Rural transformation and malnutrition: Three essays on the influence of time use, physical activity, and diet on nutritional outcomes

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Declaration of original authorship

I confirm that this is my own work, and the use of all the material from other sources has been properly and fully acknowledged.

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Dedication

For Adedayo

Abstract

Rural areas of low- and middle-income countries are experiencing growth in labour productivity and rural incomes, but these have not translated into proportional improvements in nutritional outcomes. Instead, the incidence of undernutrition has fluctuated over time, while overweight and obesity are rapidly increasing. The persistence of malnutrition in the face of rural and agricultural transformation require investigating the hypothesized nutrition factors beyond the issues of income and productivity. Taking the agriculture-nutrition approach forward, this research adopts the rural transformation framework to study the influence of time use, physical activity, and diet composition on nutritional outcomes. First, this research identified pathways linking the rural transformation processes with nutritional outcomes. Three of these linkages, framed independently into research questions, were investigated in three empirical chapters of this thesis.

The first research question presented evidence on couple interdependencies in time use and nutritional outcomes. The empirical analysis adopts the Actor-Partner Interdependence Model (APIM) to examine own and partner effects of time use on nutritional outcomes. Results indicates that there are large differences in the time allocation patterns between spouses in a household – and the time allocation patterns of the spousal partners have an effect on an individual’s nutritional outcomes; larger allocation of time to economic activities by the male spouse reduces the energy intake adequacy of the female spouse. Larger allocation of time to domestic activities by the female spouse reduces the energy intake adequacy of the male spouse. The results suggest that reducing the gender differences in the allocation of time could improve nutritional outcomes for male and female spouses.

The second research question empirically assessed the change in energy expenditure if participation in agricultural activities increases. The hypothesis here is that, as agricultural time use increases, the nature of the change to wellbeing will depend on the energy demands of the

activity that agriculture is substituting in rural livelihoods. Using compositional data analysis methods and a novel datasets that combines information on individual's 24-hour time use, physical activity energy expenditure, and socio-demographic characteristics, this chapter provides empirical evidence on the change in human energy expenditure resulting from time trade-offs to agriculture. The notion that more energy is required when more agricultural work – relative to other work-related time use – is performed is not supported by the results, as other time use domains in rural livelihoods are equally energy-intensive, and the effects of time use on well-being are not peculiar to agriculture. The results imply that the negative well-being consequences that may derive from the feminization of agriculture are not likely from increased energy burdens. The findings provide a justification to focus on women's time allocation instead of energy expenditure in understanding the agriculture-gender-nutrition pathways.

Along with declining physical activity levels, nutrition transition in low and middle income countries is characterized by rising per-capita calorie consumption buoyed by the rapid displacement of traditional foods by ultra-processed foods. The third research question assessed physical activity, time use and diet composition in relation to nutritional outcomes for adolescents in Telangana State in India as well as in Dhading and Nawalparasi districts in Nepal. Quantile regression in compositional data analysis methods were used to assess the relationship between nutritional outcomes and the composition of daily time allocated to sedentary, light, moderate and vigorous activity. In addition, the relationship of nutritional outcomes with the composition of diet involving ultra-processed and non-ultra-processed foods were assessed. The situation that adolescents in low- and middle-income countries are facing is that of increasing sedentary lifestyles through technology and improved infrastructures. Although these are avenues where physical activity is reducing, the data shows that there is still substantial physical labour under which adolescents continue to perform. The substitution of non-ultra-processed food by ultra-processed food improves nutritional (calorie) outcomes but likely presents a burden of unhealthy diets. That the influence of physical activity and diets varies across the spectrum of nutrition status implies that addressing all forms of malnutrition among rural adolescents will require different kinds of interventions – some targeted at the lower ends of the nutrition status and a different set for the upper end of the nutrition status.

This research concludes by summarizing the role of time use, physical activity and diet on nutritional outcomes in rural livelihoods. The implications of the research findings and the suggestions for addressing malnutrition based on the identified rural transformation-nutrition pathways were discussed.

Chapter 1: Introduction

The introduction chapter is divided into six sections. The first section discusses the problem of malnutrition in the context of the rural transformation processes, which is followed by relevance of the research, the research objective and questions, a brief introduction of the study areas, the description of data used in the research, and the chapter closes by explaining the structure of the research.

1.1 Malnutrition in the context of the rural transformation processes

Rural transformation processes are expected to reduce poverty and undernourishment in rural livelihoods[1](W. A. Lewis, 1954; Timmer, 1988). However, many low and middle-income countries (LMICs) have been witnessing a non-uniform pattern of rural transformation within localities and regions (IFAD, 2016): labour productivity, rural incomes and per capita dietary energy intake are increasing, but these may not translate into proportional improvements in individual nutritional outcomes (Gillespie et al., 2012; Masters et al., 2018). Indeed, the rates of poverty, food insecurity and malnutrition have fluctuated over time[2]. According to report published by FAO, IFAD, UNICEF, WFP & WHO (2022), the progress made over the last decades on reducing the number of people affected by undernutrition has stalled since 2018. Approximately 800 million people are currently facing hunger globally. These individuals are more likely to be in Africa and Asia, living in rural areas and be female. The United Nation's Food and Agricultural Organization (FAO) data[3] indicates that 16.9 per cent of the Southern Asia population are undernourished[4] in 2021, which is the same level recorded for the region

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[1] Rural transformation can be defined as rural and agricultural development characterized by the increase in per capital agricultural labour productivity, which is accompanied by the exit of labour from agriculture to other sectors of the economy. Rural transformation causes changes in the social, economic, and demographic attributes of rural areas (N. Rao & Nair, 2003).

[2] https://data.worldbank.org/indicator/NV.AGR.EMPL.KD?locations=XO-NP-IN accessed on 24.02.2023.

[3] https://www.fao.org/faostat/en/#data/FS/visualize. Accessed on 06.03.2023. It is noteworthy that the reversal in the trend of undernourishment started prior to the COVID-19 global health pandemic, and apparently precedes the war in Ukraine, which started in February 2022. Both crises have heightened global food insecurity, and malnutrition (FAO, IFAD, UNICEF, WFP and WHO, 2022).

[4] Undernourishment is defined as the "inability of an individual to acquire enough food to meet the daily minimum dietary energy requirements".

in 2007. Equally in sub-Saharan Africa, undernourishment incidence is at 22.9 per cent in 2021 – similar to the rate recorded for the region in 2007. Such an outlook implies the obliteration of fourteen years of steady improvement in malnutrition. Concurrently, overweight and obesity incidences are increasing, as diets shifts toward the consumption of ultra-processed foods[5], and lifestyles reflects less physically demanding activities in many LMICs (Popkin et al., 2020; WHO, 2017). The spread of the "double burden of malnutrition" with rural transformation processes suggests that factors beyond income and productivity growth influences nutritional outcomes.

The threat of widespread malnutrition to health, poverty reduction and development is substantial and has long been recognized. Among all forms of malnutrition, undernutrition is more prevalent in resource-constrained contexts – disproportionately affecting poor people relative to the rest of the population (The World Bank, 2006). The consequences of undernutrition are diminished cognitive functions (Nyaradi et al., 2013), increased susceptibility to ill-health and death, lower productivity and poor human capital outcomes (Adair et al., 2013; M. M. Black, 2003). For instance, the costs of undernutrition to productivity and income is estimated at 0.8 - 2.5 per cent of the Gross Domestic Product in India (A. J. Stein & Qaim, 2007). Increases in overweight and obesity is associated with higher incidence of the non-communicable diseases and death, healthcare costs increases, and productivity decreases (The GBD 2015 Obesity Collaborators, 2017).

Eradicating malnutrition is necessary for development, and will require multi-pronged approaches (Hawkes et al., 2020), which are based on understanding of the extensive factors influencing nutritional outcomes in rural areas.

[5] Ultra-processed foods have high fats, sugars, low fibre and nutrient content, and are increasingly of public health concern.

1.2 Research relevance

Relevant to the development objectives of ending hunger and all forms of malnutrition[6], prior research have extensively explored the links between agricultural development and nutritional outcomes through income and productivity growth (Bhagowalia et al., 2012; Headey et al., 2011; Sibhatu & Qaim, 2018). Kadiyala et al., (2014) described equally important agriculture-nutrition pathways operating through the patterns of time use and energy expenditure, but empirical evidence on the later is limited (Stevano et al., 2019). Especially in resource limited contexts, understanding the time use and physical activity energy expenditure pathway is important because it may explain why rural transformation and agricultural development have not always translated into better nutritional outcomes.

For interventions aiming to address malnutrition, changes in time use and dietary intake can be hypothesized proximate determinants of the double burden of malnutrition (Popkin, 1993; Popkin et al., 2012). But research evidence on this important topic seems to have focused mainly on diets (Ruel et al., 2018). The potential to eradicate all forms of malnutrition is unlikely to depend on diets alone, but the other key factors such as time use, and physical activity are still understudied in this regard. The consequence of this knowledge gap is that agricultural and development interventions aiming at the enhancement, diversification and substitution of livelihoods means – to improve nutritional outcomes can be confounded by time poverty, time inequality, time trade-offs and the inherent additional labour requirements (D. Johnston et al., 2018). Notably, female economic empowerment is recognized as essential to reduce poverty, achieve gender equality, and thus improve household nutrition but economic empowerment may engender time and activity-related energy burdens (Quisumbing et al., 2021). This trade-off is acknowledged in the development literature, however, disentangling such trade-offs from the benefits of interventions remain a key issue.

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[6] The United Nation's Sustainable Development Goals https://sdgs.un.org/goals/goal2

Further, rural transformation through changes in the agri-food system[7] influences nutrition – causing desirable as well as negative outcomes (Masters et al., 2018; Webb & Block, 2012) [8]. This mixed outlook has led to debates about transforming the current agri-food systems (FAO et al., 2020). However, efforts to reduce the nutritional (and environmental) consequences of the prevailing agri-food systems often overlook trade-offs to the well-being and livelihoods of poor producer farmers, thereby failing to achieve its objectives (Davis et al., 2022).

This research proposes that knowledge of the patterns of time use, physical activity and diet, as well as how they relate to nutritional outcomes is necessary to address malnutrition in rural livelihoods. The underlying premise of this notion is that rural transformation – whether desirable or deleterious – changes households' organization of production and consumption, leading to changes in time use and dietary patterns, and consequently, nutritional outcomes. The finding of this research work will highlight the role of time use and physical activity in influencing the incidence of malnutrition in rapidly changing, resource-constrained contexts.

1.3 Research objective and questions

The over-arching aim of this research is to investigate the relationship between time use, physical activity and nutritional outcomes in the context of rural transformation. The objective is separated into three research questions on (1) interdependencies in intrahousehold time allocation and its association with nutritional outcomes (2) changing work patterns involving greater agricultural participation and its effects on energy expenditure and (3) changing lifestyles – diets and time allocation patterns – and its relationship with nutritional outcomes among adolescents. The research questions as well as their motivation are stated as follows:

[7] Agri-food system includes the production, processing, distribution, consumption and waste associated with food.
[8] In addition to the varied nutritional outcomes, many places are experiencing environmental damage and climate change as a result of primary agricultural production (Polly Eriksen, 2008).

1. How does time allocated to economic, domestic and leisure activities in a household relate to own and partner's nutritional outcomes?

To improve nutritional outcomes, recent debates have suggested that household production be shared between spouses, but the suggestions fail to highlight the mechanism and the nutritional outcomes of nudging men into such activities (Asadullah & Kambhampati, 2021; Madzorera & Fawzi, 2020; N. Rao & S. Raju, 2020). In the context of the ongoing rural transformation processes, leading to better employment opportunities for women outside the home, there is a knowledge gap in how spouses in rural agricultural households can adapt to the increasing opportunity cost of women's time in domestic activities as well as how women's increased work burdens can be managed to minimize adverse nutritional outcomes. Premised on the interdependence view of couples' behaviour – which suggests that couples share work, and they also share food, especially in rural agricultural contexts where production and consumption decisions are interwoven and are often made within the household, this chapter hypothesizes that the interdependencies in the time allocation of male and female spouses are consequential for nutritional outcomes.

2. What is the nature of the change to energy expenditure resulting from greater participation in agricultural activities?

Despite the drudgery associated with agriculture in rural livelihoods, greater agricultural participation in the context of rural transformation may not necessarily translate to negative nutritional and well-being outcomes if agriculture increases incomes and food availability and, if the activity that agriculture is substituting has an equal or higher energy requirements (Kadiyala et al., 2014). Therefore, increased agricultural participation can be beneficial or adversarial to well-being. This potential well-being trade-off requires research attention. Although the work intensity involved in performing agricultural activities is substantial, other time domains can place equally high energy demands – especially for poor women in rural livelihoods (Barrett & Browne, 1994; S. Rao et al., 2008). This argument forms the basis for the hypothesis in this chapter, that, as agricultural time use increases, the changes to well-being will depend on the type of activity (and its energy requirements) that agriculture is substituting in daily livelihoods.

3. How can physical activity, time use, and diet composition influence nutritional outcomes among rural adolescents?

Malnutrition is highly prevalent and lies in underweight than overweight among South Asian adolescents, but the transition to overweight and obesity can be swift (Bentham et al., 2017; Jaacks et al., 2015). The coexistence of nutrition extremes within a population require "double-duty actions" – interventions, which simultaneously address undernutrition- and overnutrition-related health problems. Yet, available information is insufficient to design double-duty actions for rural adolescents (Hawkes et al., 2020). The ongoing rural transformation is shifting the levels of physical activity towards less-intensive activity time use, while non-ultra-processed foods are being substituted by ultra-processed foods. Less physical activity levels may reduce energy requirements while ultra-processed foods are affordable, convenient, energy-dense foods that may contribute to reducing hunger in food insecure settings. But ultra-processed foods constitutes a departure from healthy diets.

1.4 Study areas – a brief introduction

The study areas are located in four (out of thirty-three) districts of Telangana State in India, namely: Adilabad, Khammam, Mahbubnagar and Jogulamba Gadwal districts, while the study sites in Nepal are in Dhading and Nawalparasi East districts (two of the seventy-seven districts in the country). In this section, a brief introduction to changes occurring at the country levels of the study areas is presented[9]. A more detailed district-level description of the study areas is presented in each independent chapter of the research.

India and Nepal are neighbouring countries in the South Asia region. Both countries are classified as lower middle-income countries by the World Bank based on their Gross National Income per capita ranging between USD1086 – 4255[10]. At the national level, India and Nepal have seen substantial increase in the average standard of living over time, as measured by their respective GDP per capita but poverty is still widespread in both countries. By sector, agriculture remains the largest employer of labour, followed by service and industry. The contribution of agriculture to the economy of the two countries is decreasing following the expansion of the industry and service sectors. Between the years 2000 and 2019, female agricultural employment declined from 74.39 to 54.69 per cent in India and 84.63 to 74.08 per cent in Nepal[11]. The persistently high female agricultural employment in relation to male agricultural employment in both countries attests to the ongoing feminization of agriculture trend being recorded in many regions of low and middle-income countries (FAO, 2011b). Total female labour force participation in India has declined over the years, while it has remain largely unchanged in Nepal. However, the Gender Inequality Index (GII)[12] shows a positive trend towards gender equality in both countries over the past two decades.

Undernutrition prevalence marked by thinness and shortness is high and still prevalent than overweight and obesity among adolescents in India; among boys, 32 per cent are thin, 23 per cent are short and 5 per cent are overweight/obese. Among girls, 23 per cent are thin, 29 per

[9] All the information presented in this section relied on longitudinal data sourced from the World Development Indicator database compiled by the World Bank. Available at https://databank.worldbank.org/source/world-development-indicators accessed on the 23.01.2023. Summary of the data is presented in Tables 1-4 in the Chapter 1 of the appendix section.

[10] The 2023 fiscal year classification is available at https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups accessed 25.01.2023. USD is United States Dollar.

[11] Male agricultural employment also declined from 54.56 to 39.56 in India and 66.37 to 52.11 over the same period but male exit from agriculture is seen to be greater than that of female.

[12] The GII is a composite index capturing gender equality using country level information on reproductive health, empowerment, and labour market participation. The lower the GII, the better the gender equality between males and females.

cent are short and 5 per cent are overweight/obese (Sethi V. et al., 2019). Among adults aged 15 – 49 years, underweight is 18.7 per cent for females and 16.2 per cent for males in India (Ministry of Health and Family Welfare; Government of India, 2021), while it stands at 17 per cent for both females and males in Nepal (Ministry of Health Nepal, 2017). The government reports also shows that overweight and obesity stands at 24 per cent among women and 22.9 per cent among males in India, and 22 per cent among women and 17 per cent among men respectively in Nepal (Ministry of Health Nepal, 2017). The figures shows that whilst undernutrition continue to be a challenge, overweight incidence is increasing in both countries[13].

1.5 Data

Three datasets were used to answer the three research questions of this research. Essentially, all the datasets were composed of information on socio-demographic characteristics- individual and household, anthropometric measurements, health status, 24-hour individual daily time use with a 24-hour recall period (Alkire et al., 2013), individual level daily food intake with a 24 hour recall period (Gibson & Ferguson, 2008) and physical activity data collected through body worn accelerometer devices (Zanello et al., 2019).

To answer the first research question, secondary datasets collected for the project "New keys for old black boxes: developing methods to improve nutrition assessment by measuring energy expenditure" published in Zanello et al., (2020) were used. The datasets were collected between June – December 2018. These datasets contain information collected from two household heads – one male and female in twenty households in Jogulamba Gadwal district in Telangana State in India. The data consists of information about individual anthropometrics, accelerometer-based physical activity data, household socio-demographic characteristics, employment and

[13] Underweight reduced from 22.9 per cent and 20.2 per cent in 2015-2021 to 18.7 per cent and 16.2 per cent among females and males respectively. Meanwhile, overweight/obesity increased from 20.6 per cent and 18.9 per cent in 2015-2021 to 24 per cent and 22.9 per cent in 2019 among females and males respectively in India.

labour force activities, asset ownership, food intake and daily time use (awake period only) with a 24-hour recall.

The second research question relied on secondary datasets collected for the University of Reading GCRF Substantial Response Project. The datasets were collected between August 2019 – August 2020. Similar to the first, the datasets contained information collected from one male and female heads in thirty-two households in Adilabad district in Telangana State India. The datasets contain information about household and individual socio-demographic characteristics, anthropometric information, accelerometer-based physical activity data, food intake and full 24-hour daily time use data with 24-hour recall.

The third research question relied on secondary datasets collected among adolescents for the University of Reading GCRF Project titled "Breaking the intergenerational cycle of malnutrition, food security and poverty in low and middle income- countries – making the case of adolescent boys and girls". Data collection was carried out between October 2019 – March 2020 among 407 male and female 10 – 19 year olds in Khammam and Mahbubnagar districts in India and among 360 male and female adolescents in Dhading and Nawalparasi districts in Nepal. The data contains anthropometric information of weight and height, accelerometer-based physical activity, individual and household socio-demographic characteristics information, food consumption with a 24-hour recall, and time use data with a 24-hour recall.

1.6 Research structure

The remainder of the research is structured as follows: the background of the study in Chapter 2 contains three sections discussing (1) the pathways of influence between rural transformation and nutrition, (2) the review of the literature on time and physical activity changes in rural India and Nepal, and (3) the conceptual framework for the research. Each one of chapters 3 to chapter 5 focuses on answering one research question and can be read on their own. Chapter 3 addresses research question 1 by assessing interdependencies in intra-couple time allocation and its relationship with nutritional outcomes. Chapter 4 addresses research question 2 by investigating the effects of greater participation in agriculture and the changes to energy requirements. Chapter 5 addresses research question 3 by examining the association of time use and diet patterns on nutritional outcomes among adolescents. The summary of the research, the implications of findings for policy, study limitations, suggestions for further research, and conclusions of research were discussed in Chapter 6. References and the appendices sections completes the research.

Chapter 2: Research background

2.1 Pathways of influence between rural transformation and nutrition

In rural agricultural settings, the factors that affect nutritional outcomes are multi-dimensional and interconnected. The agriculture-nutrition literature highlights six potential pathways through which agriculture affects nutrition, namely: (1) consumption of food produced on the farm, (2) income from agriculture used to purchase food items, (3) food prices and agricultural policies, (4) women's income and their intrahousehold economic position, (5) women's time use and, (6) women's energy expenditure (Gillespie et al., 2012; Kadiyala et al., 2014). However, agriculture does not only contribute to the rural transformation processes, it is also affected by rural transformation (B. F. Johnston & Mellor, 1961). This relationship implies that structural changes in the rural economy are expected to alter the pathways through which agriculture affects nutrition. Hence, the agriculture-nutrition linkages may not capture all the processes leading to the shifts affecting nutrition. We identified four overlapping pathways through which rural transformation may effect changes in nutritional outcomes among rural households. These pathways are discussed hereafter.

2.1.1 Income and per capita agricultural labour productivity growth: Widespread adoption of farm machinery and crop technologies increases farm productivity, reduce food prices and make food more accessible to the rural poor (Hazell et al., 2007; B. F. Johnston & Mellor, 1961). Rural transformation spurred by increased agricultural productivity, for instance, the green revolution (Prabhu Pingali, 2012), the subsequent increase in public expenditures on social safety nets and subsidies (Breitkreuz et al., 2017; Drèze & Khera, 2017), foreign direct investments in agriculture, and income from personal remittances can contribute significantly to reducing poverty and consequently, improving nutrition (Prabhu Pingali, 2012; The World Bank, 2008). However, even as agricultural productivity growth offers a path out of poverty, majority of smallholder farmers do not have enough productivity growth due to lack of capital, and they also lack the know how to participate in the rapidly changing food systems (Davis et al., 2022). Income and agricultural productivity growth may thus coexist with poverty and food insecurity (FAO, 2013). The effects of these challenges on nutrition can be exacerbated by environmental degradation and the effects of climate change (Polly Eriksen, 2008).

2.1.2 Changes in the nature and pattern of work: Even as rising incomes is the most obvious outcome of economic development; the changing nature of work is an important element of rural transformation. Depending on scale, labour-reducing technologies has long been seen as a pathway towards equitable rural development (D. Lewis et al., 2022). But rural livelihoods are still labour intensive in many LMICs. Mechanization in rural areas can impact work patterns by reducing the time required to complete certain tasks, displace labour from agriculture, and increase time spent in agricultural activities following farming extensification (Afridi et al., 2022). The resulting nutritional outcomes can be beneficial (Daum et al., 2019b) or deleterious if, for instance, the mechanization of land clearing and planting activities increases workloads in harvesting. The negative nutritional effects may be adversarial for females who are primarily responsible for harvesting (Komatsu et al., 2019).

In particular, rural transformation processes having unequal gender outcomes tend to reinforce gender-differentiated work patterns especially in places where social norms are firmly biased against females (Kawarazuka et al., 2022). Distress-led agriculture and pull factors such as better wages and employment opportunities in the other sectors of the economy can encourage male out-migration from agriculture and from rural areas (Paris et al., 2005). Out-migration of males can have negative long-term effects on food security through labour shortages during peak agricultural seasons and unemployment during the other periods of the year (Craven & Gartaula, 2015; de Janvry et al., 2022). Beside male out-migration, agricultural technological improvements seems to have targeted male-dominated tasks (Padmaja et al., 2019). The result is women’s higher agricultural work burdens that can negatively impact women’s own health and nutrition (Lei & Desai, 2021). Whether as an outcome of economic growth or economic distress, the ensuing "feminization of agriculture" impacts women's wellbeing through time use changes (Katz, 1994; Lastarria-Cornhiel, 2006; Mu & van de Walle, 2011). For instance, increasing economic opportunities increases women's incomes and socio-economic status. However trade-offs to nutritional outcomes could arise from a decline in the time and attention that women are able to allocate to self-care, childcare, and sleep (Quisumbing et al., 2021). A more direct effect can be transmitted through the physical activity dimension of time use, where energy expenditure is greater than energy intake and the demands of subsistence places physical burdens on men and women (Jackson & Palmer-Jones, 1998; Srinivasan et al., 2020). The impact of work intensity on nutritional outcomes can be intensified by the seasonal nature of agricultural work (Picchioni et al., 2020).

2.1.3 Changes in intrahousehold dynamics: Even in rural areas, social norms that are biased against females are gradually changing through the influence of media, role models, technological change, policies, and programs improving the status of women (Afridi et al., 2016; Chattopadhyay & Duflo, 2004; Kipchumba et al., 2021). As a result of these changes, women and girls are getting education and are increasingly employed outside the home. In agricultural livelihoods, this could take the form of women shifting from producing food crops into growing commercial crops and actively participating in the agricultural value chain beyond the farm (Agarwal, 2018; Katz, 1994; Lastarria-Cornhiel, 2006). Increasing economic labour participation of women can lead to changes in intrahousehold dynamics such as males performing more household tasks (Abdelali-Martini & Pryck, 2015; Newman, 2002). Despite this progress, significant gender gap exists with regard to women's access and ownership of productive resources, gender wage gaps and higher female poverty rates persists (C. Doss et al., 2021). More income in the hands of women and being able to exercise control over such incomes have been shown in some studies to have positive effects on household nutrition

(Bisgrove & Popkin, 1996; Quisumbing & Maluccio, 2003). The benefits of female empowerment extends beyond nutrition, it contributes to economic development in places where development relies on the quality of the human capital stock (Doepke & Tertilt, 2014).

2.1.4 Nutrition transition: Over time, economic growth facilitated by the adoption of technologies, including in agriculture, can influence lifestyle changes towards less work-related physical activity (Ng & Popkin, 2012). This change has the potential to improve nutritional outcomes through a reduction in individual calorie requirements (Headey et al., 2011). Concurrently, sustained income growth can lead to rapid dietary changes (Popkin, 1993; Popkin et al., 2012). The trend in declining physical activity levels and increasing per capita calorie intake is known as the "nutrition transition" (Popkin, 1993). At the initial stages of the nutrition transition, dietary changes entails the substitution of starchy staples with fats, animal-sourced foods, fruits and vegetables – some of which were sourced outside of the local food production system. This stage is instrumental to reducing undernutrition rates within the population (Popkin et al., 2020). Rapidly following the trend of more diversified diets is the increased consumption of food prepared away from home (Popkin et al., 2012; Popkin & Reardon, 2018). This stage is associated with rising coexistence of overnutrition and undernutrition within the population.

In addition to income growth, dietary shifts are driven by other factors such as efficiency gains in food processing and widespread innovation in food retailing (Popkin & Reardon, 2018; Reardon & Timmer, 2012), urbanization of towns and cities, improvements in infrastructures linking rural and urban centres (Aiyar et al., 2021; Pingali et al., 2019), female labour force participation – leading to increased opportunity costs of time for home food preparation, the proliferation and affordability of convenient ready-to-eat foods, as well as governments' agricultural policies (Prabhu Pingali, 2006; Webb & Block, 2012).

In contrast to the form of nutrition transition experienced in high income countries, LMICs are witnessing nutrition transition simultaneously with high poverty rates in the population (Reardon & Timmer, 2012). As such, household exposure to the impacts of the nutrition transition on nutritional outcomes may depend on whether a household is a net food producer or a net food consumer – and calorie adequacy may not be accompanied by micronutrients adequacy (Prabhu Pingali, 2012).

