.5				
Time spent in SED	-0.002 (0.054*)	1.516	0.023	0.120
BMI z-score	-0.031 (0.386)			

MVPA = moderate-to-vigorous physical activity
SED = sedentary behaviour
* p<0.10
**p<0.05

5.2. Dietary diversity and physical activity

Dietary Diversity Score was generally low, mean score reaching 3.38 without significant difference between the areas (Table 2). Cereals and grains were used by almost all participants, but most used also oils and fats, vegetables and fruits (Figure 6). Legumes, nuts and seeds, dairy and meat, poultry and organs were used by 10-20% of adolescents. Roots and tubers, fish and seafood and eggs were used daily by only few. The consumption of food groups was relatively similar in both areas, especially in both ends of the usage frequency scale.

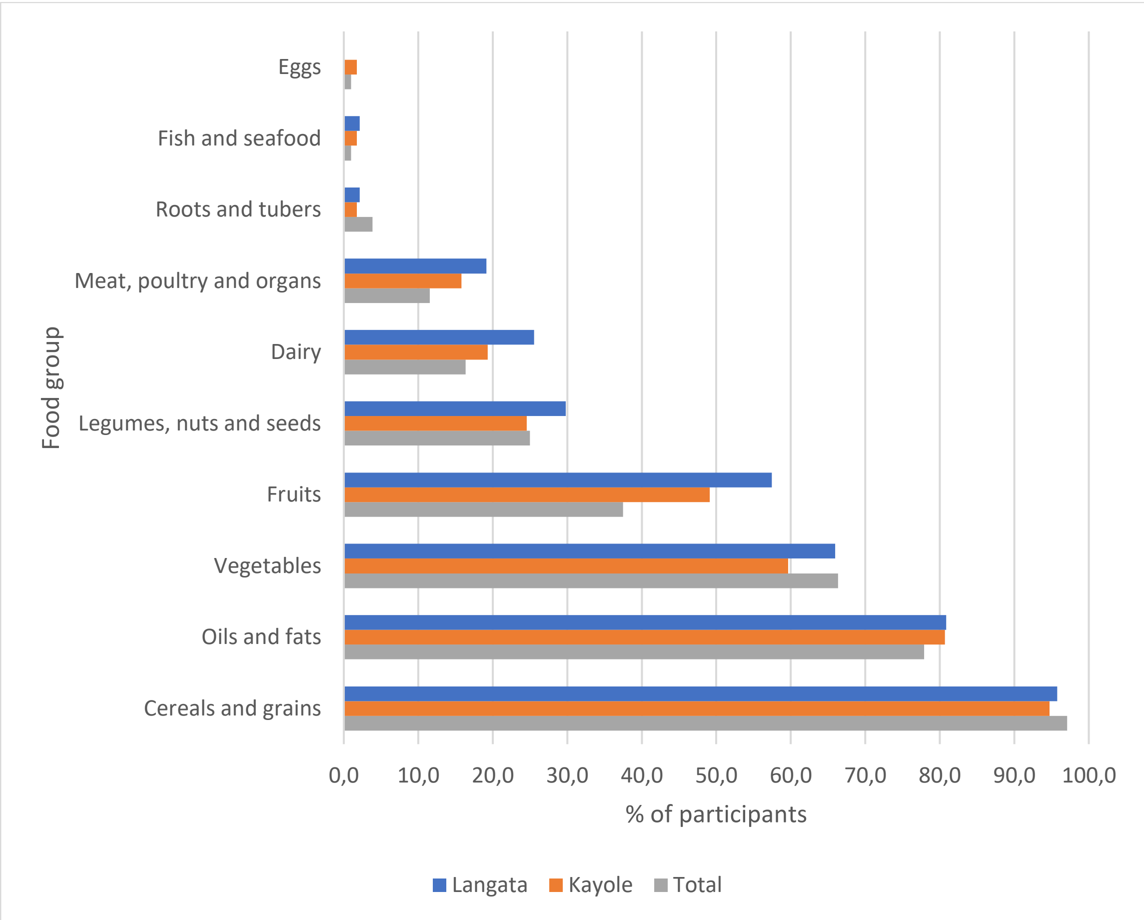

Figure 6. Consumption of food groups in Dietary Diversity Score by area.