2.2 Literature review on changes in time use, physical activity patterns and nutritional outcomes in rural India and Nepal

In the theory of economic development, economic change corresponds to the reorganization of employment, work, and time use (W. A. Lewis, 1954). Consequently, understandings of time use changes have emanated largely from the different strands of research investigating the shifts in the nature of work following structural and rural transformations. The nutrition transition stipulates a trend towards the reduction in work-related physical activity as countries experience economic growth (Popkin, 1993). Using data collected from different secondary sources between 2000-2005, Ng & Popkin (2012) reported large reductions in physical activity levels over time in high-income countries. However, their study projected only "a noticeable decrease" in the time allocated to domestic, occupational, and travel activities in India. The authors predicted that time in sedentary activities will increase from 18.6 hours to 20 hours per week by the year 2030. Li (2023) used data collected in the years 1998 and 2019 to study changes in time use in the States of Gujarat, Haryana, Madhya Pradesh, Meghalaya, Orissa and Tamil Nadu in India. The author reported a significant increase in the leisure time use of rural women and men, and a reduction in the number of time allocated to economic work by rural women by an average of 90 minutes per day in 2019 compared with 1998. The time allocated to work also reduced by 60 minutes per day among men over the same period. However, these time use changes may not be regarded as representative of the whole country as there are heterogeneities in (women's) time use, due to stark differences in sociocultural norms across the regions of India (Eswaran et al., 2013). Using the same India data, Sheikh et al., (2023) also reported a reduction in paid time use of rural women, but explained that women working full time are less likely to reduce their work time whereas, women who spend few hours on paid work in 1998 are more likely to have substantially reduced their paid work time or exited the labour market in 2019.

Another study which examined changes in physical activity patterns highlighted the trend in the declining activity levels in the Indian population (Eli & Li, 2021). The authors noted that although activity levels are on a downward trend, the levels of total energy expenditure have been steady due to (1) the increase in the average population basal metabolic rate and (2) a reduction in the proportion of children to the total population between 1983 and 2012 (Eli & Li, 2021). Their methodology of matching the Indian Time Use Survey data with the FAO/WHO/ UNU physical activity formulae, produced physical activity levels[14] (PAL) of 2.03 and 1.96 among 15 - 49 years old males and females respectively, while PAL values of 1.50 and 1.53 was reported among 6 - 14 year old boys and girls respectively. However, other studies using objective wearable technologies to capture physical activities in free living populations recorded remarkably lower PAL. Analysing primary data collected in 2017 - 2018, (Srinivasan et al., 2020) reported PAL of 1.56 and 1.58 among males and females respectively in rural households in Telangana, India and PAL of 1.75 and 1.81 were reported among males and females respectively in Nepal (Picchioni et al., 2020).

The feminization of agriculture literature points to changing work patterns in rural livelihoods, which is characterized by a reduction in the time committed to agricultural-related work by

[14] Based on time use, PAL values are classified as sedentary or light (1.40-1.69), active or moderately active (1.70-1.99), and vigorous (2.00-2.40) in free-living populations (FAO, 2001).

males and an increase in the time allocated to such work by females (Deere, 2005; FAO, 2011b; Padmaja et al., 2019; Slavchevska et al., 2016). Due to predominantly male out-migration in Nepal, female agricultural workload usually tend to increase, but this may depend on household composition, access to and control over productive assets (Adhikari & Hobley, 2015; Gartaula et al., 2010). Panel data collected between 1974 – 2014 from the rural areas of Telangana in India shows that women now spend on average, an additional 120 minutes per day in agricultural activities than men, and perform male-associated tasks such as land clearing, irrigation and plant protection on the farm (Padmaja et al., 2019). This trend of feminization of agriculture is observed in almost all regions of the global south (Asadullah & Kambhampati, 2021). It is influenced by diverse factors and possesses different characteristics across the regions (Kawarazuka et al., 2022). However, information about the time allocation of men leaving agriculture to the industry and service sectors are limited. The implication of this knowledge gap is that it is unclear whether women remaining in agriculture have a higher work-related energy expenditure relative to men. The changes in household time use have also been influenced by the spread of agricultural technologies (Afridi et al., 2022; D. Lewis et al., 2022), agricultural and development interventions (D. Johnston et al., 2018; Nichols, 2016; van den Bold et al., 2021), changes in agricultural practices and socio-cultural norms (Eswaran et al., 2013).

While the literature on time use changes is nascent, the empirical evidence on the effects of time use on nutritional outcomes in rural areas remain largely underexplored. Aiyar et al., (2021), reported that the number of people employed in non-farm work is directly related to obesity rates in rural/peri-urban India. Examining the impact of drudgery reduction on calorie requirements, Srinivasan et al., (2020) found that the substitution of less intense activities for more intense activities reduces calorie requirement of males and females across different socio-demographic groups. Using normative energy requirement classification for activities, Padmaja et al., (2019) found direct associations between time allocated to high intensity activities and underweight, and a negative association between time allocated to high intensity activities with overweight status. Further, employment in agriculture is associated with lower body weight among males and females in India (Headey et al., 2011; N. Rao et al., 2019), and in their study of two districts in India, Rao & Raju (2020) reported seasonal changes in body mass index of males and females resulting from higher work intensities during peak farming seasons.

The gap identified in this review is that there is an emerging literature on changes in time use and physical activity patterns in India and Nepal, but such studies did not consider the effects of these changes on nutritional outcomes. The other lacuna pertains to the tendency to focus on agricultural time use among studies which examined nutritional outcomes in rural livelihoods. These knowledge gaps justifies further research consideration.

2.3 Conceptual framework

The conceptual framework discussed in this section describes rural transformation and its linkage to nutritional outcomes as illustrated in Figure 1. The framework was derived from a comprehensive review of the literature and it informs the empirical analyses that follows in the standalone chapters. Berdegue et al., (2014) describes rural transformation as a "process of comprehensive societal change whereby rural societies diversify their economies and reduce their reliance on agriculture; become dependent on distant places to trade and to acquire goods, services, and ideas; move from dispersed villages to towns and small and medium cities; and become culturally more similar to large urban agglomerations. Despite these common trends, the rural transformation within different countries has different outcomes in terms of economic growth, social inclusion, and environmental sustainability. While global forces drive this transformation, they are mediated by localized social structures and institutional frameworks, and local societies at any given time have different potentials to do and see things—that is, they have different levels of human agency." This definition underscores external global factors as the principal drivers of the rural transformation processes through non-farm diversification, the globalization of the agrifood systems, urbanization, and the spread of road and telecommunication infrastructures (Berdegue et al., 2014 chap. 27 p.5).

Further, Hazell et al., (2007) describes rural transformation as caused by non-farm diversification within rural areas. Their work detailed four phases through which rural households diversify from farm to non-farm activities; at the first stage, increasing farm productivity leads to market exchange, wherein households invest incomes from farm into the non-farm economy. Such investments help households specialize in the production of goods and services at the second stage. Gradually, small shops where goods are sold, and services are offered concentrates in small rural towns – marking the third stage. The rural towns further boosts agricultural production by attracting high value produce from the more rural areas. Increased production in the rural towns gradually leads to wage increases in the rural towns. At the final stage of the transformation process, agricultural workers are attracted to migrate to the rural towns due to better wages – leaving behind farm activities. This form of rural transformation process points to declines in the rates of rural poverty and undernourishment, and it is desirable for economic development. Conversely, a distress-led rural transformation is characterized by land fragmentation and soil degradation, which is caused by considerable rural population growth in mostly economic-stagnant areas (Timmer, 1988). In such places, individuals leave agriculture to migrate out or they engage in low-rewarding rural non-farm work.

As the rural transformation processes unfolds, the reorganization of food production, food distribution, consumption and waste also takes place (Polly Eriksen, 2008). This evolution of the food system creates extended food supply chains, which influences food characteristics as a result. The use of natural resources for food production also reduces as a result of increase in the adoption of technology.

Over time, the patterns of rural transformation will be steered by government policies (or the absence of such policies) – which are necessary to guide rural areas towards continuous development (The World Bank, 2008). When rural transformation has been distress-led, government's directives for achieving subsistence for the poor in rural areas may include social

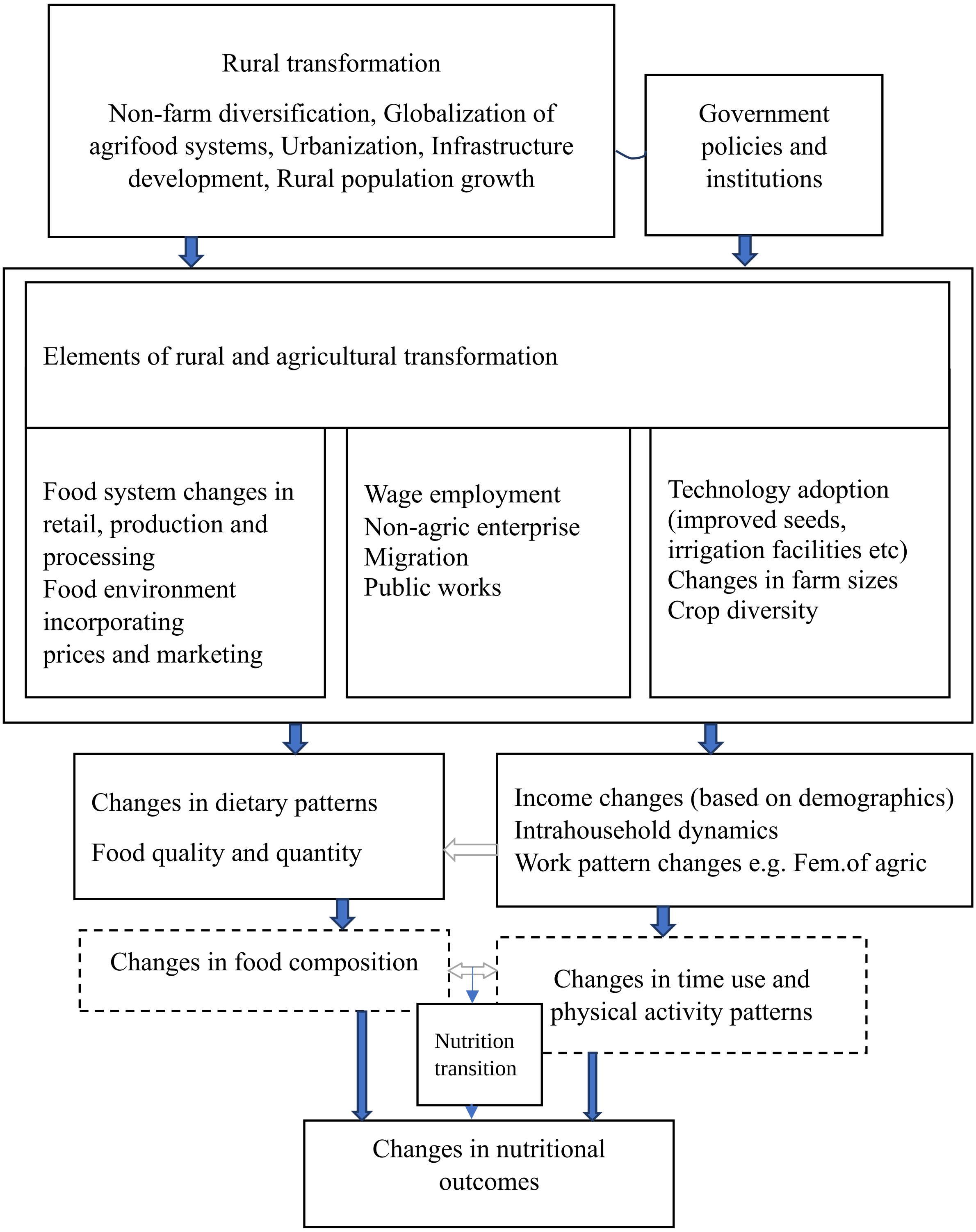


Figure 1: Conceptual Framework of the research.

safety nets through food subsidies, cash transfers and public works. Such policy levers have the potential to the reduce poverty and inequality, unemployment, and undernutrition (The World Bank, 2018). The well-being outcomes of rural transformation for rural households can therefore be beneficial or detrimental. In areas where rural transformation has been successful, individuals and households may experience the changes differently based on their economic and socio-demographic statuses (Binswanger-Mkhize, 2012; Koustab Majumdar, 2020; Ohlan, 2016; N. Rao & Nair, 2003; The World Bank, 2008).

Taken together, rural transformation as a micro and macro-level phenomenon is essentially characterised by changes in rural households' organization of production and consumption. To relate rural transformation with malnutrition, the empirical analyses in this research relied on Becker's "The Theory of the Allocation of Time", which stipulates time as a necessary input in the production process (Becker, 1965). We used time-based (and food consumption) metrics because time is an important asset for the poor. Time poverty, intrahousehold time use inequality (Blackden & Wodon, 2006), and time trade-offs (Gronau, 1977) necessitated by constrained livelihood choices of rural individuals may be responsible for persistently poor nutritional outcomes but research evidence is limited. Especially among women, gender-intensified constraints continue to limit access to productive assets, leaving time as the major resource with which poor women participate in production (C. Doss et al., 2011; Kabeer, 2001). In addition to income generating activities, the literature highlights "expenditure-saving activities" such as food processing, firewood collection, and cooking – that rural women and girls engage in to achieve household nutritional well-being (Desai & Jain, 1994; Eswaran et al., 2013). While such activities are essential to nutrition, they can pose health and nutrition challenges. The research questions examined in the following three independent chapters concern understanding the relationship between time allocation, physical activity, diet composition and nutritional outcomes.

Chapter 3: Sharing work and food within the household: Intra-couple time allocation effects on nutritional outcomes in rural Telangana, India[15]

Abstract

This chapter presents evidence on couple interdependencies in time use and nutritional outcomes. The empirical analysis adopts the Actor-Partner Interdependence Model (APIM) to examine own and partner effects of time use on nutritional outcomes. We find that there are differences in the time allocation patterns between spouses in a household – and the time allocation patterns of the spousal partners have an effect on an individual's nutritional outcomes; allocation of time to economic activities by the male spouse reduces the energy intake adequacy of the female spouse. Allocation of time to domestic activities by the female spouse reduces the energy intake adequacy of the male spouse. The results suggest that reducing the gender differences in the allocation of time could improve nutritional outcomes for male and female spouses.

Keywords: *Intra-couple time allocation; nutritional outcomes; time use and physical activity; actor-partner interdependence model; India.*

[15] Revise and resubmit at the *Feminist Economics* journal

3.1 Introduction

Malnutrition continues to be a development challenge in many low- and middle-income countries (LMICs), where around 185 million people cannot afford sufficient daily energy intake at an average cost of $0.79 (FAO et al., 2020). In the past decades, many agricultural and development interventions aimed at the enhancement, diversification and substitution of livelihoods means have targeted women based on the central role they play in ensuring household food security (FAO, 2011b; Fiorella et al., 2016; Haddad et al., 1997). Even if the interventions targeted at women lead to greater participation of women in agriculture and resultant increases in productivity and household incomes, it is not certain that nutritional outcomes will improve. This may be because women in male-headed household still lack the ability to influence household decision-making in relation to how increased incomes and their own time are utilised. (Kadiyala et al., 2014).

Building on the intrahousehold resource allocation literature, this chapter presents empirical evidence on spousal interdependencies in time use and nutritional outcomes. We investigate own and partner effects[16] of intrahousehold work division on nutritional outcomes among rural households. Inequity in intrahousehold work division has been linked to malnutrition, as women disproportionately bear household domestic work (including child-care) in addition to economic labour (Gillespie et al., 2012). Even so, development efforts to improve nutrition may reinforce gender-differentiated patterns of work allocation (Molyneux, 2006). Recent debates have suggested that domestic responsibilities can be shared with men to reduce the burden borne by women (Asadullah & Kambhampati, 2021; Madzorera & Fawzi, 2020; N. Rao & S. Raju, 2020), yet the mechanism and nutritional outcomes of such an undertaking is less clear. We

[16] Own effects captures intra-individual outcomes while partner effects, interpersonal outcomes.

propose that the time allocation of male and female spouses and the interdependencies between them, are consequential for nutritional outcomes.

This chapter is motivated also by the knowledge gap in how spouses in rural agricultural households in LMICs can adapt to rural transformation. Although agriculture remain a major contributing sector to the rural economy in terms of employment and incomes, increases in agricultural labour productivity and mechanization of farm activities is leading rural households to diversify into the rural non-farm sector (IFAD, 2016). Rural non-farm employment participation, including the time allocated to such activities is dominated by men (Binswanger-Mkhize, 2013; IFAD, 2016), but there are increasing opportunities for women to participate in economic activities outside of the home as a result of better education, changing socio-cultural norms and improvements in rural-urban transportation linkages (Binswanger-Mkhize, 2013; Ohlan, 2016). This form of rural transformation increases women's opportunity cost of time spent on food preparation and care activities. Conversely, changes in developing countries' subsistence agriculture and factors such as better wages and work conditions in manufacturing and service sectors are driving men out of agriculture and from rural areas – where economic growth is stagnating (Binswanger-Mkhize, 2013). The ensuing feminization of agriculture can have implications for household nutritional outcomes through increase in women's agricultural workload (Da Corta & Venkateshwarlu, 1999).

A large body of literature looked at intrahousehold dynamics (Fafchamps & Quisumbing, 2007), but an oft-times missing view of the household behaviour is the interdependence shared between spouses. Intrahousehold production and consumption behaviour proposed by unitary models relies on the exchange of "effective altruism" between couples (Becker, 1981). These models assume total cooperation between spouses. The male economic actor is assumed to be altruistic towards his spouse and other members of the household therefore, he could be entrusted with sharing additional resources with them. However, aggregating individual preferences through altruism oversimplifies intrahousehold negotiations – on the basis of bargaining power concentrated with the male, who may not be always altruistic (Chiappori, 1992). Collective models posit independence in preferences and in the process of decision making. They argue that intrahousehold allocation is guided by bargaining even when couples cooperate (Apps & Rees, 1997; Chiappori, 1992; Lundberg & Pollak, 1993; McElroy & Horney, 1981). Therefore, interventions should target the individual. The drawback to this approach is when bargaining for leisure and other goods like food and healthcare is bounded by cultural norms, this approach becomes akin to the altruistic male providership model, which results in unsuccessful intervention outcomes (Agarwal, 1997; Duflo & Udry, 2004).

The analysis in this chapter adopts an interdependency framework - the Actor Partner Interdependence Model (APIM). The APIM is a model of interdependency between individuals in a dyadic relationship (Cook & Kenny, 2005). It postulates that own and partner's characteristics simultaneously influence the outcomes of both individuals. The interdependence view of couples' behaviour in this study is based on the premise that couples share work and they also share food, especially in rural agricultural contexts where production and consumption decisions are interwoven and often made within the household (C. R. Doss & Quisumbing, 2020; Folbre, 1986; Singh et al., 1986). Even when couples adopt separate production spheres as many African farming households do, it can be expected that they share some production and consumption between them wherein time is an input. This paper therefore contributes to intrahousehold literature by assessing couple's own and partner effects of time allocation on nutritional outcomes in rural livelihoods using the APIM. We attempt this by examining the following research question: How does time allocated to economic, domestic and leisure activities in a household relate to own and partner's nutritional outcomes among couples in farming households?

The rest of the chapter is structured as follows: the literature review on women's time allocation and nutritional outcomes, as well as intrahousehold time allocation and nutrition externalities are presented in section two. The data, including the study area and data collection is described in section three. This is followed by the empirical methods in section four. The results of analysis is presented in section five. The discussion of results is presented in section six. The chapter ends with the conclusions in section seven.

3.2 Literature review

This literature review is concerned with the agriculture-gender linkages to nutrition. It explores time allocation and nutritional outcomes in rural agricultural settings, first distilling evidence on the effects of women's time allocation on own nutritional outcomes and then focussing on the effects of women and men's time allocation on the nutritional outcomes of other family member(s).

3.2.1.1 Women's time allocation and nutritional outcomes

As a result of the ongoing rural transformations, there has been an increase in the number of women active in agriculture, including in the time women allocate to agricultural activities across all regions in LMICs – a trend known as "feminization of agriculture"(Asadullah & Kambhampati, 2021; FAO, 2011b). Data collected from the rural areas of Telangana in India shows that women now spend on average, an additional two hours per day in agricultural activities than men, and perform male-associated tasks such as land clearing, irrigation and plant protection on the farm (Padmaja et al., 2019). Conversely, male time commitment to farm work is on a downward trend due to the mechanization of male-dominated tasks and out-migration from rural areas (Padmaja et al., 2019). These changes in male and female time allocation are expected to have consequences for nutritional outcomes.

Women’s time use in particular has a strong effect on their own nutritional outcomes, however, the direction of effect is not univocal (Ghosh & Bharati, 2005; D. Johnston et al., 2018; Ruel et al., 2018). Komatsu et al., (2018) found that agricultural time use is associated with a reduction in the consumption of diverse diets among women in Mozambique. However, they reported better nutritional outcomes among individuals in poor farming households, which signals the importance of agriculture time use in securing subsistence among the poor. Choitani (2020) argued that de-facto female heads in farming households are particularly vulnerable to food insecurity because of their increased agricultural workload and low remittance receipts. Employment in agriculture may impact nutritional status as in Ghana, India and Tanzania, where men and women in farming households have lower body mass index and higher chronic energy deficiency compared with their counterparts in non-agricultural occupations (Higgins & Alderman, 1997; Komatsu et al., 2019; Subasinghe et al., 2014). Besides, the ability to translate women’s agricultural time allocation into desirable nutritional outcomes is mediated by diverse factors. For instance, long hours of agricultural work is associated with less diet diversity among non-poor compared with poor women (Komatsu et al., 2018). Ghosh & Bharati (2005) found that the effect of time allocation on body mass index is mediated by sociodemographic factors, although women in paid agricultural work fared nutritionally better than the unpaid working women. Also examining the differentiating effects of paid and unpaid work on household nutrition among women in five Indian states, found that women in paid farm work have better nutrition compared with peers in non-paid work as a result of increase in bargaining power emanating from women’s labour force participation. Further, the effects of time use on the nutritional wellbeing of women and men varies across agricultural seasons as the energy demand of work is highest during land maintenance and harvest seasons (Picchioni et al., 2020; N. Rao & S. Raju, 2020; Srinivasan et al., 2020). This seasonality effects is intensified among individuals in non-mechanized farming households (Daum et al., 2019b; Komatsu et al., 2019) and the landless (Vemireddy & Pingali, 2021). In their review, Johnston et al., (2018) concluded that attempts to improve well-being outcomes through agricultural interventions often increase time allocated to agriculture, and nutritional outcomes will depend on how individuals in an agricultural household respond to the change in time use.

Women (and girls) disproportionately perform more than three-quarter of household domestic and care work (Jacques Charmes, 2019). But the evidence linking participation in domestic work and wellbeing in rural areas is very limited. Often, time use in domestic activity is explained in the context of trade-offs with agricultural and childcare activities, but not how it directly relates to wellbeing. Desai & Jain (1994) argued that domestic work reduces women's available time to both childcare and economic activities; to the extent that domestic work can be a greater obstacle than childcare to female labour force participation. A multi-country study across Asia and Africa on women's time use and dietary diversity found that time spent cooking is positively associated with women's dietary diversity in Bangladesh and Cambodia, while time committed to domestic work is positively associated with diverse diets among women in Cambodia, in Ghana (poorer households), and in Nepal (Komatsu et al., 2018). The authors suggests that the positive association between domestic tasks and more diverse diets could be a result of "staying close to the pot". Further, investigating the association of women's time poverty and household nutrition in Bangladesh, Seymour et al., (2019) found that women's time poverty (defined as allocating less than 50 per cent of median time on leisure and self-care related activities) is not significant in its association with household nutritional outcomes. Indeed, time poor women have relatively better nutritional outcomes.

The paradox seen in this strand of literature is that although female agricultural economic time use suggests better nutritional outcomes through the increase in and control of incomes, benefits can be outweighed by increasing time spent in strenuous physical activities leading to greater energy expenditure (Nichols, 2016), and sociocultural norms entrenched in intrahousehold negotiations can limit a woman's use of her monetary and time resources (Agarwal, 1997;

Bittman et al., 2003). However, Sangwan & Kumar (2021b)and van den Bold et al., (2021) found no deleterious effects resulting from increasing agricultural time on nutritional status. Their conclusions may be due to the small additional time spent in agriculture following the interventions reported in their studies. Moreover, women may regard improvements in household food security and income as beneficial even though such involves trade-offs to their own well-being (Kabeer, 2001).

Review undertaken by FAO et al., (2020) shows that the information about men's time use are often not reported and despite the significant focus on women's time use and nutritional outcomes, women more than men continue to be malnourished in rural areas of LMICs where most people depend on agriculture for their livelihoods

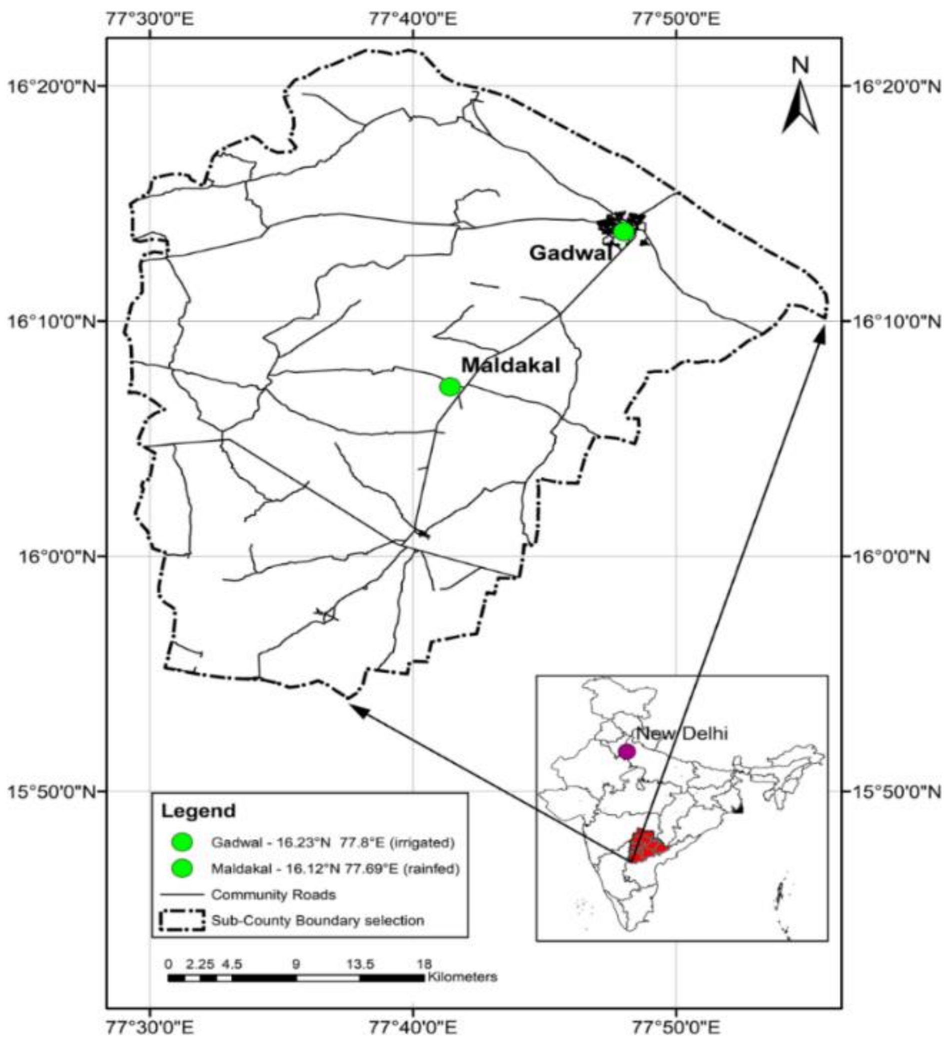
3.2.1.2 Intrahousehold time allocation and nutritional externalities

Intrahousehold externalities affect individual wellbeing (Basu, Narayan, & Ravallion, 2001) but there are few empirical evidence assessing the relationship between men's time allocation and women's nutritional outcomes and vice versa. Fleary & Joseph (2022) using APIM to analyse data from the United States show interdependence in health literacy, time use and dietary behaviours between parents and adolescents. In the development discourse, the literature on intrahousehold externalities is largely streamlined to maternal time use and its consequences on women's caring responsibilities for their children (Fadare et al., 2019; Ruel & Alderman, 2013). Such focus on maternal time use and child nutrition is based on established linkages between the wellbeing of mother and child. However, in the face of deprivation, gendered pay gaps and ownership of assets, the maintenance of subsistence among poor and the very poor may lie in interdependencies between men and women within the household (N. Rao et al., 2017). Such interdependent view has not been adopted in the development practice, and women tend to have been targeted individually.