Time spent in MVPA alone explained only 1.3% of the variation in DDS without significance (Table 7). Wealth index was the only confounding factor that alone proved to be statistically significant determining DDS. Considering time spent in MVPA in combination with wealth index, gender, age or area did not reach significance, also none of the models showed that time spent in MVPA could explain the variation in DDS significantly.

Time spent on sedentary behaviour explained only 0.9% of the variation in DDS in the regression analysis and no significance was reached. Combining time spent in sedentary behaviour with wealth index was the only model that resulted in significance (p = 0.027). However, in this model time spent in sedentary behaviour remained non-significant.

Table 7. Regression results for Dietary Diversity Score and other variables.

	B coefficient (p value)	Constant	R-square	Model p value
Time spent in MVPA	-0.006	3.806	0.013	0.246
Time spent in SED	-0.002	4.458	0.009	0.332
Wealth Index	0.319	3.307	0.050	**0.022****
Age	-0.140	4.934	0.020	0.149
Gender (female)	0.390	3.176	0.018	0.174
Area (Kayole)	-0.403	3.596	0.019	0.161
BMI z-score	-0.033	3.345	0.004	0.510
Model 1.1				
Time spent in MVPA	-0.001 (0.823)	3.400	0.032	0.073*
Wealth Index	0.304 **(0.049**)**			
Model 1.2				
Time spent in MVPA	-0.006 (0.273)	5.282	0.013	0.195
Age	-0.135 (0.165)			
Model 1.3				
Time spent in MVPA	-0.005 (0.329)	3.563	0.027	0.247
Gender (female)	0.349 (0.228)			
Model 1.4				
Time spent in MVPA	-0.004 (0.463)	3.843	0.024	0.287
Area (Kayole)	-0.328 (0.283)			
Model 1.5				
Time spent in MVPA	-0.005 (0.308)	3.696	-0.005	0.478
BMI z-score	-0.028 (0.577)			
Model 2.1				
Time spent in SED	-0.003 (0.155)	4.873	0.051	**0.027****
Wealth Index	0.353 **(0.012**)**			
Model 2.2				
Time spent in SED	-0.001 (0.478)	5.558	0.006	0.276
Age	-0.127 (0.202)			
Model 2.3				
Time spent in SED	-0.002 (0.296)	4.331	0.009	0.230
Gender (female)	0.405 (0.158)			
Model 2.4				
Time spent in SED	-0.002 (0.265)	4.845	0.012	0.202
Area (Kayole)	-0.433 (0.134)			
Model 2.5				
Time spent in SED	-0.001 (0.468)	4.112	-0.010	0.618

BMI z-score	-0.036 (0.478)

MVPA = moderate-to-vigorous physical activity
SED = sedentary behaviour
* p<0.10
**p<0.05

6. Discussion

Greater time spent in MVPA was associated with lower adherence to Snacks, fast food and meat dietary pattern alone and in combination with BMI z-score, age and gender, while no association of time spent in sedentary behaviour was found. Time spent in sedentary behaviour showed negative association to adherence to the traditional Kenyan diet pattern both alone and in combination with any confounding factor, although it did not reach statistical significance. No association of time spent in MVPA and Traditional Kenyan diet pattern was found. Neither time spent in sedentary behaviour nor time spent in MVPA could explain variation in adherence to the Dairy and plant protein pattern or the variation in DDS.

6.1. Comparison of the results

DDS formation did not follow any previous guidelines when it came to data collection, food grouping and scoring and thus no direct comparisons can be made. In addition, data on the dietary diversity in urban Kenya was not widely available, especially in adolescents. Our data found the dietary diversity to be low in both areas. Wagner et al (2019) found some signs of urban food deserts in Nairobi that could explain the low diversity in low-SES setting such as Kayole. Previously, Steyn et al. (2012) found SES to negatively associate with dietary diversity in urban women, which could explain the low DDS in Langata as well. Bellows et al (2019) who used the same scoring system found low dietary diversity as well but there are disparities in the populations as they studied rural Tanzanian women and in addition used longer, 30-day FFQ and different food grouping. It is possible that in the two areas low dietary diversity is driven by different factors.