3.3 Data

3.3.1 Study area

The secondary dataset used in this paper was collected for the project "New keys for old black boxes: developing methods to improve nutrition assessment by measuring energy expenditure" published in Zanello et al., (2020). Data collection was carried out in Jogulamba Gadwal District, south of Telangana State in India. The district has 20 per cent scheduled castes, 1.5 per cent scheduled tribes[17] and more than three-quarters of its 609,990 population living in 255 rural villages. About 60 per cent of its total land area is cultivated for food and cash crops, often on small and marginal plots.



[17] "Scheduled" refers to schedules in the Indian constitution identifying socially and economically deprived/marginalized caste groups and tribal (indigenous) groups as being entitled to affirmative actions in education, employment and development programs (Lelah Dushkin, 1967).

Figure 2: Survey area in Telangana State, India. Source: Zanello et al., (2020)

Due to a substantial increase in the amount of monsoon rainfall and the adoption of irrigation facilities in recent years, the semi-arid climate is increasingly turning favourable to agricultural production (Government of Telangana, 2019). State government report shows a gradual decline in poverty in these areas; between 2014 and 2020, per capita income (adjusted for inflation) rose more than 10 per cent to 69,113 Rupees[18]. Rural income growth is driven by agricultural production expansion and participation in the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) social welfare program. Data show that about 20 per cent of the Jogulamba district population participates in MGNREGA and despite the mixed impacts[19] of the MGNREGA on agriculture in the area, agriculture and allied (crops, livestock, fisheries, forestry) sector contribution to the overall product output[20] rose by 20.9 per cent in 2021 (Government of Telangana, 2021b). The growth can be attributed, in part, to other government interventions in the form of inputs support, land redistribution, irrigation, and insurance schemes.

Despite per-capita income increase in the study area over the last decade, malnutrition within the population has remained high, especially among women. Figures from the Indian National Family Health Survey shows that 22 per cent of women and 17 per cent of men are underweight (BMI < 18.5kg/m^2) in rural Telangana in 2019-2020[21]; this is a decline from 29 per cent among women and 25 per cent among men in 2015-2016. The current rate of anaemia among women is at 58 per cent, up from 57 per cent in 2015-2016 (Christopher et al., 2021; Ministry of Health

[18] 1 USD averaged 62.78 Indian Rupees in 2014 (Reserve Bank of India, 2022).
[19] The MGNREGA has led to an increase in agricultural wages especially for women than men and a subsequent tightening of the agricultural labour market. In some instances, this agricultural labour shortage has been linked to shrinking farm plots in places where mechanization of farm work is elusive (Reddy et al., 2014).
[20] The contribution of agricultural product output to the Gross Domestic Product was estimated using Gross State Value Added (GVA). "The GSVA of any unit (sector, sub-sector, firm, etc) measures the contribution of that unit to the overall output of a country. It is calculated by subtracting the value of all intermediate goods and services from the total value of units output" (Government of Telangana, 2021b) .
[21] Data was collected prior to the COVID-19 pandemic.

and Family Welfare; Government of India, 2020). In comparison to the other States in India, the high malnutrition rate is linked to the large number of scheduled castes and scheduled tribes in Telangana.

Further, the patterns of time use in this region shows rural men and women commit over eight hours to work-related activities daily (Government of India, 2020). There are however substantial gender disparities albeit to a lesser degree compared to the rest of India: 55.7 per cent of rural Telangana women participate in paid work, a figure three times the national average (Government of India, 2020). Using data from the Time Use Survey-2019, Figure 3 shows the allocation of time among males and females living in rural areas of Telangana state. Compared to men, women allocate on average 225 minutes more per day to care, domestic and volunteer work, 158 minutes less to employment and production of goods for own use and tend to spend on average 29 minutes more in work-related activities daily than men – the time they seem to reallocate from socializing, self-care, and maintenance activities.

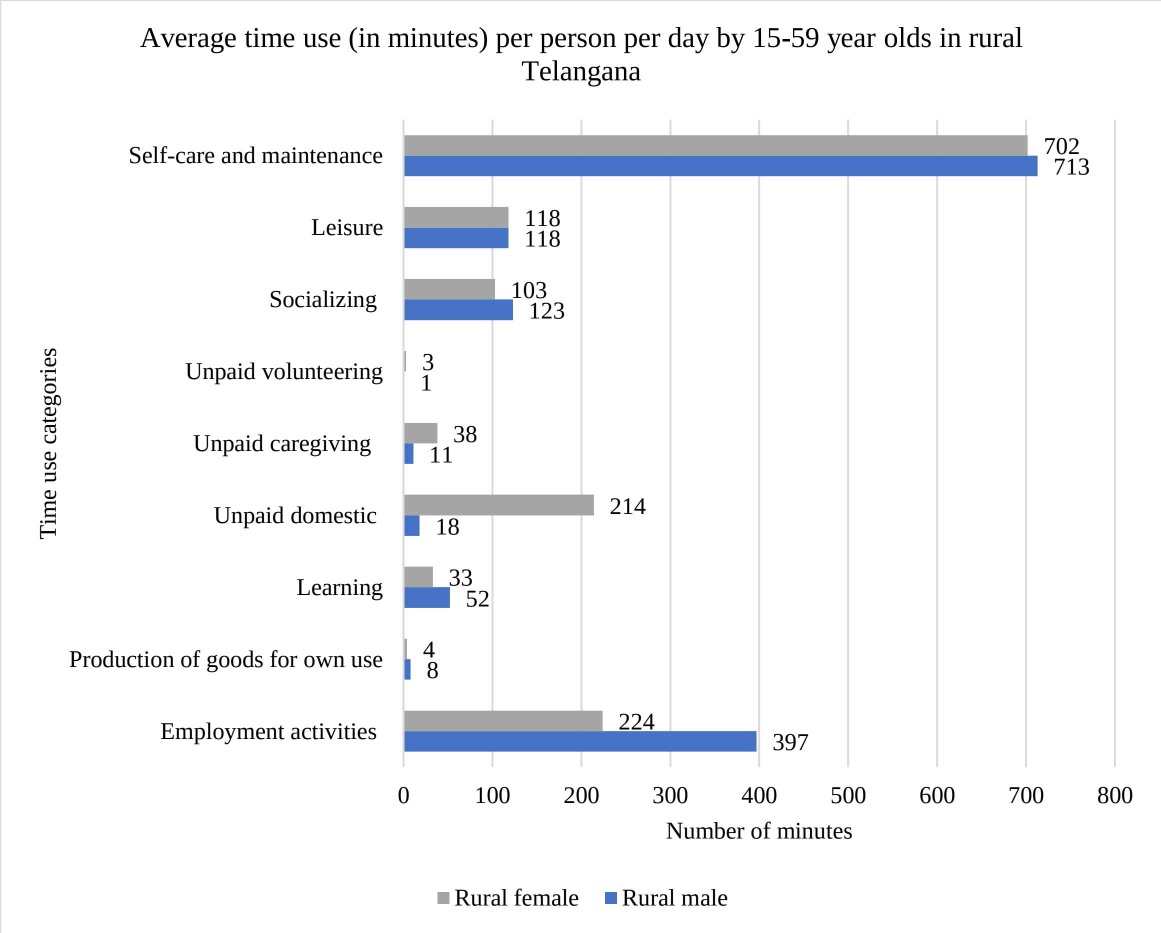


Figure 3: Time use patterns in rural Telangana. Source: Author, based on data extracted from the Indian Time Use Survey-2019, National Statistical Office, Government of India.

3.3.2 Data collection

3.3.2.1 Survey

Twenty households were randomly selected after households in the area were stratified by ownership of irrigation infrastructures and size of landholdings. In each household, an economically active man and woman, aged between 16-64 years old took part in the study. All respondents were employed primarily in crop production, eighteen households cultivated their own land and two were sharecroppers. They cultivated predominantly rice, cotton, yam, chillies, and groundnuts. Their secondary employment entailed the supply of labour in agriculture and other wage activities. Respondents were visited daily for four non-consecutive weeks during June – November 2018, corresponding to each of the four agricultural seasons of land preparation, sowing, land maintenance, and harvest when Kharif[22] crops are cultivated.

At the beginning of the fieldwork, individuals self-reported information on their own health, and anthropometric measurements of height and weight were taken. All the questionnaires administered to respondents were translated to Telugu – the local language. The survey was carried out by enumerators living in the same district and who spoke the local language. Each enumerator was allocated to four individuals in two households. Information on household characteristics were collected from the household head. In addition, individual food intake data were collected daily based on a 24-hour recall throughout the four weeks (Gibson & Ferguson, 2008). Enumerators used structured interviews to ask each respondent to recall the type and amount of food and beverages consumed at breakfast, mid-morning, noon, mid-afternoon, evening and before bedtime. To reduce recall bias, standard dimension containers were provided to respondents during interviews. During the daily visits, enumerators also collected time use information at one hour-intervals based on 24-hour recall. The time use questionnaire relied on respondents narrating their time use the previous day in no particular format to accommodate the varying daily time -use patterns that are characteristic of rural areas (C. Doss et al., 2020).

3.3.2.2 Accelerometers

In addition to questionnaires administered daily, raw 30Hz[23] physical activity data were collected using research-grade, tri-axial Actigraph GT3X+ accelerometers worn on the waist by respondents during awake hours of 5 am – 11 pm. Over time, the approaches to measuring energy expenditures involve laboratory-based methods, hearth-rate monitoring and the factorial

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[22] In India, kharif crops are monsoon crops such as rice, maize, sugarcane, groundnut planted in July and harvested around October. Rabi crops are winter crops such as wheat, barley, carrot, chickpea planted in November and harvested around April and May.

[23] 1Hz (Hertz) is one cycle per second

method (Dufour & Piperata, 2008). The recent advent of accelerometer technology has expanded physical activity energy expenditure measurement tools. Accelerometers are portable, motion sensor devices used in the collection of objective physical activity data in free-living population (Troiano et al., 2014; Zanello et al., 2019). The activity data collected from accelerometers were converted into activity energy expenditure (in kilocalories) using validated algorithms (Freedson et al., 1998). The accelerometers, however, may not capture the differences in types, frequency, intensity, and duration of movement. Therefore, the time use data collected using questionnaires were matched with energy expenditure data derived from accelerometers to determine activity-specific energy expenditure (Zanello et al., 2019). A major problem usually associated with using accelerometers in physical activity research in free-living populations is non-wear (Troiano et al., 2014). However, accelerometer wear compliance in the data was high – 82 per cent of respondents wore the device throughout the survey period. The occurrence of non-wear above 5 hours per day is less than 3 per cent of the survey time.

The unique datasets used in this study combine information on individual and household sociodemographic characteristics, food intake data based on a 24-hour recall, time use data based on a 24-hour recall and physical activity data collected through accelerometers. No sample attrition was recorded during the four weeks of data collection.

3.4 Empirical Methods

3.4.1 Independent variables

The main independent variables used in this study are time use variables measured as the number of minutes allocated to each of economic, domestic and leisure activities (Moser, 1989). Every recorded activity in the hourly time use data was identified as either the primary or secondary activity to ensure that typical secondary activities such as leisure and childcare are also considered (Ironmonger, 2005). In cases where no secondary activities were recorded, a weight of 1 was assigned to the hourly observation. The weight of 0.6 was assigned to primary and weight of 0.4 was assigned to secondary activity, where respondents reported they carried out simultaneous activities (Picchioni et al., 2020). We aggregate each of economic, domestic and leisure time use data from hourly to day-level. Economic time use includes time spent in agricultural activities such as crop and livestock production, forest produce collection and related travel. Non-agricultural economic activities are salaried employment, non-farm wage employment in construction and public work schemes, business, petty trading, and professional development training. Domestic and care provision time use include household maintenance and chores, food management, caring for children, elderly, sick and disabled. Leisure time use includes time allocated to socializing and personal care.

3.4.2 Dependent variables

A set of three dependent variables are used in the analysis to capture the association between time allocation and own and partner's caloric intake adequacy: Physical Activity Level (PAL), Total Individual Energy Intake (EI), and Caloric Adequacy Ratio (CAR). We examine the associations of time allocation with PAL, EI and CAR outcomes.

3.4.2.1 Physical Activity Level (PAL)

Physical Activity Level (PAL) is a measure of the intensity of physical activity over a day (or other time period). PAL controls for individual anthropometric differences, allowing for comparisons across males and females. To calculate individual PAL, raw 60-second epoch length physical activity data collected from accelerometers were converted to Activity Energy Expenditure (AEE) in kilocalories using a validated algorithm (Freedson et al., 1998). PAL was then computed as the ratio of Total Energy Expenditure (TEE) and Basal Metabolic Rate (BMR), where TEE is the sum of BMR (energy required to maintain vital physiological processes in the body) and AEE[24]. We compute the BMR using the Harris-Benedict equation

[24] TEE is the sum of BMR, AEE, and Thermal Effect of Feeding (TEF). TEF is energy required for metabolism, but TEF data is not available for this study. However, we assume the effect of this limitation to be minimal, since TEF accounts for only about 5-10 per cent of TEE (FAO, 2001).

(Harris & Benedict, 1918). PAL values of 1.40 - 1.69 reflects sedentary or light activities, 1.70-1.99 moderate activity and >2.00 indicates vigorous activity in free-living population. PAL is used in the literature to model energy expenditure among free-living populations (Friedman et al., 2021; Picchioni et al., 2020; Srinivasan et al., 2020).

3.4.2.2 Total Individual Energy Intake (EI)

Total Individual Energy Intake (EI) is the total dietary energy reportedly consumed by individual respondents in the last 24 hours. It captures the calorie (kcal) equivalent of food and beverages per-adult day energy consumption (FAO, 2003). We use individual's food intake data recorded through a 24-hour recall to compute the caloric values. The Indian Food Composition tables were used to determine the calorie content of local recipes (Bowen et al., 2011) and the United States' National Nutrient Database for Standard Reference was used for calorie conversion of ultra-processed foods (U.S. Department of Agriculture, 2019). While EI captures individual caloric availability, the nutritional components of the food, and the quality of individual diets cannot be ascertained.

3.4.2.3 Caloric Adequacy Ratio (CAR)

We use Caloric Adequacy Ratio (CAR) as a measure of nutritional outcomes. CAR is a metric of energy balance – which quantifies the overall dietary energy adequacy of an individual based on their food intake and energy expenditure (Randolph et al., 1991). We compute CAR as the ratio of energy intake (EI) relative to total energy expenditure (TEE). An individual whose CAR is equal to 1 is classified as energy balanced, a CAR below 1 is classified as being energy deficient, and a CAR value above 1 indicates that the individual is in energy surplus for a given day (FAO, 2001). The CAR as an indicator of nutritional outcomes allows to measure individual energy intake adequacy. However, its focus on calories prevent measuring the adequacy of the other nutrients necessary for a diverse diet which implies that a person with a CAR equals or above 1 may be deficient in essential nutrients. The description of all dependent and independent variables used in the analysis (including intermediate variables) is presented in Table 1.

Table 1: Description of variables

Dependent variables	*Variable description*
Physical Activity Level	Ratio of total energy expenditure and basal metabolic rate over a 24-hour period
Total Individual Energy Intake (Kcal/day)	Total amount of calories from food consumption over a 24-hour period
Calorie Adequacy Ratio	Ratio of daily energy intake to energy expenditure
Independent variables	*Variable description*
Age	Age in years
Literacy	Dummy for whether an individual can read and write
Domestic activity	Total amount of hours spent in domestic work per day
Economic activity	Total amount of hours spent in economic work per day
Leisure	Total amount of hours spent in leisure per day
Accelerometer wear	Daily accelerometer wear compliance between 5am-10pm
Day 1	Dummy for the first day of the week when data was collected
Day 2	Dummy for the second day of the week when data was collected
Day 3	Dummy for the third day of the week when data was collected
Day 4	Dummy for the fourth day of the week when data was collected
Day 5	Dummy for the fifth day of the week when data was collected
Day 6	Dummy for the sixth day of the week when data was collected
Number of adult females (18-64 years)	Total number of female adults aged 18-64, within the household
Number of adult males (18-64 years)	Total number of male adults aged 18-64, within the household
Number of children (0-1 years)	Total number of male and female children aged between 0 and 1 years old within the household
Number of infants (2-12 years)	Total number of male and female children aged between 2 and 12 years old within the household
Number of adolescents (13-17 years)	Total number of male and female adolescents aged between 13 and 17 years old within the household
Female	Dummy for if gender of respondent is female
Male	Dummy for if gender of respondent is male
Irrigation	Dummy for if household adopts irrigation system
Land cultivated (acres)	Total area of land cultivated by household
Asset index	Index of sum of values of household assets
Land preparation	Dummy for agricultural season whether agricultural season is when land preparation takes place

Sowing	Dummy for agricultural season whether agricultural season is when sowing and seeding takes place
Land maintenance	Dummy for agricultural season whether agricultural season is when land maintenance takes place
Harvest	Dummy for agricultural season whether agricultural season is when harvest takes place
Self-reported health	Dummy for if self-reported health reduced the amount of work done at work and home
Caste	Dummy for if respondent belong to the backward caste, scheduled caste if otherwise

3.4.3 Empirical strategy

3.4.3.1 The Actor-Partner Interdependence Model (APIM)

The Actor-Partner Interdependence Model (APIM) explains dyadic relationships by incorporating the concept of interdependence between two linked individuals with the statistical methods to test such interdependence (Cook & Kenny, 2005). The APIM postulates that own (actor), and partner’s characteristics simultaneously influence the outcomes of both individuals in a dyadic relationship. This methodological approach assumes correlations and interdependencies in the process and outcomes of individuals within the same unit. Conventional statistical procedures assume independent observations but ignoring nonindependence of observations between linked individuals will likely lead to biased statistical estimates (Cook & Kenny, 2005). Non-independence in the observations of dyads may arise as a result of *common fate, mutual influence* and *partner effects* (Kenny & Cook, 1999). APIM focuses on modelling the interdependence between two individuals through partner effects. Partner effects measure the bi-directional influence of one person on the other member of the dyad, in contrast to the intrahousehold behaviour theories that posits that individual outcomes are determined either by individual preferences or by effective altruism (Fafchamps & Quisumbing, 2007). This approach has been used extensively to study dyadic relationships, for example, in the analysis of health behaviors in parent-adolescent dyads (Fleary & Joseph, 2022), work division, communication, and couples’ relationship satisfaction

(Carlson et al., 2020). APIM is used in this study to predict the influence that time allocation of spouses has on own and partner's PAL, EI, and CAR outcomes. The dyad is treated as the unit of analysis.

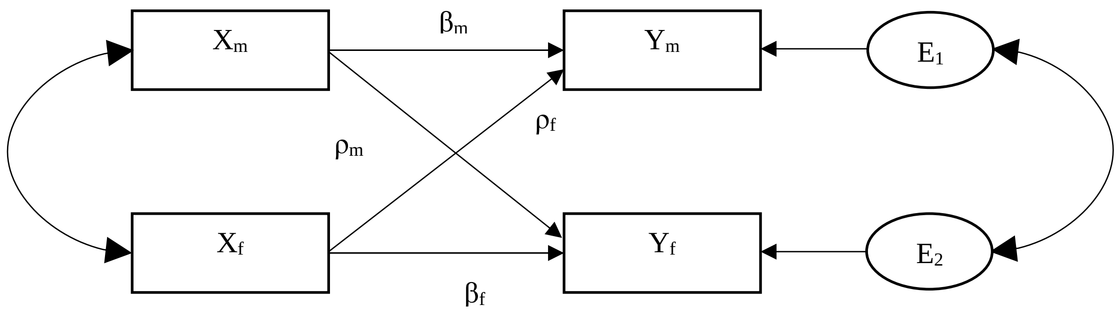

Figure 4: Path depiction of the APIM model (Adapted from Kenny et al., 2006)

Notes: X_m = independent variable of the male, X_f = independent variable of the female, Y_m = outcome variable of the male, Y_f = outcome variable of the female, β_m = male own (actor) effects, ρ_m = male partner effects, β_f = female own (actor) effects, ρ_f = female partner effects, E_1 and E_2 = error term.

We assess own (intrapersonal) and partner (interpersonal) effects of time use on dependent variables of PAL, EI and CAR using the APIM for dyadic data depicted in Figure 4 (Cook & Kenny, 2005). To treat individuals as nested within a dyad, we use the gender of each respondent as the distinguishing variable within couples – and to capture role-specificity of individuals. This differentiation allows for estimating the main components of the APIM: own effects - β_m, β_f and partner effects - ρ_m, ρ_f; by using the main independent variables - X_m, X_f; and the dependent variables - Y_m and Y_f. Own effects (β_m, β_f) capture the association between own independent variables and dependent variables (X_m; and Y_m; X_f and Y_f for male and female respectively), while partner effects (ρ_m, ρ_f) capture the association between own independent variables and partner's dependent variable (X_m and Y_f; X_f and Y_m). E_1 and E_2 control for the correlation within couples. Interdependency between couple occurs when the partner effects ρ_m, ρ_f are significantly associated with the dependent variables (Kenny et al., 2006).

To estimate own (β_m, β_f) and partner (ρ_m, ρ_f) effects of the time use variables on the dependent variables of PAL, EI and CAR, we structure the data in a pairwise or double-entry structure, whereby each row includes both the male and female observations in column pairs (Kenny et al., 2006). Own and partner time use variables are derived by multiplying male and female dummy variables with the number of minutes spent in specific activities. For instance, in creating male own economic time use variable X_m, male dummy variable is multiplied by the male economic time use variable. However, to create the corresponding male partner economic time use variable, that is, the time use variable of the male which influences the female's own outcome, the female dummy variable is multiplied by male economic time use variable, which creates male predictor observations on the same row as female outcome observation and this transformation leaves zero values elsewhere in the new variable (Cook & Kenny, 2005). A similar procedure is used to create female own variable X_f and the female partner variable. The pairwise structure is illustrated for four individuals in two households in Table 2. X1, Y1, Z1 are variables capturing own observations, while X2, Y2, Z2 are variables capturing partners' observations.

Table 2: Pairwise data structure illustration for two households (Kenny et al., 2006)

Household	Individual	X1	Y1	Z1	X2	Y2	Z2
1	1	5	9	3	2	8	3
1	2	2	8	3	5	9	3
2	1	6	3	7	4	6	7
2	2	4	6	7	6	3	7

3.4.3.2 Own and partner effects - couple composition, context, and the endogeneity of time use variables

Ordinary least squares, structural equation modelling and multilevel modelling can be used in the analysis of the APIM. We apply a multilevel model (MLM) to analyse the APIM framework. This allows for the simultaneous estimation of hierarchies in the nested data- two individuals (level-1) nested in a household (level-2) – whilst accounting for the inherent nonindependence within each couple. To obtain the actor and partner effects by male and female gender, the random two-intercepts model for MLM using the restricted maximum likelihood method (Kenny et al., 2006; Rabe-Hesketh & Skrondal, 2012; Raudenbush et al., 1995) estimates fifteen separate panel equations with separate observations for each day of the form $Y_{ijt} \epsilon$ {PAL_{ijt}, EI_{ijt}, CAR_{ijt}, $CAR_{ijt} > 1$, $CAR_{ijt} < 1$} and k = {Economic, Domestic and Leisure time uses}:

$$Y_{ijt} = \alpha^k_m \delta_i + \alpha^k_f (1- \delta_i) + \beta^k_m X^k_{mjt} \delta_i + \beta^k_f X^k_{fjt} (1- \delta_i) +$$

$$\rho^k_m X^k_{mjt} (1- \delta_i) + \rho^k_f X^k_{fjt} \delta_i + \theta^k_j \overline{X}^k_j + \boldsymbol{\omega}^\mathbf{k}\mathbf{I}_j + \boldsymbol{\sigma}^\mathbf{k} \mathbf{H}_j + \boldsymbol{\gamma}^\mathbf{k}\mathbf{C}_t + \boldsymbol{\tau}^\mathbf{k}\mathbf{Z}_s + \varepsilon^k_{ijt} \qquad (3.1)$$

where i is the person (subscript m = male, f = female), j is household and t is day of the week; male α_m and female α_f intercepts; δ_i indicates that the person is male, female is $(1- \delta_i)$; $X^k_{mjt}\delta_i$ is the time spent in activities type k by the male in the jth household in t^h period (day); $X^k_{fjt} (1- \delta_i)$ is the time spent in activities type k by the female in the jth household in t^h period (day); $X^k_{mjt}(1- \delta_i)$ is the time spent in activities type k by the male partner in the jth household in t^h period (day); $X^k_{fjt} \delta_i$ is the time spent in activities type k by the female partner in the jth household in t^h period (day); $\overline{X}^k_j$ is the mean of couple time use; I_j is a vector of couple-mean centred variables of age and literacy[25], H_j is vector of household socio-demographic characteristics such as irrigation system, size of cultivated land, household composition and assets index, and controls such as accelerometer wear, self-reported health, caste; C_t is day dummies; Z is seasonal dummies; and the error term is $\varepsilon_{ijt} = \zeta_j + \mu_{ij}$ where ζ_j is household component, and individual-specific component μ_{ij}

The composition of groups, their contexts and the endogeneity of variables are likely sources of bias in multilevel analysis of APIM. For instance in our analysis, if higher couple literacy is

[25] Couple mean centering of age and literacy was obtained by subtracting the household mean from individual observation.

associated with higher CAR for household j, comparing own and partner effects among couples is confounded by higher estimates among more literate couples (Bingenheimer & Raudenbush, 2004; Rabe-Hesketh & Skrondal, 2012). This confounding by average household level characteristics is referred to as compositional effects (Duncan et al., 1998). We address compositional effects by including couple-mean centred variables of age and literacy in equation 3.1 (Rabe-Hesketh & Skrondal, 2012).

In addition to bias that may be introduced by compositional effects, individual's patterns of time use is known to correlate with unobserved household-level characteristics such as sociocultural norms, resulting in level-2 endogeneity (Kevane & Wydick, 2001). We used the Mundlak or "including-the-group-means approach" to address level-2 endogeneity of the time use variables (Mundlak, 1978). This was done by including the means of couple time use variables in equation 3.1. The Mundlak approach results in own and partner time use effects that captures pure within-couple variation, which is unaffected by level-2 endogeneity.

Further, to ascertain the exogeneity of the within-couple time use estimates, we conduct post regression tests of equal between and within time use effects (Rabe-Hesketh & Skrondal, 2012). Results shows that the within-couple effects is uncorrelated with the household couple time use effects. However, the Mundlak approach can produce biased estimates due to other omitted variables, and the effects of time-invariant variables may not be consistent, as the within and between effects are estimated separately in equation 3.1 (Hanchane & Mostafa, 2012). This limitation is addressed by the instrumental variable or Hausman-Taylor (HT) approach (Hausman & Taylor, 1981). The HT approach can consistently estimate models with endogenous time-invariant variables and time-variant variables, which are uncorrelated with the residuals. The purpose of the HT method is that estimates of the within effects for the time-varying variables are obtained through a standard fixed effect estimator, producing residuals by using uncentered time-varying variables together with estimated coefficients. The residuals are then regressed on time-invariant variables, using the exogenous variables as instrumental variables (Rabe-Hesketh & Skrondal, 2012). As such, using the HT approach requires independent variables to be classified into four kinds as: exogenous time-varying variables, endogenous time-varying variables, exogenous time-constant variables, and endogenous time-constant variables. In addition to this criterion, the number of exogenous time-varying variables must be equal or higher than the number of the endogenous time-constant variables. Both conditions are satisfied in equation 3.2[26], where we estimated nine separate regression models where each outcome variable PAL, EI and CAR depend on each set of economic, domestic and leisure activities of the form $Y_{2ijt} \in \{PAL_{ijt}, EI_{ijt}, CAR_{ijt}\}$ and k = {Economic, Domestic and Leisure}:

$$Y_{2ijt} = (\beta_{2i} + \zeta_j) + \beta^k_{2m} X^{k,\,end}_{mjt}\, \delta_i + \beta^k_{2f} X^{k,\,end}_{fjt} (1-\delta_i) +$$

$$\rho^k_{2m} X^{k,\,end}_{mjt} (1-\delta_i) + \rho^k_{2f} X^{k,\,end}_{fjt}\, \delta_i + \pi^k_{ij} P^{k,\,end}_{ijt} + \omega^k_2 \mathbf{I}_j + \tau^k_2 Z_s + \gamma^k_2 \mathbf{C}_t + \varepsilon^k_{ijt} \qquad (3.2)$$

where i is the person (subscript m = male, f = female), j is household and t is on day t; superscript *end* indicates endogenous variables; subscript 2 here distinguishes equation 3.1 and 3.2; $(\beta_{2i} + \zeta_j)$ is the intercept; δ_i indicates that the person is male = 1, female = $(1-\delta_i)$; $X^{k,\,end}_{mjt}$ is the time spent in activities type k by the male in the jth household in t^h period (day); $X^{k,\,end}_{fjt}$ is the time spent in activities type k by the female in the jth household in t^h period (day); $X^{k,\,end}_{mjt}(1-\delta_i)$ is the time spent in activities type k by the male partner in the jth household in t^h period (day); $X^{k,\,end}_{fjt}\, \delta_i$ is the time spent in activities type k by the female partner in the jth household in t^h period (day); $P^{k,\,end}_{ijt}$ is a vector of gender and literacy; I_j is a vector of household socio-demographic characteristics such as irrigation system, size of cultivated land, vector of

[26] Exogenous time-varying variables: seasonality dummies, day dummies, accelerometer wear, self-reported health; endogenous time-varying variables: own and partner economic, domestic, and leisure time use variables; exogenous time-invariant-variables: number of females, number of males, number of children, number of adolescents, number of infants, irrigation system, land size, asset index, caste; endogenous time-invariant variables: sex, age and literacy.

household composition and assets index, and controls such as accelerometer wear, self-reported health, caste; Z is seasonal dummies; C_t is daily dummies; error term = ε_{ijt}. Own and partner time use variables and individual characteristics variables of gender and literacy were designated as endogenous in the random intercept model in equation 3.2. The regression analysis was carried out using the "xthtaylor" command in Stata software (Castellano et al., 2014; Hausman & Taylor, 1981; StataCorp, 2013). The other form of endogeneity in MLM is the level-1 endogeneity of level-1 covariates. For instance, individual preference for certain activities may influence the amount of time spent on such activity. However, level-1 endogeneity in MLM is not directly testable (Rabe-Hesketh & Skrondal, 2012). Post-regression estimates of the own and partner effects of each time use category were computed using elasticities – as the percentage change in dependent variable divided by the percentage change in the independent variable.

3.5 Results

3.5.1 Descriptive statistics

Table 3 presents descriptive statistics of household-level characteristics. The asset index is computed using the principal components analysis whereby households are scored based on ownership of assets related to dwelling characteristics, farm equipment, means of transportation, and consumer durables (Filmer & Pritchett, 2001). On average, households in our sample cultivate around 10 acres of land, which is greater than the 3 acres district average (Government of Telangana, 2021b). There is however variability in the sample with 35 per cent being smallholders, 35 per cent medium and 30 per cent large farmers based on classification of landholding by the Indian Ministry of Agriculture and Farmers Welfare (smallholders <4.94 acres, medium 4.94-9.88 acres and large farmers >12.35 acres). The average household size of 4.3 is slightly below the Indian national average of 4.6 people (UNDESA, 2019), with the number of males slightly higher than the number of females. The respondents belong to the backward castes [27]- only one household identifies as belonging to the scheduled caste.

Table 3: Descriptive statistics of household-level characteristics

	Mean	SD	Min	Max
Asset index	0.00	1.68	-3.59	4.02
Land cultivated (acres)	10.00	7.06	2.47	29.65
Irrigation system (yes = 1, no = 0)	0.50	0.50	-	-
Number of adult males (18-64 years)	1.70	0.90	1.00	4.00
Number of adult females (18-64 years)	1.55	0.58	1.00	3.00
Number of infants (0- 1 years)	0.05	0.22	0.00	1.00
Number of children (2-12 years)	1.10	0.99	0.00	3.00
Number of adolescents (13-17 years)	0.35	0.73	0.00	2.00
Caste (whether backward caste)	0.95	0.01	-	-

Notes: The asset index was computed by projecting data on households' ownership of equipment, means of transportation, consumer goods and living characteristics using the principal component analysis technique. SD = standard deviation.

Descriptive statistics of individual-level characteristics are reported in Table 4. An average PAL value of 1.55[28] suggests that men and women spend a significant amount of time engaged in light and moderate-intensity activities. Energy intakes for males and females are below the Indian recommended daily dietary allowance of 2730 and 2230 kcal for moderately active people (National Institute of Nutrition, 2011). There are indications of calorie deficits among survey participants, but larger deficits are observed among men. On average, men have a higher energy intake (158kcals/day) than women. However, relative to their energy expenditure needs, they also have higher energy shortfalls compared to women. The difference in energy adequacies is explained by higher daily energy expenditure (485.50 kcals/day) among men. These findings are similar to (Daum et al., 2019b) and (Zanello et al., 2017).

Table 4: Descriptive statistics of individual-level characteristics by gender.

	Males		Females		Mean difference
	Mean	SD	Mean	SD	
Dependent variables					

[27] Backward castes means such "backward classes of citizens other than the Scheduled Castes and the Scheduled Tribes as may be specified by the Central Government of India" (The National Commission for Backward Classes Act, 1993).
[28] Based on time use, PAL values are classified as sedentary or light (1.40-1.69), active or moderately active (1.70-1.99), and vigorous (2.00-2.40) in free-living populations (FAO, 2001).

Physical Activity Level (PAL)	1.53	0.31	1.56	0.26	-0.02
Energy Intake (kcal/day)	1751.18	543.86	1593.13	510.83	158.05***
Caloric Adequacy Ratio (CAR)	0.85	0.29	0.99	0.38	-0.15***
Independent variables					
Age (years)	39.84	10.15	34.29	9.55	5.55***
Literacy (can read and write)	0.30	0.02	0.05	0.01	25.00***
Domestic and care activities (minutes/day)	27.11	52.05	205.5	103.05	-178.39***
Economic activities (minutes/day)	516.32	136.51	419.36	135.76	96.96***
Leisure (minutes/day)	327.32	102.55	254.89	91.73	72.43***
Accelerometer non-wear (minutes/day)	31.07	87.98	36.86	108.52	-5.79
Self-reported health (health status did not reduce work ability)	0.99	0.11	0.99	0.11	0.00

Notes: SD = standard deviation. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01. own and partner time use variables are dummy variable-based, as such, they are not included in Table 3.

Further, men are on average slightly older than their wives. About 30 per cent of the men can read and write compared with only 5 per cent of women. The amount of time spent in economic activities among males and females in our sample is remarkably higher than the state-wide average reported in Figure 2. Of the three work categories considered for the couples, economic activities dominate daily time use, followed by leisure, then domestic and care activity. Men spend 96 minutes more on economic activities than women while women spend around 178 minutes in domestic and care activities more than their spouses. Such time allocation patterns imply that men spend 72 minutes in leisure activities more than women daily. Similar unequal pattern of intrahousehold work division have been reported in developed countries (Bittman et al., 2003).

3.5.2 Own and partner effects

As explained in section 4.3.2, we ran fifteen separate regressions such that own and partners' time spent in economic, domestic and leisure activity were regressed on the outcome variables of PAL, EI, CAR, CAR<1 and CAR>=1. The time use coefficients can be interpreted as the effect of a one minute change in the time devoted to an activity category on the dependent variable. Full regression tables are reported in Appendix B. Table 5 reports an overview of own and partner effects elasticities computed post-MLM analysis of the Mundlak approach in equation 1. The effect sizes in Table 5 are expressed in percentages.

Table 5: Own and partner elasticities of time use relative to PAL, EI, and CAR (CAR, CAR<1, CAR>1)

Economic activities	PAL	EI	CAR	CAR<1	CAR>=1
Male Own	0.10*** (0.01)	-0.01 (0.02)	-0.09*** (0.03)	-0.03 (0.03)	-0.02 (0.02)
Female Own	0.08*** (0.01)	0.06*** (0.02)	-0.00 (0.02)	0.03 (0.02)	0.04 (0.03)
Male Partner	-0.02*** (0.04)	-0.07*** (0.02)	-0.05* (0.03)	-0.06*** (0.02)	-0.06 (0.04)
Female Partner	0.01 (0.01)	0.06*** (0.02)	0.02 (0.03)	0.03 (0.02)	0.00 (0.02)
Mean Household	-0.09 (0.23)	-0.04 (0.39)	-0.15 (0.37)	-0.31 (0.23)	0.01 (0.27)
Domestic activities					
Male Own	-0.01*** (0.00)	-0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.03)
Female Own	-0.01* (0.01)	-0.04*** (0.01)	-0.04*** (0.01)	-0.02** (0.01)	-0.00 (0.04)
Male Partner	0.00** (0.00)	0.01* (0.00)	0.00 (0.00)	0.00 (0.00)	0.01** (0.00)
Female Partner	-0.01 (0.01)	-0.04*** (0.01)	-0.03* (0.01)	-0.02 (0.01)	0.00 (0.01)
Mean Household	0.07 (0.12)	0.20 (0.15)	0.25 (0.25)	0.05 (0.08)	0.15 (0.18)
Leisure activities					
Male Own	-0.04*** (0.01)	-0.02 (0.02)	0.01 (0.02)	-0.00 (0.02)	0.01 (0.02)
Female Own	-0.05*** (0.01)	0.00 (0.02)	0.05*** (0.02)	0.02 (0.02)	0.01 (0.02)
Male Partner	0.01 (0.01)	-0.01 (0.02)	-0.03 (0.02)	0.01 (0.02)	-0.02 (0.03)
Female Partner	-0.00 (0.01)	-0.00 (0.02)	0.01 (0.02)	-0.01 (0.02)	-0.00 (0.02)
Mean Household	-0.13 (0.18)	0.25 (0.39)	0.58 (0.61)	0.05 (0.26)	-0.09 (0.37)

Notes: Restricted maximum likelihood post-regression elasticity estimates of the effects of own and partners time use in economic, domestic and leisure time use on dependent variables - Physical Activity Level (PAL), Energy Intake (EI), Caloric Adequacy Ratio (CAR), Caloric Adequacy Ratio less than 1 (CAR<1), Caloric Adequacy Ratio greater or equals to 1 (CAR>=1). Mean Household is the average household time use which accounts for household-level contextual effect of time use. Standard errors in parenthesis. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01. The elasticities were computed as the percentage change in dependent variable/ percentage change in independent variable (that is, time use) in minutes.

3.5.2.1 Physical Activity Level (PAL)

The highest PAL effect is observed in the time allocated to economic activities followed by the time allocated to domestic activity and the smallest PAL effect is seen in leisure activities for females and males. The association between time spent in economic work and PAL is large and significant for males and females - a one per cent increase in the time allocated to economic work leads to a ten per cent and eight per cent increase in own PAL for males and females respectively. Male economic time use is associated with a one per cent reduction in female PAL which suggests that male economic time use has a positive partner effect of reducing female physical activity level. As for domestic activity, there is a negative association between time use in domestic work and PAL for males and females. Male domestic time use has a positive partner effect on female PAL while female domestic time use has a negative partner effect on male PAL. Further, given that men spend considerably less time in domestic activity, the equal PAL effect size observed for time use in domestic activity time use among males and females may be attributed to short duration but more energy-intensive activities done by males in contrast to longer duration but less energy-intensive tasks performed by women.

Time use in leisure is inversely related to PAL, and more so among women than men - a one per cent increase in the time allocated to leisure is associated with a five and four per cent reduction in PAL for females and males respectively. A one per cent increase in male leisure time use increases female PAL by 2 per cent.

3.5.2.2 Total Individual Energy Intake (EI)

No significant energy intake effects for time use in all the three activity categories for males were observed. However, increase in female energy intake appears to increase by six per cent with a per cent increase in time spent in economic activity. Such patterns of intrahousehold food allocation suggest that time spent in economic activity is an important but not the sole determinant of intrahousehold food distribution. The significant partner effects of domestic time use confirms couple interdependence in this time use category and energy intake. We also observe contrasting partner effects in energy intake; male time use in economic activity is correlated to a decreasing quantity of food calories consumed by his spouse whereas female time spent in economic work is positively associated with the energy intake of males. The effects of female time spent in economic work on the couples' energy adequacy is large enough – in kcal values – to offset the less calorie intake due to male partner effects. In other words, for females, herself and her spouse are better off with her spending time in economic work. This result aligns with the findings in studies that women economic work improves not only their nutritional outcomes but also for other household members (Ruel et al., 2018).

We see also that female's energy intake declines with increasing time allocated to domestic activity as opposed to the increasing effect observed for time spent in economic work. This result contradicts the positive nutritional outcomes reported for domestic work in a prior multicountry study (Komatsu et al., 2018). The male partner EI effects of domestic activity show that female EI tends to increase as men engage in domestic activity. We see this pathway validated by the EI effects observed in economic activities, whereby males participation in economic activities negatively influences EI of females. There is no statistically significant relationship between EI and leisure time use for both females and males.

3.5.2.3 Caloric Adequacy Ratio (CAR)

Results show that a one per cent increase in male economic time use leads to a nine per cent decrease in CAR. A corresponding significant relationship for females was not observed. This result is a contradiction to what we observed for the EI outcome variable in section 5.3.2 above, where female economic time use is a significant predictor of EI but not CAR and vice versa for men. Such an outcome underscores the importance of accounting for energy requirements in nutrition assessments. For partner effects, female CAR tends to decrease with increasing male economic time use- a one per cent increase in male economic activity participation leads to a five per cent decrease in CAR for females. These results corroborate the partner effects observed for EI.

The effect of female domestic time use on female CAR mimics male economic activities on their male CAR. Similar to the results that we observed for EI, female domestic time use reduces female CAR economic time use tend to reduce male CAR. In addition to own effects, female domestic time use is also negatively associated with the CAR of their spouses. Our results provide no evidence of the effect of time use in domestic activity and CAR for men, as there are no significant effects seen for males in both their own and partner effects.

The association between leisure time use and CAR shows that for every one per cent time spent in leisure, female CAR increases by five per cent. Corresponding own male effects are not significant and there are no partner effects of leisure on CAR for both males and females.

We decompose CAR into energy sufficient (CAR≥1) and energy deficient (CAR<1) groups to provide additional insights on intra-couple time allocation by their energy adequacy status. Again, caloric adequacy tends to decrease with increasing own domestic time use among energy-deficient females. Among females with a caloric adequacy ratio greater than 1, CAR appears to increase with male partner domestic time use. There are no significant effects observed in the relationship between household context and time use among the caloric-deficient and sufficient groups.

Equation 2 regression results are presented in Table 6. Post-regression elasticity estimates of the Hausman-Taylor estimator are quite similar to the Mundlak approach already described in subsections 5.2.1, 5.2.2 and 5.2.3, except for the insignificant female partner domestic time use effect on CAR in the Mundlak approach and the insignificant male partner leisure time use on PAL in the Hausman-Taylor approach.

Table 6: Own and partner elasticities of time use relative to PAL, EI and CAR using Mundlak and Hausman-Taylor approaches.

	PAL		EI		CAR	
Economic activities	Mundlak	HT	Mundlak	HT	Mundlak	HT
Male Own	0.10*** (0.01)	0.10*** (0.01)	-0.01 (0.02)	-0.01 (0.02)	-0.09*** (0.03)	-0.09*** (0.03)
Female Own	0.08*** (0.01)	0.08*** (0.01)	0.06*** (0.02)	0.06*** (0.02)	-0.00 (0.02)	-0.01 (0.02)
Male Partner	-0.02*** (0.01)	-0.03** (0.01)	-0.07*** (0.02)	-0.07*** (0.01)	-0.06** (0.03)	-0.05* (0.03)
Female Partner	0.01 (0.01)	0.01 (0.01)	0.06*** (0.02)	0.07*** (0.02)	0.02 (0.03)	0.02 (0.03)
Mean Household	-0.09 (0.11)		-0.04 (0.39)		-0.15 (0.37)	
Domestic activities						
Male Own	-0.01*** (0.00)	-0.01*** (0.00)	-0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Female Own	-0.01* (0.01)	-0.01* (0.01)	-0.04*** (0.01)	-0.04*** (0.01)	-0.04*** (0.01)	-0.04*** (0.01)
Male Partner	0.00** (0.00)	0.00** (0.00)	0.01* (0.00)	0.01* (0.00)	0.00 (0.00)	0.00 (0.00)
Female Partner	-0.01 (0.01)	-0.01* (0.01)	-0.04*** (0.01)	-0.04*** (0.01)	-0.02* (0.01)	-0.03* (0.01)
Mean Household	0.08 (0.12)		0.20 (0.15)		0.25 (0.25)	
Leisure activities						
Male Own	-0.04*** (0.01)	-0.04*** (0.01)	-0.02 (0.02)	-0.02 (0.02)	0.01 (0.02)	0.01 (0.02)
Female Own	-0.05*** (0.01)	-0.05*** (0.01)	0.00 (0.02)	0.00 (0.02)	0.05*** (0.02)	0.05*** (0.02)
Male Partner	0.02* (0.01)	0.01 (0.01)	-0.01 (0.02)	-0.01 (0.02)	-0.03 (0.02)	-0.03 (0.02)
Female Partner	-0.00 (0.01)	-0.00 (0.01)	-0.01 (0.02)	-0.01 (0.02)	0.01 (0.02)	0.01 (0.02)
Mean Household	-0.13 (0.18)		-0.25 (0.39)		0.58 (0.61)	

Notes: Elasticities of multilevel model estimates of the effects of own and partners time use in economic, domestic and leisure work on dependent variables using Mundlak and the Hausman-Taylor (HT) approaches – Physical Activity Level (PAL), Energy Intake (EI), Caloric Adequacy Ratio (CAR). 'Male (female) own' is male (female) time use effect on own outcome. Mean Household is the average household time use which accounts for household-level contextual effect of time use. 'Male (female) partner' is male (female) time use effect on female (male) outcome. Standard errors in parenthesis. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01.

3.5.3 Robustness checks

To assess the robustness of regression results to the different estimation methods of the MLM, we compare magnitudes and significance values between coefficient estimates of restricted maximum likelihood (REML) and full information maximum likelihood (FIML) for all models. Estimates are similar and our conclusions hold for both REML and FIML parameter estimation methods. However, our preferred approach is REML as it is more suitable to estimations of small sample sizes than FIML (Peugh, 2010). The regression tables and post regression elasticities tables of the FIML are presented in Appendices C1 – C4.

3.6 Discussion

The time use patterns of women may be responsible for the persistence of malnutrition among women; however, previous empirical studies have only examined the effects of time use allocations of women on their maternal functions. Empowerment programmes for women that focus solely on increasing women's productive assets may not guarantee any improvement in nutritional or other outcomes, because these outcomes also depend on time allocation, which is influenced by women's ownership and control over assets and partner time allocations.

Results of analysis show a significant relationship between time use and caloric intake adequacy. Specifically, female caloric adequacy ratio is negatively correlated to male time use in economic work and female domestic time use is negatively associated with male caloric intake adequacy. Economic time use by males, domestic time use by females tend to reduce own caloric intake adequacy, alongside the positive caloric intake adequacy effects of leisure for females. Despite significant partner effects confirming couple interdependence in the results, sizable asymmetry in time use between males and females emerged.

By considering physical activity level and energy intake as dependent variables, we uncover which pathways were important to generate the observed caloric intake adequacies. First, as shown in the dissimilarities between energy intake and energy adequacy effects of time allocation, the analysis expounds on the importance of physical activity energy expenditures in individual energy requirement assessments. Second, we find that female economic time use is associated with increased energy intake especially among caloric deficient households. The benefits of female economic time use to self and spouse outweighs the negative male partner economic time allocation effects. This finding underscores the contribution of female economic work to securing own caloric intake and that of other members in line with existing literature (Kabeer, 2001; Quisumbing & Maluccio, 2003). The net energy intake effect of female domestic time use is negative for own and partner, contrary to previous evidence linking time use in domestic work to better nutritional outcomes (Komatsu et al., 2018). These results suggest that female empowerment programs that redistribute time burdens by encouraging sharing of work between spouses have the potential to improve nutritional outcomes of females and males.

The empirical analysis largely corroborates recent reviews and commentaries suggesting that a change in socio-cultural norms around intrahousehold allocation of work may be required for achieving desirable nutritional outcomes in many LMICs (Asadullah & Kambhampati, 2021; Madzorera & Fawzi, 2020; N. Rao et al., 2017). Results show that male energy expenditure tend to reduce when time is allocated to domestic work. Female economic time use tends to increase both couple's energy intake. Hence, a gender-equal redistribution of economic and domestic work appears to be a pathway to improve household nutritional outcomes, especially among food-insecure households. However, as spousal cooperation tend to vary by household and cultures, understanding the interdependency contexts will be paramount to relaxing norms influencing how work and food are shared within the household (Kabeer, 2010; Lecoutere & Wuyts, 2020; Ragasa et al., 2019; Spark et al., 2021).

On whether increasing women's economic labour will not be detrimental to women's health, growing evidence from the feminization of agriculture literature reveals that increasing female employment opportunities especially in the agricultural sector has not always led to female empowerment due to social norms and gender-intensified constraints such as lack of productive assets, lower pay and higher unpaid work burdens among women relative to men (Asadullah & Kambhampati, 2021; Da Corta & Venkateshwarlu, 1999; Supriya Garikipati, 2006). The goal of policymakers concerned about female empowerment should be to address these constraints and ensure that increases in female economic work is accompanied by reduction in their domestic and care work burdens. Indeed, intra-couple sharing of work and food will likely embody "unequal interdependence"- whereby women bear higher labour burdens relative to men (Kabeer, 2001). Yet, paid economic work constitutes the "start of the breaking of traditional (social) norms" for some women especially in countries like India where female agricultural employment accounts for 58 per cent of the 17 per cent total female employment (Banerjee, 1997; ILO, 2022).

3.7 Conclusion

Economic theories of the household have either considered household members as unified in their interests and preferences or treated individuals as independent decision-making units (C. R. Doss & Quisumbing, 2020). This paper set out to find evidence of couple interdependency through partner effects among households in Jogulamba district in rural Telangana, India. This analysis investigates own and partner effects of intra-couple time allocation on nutritional outcomes. We contribute to the literature on intrahousehold time allocation and nutritional externalities by looking beyond women's time use and child's nutritional outcomes. We assess couple interdependencies in time allocation and nutritional outcomes using the Actor-Partner

Interdependence Model framework. The contribution is relevant, given that time use changes caused by rural transformation are expected to have consequences for nutrition. The major finding of this paper is that gender differences in the allocation of time is negatively linked with nutritional outcomes; economic time allocation by males and domestic time allocation by females tend to reduce own and partners' nutrition. However, spending time in economic work is associated with an improvement in nutritional outcomes for females and nutritional improvements among males is associated with allocating time to less physically intensive tasks like domestic work.

The results suggests that interventions that seek to improve nutrition in rural LMICs may need to aim beyond improving autonomy for women as current evidence shows that women already are experiencing time and energy expenditure burdens. Intrinsically, development efforts can minimize nutrition trade-offs to women empowerment by encouraging cooperation between spouses, especially with regards to intrahousehold sharing of work activities. The results also corroborate suggestions that a change in the norms surrounding intrahousehold work division in many LMICs is required to alleviate food and nutrition insecurity for men and women. While this study shows evidence on partner effects within couples, there is a need to further understand the welfare effects of women's time use in relation to their spouses. For instance, whether individual characteristics, type of work, or income levels moderates own and partner effects.

The innovative methodology used to collect and triangulate multiple data streams is not without shortcomings. The sample size cannot be considered representative of the country where the data was collected but rather an exemplary case study. The empirical analysis is supported by simulation studies that have proven that fixed-effects estimates (unlike variance components) and standard errors of the multilevel analysis are not necessarily biased as a result of sample size limitation (Bell et al., 2014; Huang, 2018; Peugh, 2010). Nevertheless, weak significance values should be interpreted with caution. Also, due to statistical software limitations, we have not examined heterogeneities across households through cross-level effects of household characteristics or seasonality that may mediate the level of spousal interdependency observed in this study. For instance, household composition has been shown in earlier literature to determine the division of domestic work within couples with small children (Lundberg, 1988). Indeed, households in the sample are composed of more than the two individuals that were sampled. Even if we had no data for the other household members, we controlled in the analysis for the presence of other members by including household size in the vector of household characteristics as well as included a vector of seasonality to control for seasonal changes in time allocation. In addition, time use as an indicator of livelihood may be a lesser metric compared to energy expenditure in understanding the consequences of day-to-day living on nutritional outcomes (Jackson & Palmer-Jones, 1998; Picchioni et al., 2020). However, combining data points on time use and energy expenditure provides better insights into understanding nutrition in rural livelihoods (Zanello et al., 2017). A richer picture of the analyses contained herein would be the consideration of anthropometric measures. However, the anthropometric measurements in the data were collected only during the first round of data collection – making them less suitable to capture nutritional outcomes over time. In the APIM analysis, in addition to partner effects, couples' outcomes may have been affected by other forms of non-independence such as common fate and mutual influence. Food intake data are known to be subjected to under-reporting due to social desirability and recall bias particularly in terms of food consumed outside the home. It is possible that under-reporting bias in the study is larger for men than women in relation to calories derived from alcohol consumption and food consumed outside the home. Also, cultural aspects of intrahousehold food sharing such as order of food servings and the tendency to allocate more nutritious meals to males are not explicitly considered in this study due to data limitation. These are aspects that future work may seek to improve upon.

Chapter 4: Greater agricultural participation and changes to energy expenditure in Adilabad, India

Abstract

This chapter empirically assess the change in energy expenditure if participation in agriculture increases. We hypothesize that as agricultural time use increases, the nature of the change to wellbeing will depend on the energy demands of the activity that agriculture is substituting in rural livelihoods. Using compositional data analysis methods and a novel data collection methodology that combines information on individual's 24-hour time use, physical activity energy expenditure, and socio-demographic characteristics, this chapter provides empirical evidence on the change in human energy expenditure resulting from time trade-offs to agriculture. The notion that more energy is required when more agricultural work is performed is not supported by the results as other time use domains in rural livelihoods are equally energy-intensive, and the effects of time use on well-being are not peculiar to agriculture. The results imply that the negative well-being consequences that may derive from the feminization of agriculture are not likely from increased energy burdens. The finding provide a justification to focus on women's time allocation instead of energy expenditure in understanding the agriculture-gender-nutrition pathways.

Keywords: *Feminization of agriculture; time use and physical activity; nutritional outcomes; compositional data analysis methods; India.*

4.1 Introduction

As economies grow and incomes increases, societies transition from their reliance on agriculture to the non-agricultural sectors. This structural transformation is usually accompanied by a change in the economic roles of females and males; a reduction in female labour force participation at the initial stages of development, accompanied by an increase in the female labour force participation at the later stages (Goldin, 1995). Empirical evidence have not supported this hypothesis in some middle-eastern and south Asian countries (Verick, 2014). Instead, many low and middle-income countries (LMICs) are witnessing an increase in female agricultural labour supply as their economy develop (Boserup et al., 2007). Notably, the recent increase in the participation of women and the corresponding reduction in the time committed to agricultural activities by men – a trend referred to as feminization of agriculture (Deere, 2005). The feminization of agriculture concept, in the context of rural transformation involve changes in the gendered pattern of agricultural labour. However, such changes may vary across contexts due to the scale of agricultural production, the nature of agricultural employment contracts available to women, and the role of women on the farm (Kawarazuka et al., 2022). Feminization of agriculture may connote an increase in female agricultural employment as farm workers and managers, a higher number of women relative to men in agricultural employment, or the increase in the female time allocated to agricultural activities relative to male (Slavchevska et al., 2016). We define feminization of agriculture in this study as the greater participation of women in agriculture, measured by the increase in time spent in agriculture (Deere, 2005; Mu & van de Walle, 2011), where the increase in agricultural time use is the result of reallocating time from other daily activities to agriculture.