The diet patterns found in this principal component analysis were Snacks, fast food and meat pattern, Dairy and plant protein pattern and Traditional Kenyan pattern. Previously ISCOLE research project identified two dietary patterns in 9-11-year-old Nairobians: unhealthy and healthy pattern (Mikkilä et al. 2015). These patterns do resemble the Snacks, fast food and meat, and Dairy and plant protein patterns, although there were few differences in, in example dairy product and fish consumption. The Snacks, fast food and meat pattern was more prevalent in Langata than Kayole, as was expected, since greater wealth index makes these products more accessible. Adherence to

Dairy and plant protein pattern did not differ between the areas significantly. The traditional Kenyan diet included vegetables, tea, white cereal products and oils and margarines – all products that are of relatively low price and vegetables for one are often seen as the food of the poor (Oniang'o et al. 2003). As such, it was expected to see greater adherence to this pattern in Kayole, but surprisingly it was Langata that showed greater adherence. This could be due to these food groups being consumed very widely in Kenya: for example, tea and ugali form the basis of Kenyan food culture (Noack & Pouw 2014).

In this study, Nairobian pre-adolescents spent daily on average 71 minutes in MVPA, which exceeds the WHO recommended 60 minutes. This is well in line with the results of ISCOLE research project that found 9-11-year-olds in Nairobi area engaged daily in 72 minutes of MVPA on average (Zakrzewski-Fruer et al. 2019). In Langata, average time in MVPA was statistically significantly lower than Kayole. This could be explained by greater access to motorized transportation and communication technology in Langata. Interestingly, this did not translate to significant differences in time spent in sedentary behaviour. An evident explanation is not known but considering light physical activity could have provided more understanding. In comparison to ISCOLE reporting that the average time spent in sedentary activities in 9—11-year old children in Nairobi was 495 minutes (Zakrzewski-Fruer et al. 2019), the present study found the average to reach 608 minutes. The present study included also older adolescents which could explain the difference in these results. It is possible that age and sedentary time are related in a way that did not come up in this study. Previously, physical activity has found to decrease by age in Nigeria whereas in Ghana, heavy physical activity was found to increase in transition from childhood to adolescence (Mogre et al. 2013, Oyeyemi et al. 2016).

Greater time spent in MVPA associating with lower adherence to a diet pattern that included many unhealthy foods is in line with many studies conducted in the high-income countries as well as some of those conducted in Latin America (McArthur et al 2008, Sabbe et al. 2008, Cabanas-Sanchez et al. 2018, Mayne et al 2020). Then again, many studies have also found greater time spent in MVPA to associate with diets including healthy foods (Storey et al. 2009, Bibiloni et al. 2012, Grao-Cruces et al. 2012, Wendpap et al 2014, Yannakoulia et al. 2015, Guillamon et al. 2017, Tambalis et al. 2019). This was not supported in present study as the Dairy and plant protein pattern was not associated with neither time spent in MVPA nor sedentary behaviour. Since this kind of research has not been conducted widely in the African context, it is an interesting finding. It is possible, that by time spent in MVPA linking only with the diet pattern with more unhealthy foods, the results point to the lack of direct connection of physical activity and healthiness of the diet. Instead, it might be that the area and wealth index, which were associated with Snacks, meat and fast food pattern and time spent in MVPA, explain both of these behaviours. This would mean that those living in Langata, with higher wealth index could afford both the more western-type diet and lower physical activity whereas those with lower wealth index and living in Kayole could not afford to buy for example fast foods and meat. Moreover, car ownership is rare in Kayole.

Moreover, the results on the association of physical activity with Traditional Kenyan diet pattern and DDS could support the conclusion on independence of healthiness of the diet and physical activity. Adherence to the Traditional Kenyan diet pattern was not significantly associated with time spent in MVPA, instead time spent in sedentary behaviour showed negative association, weak but consistent, with adherence to this diet pattern. This indicates that those who are less sedentary follow this less diverse diet pattern consisting of affordable foods. The lack of association with MVPA could be due to higher light physical activity instead, which was not accounted for in our study. Light physical activity can contribute to significant proportion of total physical activity (Oyeyemi et al. 2016, Muthuri et al. 2014b).

DDS formed to account especially for micronutrient adequacy associated only with wealth index, which too indicates that diverse diet is not available for all and the knowledge of nutrition may be lacking in the low-SES population. Still, it is interesting that no association with physical activity was found, especially since wealth index correlated also with reaching the recommended daily 60 minutes of MVPA (results not shown). Considering all the foods consumed could have changed the result. Previously, greater DDS was associated with both physical activity as well as physical inactivity in Belgian children and in Spanish university students no association was detected (Sabbe et al 2008, Moreo-Gomez et al 2012). In African context, Mathiassen et al. (2014) associated greater physical activity with less diverse diet: in their study those more active reached for greater energy intake at the expense of the diversity. Having to choose between energy and nutrient-dense options can be driving the food choices in the low-SES population in this study as well.

No significant sign of health thinking driving the food consumption and physical activity patterns can be concluded from these results. Previously, cluster of unhealthy diet and high screen time has been found in Nairobian pre-adolescents (Dumuid et al 2017). The results of this study support also the findings on the association of time spent in MVPA and Snacks, fast food and meat diet pattern as greater screen time is likely to reduce the physical activity. It is certain that in any setting, unhealthy and healthy lifestyle behaviours can cluster. Still, neither one of these studies show that reasons for healthy or unhealthy lifestyle choices stems from health thinking but possibly from the possibilities and challenges that the wealth and also the living environment provide in combination. For example, while wealth determines which food is affordable, the environment determines what is available (Darmon & Drewnowski 2008, Conklin et al 2019). There can be also differences in the safety of the environments and the distances between home and school as well as ownership of vehicles for transportation (Muthuri et al. 2016, Oyeyemi & Larouche 2018).

Interestingly, neither age nor gender was associated with any of the dietary variables alone or in combination with physical activity. Previously, Mayne et al. (2020) found that being older was associated with greater likelihood of clustering of unhealthy behaviours in American children and youth. Looking at the diet alone, Yannakoulia et al. (2015) found age to significantly associate with diet quality in Greeks whereas Wendpap et al. (2014) did not find this association in Brazilians. Whereas in high-income countries aging could give children and adolescents more possibilities to make their own lifestyle choices, it could be that in LMICs the guardians, the environment and the living conditions do not permit it the same way.

Previously, gender was not found to associate with the interaction of movement behaviours and dietary patterns across 12 countries in a study by Thivel et al. (2019). It is interesting that when looking at physical activity and diet separately in Kenya, gender was associated with physical activity levels but not with dietary pattern (Muthuri et al. 2014 b, Mikkilä et al. 2015). It seems like the diet evens out the differences in this analysis.

BMI z-score did not associate with diet. Previously, physical activity has been negatively associated with overweight and obesity (Chung et al. 2012, Hohensee & Nies 2012, Basterfield et al. 2014). However, while BMI can be quite easily connected to energy intake, association with diet quality seems to be less conclusive, which might explain the lack of association here (Elliot et al. 2011, Baxter et al. 2014, Hebestreit et al. 2014, Shan et al 2018, Kelishadi et al 2019, Thomson et al. 2020).

In general, the degree to which a single factor could explain the diet was small. Especially true this was for physical activity variables which alone reached up to 3.6% of variation explained. It is not likely that a single factor could alone explain the complex nature of diet and food behaviour. Similarly, Zezelj et al. (2019) found relatively small explanation proportions in regression analysis, even when multiple factors were combined.

6.2. Strengths and limitations

One of the major limitations of this study was the relatively large drop-out in the study, which could have caused the lack of significant association. This is supported by the notion that many results were close to statistical significance, yet in many cases they were quite consistent. The final population of 104, as opposed to the 140 that were originally required, might not provide the statistical power needed. The original power analysis for the project was done from the FFQ validation point of view and thus it is unclear how many participants were needed for the analyses conducted in present study. For future studies in similar settings, more attention should be payed to accelerometer data collection. In this study, some participants only wore it part of the day. In addition, some participants or their environment, such as school or family members, also felt mistrust towards the accelerometer. Most of the time this was cleared through additional explanation of the study objectives and accelerometer use. Hence, more effort should be put into the instruction of use, ensuring that both guardians are aware of the study and information division also to the schools the participants attended.

The sample itself is not representative of all of Nairobi. Only two areas of the city were included, which can also be seen on the polarization of wealth index: majority of the participants scored closer to the ends of the range and only few to the middle of it. Hence the results found in our study cannot be generalized to the whole of Nairobi.

The use of FFQ as a base for DDS reduces the comparability of the results with other studies. In addition, no previously formed guidelines were followed on the selection of foods, allocation of food to the food groups or the scoring system. The consumption of certain products such as fish and seafood were rarely daily and thus different scoring systems for each food groups could have been needed (FAO 2015). Unhealthy foods, such as sweets, sugar sweetened beverages, snacks and fast foods were excluded from the analysis, which was likely to have an effect on the score. As Snacks, fast food and meat pattern was more commonly adhered to in Langata, this exclusion likely had greater effect on the scores there. While most studies that have based their DDS on FFQ also considered the minimum portions, present study did not look into the portion sizes, which could have affected the score as well. For the future, validity of FFQ as a base for DDS should be examined more closely.