In India, female employment in agriculture as a proportion of formal and informal employment currently stands at 55 per cent, this figure is higher than the 31 per cent average reported for low and middle income countries (The World Bank, 2021). For the women employed in agriculture, the welfare implication of a contraction in their labour use can be tremendous; to the extent that unemployment in the agricultural sector mostly translates to exit from the labour market because women are unable to take up employment in the non-agricultural sector (Afridi et al., 2022; Rawal & Saha, 2015). This reliance on agriculture has been attributed to a lack of opportunities, less physical mobility (Pattnaik & Lahiri-Dutt, 2021), and social and religious norms that make paid work outside of the home unattractive (Desai & Jain, 1994). Given the substantial contribution of agriculture to livelihoods, agricultural work will need to be compatible with the development goal of improving women's well-being.

The work effort involved in farming is usually assumed to be high especially in rural areas of low- and middle-income countries. Recent studies however suggests that physical activity levels in rural livelihoods tend to be in the light and moderate ranges, and varies within and among populations (Dufour & Piperata, 2008; Srinivasan et al., 2020). Also, households adapt to the changing gendered pattern of agricultural labour by adopting less time and energy-intensive crops, reducing cropping area, and by engaging other household members in farm tasks (Kawarazuka et al., 2022). The burden of women's farm work, in addition to participation in post-harvest food processing, domestic and care activities likely has consequences for household nutrition (Kadiyala et al., 2014). Despite the arduous, time and energy intensity of work associated with agricultural activities in rural livelihoods, increasing women's time in agriculture may not necessarily translate to negative health and nutritional outcomes if, agriculture increases incomes and food availability, and the activity that agriculture is substituting has an equal or higher energy requirement (Kadiyala et al., 2014). Yet, there is a lack of empirical evidence on the well-being risks posed by time trade-offs when agricultural work substitutes other tasks and activities in rural livelihoods.

In the past, studies have examined the well-being outcomes of increasing women's agricultural time use and there are increasing discussions on energy expenditure as a pathway through which agriculture contributes to nutritional outcomes but empirical analyses are few (Aderanti et al., forthcoming; Picchioni et al., 2020). Further, the consideration of time domains in isolation have persisted even though evidence suggests interdependencies among the time use domains (Gronau, 1977). In addition, the nature of activities outside of economic (and perhaps domestic) time use domains is still poorly understood. We suggest that the trend in feminization of agriculture and the increase in women's economic participation will require understanding these issues to improve on the design and implementation of agricultural and development interventions especially, the programs that increases the time women allocate to economic work at the expense of other time uses.

This study therefore aim to contribute to the feminization of agriculture literature by quantifying the change in energy expenditure resulting from allocating additional time to agriculture. The study examines the following research questions:

(i) What is the relationship between the distribution of daily time use and energy expenditure in rural livelihoods?

(ii) How does allocating more time to agriculture affect total daily energy expenditure?

(iii) How substantial are the changes to energy expenditure resulting from reallocating time from each of non-agricultural economic, domestic, leisure, self-care, and sleep to agriculture?

The remainder of the chapter is structured as follows: the conceptual framework and related literature for understanding feminization of agriculture, and the resulting well-being impacts are presented in section two. The data, including the study area and data collection is described in section three. This is followed by the methods used in analysis in section four. The results of analysis is presented in section five. The discussion of results is presented in section six. The chapter ends with the conclusions in section seven.

4.2 Conceptual framework and related literature

The conceptual framework for understanding feminization of agriculture (greater participation of women in agriculture), and the resulting well-being impacts is presented in Figure 5. The framework builds on earlier work explaining agriculture-nutrition linkages from the time use perspective (D. Johnston et al., 2018; Kadiyala et al., 2014). This framework elaborates on the role of energy expenditure in determining how changes to women's nutrition and health may arise from changes in the composition of their daily time use. As the time allocated to agriculture increases, the changes in women's well-being will depend on the type of activity (and its energy requirements) that agriculture is substituting in rural livelihoods.

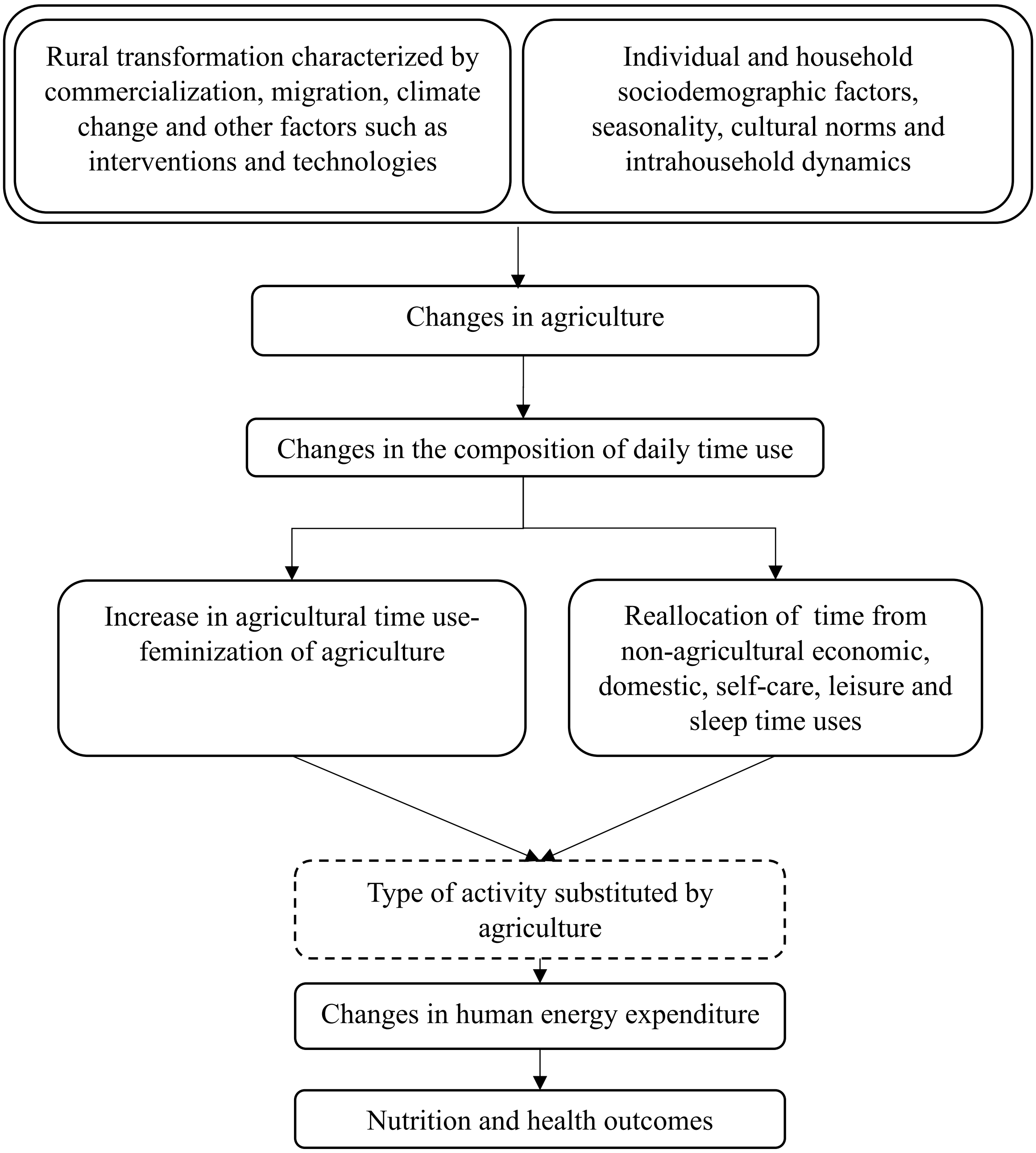

Figure 5: Conceptual framework-greater participation in agriculture.

The changes in agricultural practices and labour patterns are driven by rural transformation characterized by climate change, migration, agricultural commercialization, conflicts, and local factors such as agricultural interventions, government policies, and intermediate farm technologies (Daum et al., 2019b; C. Doss et al., 2021; Jiggins, 1998; Lastarria-Cornhiel, 2006; Padmaja et al., 2019; Repassy, 1991; Shaver, 1991; Slavchevska et al., 2016; Sommestad, 1994; Talwar & Ganguly, 2003). However, individuals and households tend to respond differently to increased time demands in agriculture (D. Johnston et al., 2015). These responses are defined by age (Mu & van de Walle, 2011), nutritional status (N. Rao & S. Raju, 2020) along with household socio-demographic characteristics. Analysing data from Kenya, Rubin (1990) finds that women who have young children allocate more time to domestic activities and childcare than agricultural tasks compared with those without young children. Although agricultural time use tends to increase with increasing size of landholdings (Lokshin & Glinskaya, 2009; Zaman, 1995), wealthier households can offset increased agricultural time pressures through hired labour and the use of agricultural machinery (Daum et al., 2019b). The way individuals in farming households allocate their time to agriculture is not always directly related to their economic or socio-demographic characteristics, mediating factors such as intrahousehold dynamics, social norms (Komatsu et al., 2019), and seasonality also play a role (Picchioni et al., 2020).

Increasing agricultural time use may obscure the link between agriculture and nutritional outcomes (D. Johnston et al., 2015). Yet, women are seen to manage increased agricultural time demands by reallocating time away from other activities. As examples, women adopting irrigation facilities in Lesotho reallocated time away from childcare, food processing and domestic activities (Riley & Krogman, 1993). Also, by participating in a nutrition-sensitive home gardening program in Zambia, women reallocated twenty-five minutes daily from leisure and nineteen minutes from domestic and childcare activities to agriculture (Kumar et al., 2018). In Nepal, commercial-scale production of vegetables and fruit shifted women's time away from childcare to agriculture (Paolisso et al., 2002) and time reallocated to agriculture following male out-migration came from non-agricultural economic activities (Mu & van de Walle, 2011; The World Bank & FAO, 2018). Nevertheless, there are evidence that reallocating time to agriculture may have consequences for the health and nutrition of women and other members of their household. The immediate downside to moving time away from childcare is that care for the child is affected by a lack of attention to meet the child's needs. Even when substitute care is provided, the quality may be inadequate (Engle et al., 1999). Likewise, for women themselves, their well-being is compromised during intense farm work that reduces time spent on sleep, leisure and self-care activities such as eating and resting (Higgins & Alderman, 1997; Komatsu et al., 2018; Nichols, 2016). Over time, competing time uses may lead to malnutrition, child labour precluding school attendance, or even lack of time for women to participate in higher rewarding economic activities (Blackden & Wodon, 2006).

Beyond the attention and time shifted to agriculture, it has been theorized that energy expenditure rather than time use is important for well-being, especially in contexts where individuals depend on physically demanding work for their livelihoods. In the nutrition literature, sustained human energy deficit resulting from higher energy expenditure relative to energy intake directly impacts wellbeing (Floro, 1995; Palmer-Jones & Jackson, 1997; Picchioni et al., 2020). In economics, the amount of income available for food and health may depend on the amount of effort applied at work, particularly in piece-rate settings (Akogun et al., 2020). Becker (1985) argues that the wage-income differential between men and women is due to the allocation of effort between paid market and unpaid domestic activities; to the extent that competing human energy demands for domestic and care responsibilities imply that women must economize the energy they expend in economic work, hence reducing their wages relative to men.

As agriculture feminizes, its effect on livelihoods and well-being of women in LMICs is being contested. On the one hand, allocating more hours to agriculture has the potential to improve women's income (Riley & Krogman, 1993), the value of their farms (Quisumbing et al., 2013), and nutritional status (Kumar et al., 2018). On the other hand, increased time use in agriculture has been associated with higher workload and negative unintended outcomes such as frequent illness (Riley & Krogman, 1993), reduced income and downward economic status (Pattnaik et al., 2018). However, Mu & Walle (2011) reported no change in health outcomes among women in China despite their substitution of non-agricultural economic time for agricultural activities. The lack of change in health outcomes, in this case, may be due to general livelihoods rather than occupation in agriculture influencing women's well-being outcomes (Gillespie et al., 2012). In addition, there will be no change to well-being outcomes if the activity that agriculture is substituting has an equal or higher energy requirement (Kadiyala et al., 2014).

In summary, increasing time use in agriculture is beneficial for women, but the conditions created by such work whereby time use, and workload intensifies is deleterious to their well-being. This is a trade-off that requires policy and research attention. Although the focus tends to be more on agriculture as the source of drudgery in rural livelihoods, non-agricultural economic, domestic and other household tasks can place equally high energy demands on women (Barrett & Browne, 1994; S. Rao et al., 2008). This argument forms the basis of our hypothesis that, as agricultural time use increases, the changes to women's well-being will depend on the type of activity (and its energy requirements) that agriculture is substituting in daily livelihoods. In other words, the nature of the change to well-being will be determined by the association between the energy required to perform agricultural work, relative to the energy to perform the activity that agriculture is substituting.

The methodological gap identified in this literature is that although energy expenditure is thought to matter more for wellbeing than time use, evaluating the unintended negative consequences of rising agricultural time demand has been done largely through time use monitoring. This gap is due to the difficulty in capturing energy expenditure and physical activity among free-living populations. Using novel datasets that integrate information on physical activity energy expenditure, time use, and individual and household characteristics, this study assesses the changes to energy expenditure resulting from increasing agricultural time use.

4.3 Data

4.3.1 Study area

This paper uses secondary data collected for the University of Reading Global Challenge Research Fund (GCRF) Substantial Response Project in Chanduri, Komaipet, Kommuguda and Mathadiguda villages in Adilabad district, north of Telangana state in India. The region, classified as a semi-arid climate, relies on rainfall distribution for crop production, but irrigation infrastructures on farms are increasing. Currently, more than 50 per cent of cropped area have access to irrigation facilities in the district (Government of Telangana, 2021b). This development is expected to intensify agricultural production.

About 76 per cent of the 708, 972 Adilabad population live in 508 rural villages, relying majorly on agriculture for their livelihoods (Government of Telangana, 2019). The district has 15 per cent of its population belonging to the scheduled castes while 32 per cent belong to the scheduled tribes[29]. Like in many parts of India, the local economy is growing; the average per capita income (adjusted for inflation) increased from 93, 254 Indian Rupees[30] in 2015/2016 to 112,152 Indian Rupees in 2017/2018 but the gross district domestic product is still below the median obtained in the state (Government of Telangana, 2019). About one-quarter of the district population participates in the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) public works. Crop production is expanding despite increasing fragmentation of agricultural land, and more people are increasingly employed on the farm. Over 70 per cent of the total 4153 square kilometre district land area is committed to agriculture and allied services-arable farming, aquaculture, livestock, forestry services. State government report shows that during the 2019/2020 to 2020/2021 agricultural seasons, paddy production grew by 29.9 per cent and the area under cotton production grew by 29.4 per cent during the same period

[29] "Schedule" refers to schedules in the Indian constitution identifying socially and economically deprived/marginalized caste groups and tribal (indigenous) groups as being entitled to affirmative actions in education, employment and development programs (Lelah Dushkin, 1967).

[30] 1 USD averaged 67.21 Indian Rupees in 2016 (Reserve Bank of India, 2022).

(Government of Telangana, 2021a). However, the burden of stunting, wasting, severe wasting, and underweight in children as well as underweight in women is substantial and among the highest in India – around 52 per cent of children are underweight, and 53.2 per cent of pregnant women are anaemic. Government report noted that this region is characterised by a relatively high, and increasing incidence of malnutrition (Christopher et al., 2021; Government of Telangana, 2021b).

4.3.2 Data collection

4.3.2.1 Survey

The secondary data used for this study was collected from sixty-four individuals in thirty-two households, over three non-consecutive weeks between August 2019 and August 2020 corresponding to three agricultural seasons when weeding, harvesting and fertilizer application activities were carried out[31]. The datasets combine information on socio-demographic characteristics of the individuals and their household, anthropometric measures, 24-hour time use and physical activity, and energy expenditure.

All respondents are predominantly farmers cultivating cotton, turmeric, rice, sorghum and soybeans. At the beginning of the fieldwork, respondents provided information on their health, and anthropometric measurements of height and weight were also given. One adult male and female household heads, aged 18-64 years in thirty-two households were followed daily for fourteen days, split over three data collection rounds. This translates into four consecutive days during the first round and five consecutive days during the second and third rounds. Information on household characteristics were collected from the household head. Anthropometric data was collected only once during the first week of the survey. Time-use data were also collected at one-hour intervals from respondents based on 24-hour recall. Respondents were asked to report

[31] This data collection methodology has been discussed in Zanello et al., (2020).

on primary and secondary activities done within the hour in no particular format to capture time use patterns typical of rural agricultural livelihoods (C. Doss et al., 2020).

4.3.2.2 Accelerometers

In addition to the time use questionnaires administered daily, physical activity data were collected using research-grade GT3X+ accelerometers worn on the waist by respondents during the survey periods. Over time, the approaches to measuring energy expenditure involves laboratory-based methods, hearth-rate monitoring and the factorial method (Dufour & Piperata, 2008). The recent advent of accelerometer technology has expanded physical activity energy expenditure measurement tools. Accelerometers are portable, motion sensor devices used in the collection of objective physical activity data in free-living population (Troiano et al., 2014; Zanello et al., 2019). The activity data collected daily over 24 hours from accelerometers were converted into activity energy expenditure (in kilocalories) using validated algorithms (Freedson et al., 1998). The accelerometers, however, may not capture the differences in types, frequency, intensity, and duration of movement. Therefore, the time use data collected using questionnaires were matched with energy expenditure data derived from accelerometers to determine activity-specific energy expenditure (Zanello et al., 2019). The 24-hour cycle of accelerometer wear extends from midnight to midnight; however, all individuals are assumed to be sleeping between 11 pm - 5 am except when a different activity has been recorded. A major problem usually associated with using accelerometers in physical activity research in free-living populations is non-wear (Troiano et al., 2014). Accelerometer wear compliance was high in the data; the final dataset resulted in 891-day level observations, after one respondent with a high attrition rate (of more than 180 minutes continuous accelerometer non-wear) during the third data collection round was dropped from the sample. This implies data collection from 64 individuals for 14 days each for a total of 896 days (minus 5 days attrition), totally 891 days.

However, anthropometric measures, household and individual characteristics were collected only once during the survey.

4.4 Empirical Methods

4.4.1 Dependent variables

Two outcome variables were used in the analysis of the relationship between time use and energy expenditure in rural livelihoods. These are activity energy expenditure (AEE) and physical activity level (PAL). Although AEE and PAL are both energy expenditure measures, the difference between them is that PAL controls for individual anthropometric and gender differences, allowing for a comparison of energy expenditure across different human groups while AEE does not allow for such comparison. We use AEE as the outcome variable in the main regression analysis, and PAL as an outcome variable as a robustness check. Both measures are standard in the economics literature to model energy expenditures in free-living populations (Friedman et al., 2021; Picchioni et al., 2020; Srinivasan et al., 2020). AEE and PAL are defined below.

Activity Energy Expenditure is the calories expended during physical activity. It is also the behavioural component of the Total Energy Expenditure (TEE) that predicts energy intake together with Basal Metabolic Rate (BMR) (Hopkins et al., 2019). To calculate AEE in this study, raw 60-seconds epoch length physical activity data collected from the accelerometer devices were converted to kilocalories using a validated algorithm (Freedson et al., 1998).

Physical Activity Level is the ratio of TEE and BMR, where TEE is the sum of AEE and BMR. We compute BMR (energy required to maintain vital physiological processes in the body) using the Harris-Benedict equation (Harris & Benedict, 1918). Based on activity time use, PAL values are classified as sedentary or light (1.40-1.69), active or moderately active (1.70-1.99), and vigorous (2.00-2.40) in free-living populations. Individuals cannot maintain activity levels at PAL values above 2.40 over a long time (FAO, 2001).

4.4.2 Time use data transformations

The 24-hour time-use data collected from respondents were grouped into agricultural, non-agricultural economic, domestic and childcare, leisure and resting, self-care, and sleep (Antonopoulos & Hirway, 2009). Since typical secondary activities like leisure and childcare can be undercounted if they are not considered in the time use data collection (Floro, 1995; Ironmonger, 2005), every recorded activity in the data was identified as either primary or secondary. Primary activities are the main activities carried out during the hour while secondary activities are carried out overlapping with primary activities. After aggregating the time use data from hourly to day-level, secondary activities occurred in about a quarter of the cases. The other methodological consideration in the time use data is zero values. In compositional data analysis discussed in section 4.3, compositional data should not contain zero values because of log-ratio computations (Martín-Fernández et al., 2003). However, time use data do have truly observed (essential) zeros or too-infrequent-to-capture (rounded) zeros. We address the issues of simultaneous activities and zero values in the time use data, as described in the subsections below:

4.4.2.1 Primary and secondary activities

Observations where no secondary activities were reported are assigned a full weight of 1 following the methodology for addressing simultaneous activities described in Picchioni et al. (2020). In cases where a secondary activity was reported within the hour, we assign 0.7 weight to the primary activity and 0.3 weight to the secondary activity. The choice of these weights is the results of sensitivity tests splitting hourly time use ratios iteratively as 0.5- 0.5, 0.6- 0.4, 0.7-0.3 and 0.8- 0.2 between primary and secondary activities respectively. The results showed no significant differences in regression estimates across the different weights for females however, only the 0.7-0.3 split showed realistic values for both females and males.

4.4.2.2 Zero values

In compositional data analysis, imputation of small values is the traditional method used to treat rounded zeros while adding up related variables and sub-grouping unrelated variables can be used to address essential zeros (Martín-Fernández et al., 2003). The time-use data contain both essential and rounded zeros, thus, we use a combination of the treatment methods for zero values. For instance, childcare has a high occurrence of zero values, especially because some households do not have young children, we therefore added childcare with domestic activities (Aitchison, 1982). We also imputed 0.01 hour (36 seconds) per/day for the activities to which zeros values are considered rounded (Aitchison, 1982; Martín-Fernández et al., 2003). Below in Table 7, we provide an overview of all the variables used in the data analysis.

Table 7: Data description for variables used in all regression models.

Dependent variable	*Variable description*
Activity energy expenditure	Total amount of calories used to perform physical activities daily. The variable measures day-level AEE information for every respondent.
Physical activity level	Ratio of total energy expenditure and basal metabolic rate. The variable measures day-level PAL information collected for every respondent throughout the survey
Independent variable	*Variable description*
Age	Individual age in number of years
Literacy	Dummy of whether a respondent can read and write
Agricultural time use	Total amount of hours spent in agricultural- crop and livestock activities in a day.
Non-agricultural economic time use	Total amount of hours spent in non-agricultural-economic activities in a day
Domestic and care time use	Total amount of hours spent in domestic, care and voluntary activities in a day
Leisure time use	Total amount of hours spent in leisure activities in a day
Self-care time use	Total amount of hours spent in self-care activities in a day
Sleep time use	Total amount of hours spent in sleep in a day
Body mass index	Body weight divided by the square of body height
Number of elderly females	Total number of female adults older than 64 years within the household
Number of elderly males	Total number of male adults older than 64 years within the household
Number of adult females	Total number of female adults aged 18-64 years within the household
Number of adult males	Total number of male adults aged 18-64 years within the household
Number of male children	Total number of male children aged between 5 and 10 years old within the household

Number of female children	Total number of female children aged between 5 and 10 years old within the household
Number of male pre-school aged children	Total number of male children aged between 0 and 4 years old within the household
Number of female pre-school aged children	Total number of female children aged between 0 and 4 years old within the household
Total land cultivated (hectares)	Total area of land cultivated by household
Total livestock unit	Ownership of livestock units based on the Food and Agricultural Organization 2011 guidelines
Wealth index	Index of sum of values of household assets
Farm production decision-making index	Additive index with scale ranging between 0 and 1 for whether the female (0) or male (1) respondent makes crop production decisions on the farm
Weeding	Dummy for agricultural season whether agricultural season is when weeding takes place
Harvesting	Dummy for agricultural season whether agricultural season is when harvesting takes place
Fertilizer application	Dummy for agricultural season whether agricultural season is when fertilizer application takes place
Day	Count of the day of the week when data was collected

4.4.3 Compositional data analysis- orthogonal log-ratio coordinates approach

Studies of time use on nutritional outcomes have largely examined time use categories in isolation, even though the consideration of the whole daily time use provides better information about the effects of time use on nutritional outcomes. Compositional data analysis is a statistical method used to study the composition of a whole, conveying relative information (Aitchison, 1982). In this study, the association of the outcome variables- AEE and PAL with the composition of daily time use categories is modelled using the ordinary least squares method. But a vector of time use variables will present multicollinearity problems in the regression analysis because the time use variables are inter-dependent; a change in one variable leads to a change in the other time use variables. The other problem is that daily time use is characterized by a constant sum constraint of 24 hours. Both the collinearity and bounded features of time use data produces biased estimated coefficients in standard statistical procedures. We used a compositional data analysis (CoDA) approach to address these analytical issues by transforming the time use data from their natural space into an ordinary real space using log-ratios (Aitchison, 1982). The log-ratios (lr) eliminates the boundedness feature of time-use data, and as lr returns d-1 variables, the collinearity in regression analysis is addressed (Hron et al., 2012). The orthogonal log-ratio coordinates approach of CoDA allows a more direct interpretation of the coefficients from the regression analysis. The orthogonal log ratio coordinates of CoDA, unlike the widely used isometric log-ratio approach eliminates the normalizing constant, and the natural logarithm is replaced by a binary logarithm (Müller et al., 2018). As a result, using log to the base 2 for the log ratio transformation instead of log to the base e makes it easier to estimate the marginal effects of the change in time use. depending on the research questions, the lr-variables can then be obtained from the sequential binary partition (Filzmoser et al., 2018). For this study, we obtain the lr variables by specifying the sequential binary partition analogous to pivot coordinates[32] – to enable interpreting the regression estimates as the effect of increasing one time component while proportionally decreasing all other time components as in Table 8 (Filzmoser et al., 2018). A time use variable of the sequential binary partition appearing in the numerator is coded as 1, a non-contributing time use variable is coded as 0, and a -1 coding indicates that the variable is in the denominator. The sequential binary partition in Table 8 is used to group the time use categories relative to all other time use categories and compute the log ratio-transformed time use variables in equations 4.2 to 4.6 as:

$$lr_i = \log_2 \left(\frac{b_i}{\sqrt[d-i]{\prod_{j=i+1}^{d} b_j}} \right) \qquad (4.1)$$

where i = 1, 2, 3,…, d – 1, b_i represents the number of minutes spent in each time use category and d is the total number of time use variables (or categories), which is six, namely: agricultural,

[32] Pivot coordinates contains relative information about a compositional part in just one coordinate. For example, all the information about b_1 (agriculture) is contained in lr_1 together with all the remaining compositional parts, and no information about b_1 is contained in the remaining log-ratio variables.

non-agricultural economic, domestic and care provisioning, leisure, self-care, and sleep. Full description of the time use categories is presented in Table 9.

Table 8: Sequential binary partition to obtain log ratio-transformed time use variables lr_i

Sequential binary partition						
b_1	b_2	b_3	b_4	b_5	b_6	Log ratio-transformed time use variables
1	-1	-1	-1	-1	-1	$lr_1 = \log_2 \frac{b_1}{\sqrt[5]{b_2 * b_3 * b_4 * b_5 * b_6}}$ (4.2)
0	1	-1	-1	-1	-1	$lr_2 = \log_2 \frac{b_2}{\sqrt[4]{b_3 * b_4 * b_5 * b_6}}$ (4.3)
0	0	1	-1	-1	-1	$lr_3 = \log_2 \frac{b_3}{\sqrt[3]{b_4 * b_5 * b_6}}$ (4.4)
0	0	0	1	-1	-1	$lr_4 = \log_2 \frac{b_4}{\sqrt[2]{b_5 * b_6}}$ (4.5)
0	0	0	0	1	-1	$lr_5 = \log_2 \frac{b_5}{\sqrt[1]{b_6}}$ (4.6)

Notes: b_1 = agricultural, b_2 = non-agricultural economic, b_3 = domestic and care provisioning, b_4 = leisure, b_5 = self-care and b_6 = sleep and rest

Hence, to assess the association of the outcome variables with agricultural time use relative to other time uses, all the information about b_1 (agriculture) is contained in lr_1 together with all the remaining compositional parts, and no information about b_1 is contained in the remaining log-ratio variables. The lr_1 is then designated as the first variable of the regression model. Similar permutations were done whereby lr_1, containing information about each of b_2 – b_6 is designated as the first variable in each of the six regression models to assess the association of the respective time use with the dependent variables.