Light physical activity was not considered in the analyses. For example, transportational and domestic physical activity could be few of the physical activity forms engaged in on light intensity. These domains of physical activity are likely to also differentiate by SES based on factors such as the access to motorized transportation and hence some differences might have been left undetected. Especially in a low-SES setting inclusion of light physical activity should be considered as well.

Lastly, this study includes multiple analyses conducted using various variables. Thus, the results found may be to some degree attributed to chance.

This study had multiple strengths as well. The sample included participants from two different areas that are characterized by different SES. This provides understanding on the lifestyle behaviour in a low and middle-income families. By assessing both wealth index and area, present study was able to account for both the wealth and the environment as both are important aspects in determining the diet and physical activity. Although interlinked, such comparison could be of value in future studies as well.

The FFQ used was very wide and thus more likely to capture the true consumption patterns. FFQ provided also a temporally longer view on the diets of the participants than the 24h recalls conducted, which makes it possible to estimate also the consumption of foods consumed irregularly. In addition, FFQ makes it possible to assess the habitual intake of foods, which reduces the day-to-day variation in data. Still, conducting also the 24h recalls, made it possible to correct the FFQ data based on it, which increased the value of the data on diet. When it comes to physical activity data, the objective measurement made it less sensitive to misreporting, although some problems in data collection was observed.

Lastly, in the analysis both diet and physical activity were considered using two different variables for each. This provided broader view on both behaviours: on the time spent both sedentary as well as higher intensity activities, and on the patterns as well as the diversity of the diet. Also the analyses were adjusted to many potential confounders. As research on the association of physical activity and diet is lacking in Africa and LMICs in general, present study provided a broad picture of the theme for future studies to continue.

7. Conclusions

In short, time spent in MVPA showed weak negative association with Snacks, fast food and meat pattern while time spent in sedentary behaviour showed weak negative association with Traditional Kenyan diet pattern. Dairy and plant protein pattern and Dietary Diversity Score were not associated with neither physical activity variable.

To answer the research questions:

1) Healthier dietary pattern was not associated with higher level of physical activity, although lower physical activity was weakly associated with the dietary pattern consisting of many unhealthy foods.

2) Physical activity was not associated with Dietary Diversity Score but interestingly, Traditional Kenyan, the less diverse, dietary pattern was weakly associated with less sedentary behaviour.

3) Wealth index and area of residence were stronger factors in determining the diet than physical activity variables and hence in many cases seemed to be the stronger driver of the results. Age, gender and BMI did not significantly associate with diet alone or in combination with physical activity variables.

More than health thinking behind these lifestyle behaviours, it is possible that environment and socio-economic position are driving the lifestyle choices of preadolescents in urban Kenya.

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SUPPLEMENT 1: Wealth index variables

Varible	Frequency of ownership (%)
Electricity 100%	100
Radio	75.6
Television	89.7
Mobile phone	97.4
Refrigerator	45.5
Solar panel	4.5
Table	95.5
Chair	87.8
Sofa	95.5
Bed	97.6
Cupboard	67.3
Wall clock	48.1
Microwave	34.6
DVD player	55.1
Cassette or CD player	34.6
Electric or gas stove	79.5
Kerosene stove	57.7
Motorcycle	8.3
Bicycle	32.4
Car or truck	23.7
Drinking water	88.5 (using improved)
Sanitation	58.3 (using improved)
Floor material	48.7 (using improved)
Wall material	90.4 (using improved)

SUPPLEMENT 2: Food groups used for the dietary pattern analysis

Food group	Foods
White cereal products	White bread Scones Bun bread White chapati Other cereals
Wholegrain cereal products	Brown bread Brown chapati Weetabix Wholegrain biscuit High-fibre biscuit
Porridges	Maize porridge Millet porridge Sorghum porridge Mixed porridge
Side dishes	White rice Brown rice Spaghetti and macaroni Noodles Maize ugali Millet ugali Mixed ugali Maize Mukimo (mashed potato and vegetables) Pilau (rice and onion) Biryiani (mostly rice, possibly also sources of protein) Rice, carrots and potatoes Rice and beans
Root vegetables	Pumpkin Plantain Irish potato Stewed plantain Sweet potato Cassava Arrowroot
Legumes, nuts and seeds	Beans Lentils Green grams Black beans Dried peas Green peas Nuts and seeds Githeri (beans with maize and vegetables)
Vegetables	Kales Spinach Traditional vegetables Cabbage Cucumber Eggplant Garlic Tomato

	Carrot Onion Salad vegetables Kachumbari (tomato and onion) Avokado
Fruits	Citrus fruits Paw paw Melon Mango Banana Passionfruit Treetomato Apple Thornmelon Pineapple Grapes Strawberries Dates Pear Guava Plum
Dairy products	Whole milk Lala Milk substitute Yoghurt Milkshake
Meat and eggs	Organ meat Offal Gizzards African sausage Beef Goat Mutton Chicken Pork Minced meat Eggs
Fish and seafood	Tilapia Nile perch Omena Fishballs
Oils and margarine	Sunflower oil Olive oil Other oil Vegetable cooking fat Margarine
Spreads and sauces	Sweet spreads Savoury spreads Ketchup Mayonnaise
Sweets	Low-sugar cookies High-sugar cookies Cookies Creamy biscuits Cakes Muffins

	Chocolate ball Ice cream Sugarcane Chocolates Candies Pancake Doughnut Wafer Mandazi Kdf
Savoury snacks	Popcorn Crisps Wow rings Bhajia
Sodas and juices	Carbonated cold drinks Diet cold drinks Fruit juices Sweetened fruit drinks Fresh juice
Fast food	Pizza Hot dog Hamburger Chips Sausages Deep-fried chicken Kebab Vegetable samosa Meat samosa Toasted ham sandwich

SUPPLEMENT 3: Factor loadings of dietary patterns

Food group	Snacks, fast food and meat	Dairy and plant protein	Traditional Kenyan
Savoury snacks	**,738**	-,039	,107
Fast food	**,725**	,094	-,209
Meat and eggs	**,657**	**,317**	,236
Sodas and juices	**,644**	,099	,018
Spreads and sauces	**,525**	**,344**	-,118
Sweets	**,510**	-,071	,085
Coffee	**,330**	-,051	-,258
Dairy products	,231	**,649**	-,256
Legumes, seeds and nuts	,048	**,593**	,199
Roots and tubers	-,133	**,572**	,084
Whole grain cereals and grains	,068	**,461**	,003
Side dishes	,018	**,430**	,104
Fish and seafood	,080	**,416**	-,363
Fruits	**,401**	**,408**	,165
Vegetables	-,036	,051	**,664**
Tea	,176	,032	**,542**
White cereals and grains	**,437**	,075	**,500**
Oils and margarine	,102	**,309**	**,424**
Porridges	-,110	-,005	,176

SUPPLEMENT 4: Food groups used for the dietary diversity score

Food group	Foods
Cereals and grain products	White bread Barrel bread Scones Bread bun White chapati Pumpkin chapati Other cereals Brown bread Brown chapati Weetabix Wholegrain biscuit High-fibre biscuit Maize porridge Millet porridge Sorghum porridge Mixed porridge Oat porridge White rice Brown rice Spaghetti and macaroni Noodles Maize ugali Millet ugali Mixed ugali Maize Pilau (rice and onion) Biryiani (mostly rice, possibly also sources of protein) Rice, carrots and potatoes Rice and beans
Roots and tubers	Pumpkin Plantain Irish potato Stewed plantain Sweet potato Cassava Arrowroot Butternut squash Mukimo (mashed potato and vegetables)
Legumes, nut and seeds	Beans Lentils Green grams Black beans Dried peas Green peas Nuts and seeds Githeri (beans with maize and vegetables)
Vegetables	Kales Spinach Traditional vegetables Cabbage Cucumber

	Eggplant Garlic Tomato Carrot Onion Salad vegetables French beans Kachumbari (tomato and onion) Avokado
Fruits	Citrus fruits Paw paw Melon Mango Banana Passionfruit Treetomato Apple Thornmelon Pineapple Grapes Strawberries Dates Pear Guava Plum Fresh juice
Eggs	Eggs
Meat, poultry and organs	Organ meat Offal Gizzards African sausage Beef Goat Mutton Chicken Pork Minced meat
Fish and seafood	Tilapia Nile perch Omena Fish balls Other fish
Dairy products	Whole milk Lala Milk substitute Yoghurt Milkshake
Oils and fats	Sunflower oil Olive oil Other oil Vegetable cooking fat Margarine Butter