Table 9: Description of time use variables

Time use variables

- Agricultural time use includes time spent in crop production such as soil ploughing, weeding, fertilizer application, irrigation, pesticides application, harvesting and threshing, and livestock production includes care and management of livestock. Other activities include forest produce collection and related travel
- Non-agricultural economic time use is spent in salaried employment, non-farm wage employment in construction and public work schemes, business and petty trading, professional development training
- Domestic and care provision time use includes household maintenance, food management, cleaning and upkeep of dwelling, home repair, washing clothes and utensils, shopping and related travel, and care provision includes caring for children, elderly, sick and disabled and voluntary activities are unpaid help to other households, and community services
- Leisure and resting include time allocated to socializing, talking, reading, watching television, internet use
- Self-care time is spent eating, bathing, brushing, and exercising
- Sleep and resting time is devoted to sleeping

The regression model to be estimated is:

$$Y_{ijt} = \alpha + \boldsymbol{\beta lr_{it}} + \boldsymbol{\gamma I_{it}} + \boldsymbol{\delta H_j} + \boldsymbol{\pi C_t} + e_{it} \qquad (4.7)$$

where i = male, female, j = 1,…32 households, and t indicates time. Y_{ijt} is outcome variables AEE and PAL, while lr is a vector of the log-ratio transformed variables $lr_1, lr_2, lr_3, lr_4, lr_5$; I_{it} denotes the vector of individual characteristics; H_{it} is a vector of household characteristics such as size of cultivated land, dwelling distance to a tarred road, total livestock unit, household composition, decision-making in crop production, wealth; C_t denotes the vector of control variables such as the day of the interview and seasonality. Finally, e_{it} captures the error term.

To estimate lr_1 for each of all the time uses – agricultural, non-agricultural economic, domestic and care, leisure and resting, self-care and sleep, the equation for each time use was estimated by turn, treating it as the variable in the numerator of lr1. In the second part of the analysis, we examine the association of agricultural time use and energy expenditure according to the hypothesized groups of wealth, size of cultivated land and having pre-school aged children under 5 years old in the household. Based on prior knowledge that socio-demographic characteristics influence how individuals and households are able to respond to increasing agricultural time demands, this part of the analysis assesses the differences in the energy expenditure resulting from increasing agricultural time use along socio-demographic lines. We split the sample by gender into groups of wealth (upper wealth and lower wealth), landholding size (large landholders and small landholders), and household composition of pre-schoolers (no pre-schoolers and having pre-schoolers). Separate regression analyses were conducted for each socio-economic group.

Finally, we quantify the change in energy expenditure resulting from consecutively reallocating 5, 10, 15 minutes per day from each of non-agricultural economic, domestic and care, leisure, self-care and sleep to agriculture by computing a change prediction from the regression models in equation 4.7 (Fairclough et al., 2017). We choose these time ranges based on evidence that the time reallocated to agriculture following an intervention can increase for as little as seven minutes (Schreinemachers et al., 2016). Computing the change prediction for energy expenditure involved first, predicting a baseline Y_1 using the estimated coefficients in equation 4.8 as:

$$\widehat{Y}_{1it} = \hat{\alpha}_1 + \hat{\boldsymbol{\beta}}_1 \mathbf{lr_{it}} + \hat{\boldsymbol{\gamma}}_1 \mathbf{I}_{it} + \hat{\boldsymbol{\delta}}_1 \mathbf{H_j} + \hat{\boldsymbol{\pi}}_1 \mathbf{C_t} + e_{it} \quad (4.8)$$

where the components of the lr vector of the log-ratio transformed variables $lr_1, lr_2, lr_3, lr_4, lr_5$ are retained as in equation 4.7 for agriculture, non-agricultural economic, domestic and care, leisure, self-care, sleep. The predicted $\widehat{Y}_1$ at baseline is a function of the intercept, $\hat{\alpha}_1$; the estimated coefficients of the log-ratio transformed time use variables, $\hat{\beta}_1$; the estimated coefficients of individual characteristics, $\hat{\gamma}_1$; the estimated coefficients of household characteristics, $\hat{\delta}_1$; and the estimated coefficients of control variables, $\hat{\pi}_1$. Following the estimation of the outcome variables at baseline, we consecutively reallocated 5, 10 and 15 minutes from each of the other time use variables to agriculture. For example, when 10 minutes is moved from sleep and rest to agriculture, the time use log-ratios are recomputed and regressed on the predicted outcome variable $\hat{Y}_2$ as:

$$\hat{Y}_{2ijt} = \hat{\alpha} + \hat{\boldsymbol{\beta}}_2 \mathbf{lr_{it}} + \hat{\boldsymbol{\gamma}}_2 \mathbf{I_{it}} + \hat{\boldsymbol{\delta}}_2 \mathbf{H_j} + \hat{\boldsymbol{\pi}}_2 \mathbf{C_t} + e_{it} \qquad (4.9)$$

where the components of the lr vectors $lr_1, lr_2, lr_3, lr_4, lr_5$ are computed at the new time composition using agriculture$_{+10}$, non-agricultural economic, domestic and care, leisure, self-care, sleep$_{-10}$. The predicted $\hat{Y}_2$ at the new composition is a function of the intercept, $\hat{\alpha}_2$; the log-ratio transformed time use estimated coefficients, $\hat{\beta}_2$; the individual characteristics estimates, $\hat{\gamma}_2$; household characteristics estimated coefficients, $\hat{\delta}_2$; and the control variables estimated coefficients, $\hat{\pi}_2$. Subtracting $\hat{Y}_1$ in equation 4.8 from $\hat{Y}_2$ in equation 4.9, that is, $\hat{Y}_2 - \hat{Y}_1$ equals the change prediction resulting from consecutively reallocating time from the other time uses to agriculture, holding other variables in the time use composition constant. The analyses were performed using “compositions” and “robCompositions” packages in the R software.

4.5 Results

4.5.1 Descriptive Statistics

Table 10: Descriptive statistics of household-level variables

Variable	Mean	Std. Dev.	Min	Max
Household size	5.04	1.60	3	11
Number of elderly male (> 64 years old)	0.07	0.26	0	1
Number of elderly female (> 64 years old)	0.13	0.33	0	1

Number of adult male (18-64 years old)	1.15	0.43	1	3
Number of adult female (18-64 years old)	1.08	0.37	1	2
Number of adolescent male (11-17 years old)	0.70	0.98	0	4
Number of adolescent female (11-17 years old)	0.70	0.81	0	2
Number of children male (5-10 years old)	0.26	0.44	0	1
Number of children female (5-10 years old)	0.26	0.58	0	2
Number of pre-school aged male (0-4 years old)	0.46	0.68	0	2
Number of pre-school aged female (0-4 years old)	0.24	0.52	0	2
Total land cultivated (Hectares)	3.07	1.59	0.81	6.89
Total Livestock Unit (FAO)	1.75	1.62	0	7.92
Wealth Index	5.13e-09	2.56	-5.27	5.63
Farm production decision-making index (decision was made by male)	3.91	1.70	0	7
Village Chanduri (per cent)	18.86	1.31	-	-
Village Kamaipet (per cent)	23.01	1.41	-	-
Village Kommuguda (per cent)	11.00	1.05	-	-
Village Mathadiguda (per cent)	47.14	1.67	-	-
Number of households	32	-	-	-

Notes: Total livestock unit variable followed on FAO guidelines for computing unit of livestock ownership based on geographical region, thus allowing for international comparison. The wealth index variable was computed using the principal component analysis technique with data on households' ownership of equipment, means of transportation and consumer goods, and living characteristics. Std. Dev. is the standard deviation.

Table 10 presents the descriptive statistics of household-level characteristics. Households are composed of medium to large family sizes based on UNESA's classification of household size – there are at least three people, and five people on average in each household (United Nations Economic and Social Affairs, 2017). The difference in the number of males relative to females is negligible especially among adolescents and children. The average landholding size of 3.7 hectares in the sample is slightly higher than the 3 hectares median land size in the study area. The relatively large landholding can be explained by market orientation in our sample as all households grow cotton. To calculate household total livestock unit, we used the United Nations Food and Agriculture Organization (FAO) guidelines for aggregating the value of livestock from the different livestock categories (FAO, 2011a). The household wealth index as a proxy for household income is computed using the principal components analysis based on respondent's dwelling characteristics, ownership of farm equipment, transportation means, and consumer goods (Filmer & Pritchett, 2001). Further, we construct the farm production decision-making index as an additive index of decision-making on eight farm operations involving crop and animal production, produce sales, control over farm income, and allocation of family labour. The index was computed by averaging the number of farm decisions made by males and females[33]. The average of 3.91 shows that men solely make more than half of all the farm decisions.

Table 11: Individual-level socio-demographic, anthropometric and physical activity variables

	Males	Females	Mean Difference
Variables	Mean (SD)	Mean (SD)	
Age (years)	37.63 (7.67)	32.38 (6.29)	5.25***
Literacy (can read and write) (per cent)	44.20 (2.32)	22.35 (2.00)	0.24***
Body mass index (kg/m^2)	19.99 (3.10)	18.23 (2.79)	1.76***
Underweight (per cent)	34.57 (2.22)	61.29 (2.34)	-26.72***
Normal weight (per cent)	57.33 (2.31)	34.33 (2.28)	23.00***
Overweight (per cent)	8.10 (1.28)	4.38 (0.98)	3.72***
AEE (kcals/day)	556.15 (232.88)	382.45 (136.92)	173.70***
TEE (kcals/day)	1901.70 (322.48)	1559.17 (184.30)	342.53***
Physical activity level	1.41 (0.15)	1.32 (0.11)	0.09***
Basal metabolic rate	1345.22 (145.44)	1176.39 (77.32)	168.83***
Number of observations	457	434	

Notes: Literacy variable captures the percentage of males and females that can read and write. Asterisks indicate level of significance *** = significance at 0.1 per cent level. SD = standard deviation. Standard deviation in parenthesis. AEE = Activity Energy Expenditure, TEE = Total Energy Expenditure.

We present individual level descriptive statistics in Table 11. Respondents in our sample are young. On average, male household heads are older than female household heads by five years. Of the 64 respondents in our sample, only 22 per cent of females can read and write compared with 44 per cent of males. The average body mass index (BMI) of 18.23 among women is below national and international guidelines for normal weight of 18.5 kg/m^2 (National Institute of

[33] The reliability of the index in determining the overall decision-making was tested using correlation tests - Cronbach alpha value of 0.76 on a scale that ranges between 0 and 1 indicates that the index is reliable. High index reliability starts from 0.7.

Nutrition, 2011). BMI for men is slightly higher but also in the lower range of normal weight. Using the World health organization's BMI cut-off values, a staggering 61 per cent of women and 34 per cent of men are underweight. These statistics indicate of a high rate of undernutrition in the sample. For the energy expenditure measurements, basal metabolic rate (BMR) accounts for the larger component of the total energy expenditure and AEE constitutes about one-quarter of the TEE. Average PAL values of 1.41 and 1.32 for males and females suggest light to moderately active livelihoods among respondents – similar to values from other recent studies (Srinivasan et al., 2020), and the values are in the lower range of daily average energy expenditures for farming households in developing countries (Dufour & Piperata, 2008). Given the high prevalence rates of underweight in the sample, the low PAL values may suggest energy-saving strategies by the respondents (N. Rao & S. Raju, 2020). We present average daily time use and activity energy expenditure values in Table 12. The proportion of time use by sub-categories of time is presented in the Table A6 of the Chapter 4 Appendix.

Table 12: Time and activity energy expenditure distribution per day.

	Females			Males		
Time use categories	Hours	Time (%)	AEE (%)	Hours	Time (%)	AEE (%)
Agriculture	4.74	19.75	6.88	5.14	21.45	11.39
Non-agricultural economic	0.76	0.25	9.14	1.34	1.68	13.39
Domestic and care	3.92	16.32	31.13	1.17	4.92	9.43
Leisure	2.62	10.95	16.49	4.18	17.45	26.57
Self-care	3.70	15.40	35.41	3.93	16.38	38.27
Sleep	8.25	37.31	0.95	8.20	38.08	0.40

Notes: AEE = Activity Energy Expenditure.

The pattern of time use among respondents is largely consistent with the literature on time use among farming households in Telangana, India (Padmaja et al., 2019), where a high proportion of wake hours is spent in agriculture relative to other activities. Agricultural economic activities occupy about 5 hours 44 minutes and 6 hours 18 minutes for women and men respectively. And The time spent in non-agricultural economic activities is relatively small, but energy expenditure is the largest. Women spend 3 hours 55 minutes of their time in domestic activities and provision of care to other household members, whereas men allocate one-third of that time to such activities. The asymmetry in daily time allocation between men and women is prominent in leisure – men spend 3 hours 37 minutes and women 1 hours 57 minutes on average. Such time allocation patterns imply that men spend 93 minutes in leisure activities more than women daily (Picchioni et al., 2020). The only activity to which both men and women allocate almost equal amount of time during wake hours is self-care, averaging about 3 hours daily. Eight hours of sleep occupies the highest share of daily time use for females and males. Average daily time use values presented in Table 13 was obtained by splitting the sample by gender and sociodemographic group.

Table 13: Average daily time use (in minutes) by socio-demographic groups

Females	Sample	Lower wealth	Upper wealth	Small land	Large land	No pre-schooler	With pre-schooler
Agriculture	284.33 (172.67)	274.96 (181.03)	293.96 (162.56)	272.61 (175.95)	295.20 (166.74)	311.44 (168.21)	254.05 (172.94)
Non-agric economic	45.66 (43.76)	45.74 (47.97)	45.58 (39.08)	43.44 (46.80)	50.13 (38.59)	48.59 (47.84)	42.39 (38.56)
Domestic and care	234.90 (147.08)	234.61 (131.69)	232.54 (106.89)	236.74 (133.55)	231.85 (104.08)	199.94 (102.69)	273.95 (125.93)
Leisure	157.74 (150.17)	159.77 (160.70)	155.66 (136.41)	154.74 (148.10)	173.68 (148.60)	163.27 (144.90)	151.57 (149.60)
Self-care	221.76 (51.64)	223.25 (49.47)	220.23 (53.86)	220.89 (49.32)	210.46 (53.31)	223.31 (50.70)	220.03 (51.33)
Sleep and rest	495.21 (78.01)	500.74 (95.05)	489.52 (54.92)	511.20 (94.94)	478.26 (47.41)	492.87 (87.81)	497.82 (65.47)
Number of observations	434	220	214	228	206	229	205
Males							
Agriculture	308.92 (186.27)	319.16 (190.32)	293.48 (180.68)	301.94 (180.68)	316.18 (192.05)	318.48 (188.18)	297.17 (183.66)
Non-agricultural economic	80.29 (110.36)	65.22 (75.56)	100.89 (136.46)	81.90 (112.98)	78.62 (107.11)	80.92 (111.57)	79.53 (109.12)
Domestic and care	70.79 (105.68)	81.81 (116.12)	59.14 (89.35)	72.71 (101.82)	68.79 (109.75)	59.06 (98.04)	85.21 (112.96)
Leisure	250.52 (171.51)	263.41 (175.51)	252.20 (168.87)	245.25 (168.76)	257.60 (174.47)	264.26 (160.64)	235.39 (183.14)

Self-care	235.94 (52.92)	222.71 (50.08)	236.24 (55.41)	241.75 (53.27)	229.90 (50.87)	232.85 (52.66)	239.73 (53.12)
Sleep	492.19 (58.46)	491.39 (62.21)	493.66 (53.50)	495.90 (56.05)	488.33 (51.99)	483.83 (61.47)	502.46 (52.88)
Number of observations	457	243	214	233	224	252	205

Across the socio-demographic groups, we see that females, and males in upper-wealth household spend more time in agriculture than the lower-wealth groups, but males and females in upper-wealth households commit similar amount of time to agriculture on average. Similarly, large landholders reported higher agriculture time use than peers cultivating smaller land sizes. Results also show that women across wealth and landholding sizes spend an almost similar amount of time in domestic and care activities. Competing time uses between economic and domestic activities is evident in the pre-schoolers (children under age five) groups especially among females. Conversely, women with no pre-schoolers allocate the least amount to time to domestic and care activities across the whole group.

4.5.2 Regression results

4.5.2.1 What is the relationship between the distribution of daily time use and energy expenditure in rural livelihoods?

Results of the regression of the time use composition on activity energy expenditure is presented in Table 14. The full regression table including the coefficients of the individual and household characteristics and control variables is in Table A2 of the appendix. The intuition behind this regression analysis is to test whether increasing a time use category at the expense of all other time use categories has any influence on the outcome variable (Coenders & Pawlowsky-Glahn, 2020). Due to the binary log-ratio transformation of the time use variables discussed in the methods section (section 4.4.3), the coefficient for *lr1* for the agricultural time use model is interpreted as the expected change in AEE value resulting from doubling the ratio of agricultural time relative to the geometric mean of all of non-agricultural, domestic, leisure, self-care, and sleep time uses by a common factor[34] (Müller et al., 2018). The doubling of the ratio of each time use category relative to the geometric mean of the other time uses represents one unit increase in the value of the *lr1* when (the time use category is) transformed using log to the base 2. To calculate the one unit increase for each time use variable, we doubled the ratio of each time use relative to the geometric mean of the all the remaining time uses. The regression coefficients for the *lr1* show that among females, agriculture, non-agricultural economic, domestic and care, self-care are positively associated with AEE, while sleep and rest are negatively associated with AEE. However, the time use variables are not all significant in their association with the outcome variable. Specifically, the AEE of females increases by 9 kcals when agricultural time use increases by 6 minutes while reducing time use in all other activities. A 2.25-minute increase in non-agricultural time use while reducing time use in all other activities is associated with 6 kcals increase in AEE. In similar vein, 5 minutes increase in domestic and care activities while reducing time use in all other activities is associated with 18 kcals increases in AEE, which indicates that increasing domestic time use for women constitutes time and energy expenditure burdens. Increasing time use in self-care by 3.44 minutes while reducing time in all other activities increases energy expenditure by 37 kcals. This value reflects the time intensity of self-care activities in rural livelihoods, which is usually due to the lack of access to water, sanitation, and other essential facilities. Also, increasing sleep time by 17 minutes while reducing time use in all other activities is related with a decrease in AEE by 71 kcals. The AEE estimate resulting for increasing leisure at the expense of other time uses is small and is not statistically significant in the time composition of women. For the non-compositional explanatory variables included in the female models, body mass index, literacy,

[34] Using the average time use values for males and females in Table 12, and computing the geometric mean therein produces the unit increase in the value of the *lr1* for each time use category. For the female sample on average, *lr1* for agricultural time use is 6 minutes, *lr1* for non-agricultural time use is 2.25 minutes, *lr1* for domestic and care time use is 5 minutes, *lr1* for leisure time use is 3.44 minutes, *lr1* for self-care is 4.54 minutes and *lr1* for sleep is 17 minutes. For the male sample on average, *lr1* for agricultural time use is 7 minutes, *lr1* for non-agricultural time use is 2.54 minutes, *lr1* for domestic and care time use is 2.46 minutes, *lr1* for leisure time use is 5.16 minutes, *lr1* for self-care is 5 minutes and *lr1* for sleep is 17 minutes.

number of adult males, adolescent males and adolescent females are positively associated with AEE, while the number of elderly females and the number of adult females is negatively associated with AEE.

Among males, the time use variables are not all significant in their association with AEE, but estimates are higher than for females. AEE increases by 16 kcals when agricultural time use increases by 7 minutes while reducing time use in all other activities. Increasing non-agricultural economic time use by 2.54 minutes while reducing time use in all other activities is associated with 13 kcals increase in AEE. Increasing sleep time use while reducing time use in all other activities is related with a decrease in AEE by 62 kcals. It is somewhat surprising that the association between AEE and leisure time use is insignificant especially since a considerable amount of time is spent in leisure activities by males. For the non-compositional explanatory variables included in the male models, body mass index, wealth index and number of adult males are positively associated with AEE while total land cultivated, the number of adolescent males, number of elderly females and the number of adult females is negatively associated with AEE.

Table 14: Regression results. Log ratio-transformed time use variables on AEE for female and male groups.

	Females						Males					
	Agriculture	Non-agriculture	Domestic	Leisure	Self-care	Sleep	Agriculture	Non-agriculture	Domestic	Leisure	Self-care	Sleep
lr1	9.32***	6.01**	18.53***	0.24	37.22***	-71.33***	16.22***	12.91***	-2.35	-9.78	45.72**	-62.72***
	(2.23)	(2.56)	(4.35)	(2.66)	(13.25)	(13.79)	(3.56)	(3.31)	(2.62)	(6.82)	(22.67)	(23.83)
lr2	7.87***	10.53***	13.03***	9.37***	16.77***	32.04***	16.16***	18.80***	15.75***	14.26***	25.36***	59.18***
	(2.27)	(1.90)	(2.46)	(2.45)	(2.91)	(10.67)	(3.19)	(3.44)	(3.61)	(4.10)	(5.48)	(20.10)
lr3	22.36***	22.36***	12.97***	8.40***	17.64***	-0.24	4.93*	4.93*	16.38***	14.52***	28.40***	15.17***
	(4.44)	(4.44)	(2.50)	(2.32)	(4.18)	(2.56)	(2.96)	(2.96)	(3.36)	(4.00)	(6.24)	(3.77)
lr4	11.53***	11.53***	11.53***	23.72***	36.05***	12.19***	-0.85	-0.85	-0.85	4.09	22.60***	4.95
	(3.23)	(3.23)	(3.23)	(4.55)	(5.94)	(3.50)	(7.47)	(7.47)	(7.47)	(4.10)	(8.10)	(4.94)
lr5	54.27***	54.27***	54.27***	54.27***	35.78***	36.97***	54.22**	54.22**	54.22**	54.22**	26.47**	55.51**
	(13.21)	(13.21)	(13.21)	(13.21)	(7.27)	(13.57)	(22.75)	(22.75)	(22.75)	(22.75)	(13.31)	(24.05)
Intercept	135.57						423.39**					
	(86.30)						(165.33)					
Observations	434						457					
F	13.56***						12.49***					
R-squared	0.52						0.48					
Adjusted R-squared	0.48						0.44					

Standard errors in parentheses * p<0.10, ** p<0.05, *** p<0.01. lr1 is designated as the first log-ratio-transformed time use variable permutated for each of agriculture, non-agriculture economic, domestic, leisure, self-care, and sleep time uses. Lr2, lr3, lr4, and lr5 are the other log ratio-transformed time use variables.

4.5.2.2 How does allocating more time to agriculture affect total daily energy expenditure?

We present results of the association of agricultural time use with the outcome variables via separate regressions for sub-groups based on groupings of wealth, landholding size and having preschool children in Table 15. Based on the knowledge that upper-wealth, large landholders, and no pre-schooler households provide more agricultural time use on average relative to their counterparts. This subsection is aimed at understanding the differences across socio-demographic groups in AEE resulting from increasing agricultural time use. Across all the groups, regression coefficients for females are smaller than for their males counterparts. Agricultural time use is positively associated with AEE across all the groups except for women in large landholding. Relative to other time uses, AEE increases with doubling of the ratio of agricultural time use to the geometric mean of time use for other categories. The AEE increase is higher among females and males in the upper wealth group than for females and males in the lower-wealth groups. Conversely, we note the smaller AEE estimates among large landholding households compared with households in the smaller landholding category although insignificant for females. Further, higher AEE estimate is seen for females and males in households with at least one pre-schooler relative to their peers in households without any preschool children.

Table 15: Regression results. Log ratio-transformed time use variables *lr1, lr2, lr3, lr4, lr5* on AEE when agriculture is *lr1*.

Females						
Variables	Lower wealth	Upper wealth	Small landholding	Large landholding	No pre-schoolers	With pre-schoolers
lr1	10.92***	11.65***	9.72***	4.92	6.46**	11.82***
	(3.14)	(2.87)	(3.49)	(3.10)	(2.94)	(3.66)
lr2	10.92***	5.53*	10.28***	7.19**	12.73***	4.93
	(3.22)	(2.84)	(3.71)	(2.92)	(2.97)	(3.73)
lr3	17.38***	17.17*	22.01***	7.49	22.63***	0.34
	(5.64)	(9.82)	(6.48)	(7.38)	(5.37)	(9.20)

lr4	15.74***	11.09**	13.45***	5.84	14.73***	2.03
	(4.25)	(5.36)	(4.52)	(5.28)	(4.68)	(5.34)
lr5	42.37**	55.65***	51.57**	44.25**	55.10***	22.82
	(19.71)	(15.67)	(20.33)	(18.84)	(18.63)	(19.48)
Intercept	184.75*	-124.00	145.92	-332.05 ***	-310.15 **	-95.33
	(97.63)	(83.09)	(102.62)	(109.11)	(123.77)	(161.06)
Observation	220	214	228	206	229	205
F	12.21***	12.98***	10.83***	9.56***	10.32***	11.25***
R-squared	0.56	0.58	0.52	0.52	0.51	0.56
Adjusted R-squared	0.51	0.54	0.46	0.46	0.46	0.51
Males						
lr1	18.56***	20.05***	21.64***	17.70***	11.06**	31.20***
	(4.79)	(5.42)	(4.48)	(5.16)	(4.66)	(5.47)
lr2	12.50***	24.20***	10.87***	20.82***	17.97***	12.60***
	(4.31)	(4.93)	(3.77)	(4.97)	(4.45)	(4.48)
lr3	1.74	16.27***	4.24	9.49**	2.66	11.46***
	(3.93)	(4.56)	(3.59)	(4.52)	(4.13)	(4.06)
lr4	4.02	5.44	4.15	-7.82	3.46	0.35
	(10.96)	(10.45)	(9.45)	(11.25)	(13.82)	(9.06)
lr5	48.19	110.78***	29.95	95.81***	66.44**	91.57***
	(32.26)	(32.43)	(27.39)	(33.56)	(30.85)	(32.79)
Intercept	615.56***	775.12***	490.61***	549.24**	902.57***	-47.26
	(151.32)	(260.26)	(137.329)	(216.10)	(186.06)	(194.90)
Observations	243	214	233	224	252	205
F	7.53***	12.55***	10.68***	11.99***	11.70***	8.62***
R-squared	0.42	0.58	0.52	0.56	0.52	0.50
Adjusted R-squared	0.36	0.53	0.47	0.51	0.47	0.44

Notes: Standard errors in parentheses * p<0.10, ** p<0.05, *** p<0.01. lr1 is designated as the first log-ratio variable for each of agriculture, non-agriculture economic, domestic, leisure, self-care, and sleep time uses. Lr2, lr3, lr4, and lr5 are the other log ratio-transformed time use variables.

4.5.2.3 How substantial are the changes to energy expenditure resulting from reallocating time from each of non-agricultural economic, domestic, leisure, self-care, and sleep to agriculture?

The aim here is to quantify the nature of time trade-offs resulting from increasing time in agriculture by consecutively substituting time in each of the time use categories. Results of the AEE change prediction are presented in Figures 6 and 7 for females and males respectively.

The first observation is the small change in energy expenditure resulting from time trade-offs from other activities to agriculture. This is an unexpected outcome given the widespread assumption that activities on the farm, relative to other livelihood activities involve high energy expenditure.

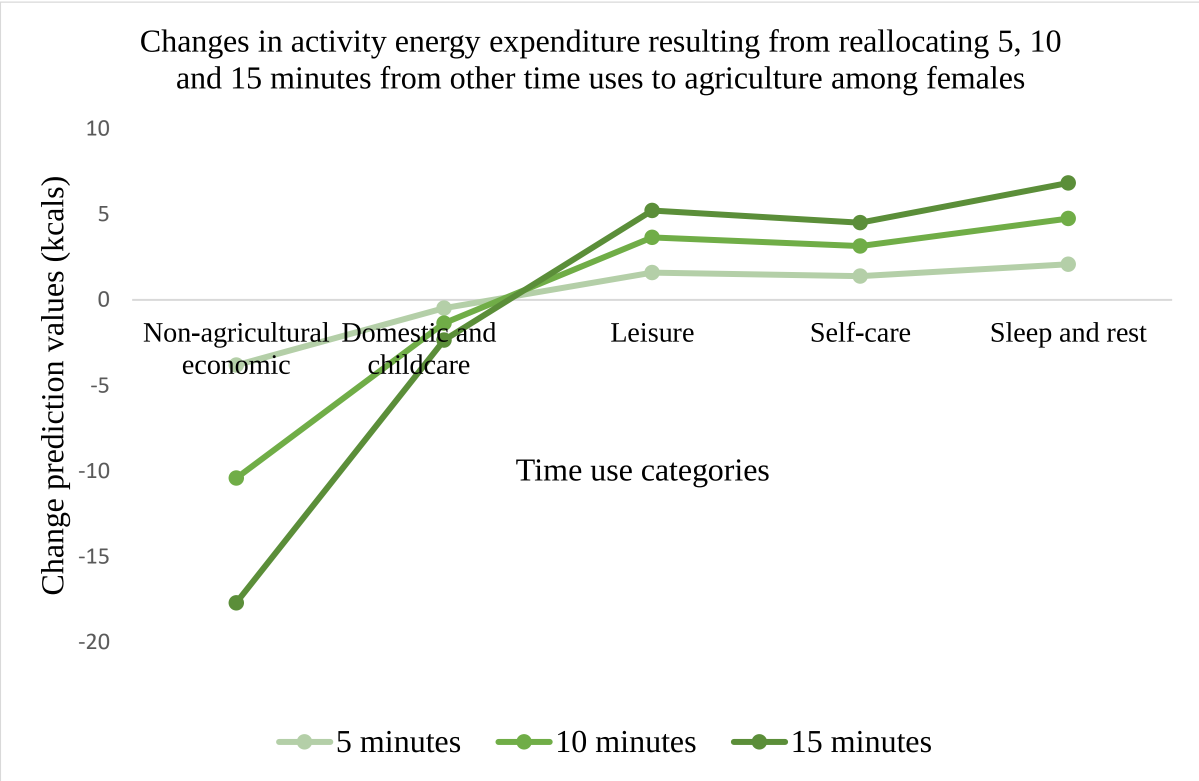

Figure 6: AEE change prediction among females

Among females, substituting non-agricultural activities and domestic activities for agricultural activities reduces daily energy expenditure. Conversely, increasing agricultural time at the expense of each of leisure, self-care and sleep time increases daily energy expenditure. The largest increase is noted for sleep followed by leisure, self-care, and domestic time use. Compared with males, the change in energy expenditure resulting from increasing time in agriculture at the expense of leisure and self-care is higher than for males.

Among males, the pattern of energy expenditure change is similar to that of females except for domestic time use- increasing agricultural time use at the expense of domestic time use increases energy expenditure for males.

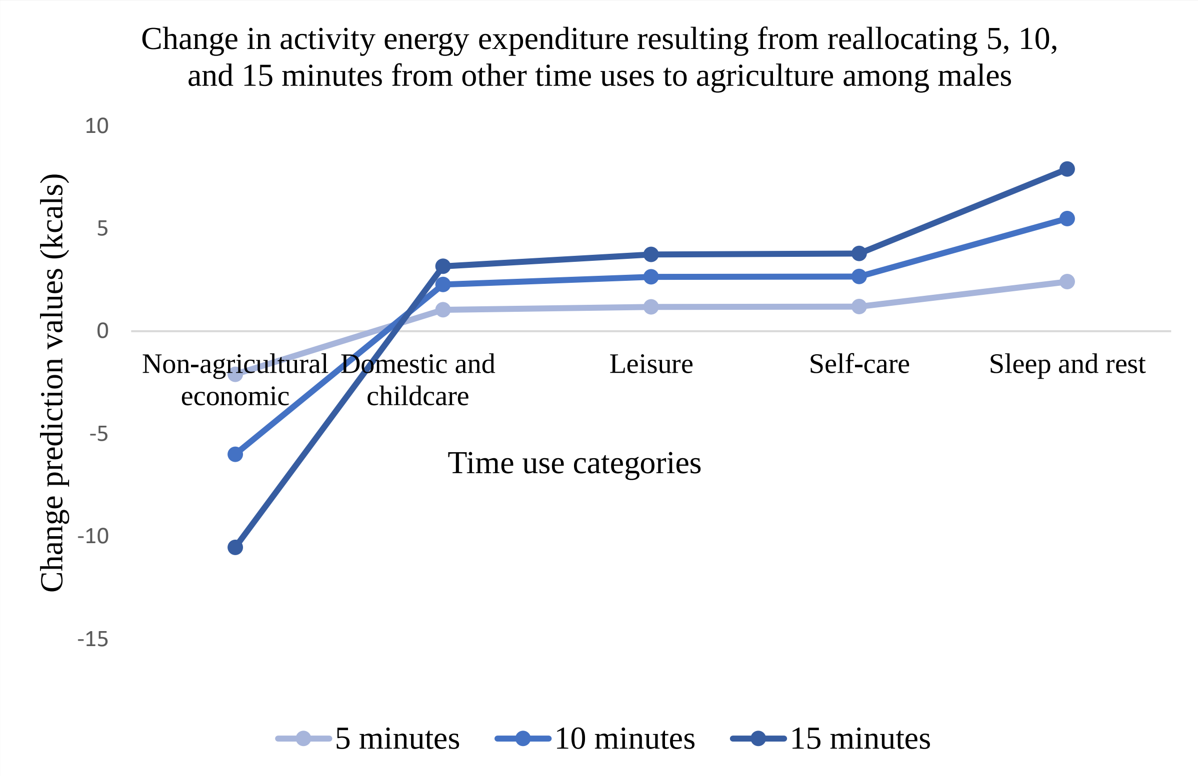

Figure 7: AEE change prediction among males.

We present the change prediction by household socio-demographic characteristics among females in Figure 8. Among the females, moving time away from non-agricultural economic to agricultural activities is beneficial for reducing energy requirements across all groups except for women with pre-school children. In fact, among this group of women, time reallocation from any of the other time uses for agriculture only increases their daily energy requirements. Similarly, reallocating domestic time use to agriculture decreases daily energy expenditure for all groups except women in lower-half wealth and those in the pre-schoolers groups. Further, we see that moving time from leisure, self-care, and sleep time to agriculture is detrimental to the daily energy requirements of women.

The AEE change prediction among males by household socio-demographic characteristics is presented in Figure 9. Increasing agricultural time use at the expense of leisure, self-care and sleep time uses is detrimental for males in lower-half wealth and upper half wealth but the effect is higher among upper wealth household males.

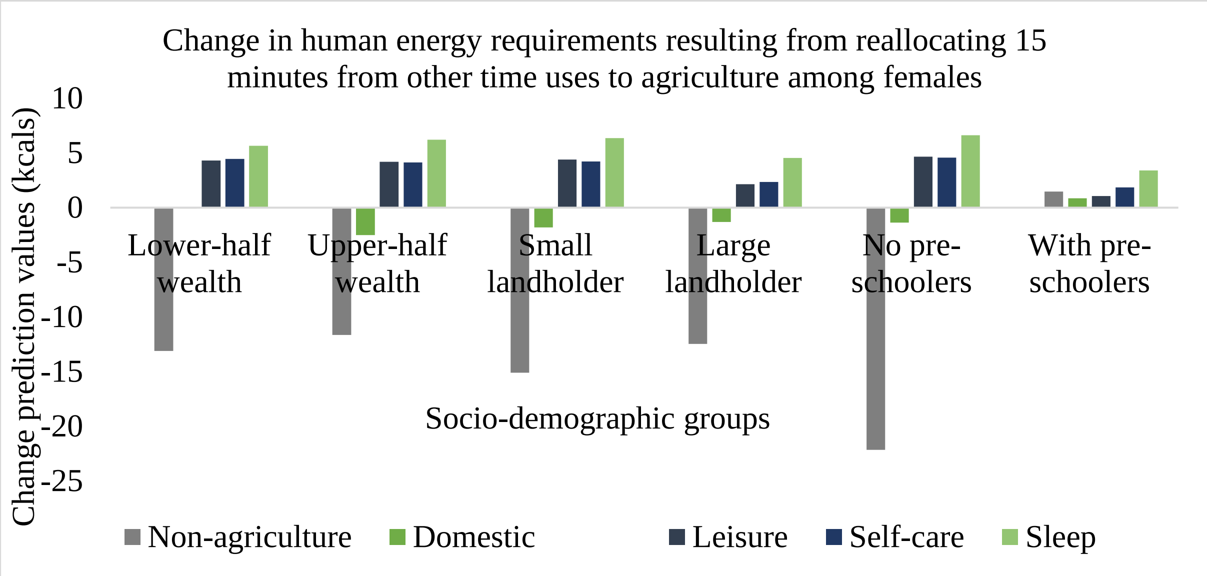

Figure 8: AEE change prediction by socio-demographic characteristics among females.

In small landholding households, increasing agriculture time use at the expense of other time uses increases daily energy expenditure. This pattern of change in AEE is also observed among males in households having pre-school aged children. Males in upper-wealth, large landholding and no pre-schooler households reduce daily energy expenditure by reallocating non-agricultural economic time to agriculture. The patterns of change in daily energy expenditure observed across female groups are different from their male counterparts.

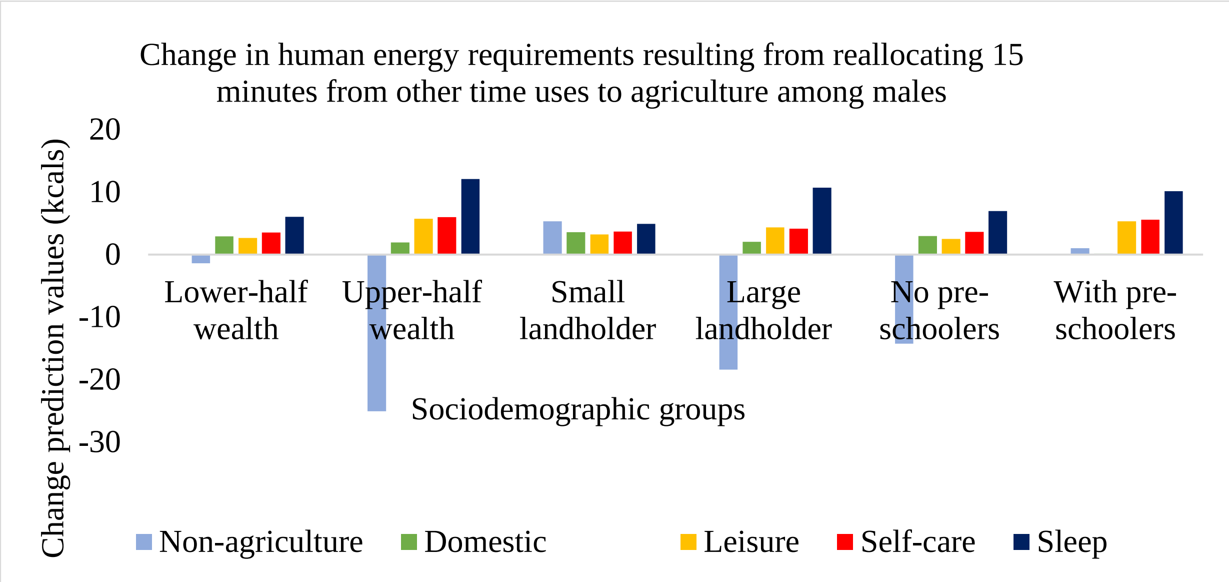

Figure 9: AEE change prediction by socio-demographic characteristics among males.

Overall, the nature of energy expenditure resulting from reallocating time from each of non-agricultural economic, domestic and care, leisure, self-care, and sleep to agricultural activities depend on the type of activities that agriculture is substituting and the household socio-demographic characteristics. The AEE and PAL estimates are consistent. The change prediction values suggest small differences between energy required to perform agriculture and the other livelihood activities. The consistent result showing that substituting agricultural for non-agricultural activity suggests that energy intensity of some non-agricultural occupations may be greater than that of agricultural occupations. This could also be due to the fact that these non-agricultural economic activities are wage employment, possibly taken on a piece-rate basis.

4.6 Discussion

Following the agriculture-nutrition pathway approach which hypothesizes that women's work in agriculture is linked with nutritional outcomes through women's income and empowerment, women's time use, and women's energy expenditure, we have explored the energy expenditure pathway, but it appears that the negative wellbeing outcomes resulting from increasing agricultural time use may be due to the other pathways, that is, income and time but not the energy demands of agriculture.

This chapter assesses the change to women's energy expenditure if they participate more in agriculture. We hypothesize that the change to energy expenditure will depend on the type of activity that agriculture is substituting among time use domains of non-agricultural economic, domestic and care, leisure, self-care, and sleep. The results, which were disaggregated by gender and household sociodemographic characteristics show that for all the women, the time trade-offs to agriculture from non-agricultural economic, domestic and care time use reduces daily energy expenditure, while moving time from leisure, self-care, and sleep increases energy expenditure. For men, non-agricultural economic time use reduces energy requirement in comparison with spending more time in agriculture. In certain cases, the change to energy expenditure is substantial; shifting time from agriculture is predicted to considerably change energy expenditure for non-agricultural economic (an increase) and sleep (a decrease). But the changes to energy expenditure from reallocating leisure, self-care, domestic and care time uses to agriculture are not substantial.

Among women, those for whom outside work may be unappealing and whose household have more productive assets allocate more time to agriculture (Eswaran et al., 2013). These are women in the upper wealth, and large landholder households. These women supplied more agricultural time than their counterparts in lower wealth, small landholding and having pre-schoolers households. As expected, this pattern of agricultural time use corresponds to changes in energy expenditure across the groups. Compared with lower wealth and no pre-schooler households, increasing agricultural time use increases total daily energy expenditure for upper wealth and with pre-schoolers households – which implies that increasing agricultural time use is more adversarial for women with children and the relatively wealthy. Further, men spend more time in agricultural tasks than women on average. The pattern observed among men in lower wealth, large landholders and without pre-schoolers is that they allocate more time to agriculture than their peers in the facing households. As a result, daily activity energy expenditure increases more for men in upper wealth, small landholding and with pre-schoolers households relative to peers in lower wealth, large landholding, and no pre-schooler households. It is noteworthy that the change in AEE associated with increasing agricultural time in the landholding size grouping is unexpected; more agricultural time is not positively associated with AEE. This result could be due to the use of farm machinery and hired labour. Agricultural technology use must however be gender-sensitive to avoid displacing women whose livelihoods depend on agriculture (Afridi et al., 2022).

The idea that women spend more energy when they perform more agricultural work is not supported by the results simply because other time uses are equally energy-intensive and the effects of rural livelihoods on wellbeing are not peculiar to agriculture. The results imply that the negative consequences that are expected from the feminization of agriculture on health and nutrition outcomes are largely not from increased energy burdens. This result justifies focusing on women's income and time allocation in understanding agriculture-gender-nutrition pathways instead of their energy expenditure.

Further, as agricultural households depend on their members' time and labour for subsistence (Blackden & Wodon, 2006), and women's time use is notably linked to their own wellbeing and that of their children (Ruel et al., 2018), increasing women's time use in agriculture has led to concerns about what the time and energy burdens would mean for women themselves. Building on evidence in the agriculture-gender-nutrition literature, this study shows that feminization of agriculture and its effects on women is a mixed picture involving trade-offs, but which operates less through energy burdens. However, while the change to women's energy expenditure is not substantial, the welfare cost to their household may be high in terms of care time and attention that is shifted to agriculture. The overlap of these results with gender equity issues is that feminization of agriculture could mean women being locked into less productive, less remunerative work in comparison to men.

Owing to the higher energy expenditure of performing non-agricultural economic relative to agricultural work, government interventions using energy-intensive public works as a safety net must ensure that the energy demands of such work do not net out potential wellbeing effects of their programs. The results in this chapter also lends support to the ongoing debate on reducing women's time and energy allocation to domestic tasks as a means to increase the time and energy available for higher rewarding economic activities especially for women in rural areas where infrastructures are limited (Desai & Jain, 1994; Gammage, 2010).

Given the broad definitions of feminization of agriculture in the literature, our results may not be generalizable in all contexts experiencing this phenomenon. This is because the conceptual pathways such as autonomy in decision making, workload and remittances that characterizes feminization of agriculture; the health, and nutrition outcomes among women in de-jure and de-facto female-headed households does not apply to our sample. The different hypotheses surrounding the different definitions of feminization of agriculture may justify addressing increasing agricultural time use and its implications differently. For example, for women who are left behind to manage farm plots in migrating households, the size of remittances they receive need to be large enough to offset the additional workload on the farm whereas in our study, we have considered only small increases to agricultural time use. Besides, our analysis focuses on women and men in male-headed households.

The daily time composition approach used in this study constitutes a more insightful conceptualization of the way in which time use can be understood. Since the number of hours in a day sums up to 24 hours, "extending the workday" implies a substitution of sleep or leisure time for work. This description better characterizes time trade-offs leading to increase in total time spent in work-related activities – and particularly because our results shows that the well-being consequences of displacing the time domains differ from one another.

4.6.1 Study limitations

The sample size employed in this paper can be considered a case study because it is not representative of the country where the data was collected. Due to the small sample size, issues of intersectionality in sociodemographic characteristics could not be considered in the analyses (Kawarazuka et al., 2022). Also, seasonality has been shown to influence the patterns of time use and energy expenditure among farming households, but we could not check for seasonality effects because the data does not allow to examine seasonal effects. Having to combine domestic and childcare activities to enable compositional data analysis is a trade-off leading to loss of detail in the analysis. Another limitation is that confidence intervals (CI) are not computed for the change prediction values because changing time between two behaviours automatically changes the ratios of these two time uses and also the remaining compositional parts (Chastin et al., 2015). For example, estimates did not consider whether CI corresponds to a change in agricultural time use from sleep or domestic and care time use. It is possible that the effect on an outcome, for increasing agriculture by either of the two time uses – sleep and domestic and care – is not the same (Chastin et al., 2015).

We have also theoretically modelled the change to energy expenditure resulting from reallocating time between activities, however, time (re)allocation process can be complex and may depend on a range of factors not considered in this study such as the relative energy demand of other activities, available food energy reserve, return to effort, potential income, and household-level factors (Becker, 1985) and it cannot be assumed that the choice of time use among respondents is made with the full comprehension of advantages and disadvantages of a particular time use. This chapter has sought to establish the association of time use composition on energy expenditure, it is also possible that energy expenditure influence time use and the factors determining time use are linked to energy expenditure. Hence, no causality is inferred from the results. Further, the feminisation of agriculture often takes place in a context where women have to take over the entire agricultural work burden (on account of migration of men) - and in such cases the patterns of energy expenditure observed for women could be quite different. We do not have households in the sample where women are entirely responsible for agricultural work. And due to the anthropometric data collected only during the first round of the survey, BMI could not be used to capture nutritional outcomes.

4.7 Conclusions

Even though energy expenditure is thought to matter more for wellbeing than time use, evaluating the unintended negative consequences of changing agricultural time demands has been done largely through time use monitoring. This lapse is due to the difficulty in capturing energy expenditure and physical activity levels among free-living populations. The analysis in this chapter provides empirical evidence of the association between agricultural time use and well-being by examining change to energy expenditure. Knowing that time use, not energy expenditure influences well-being outcomes in rural households can focus development policies and programs that are compatible with development outcomes by minimizing the unintended consequences of time trade-offs, especially in agriculture.

This chapter contributes to the literature on the feminization of agriculture in three ways; first, the empirical analysis is supported by novel datasets which integrate information on individual and household socio-demographic characteristics, time use, and physical activity. This detailed level of information enabled investigating the well-being outcomes of increasing agricultural time use relative to other time uses through the energy expenditure pathway. Second, while the economic, social and well-being effects of feminization of agriculture among de-jure and de-facto female-headed households is understood, the knowledge of the effect of feminization of agriculture on women and men in male-headed households is scarce. Third, we provide the justification for why women's time use, incomes and empowerment, and not energy expenditure may be the relevant pathways of immediate concern linking agriculture, gender, and wellbeing outcomes in LMICs.

Chapter 5: Physical activity, time use and diet in the nutrition transition of adolescents in India and Nepal

Abstract

Along with declining physical activity levels, nutrition transition in low and middle income countries is characterized by rising per-capita calorie consumption buoyed by the rapid displacement of traditional foods by ultra-processed foods. This study assesses physical activity, time use and diet composition in relation to nutritional outcomes for adolescents in Telangana State in India as well as in two districts in Nepal. We use quantile regression in compositional data analysis methods – to assess the relationship between nutritional outcomes and the composition of daily time allocated to sedentary, light, moderate and vigorous activity. In addition, we assess the relationship of nutritional outcomes with the composition of diet involving ultra-processed and non-ultra-processed foods. The situation that adolescents in low- and middle-income countries are facing is that of increasing sedentary lifestyles through technology and improved infrastructures. Although these are avenues where physical activity is reducing, the data shows that there is still substantial physical labour under which adolescents continue to perform. The substitution of non-ultra-processed food by ultra-processed food improves nutritional outcomes but likely presents a burden of unhealthy diets. That the influence of activity intensity and diets on calorie adequacy varies across the spectrum of nutrition status implies that addressing all forms of malnutrition among rural adolescents will require different kinds of interventions – some targeted at the lower ends of the nutrition status and a different set for the upper end of the nutrition status.

Keywords: *Nutrition transition; adolescents; time use and physical activity; nutritional outcomes; compositional data analysis methods; India and Nepal.*

5.1 Introduction

Adolescents in rural areas of low and middle-income countries (LMICs) have limited prospects to confront the barrage of factors affecting their well-being. While malnutrition among adults and children under five continue to receive the necessary research and development consideration, the issues affecting adolescents are only beginning to get attention. Defined as a period between ages 10-19 years, adolescence is characterized by a gradual or spontaneous transitioning into different adult roles like employment, marriage and parenthood (WHO, 2001). Early pregnancy, food insecurity, enlistment into paid and unpaid work for household subsistence can increase the vulnerability of adolescents and have adverse effects on their nutrition and health through unmet energy (calorie) needs (R. E. Black et al., 2013; Ibrahim et al., 2018; WHO, 2006).

As a result of rural transformation, the lifestyles of adolescents are changing in terms of the types of activities they undertake and how they allocate their time – towards less energy-intensive activities (Mistry & Puthussery, 2015; Urlacher & Kramer, 2018). Rural adolescents are experiencing this change in addition to the evolving trend towards increasing consumption of ultra-processed foods (Aurino et al., 2016; Neri et al., 2021). But their adaptation to these changes and the effects of these adjustments on nutritional outcomes remain less clear. The implication of this knowledge gap is the absence of data to guide interventions aiming to protect adolescents against all forms of malnutrition.

This study aim to understand how physical activity, time use patterns and diets influence the nutritional outcomes for adolescents. There has been a steady decline in the prevalence of undernutrition among children and adolescents during the last decade across LMICs, but a reversal in that trend had started to occur since 2018 (FAO, IFAD, UNICEF, WFP and WHO, 2022). Concurrently, overweight and obesity rates are increasing as populations transition to energy-dense foods and less work-related physical activity (Popkin et al., 2020). Malnutrition remain however, in underweight than overweight among South Asian adolescents (Bentham et al., 2017; Jaacks et al., 2015). For the individual adolescent, the consequences of undernutrition during childhood can be remedied during the second decade of life when up to 40 percent of adult height can be attained (Hirvonen, 2014; Prentice et al., 2013) – a process known as "catch up growth"[35]. For reproduction in adolescent girls however, malnutrition risks such as low birth weight, anaemia and protein energy deficiency increases with adolescent pregnancy, and such risks are passed on to children born by malnourished mothers, thus perpetuating the intergenerational transmission of malnutrition (Barker, 1997; Sawyer et al., 2012).

The coexistence of nutrition extremes within a population require "double-duty actions" – interventions which simultaneously address undernutrition- and overnutrition-related health problems (Hawkes et al., 2020). But double-duty approaches require information on physical activity, time use and diets in rural livelihoods. Additional physical activity is unsuited to undernutrition contexts, while processed foods are affordable, convenient, energy-dense foods that may contribute to reducing hunger in food insecure settings. Against the background that physical activity and diets are determinants that "promote both risks and protective factors" against malnutrition (Sawyer et al., 2012), this paper examine the following research questions:

i. What are the nutritional outcomes of changing activity energy expenditure patterns and diet composition among rural adolescents in India and Nepal?

[35] But catch-up may involve health trade-offs ("catch-up dilemma") later in adulthood (Adair et al., 2013; Hales & Ozanne, 2002) because overnutrition is associated with early puberty onset. Once puberty is initiated, the adolescent growth spurt stops (Wang, 2002). In contrast, undernutrition delays puberty onset, thus, aiding compensatory growth in the second decade of life (Kulin et al., 1982; Prentice et al., 2013; A. D. Stein et al., 2010; WHO, 1995). There are gender aspects to this phenomenon, which indicates that the nutrition- puberty- growth relationship may indeed apply only to girls (Wang, 2002). For girls and boys, continued weight gain without a corresponding increase in height is a risk factor for health problems later in life (R. E. Black et al., 2013). This delicate balance between nutrition and health outcomes motivates understanding adolescent nutrition.

ii. How does the influence of time use, and diet composition vary across the distribution of nutrition outcomes?

The remainder of the chapter is structured as follows: the literature review on changes in physical activity, diets and nutritional outcomes is presented in section two. This is followed by the conceptual framework in chapter three. The data, including the study area and data collection is described in section four. This is followed by the methods used in the analysis in section five. The results of analysis is presented in section six. The discussion of results is presented in section seven. The chapter ends with the conclusions in section eight.

5.2 Literature review

5.2.1 Changes in physical activity and energy expenditure of adolescents and nutritional outcomes

Urbanization is known to reduce physical activity levels and increase overweight and obesity risks, therefore, the literature on adolescents activity time use in LMICs tend to focus on understanding the patterns and associated risks of insufficient physical activity among urban adolescents. The consequence of this tendency is that evidence on adolescents' physical activity patterns in rural areas is very limited.

Activity levels has been on a decline among urban adolescents in LMICs (Swaminathan et al., 2011; Urlacher & Kramer, 2018). Recent evidence show that a large proportion of adolescents living in urban areas of LMICs do not meet the World Health Organization (WHO) guidelines on physical activity and sedentary behaviour – to spend 60 minutes in moderate-to-vigorous activities daily (Bull et al., 2020). About 62 per cent of adolescents in India (Katapally et al., 2016), 31 per cent of adolescents in Nepal (Thapa et al., 2019) and 33 per cent of adolescents in Bangladesh spend less than one hour in moderate-to-vigorous activity (Khan et al., 2017). However, these studies did not report on the magnitude of the difference between adolescent activity levels and the WHO guidelines. Among rural adolescents however, work-related activities, active transport, in addition to schooling and leisure, contributes substantially to daily energy expenditure (Raskind et al., 2020; Roy & Dasgupta, 2009; Tudor-Locke et al., 2003). Findings from cross-sectional studies showed that average daily physical activity level (2.29) among adolescents remain high in Kenya, and activity intensity tend to be in the moderate and moderately vigorous among boys, and between light and moderately vigorous among girls in Mexico (Malina et al., 2008; Ojiambo et al., 2013). Shridhar et al., (2016) assessing rural adolescents' compliance to recommended daily physical activity levels in leisure, transport, and sedentary activity domains, finds that only one-quarter of rural adolescents allocate more than one hour to moderate-to-vigorous physical activity. The authors however admit that their findings could be because domestic and economic work domains were not considered in their analysis. Reporting on her drudgery experience in rural livelihoods, an adolescent girl in a southern India village commented that: "it is indeed laborious to stand the whole day without shadow, trees and water while grazing animals, fetching fuel-wood, frequent trips to water source, weeding, picking and harvesting" (Gender and Water Alliance, 2013). But continuing expansion of agricultural technologies in rural areas is linked to decreasing work-related physical activity (Daum et al., 2019a). In their multi-country study, Tremblay et al., (2014) found that adolescents living in countries with higher physical infrastructures reported less physical activity compared to those in countries with less infrastructure.

This trend of declining physical activity likely benefits undernourished individuals but may move food-secure adolescents into overweight and obesity through reduced caloric requirements. Using repeated cross-sectional data over a ten year period, Urlacher & Kramer (2018) found that energy demand for work-related, play and childcare activities decreases during economic development. Their findings show that the downward shift in energy expenditure patterns is linked to improved growth measures among rural Yucatec Maya children. Shridhar et al., (2016) reported significant direct associations between time spent in sedentary activity and adolescents BMI-for-age in India. Adolescents who spend more than three hours in sedentary activities daily or are from a higher socio-economic background are more likely to be overweight or obese compared to their counterparts (Laxmaiah et al., 2007). Further, reviewing the factors of nutritional status among adolescents in South Asia, Mistry & Puthussery (2015) concluded that inadequate physical activity resulting from increased technology adoption, the lack of recreational spaces in cities, and widespread perception of overweight as a sign of affluence contributes to the increasing overweight and obesity rates.

Studies in this succinct review concludes that the more active profiles recorded among boys than girls is due to the influence of socio-cultural norms on adolescents' time and energy allocation (Raskind et al., 2020; Swaminathan et al., 2011; Uddin et al., 2020). Adolescent boys perform economic-related activities while girls perform domestic as well as economic-related activities. Such patterns of time use among adolescents can have adverse immediate and long-term effects on adolescents' human capital and well-being outcomes (Akabayashi & Psacharopoulos, 1999). Hedges et al., (2018) found trade-offs in time use of boys and girls; agricultural work is not compatible with schooling for boys whereas girls are able to combine domestic work with schooling at the expense of leisure.

Physical activity studies among adolescents in LMICs have largely relied on questionnaires to collect activity data due to the cost and logistics (data collection and management) of objective data collection tools such as accelerometers (Uddin et al., 2020). Muzenda et al., (2022) found that only one-third of studies in their systematic review on adolescents' activity time use in LMICs employed validated data collection tools suited to their local contexts. Physical activity studies on this age group are also limited by focusing largely on school enrolled adolescents whose activity time use patterns diverge from their out-of-school counterparts (Guthold et al., 2020).

5.2.2 Changing diets among adolescents and nutritional outcomes in LMICs

Along with declining physical activity levels, nutrition transition in LMICs is characterized by rising per-capita calorie consumption buoyed by the rapid displacement of traditional foods by ultra-processed foods (Masters et al., 2016; Monteiro et al., 2013; WHO/FAO, 2003). Ultra-processed foods have high fats, sugars, and low fibre content and are increasingly of public health concern (Monteiro et al., 2019; WHO, 2015). Its consumption in food insecurity contexts has been described as presenting the "double burden of suboptimal diet" (Contreras et al., 2015). However, ultra-processed foods have the appeal of being relatively affordable, energy-dense, and convenient than non-ultra-processed foods (Monteiro et al., 2019).

Neri et al., (2021) found that ultra-processed foods constitutes 18 – 68 per cent of total daily energy intake among children and adolescents across low, middle and high income countries. On average, 50 – 70 per cent of adolescent girls in some LMICs consume sugar-sweetened beverages and sweet snacks between 4 - 6 times a week (Keats et al., 2018). Jain & Mathur (2019) found that energy from ultra-processed foods constitutes between 11 – 19 per cent among adolescents in Delhi, India. These values are higher than WHO recommendation of deriving less than 10 per cent of the total daily energy intake from free sugars (WHO, 2015).

The contribution of ultra-processed foods to diet is highest among adolescents compared to any other age groups and this is influenced by a complex interplay of factors (Neri et al., 2021). At the household level, adolescents' nutrition is moderated by wealth, household composition, castes/ ethnicity, gender, and occupation of the household head. Unlike in high income countries where poverty is linked to ultra-processed food consumption and anthropometrical risks, household wealth in LMICs is positively correlated to consuming food away from home

(Aguayo & Paintal, 2017). Such eating pattern increases adolescents' risk of the double burden of malnutrition - whereby overweight and obesity coexists with the lack of essential micronutrients (Harding et al., 2019; Popkin et al., 2020). Other studies find no significant association between fast food consumption and unhealthy body mass index in Ghana (Abizari & Ali, 2019; Maehara et al., 2019). Similarly in their systematic review, Trumbo & Rivers (2014) finds no association between ultra-processed foods and the risk of obesity when controlling for physical activity. Further, Abizari & Ali (2019) reported no association between maternal education or occupation on adolescent dietary pattern, however, formal employment among fathers is associated with industrially processed food consumption in urban Ghana. Similarly in Nepal and Bangladesh, adolescents, whose fathers are service workers are more likely to consume ultra-processed foods in comparison with their counterparts living in agricultural households (Upreti et al., 2021). Qualitative data shows that maternal education is positively associated with healthy diets in Sri Lanka (Williams et al., 2019), in Ethiopia (Tamiru et al., 2016) and in Bangladesh (Islam et al., 2020) while lower parental permissiveness is inversely associated with less consumption of ultra-processed foods (Verstraeten et al., 2014).

Adolescents' own characteristics also mediate their food choices. For example, higher food autonomy in late adolescence has been suggested to influence poorer diets among 15- 19 year olds in comparison with 10-14 year olds (Verstraeten et al., 2014). Islam et al., (2022) found that adolescents' educational status is negatively associated with the consumption of sugar sweetened beverage. Studies relate the gender difference in snack consumption to higher leisure time spent by boys with friends, in contrast with girls who spend their out-of-school time in household chores and sometimes restrict food intake as a body weight management strategy (Aurino, 2017; Islam et al., 2019; Mallick et al., 2014).

Taken together, there appear to be less active lifestyle and a higher incidence of the consumption of ultra-processed foods among upper socioeconomic groups, and older adolescents compared with their counterparts. Extant literature however, show that undernutrition is prevalent among individuals in lower socioeconomic groups, female (more girls are stunted but thinness is prevalent among boys), lower castes and younger adolescents compared with their counterparts (Pandurangi et al., 2022; Van de Poel & Speybroeck, 2010; van Tuijl et al., 2021). The gap identified in this literature is that while nutrition transition is characterized by changes in both diet composition and physical activity, much research focus has been directed to diets. Available evidence showing how these changes influence nutritional outcomes in rural livelihoods are also sparse. Reproductive roles have warranted keener attention to girls in literature and practice. However, boys and girls require sufficient, healthy diets for physical growth and development.

5.3 Conceptual Framework

Drawn from quantitative and qualitative evidence in the literature, the conceptual framework in Figure 10 is used to explain lifestyle changes involving physical activities and diets among adolescents and how these changes influences nutritional outcomes in rural areas of LMICs. The changes in rural diets and livelihoods are driven primarily by rural transformation in LMICs (Masters et al., 2016; Reardon & Timmer, 2012). This relationship is often mediated by socio-cultural, community, household, and individual characteristics. Rural transformation involving changes in the socio-economic, and demographic attributes of rural areas is caused by the spread of international trade, foreign direct investments in the local agriculture and food sectors, globalization, improved infrastructures, diversification into the rural non-farm economy, technology, media and marketing (Berdegue et al., 2014; Reardon & Timmer, 2012).

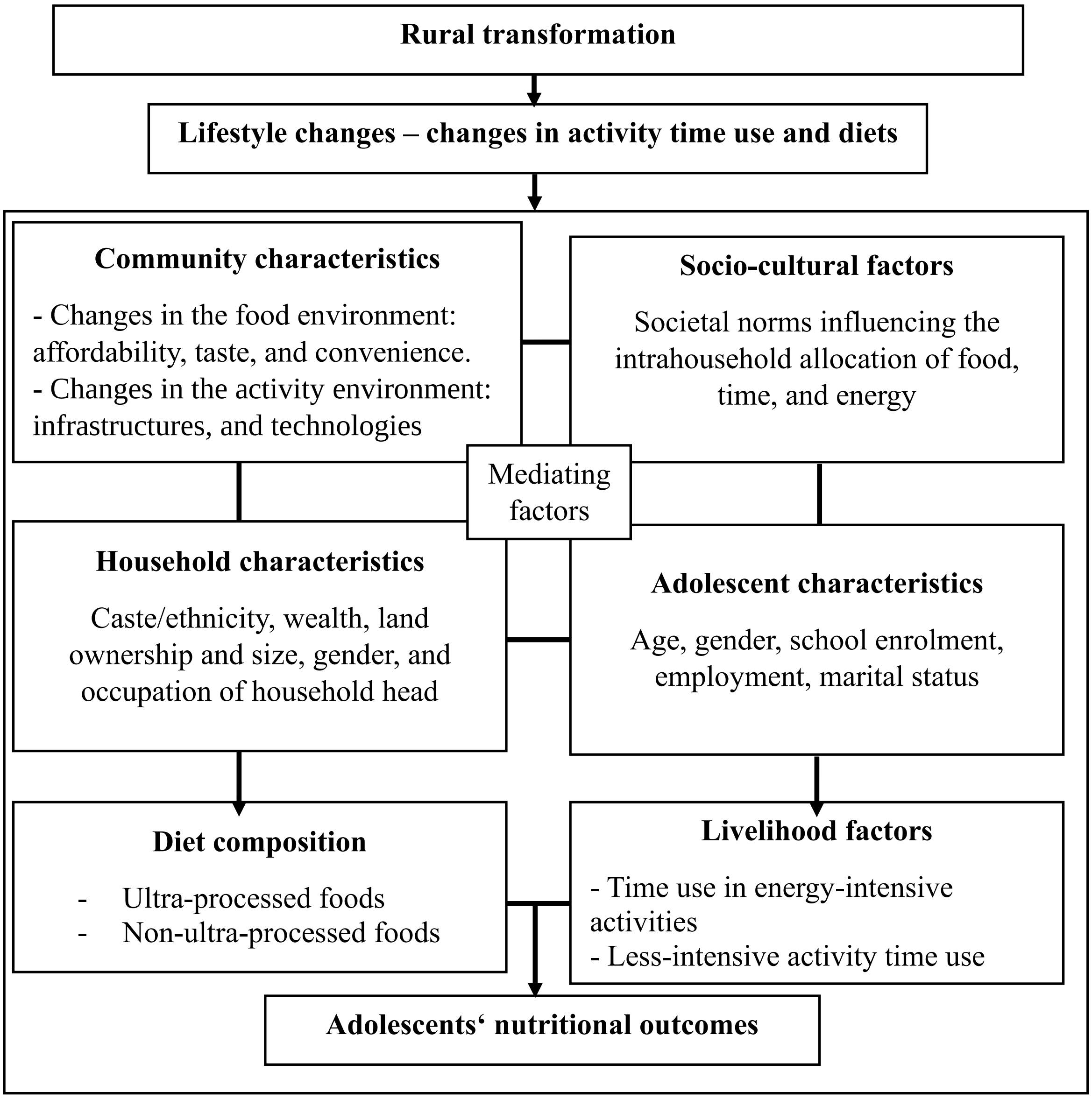

Figure 10: Conceptual Framework - Adolescent nutrition transition. Adapted from Kadiyala et al., 2019.

Economic growth facilitated by infrastructure development and adoption of technologies, including in agriculture, effect lifestyle changes towards reducing work-related physical activity (Ng & Popkin, 2012). Adolescents having access to such development may substitute some active time use with sedentary activities. Less physical activity levels can help achieve caloric adequacy among undernourished adolescents according to the life history theory, which states that malnutrition (undernutrition) during adolescence is a result of the tradeoffs between energy available for physical growth and activity-related energy expenditure (Kramer & Ellison, 2010). Complementing the trend of reducing physical activity is the shift in the composition of diets towards more diverse diets and processed food items, both which increases per capita food-calorie consumption (Masters et al., 2016; Popkin et al., 2012). For rural adolescents, the rapid proliferation of processed foods may benefit or intensify existing nutrition and health issues (Kadiyala et al., 2019). Over time, energy imbalance caused by higher energy intake relative to energy expenditure will result in overnutrition, while lower energy intake relative to energy expenditure will result in undernutrition (Popkin et al., 2012).

5.4 Data

5.4.1 Study areas

This study utilizes secondary datasets collected for the University of Reading Global Challenges Research Fund (GCRF) Project titled "Breaking the intergenerational cycle of malnutrition, food security and poverty in low and middle income- countries – making the case of adolescent boys and girls". Data collection was carried out in Khammam and Mahbubnagar districts of the central and southern parts of Telangana state in India and in Dhading and Nawalparasi East districts in Nepal[36]. In the India study sites, about 77 per cent of the 1.4 million population of Khammam, and 63 per cent of the 920,000 Mahabubnagar population live in rural areas. One-third of the districts' population belong to the scheduled castes and scheduled tribes. The rural households rely on agriculture for income and food, typically owning small (2.47 – 4.93 acres) and marginal (below 2.47 acres) farm plots. Agricultural production is largely dependent on rainfed farming systems to cultivate paddy, cotton, maize, and other crops. In addition to crop production, animal husbandry is prominent.

[36] This district and provincial classification follows the recent local level bodies restructuring by the Government of Nepal in 2017.

State government report show a steady rise in per-capita income growth (controlled for inflation) between 2015 to 2018 from 79,522 to 92,019 Rupees in Khammam and 57,827 to 71,186 Rupees in Mahabubnagar[37]. Over the same period however, the trend in nutritional status indicate that stunting, wasting, severe wasting, underweight and anaemia among children and adolescents have continued; 23 per cent of girls and 34 per cent of boys are thin, 24 per cent of girls and 18 percent of boys are stunted, 7 per cent of girls and 5 per cent of boys are obese, while 47 per cent of girls and 15 per cent of girls have anaemia (Sethi V. et al., 2019). These figures indicate a higher malnutrition rate among boys than girls. In addition, marriage among adolescent girls in Telangana stands at 12.9 per cent, a figure that is higher than the national average of 11.9 per cent. Among married adolescents, 42 per cent have at least one child (Young Lives India, 2019). Reproductive roles of these adolescent girls places additional nutritional needs and suggests the need to monitor adolescents' nutrition to avert the transmission of malnutrition risks from the young mother to child.

In the Nepal study sites, Dhading is located in the central Hill subregion, while Nawalparasi East is located in the Western Terai (or plains) subregion. In Dhading, data collection was carried out in Dhunibeshi, Galchhi and Netrawati rural municipalities, each having 31,029, 27,784 and 12,870 population respectively. The major ethnicities/castes in this district by percentages are the Tamang (22.1), Brahman-Hill (15), Chhetri (14.7), Newar (9.4) groups and others (38.8). Data collection in the Nawalparasi East district was conducted in Hupsekot rural municipality where the 25, 065 population is composed of Brahmin-Hill (17.5), Magar (17.5), Tharu (15.1) and Chhetri (5.5) and others (44.4) (CBS, 2014).

[37] 1 USD averaged 67.21 Indian Rupees in 2016 (Reserve Bank of India, 2022).

Across Nepal, agriculture remains the largest sector by total employment: 33 per cent of females and 14 per cent of males are involved in farming activities, which is followed by trade, manufacturing, construction and others (Government of Nepal, 2019). Although 79 per cent of the total population in Nepal still live in the rural areas (The World Bank, 2021), substantial progress has been made towards improving well-being over time as shown in the Human Development Index (Dhungel, 2018). Further, the prevalence of stunting, underweight and wasting among children has markedly decreased nation-wide (Poudel Adhikari et al., 2021), food and nutrition security remained largely resilient even in the aftermath of the 2015 earthquake that severely disrupted livelihoods (Dhoubhadel et al., 2020; Thorne-Lyman et al., 2018). Yet, malnutrition is rife among poor farming households and the lower castes, as caste-based hierarchy still profoundly influence ownership and access to livelihood resources (Ministry of Health Nepal, 2017; van Tuijl et al., 2021).

Like in many LMICs, the double burden of malnutrition has been observed in Nepal – 29 per cent of the children are stunted, 33 per cent are underweight and 43 per cent are anaemic. Among 15-49 year old females, the prevalence of overweight or obesity at 22 per cent is higher than the incidence of underweight 17 per cent (Ministry of Health Nepal, 2017). Among 15-49 year old males, the prevalence of overweight or obesity and underweight stands equal at 17 per cent (Ministry of Health Nepal, 2017). This nutritional status has been linked to the nutrition transition characterized by a gradual shift in dietary intake from traditional staple foods to more diversified diets typified by higher fats, protein and sugar in Nepal (Subedi et al., 2017).

5.4.2 Data collection and processing

Individual and household level data were collected over five consecutive days between October 2019 and March 2020 from 400 adolescents – 198 boys and 202 girls in 357 households in India, and from 352 adolescents – 179 boys and 173 girls in 352 households in Nepal. The adolescents were aged 10-19 year old. Trained enumerators used individual questionnaire, household questionnaire and accelerometers to collect information used in this chapter.

Household questionnaires were administered to the parents/carers of the adolescent on the first day of the data collection. The questionnaires captured information about household socio-demographic factors, dwelling characteristics, assets ownership, employment and livelihood activities, food consumption, and food consumption habits.

Individual questionnaires were administered by enumerators to adolescents daily throughout the data collection period. Using the 24-hour recall method, the questionnaires captured information separately on food intake and time-use of the adolescents. In addition to food intake and time use data, socio-demographic characteristics, and anthropometric measurements of height and weight, were also collected.

Time use data collection and transformations: The 24-hour time use data collected from adolescents were aggregated from hourly to day-level and grouped into seven categories well-being (self-care, sleeping and resting) , education related (study, non-study-related activities), economic activities (paid and unpaid work), domestic activities (in-house and outside domestic work), leisure (physical exercise & sports, attending events, socialising, digital entertainment and creative activities), travel (traveling & commuting) and others.

Accelerometer data collection and processing: After prior informed consent of the parents/carers, adolescents were invited to wear an accelerometer device for five consecutive days on the waist fastened by an elastic belt and positioned over their right iliac crest. Research-grade GT3X+ model ActiGraph accelerometers were used to collect physical activity data from adolescents. These tri-axial accelerometers have been used extensively in research in different settings and they provide the end-user with raw data on movement along the three axes. The raw movement data were downloaded from the accelerometers at 60 Hertz per second, after which the data was compressed into 3-second epochs and then to one-hour intervals to match the hourly time use data collected through questionnaires. Combining all three data streams followed the methodology described in Zanello et al., (2020). Using validated algorithms, the activity data were converted to activity energy expenditure (AEE) in kilocalories (Freedson et al., 1998).

When using accelerometer data, it is important to identify accelerometer non-wear time so as not to conflate non-wear with sedentary time use (Toftager et al., 2013). We set a criteria of 180 minutes of accelerometer non-wear within each day (Cain et al., 2013). A 91 per cent wear compliance level was recorded at the day/participant level in India and 89 per cent wear compliance in Nepal. After excluding observations that have more than 180 minutes of non-wear in a day, the final imbalanced data set include a sample of 746 male and female adolescents in 695 households over 3321 days. Ethical approval was obtained from the University of Reading (1113D) before data collection.

5.5 Empirical Methods

5.5.1 Dependent variable

We use Caloric Adequacy Ratio (CAR) as the dependent variable in this study. CAR measures the energy balance of an individual based on dietary energy intake and expenditure (Randolph et al., 1991). The advantage of CAR as an indicator of nutritional outcomes over individual caloric intake is that CAR considers individual energy expenditure to determine adequacy. However, CAR is limited, in that, the quality of diet remain unknown. We computed CAR as the caloric value of food consumed relative to total energy expenditure (TEE). For India, the Indian Food Composition tables were used to determine the caloric content of local recipes (Bowen et al., 2011) and the United States' National Nutrient Database for Standard Reference was used for calorie conversion of ultra-processed foods (U.S. Department of Agriculture, 2019). For Nepal, the Bangladesh food composition tables (Shaheen et al., 2013), Nepalese food composition table (Department of Food Tech. & Quality Control, 2017) and the United States' National Nutrient Database for Standard Reference were used to determine food calorie content. The TEE was computed as the sum of energy used in physical activity, that is, activity energy expenditure (AEE), and the energy used for physiological functions, that is, the basal metabolic rate (BMR). The activity data collected from accelerometers were converted into AEE (kilocalories) using validated algorithms, while BMR was computed using the Harris-Benedict equation (Harris & Benedict, 1918).

5.5.2 Independent variables

To relate changes in physical activity with CAR, we assume that physical activity influences nutritional outcomes (caloric adequacy) by determining the energy expenditure. Physical activity energy expenditure depend on how time is distributed between activities of different intensity levels, that is, between sedentary[38], light-intensity, moderate and vigorous-intensity activities in any given day (Srinivasan et al., 2020). The effect of the changes in physical activity on the dependent variable CAR is captured by the proportion of time spent in sedentary activities, the proportion of time spent in light activities, and the proportion of time spent in moderate and vigorous activities. We computed these variables using accelerometer data, splitting daily time use into sedentary, light, moderate, and vigorous activities using cut-points[39] for predicting activity intensity in youths (Trost et al., 2011). Each of these activity

[38] Sedentary behaviour is defined as "any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture" (Tremblay et al., 2017). Sedentary time use in this study included waking and sleeping hours of the 24-hour day.
[39] Accelerometer cut points are thresholds for converting accelerometer output, in average counts per minute (CPM) into estimates of physical activity intensity. Sedentary activity ranges between 0-100 CPM, light intensity activity between 101 – 2295 CPM, moderate-intensity activity 2296 - 4011 CPM and vigorous intensity activity between 4012 CPM and above.

time uses is then divided by total number of minutes in a day, that is, 1440 minutes. The proportions of time spent in activities of different physical intensity will add up to 1.

Given that the changes in rural diets are characterized by the displacement of traditional foods by processed foods (Popkin, 1993), we relate changes in diet to CAR, using the proportion of diet derived from ultra-processed foods and the proportion of diet derived from non-ultra-processed foods. We compute both variables by converting the individual daily food intake into caloric values. The total daily caloric values was divided into ultra-processed and non-ultra-processed components following the NOVA classification (Monteiro et al., 2010, 2019). The NOVA classifies food into four groups based on the level of processing, namely: unprocessed and minimally processed foods, processed culinary ingredients, processed foods and ultra-processed foods. This chapter employs a subgrouping of the NOVA classification; the non-ultra-processed food (consisting of unprocessed and minimally processed foods, processed culinary ingredients, processed foods) and the ultra-processed group. The NOVA regard food items in the first three categories as non-ultra-processed foods, while ultra-processed food should be avoided due to their high energy density, sugar, salt, and low fibre content, which are associated with heightened health risks (Monteiro et al., 2019). The other reason we used two groups based on the level of processing is that the majority (85 per cent) of foods consumed in South Asia have undergone some level of processing (Reardon & Timmer, 2012) – posing a challenge to classifying food items using the four NOVA groups.

In summary, the proportion of time spent in sedentary, light, moderate and vigorous activity constitutes the physical activity intensity variables, while the proportion of calories derived from ultra-processed foods and the proportion from non-ultra-processed food constitutes the diet composition variables. In addition to the main independent variables, individual and household socio-demographic, anthropometric and health variables were included in the models. We describe all the variables in the Table 16 below.

Table 16: Data description for variables used in the regression analysis.

Dependent Variable	*Variable description*
Calorie Adequacy Ratio	Ratio of daily energy intake to energy expenditure per day
Independent Variable	*Variable description*
Ultra-processed foods	Proportion of daily total calories intake derived from ultra-processed food per day. From this variable, we compute the log ratio variable for ultra-processed foods z1
Non-ultra-processed foods	Proportion of daily total calories intake derived from unprocessed and minimally processed foods, processed culinary ingredients, and processed food per day. From this variable, we compute the log ratio variable for non-ultra-processed-foods z1
Sedentary activity	Proportion of daily time spent in sedentary activities per day. From this variable, we compute the log ratio variables for sedentary activity z1 and z2
Light activity	Proportion of daily time spent in light-intensive activities per day. From this variable, we compute the log ratio variables for light activity z1 and z2
Moderate and vigorous activity	Proportion of daily time spent in moderate- and vigorous-intensive activities per day. Moderate and vigorous activities were combined because the later constitutes only a small part of daily time use. From this variable, we compute the log ratio variables for moderate and vigorous activities z1 and z2
Accelerometer wear	Daily accelerometer wear compliance over 1440 minutes
Day 1	Dummy for the first day of the week when data was collected
Day 2	Dummy for the second day of the week when data was collected
Day 3	Dummy for the third day of the week when data was collected
Day 4	Dummy for the fourth day of the week when data was collected
Household size	Total number of persons living under the same roof
Number of adult females (aged 20-64 years)	Total number of female adults aged 18-64, within the household
Number of adult males (20-64 years)	Total number of male adults aged 20-64, within the household
Number of children (0-9 years)	Total number of male and female children aged between 0 and 9 years old within the household
Number of adolescents (10-19 years)	Total number of male and female adolescents aged between 10 and 17 years old within the household

Sex	Dummy variable for gender of respondent, male = 1, female = 0
Total land (hectares)	Total area of land cultivated by household
Wealth index	Index of the sum of values of household assets
Districts India	Categorical variable of district in India for Khammam and Mahbubnagar districts
Districts Nepal	Categorical variable of districts in Nepal, namely: Hupsekot, Dhunibeshi, Galchhi, Netrawati municipalities
Primary occupation of household head (whether in agriculture)	Dummy variable for occupation of household head is agriculture = 1, others = 0
Age of household head	Age of male or female household head in number of years
Household head literacy	Dummy variable for whether household head is literate, can read and write = 1, cannot read and write = 0
Castes India	Dummy variable indicating caste membership in India – lower castes = 1 and upper castes = 2
Castes / ethnicities Nepal	Dummy variable indicating caste membership in Nepal – lower castes/ethnicities = 1 and upper castes /ethnicities = 2

5.5.3 Regression analysis

We assess separately (1) the relationship between CAR and the proportion of time spent in physical activities of different intensities (light, sedentary, moderate, and vigorous), (2) the relationship between CAR and the proportion of calories derived from ultra-processed and non-ultra-processed foods in the regression analysis. However, conventional statistical methods will produce inconsistent regression estimates and inference statistics because (1) the variables representing the proportion of time spent in physical activity of different intensities and (2) the variables representing the proportion of calories derived from ultra processed foods and non-ultra-processed foods each sum up to a constant (Hron et al., 2012), and there is interdependence within each variable group. Therefore, we use compositional data analysis (CoDA) methods (Aitchison, 1982) to estimate the relationship between CAR and the independent variables. CoDA has already been used in development economics (Aitchison, 1982), nutrition (Monteiro et al., 2019), and health studies (Chastin et al., 2015). Specifically, we use CoDA with the isometric log ratio (ilr) transformations to address multicollinearity and the constant sum constraint issues (Egozcue et al., 2003). CoDA with quantile regression modelling allows us to assess the relationship between the dependent and independent variables across the distribution of the dependent variable (Koenker & Bassett, 1978). The distribution of CAR in the sample is illustrated in Figure 11. CAR ranges, on average, between 0.08 to 1.99 per day in India and between 0.22 to 1.98 per day in Nepal. Given that CAR equals 1 is classified as energy-balanced, a CAR below 1 as energy-deficient and a CAR value above 1 as energy surplus, it is possible that estimating average effects such as in linear regression across this widely ranged CAR distribution hides the heterogeneity across CAR distribution.

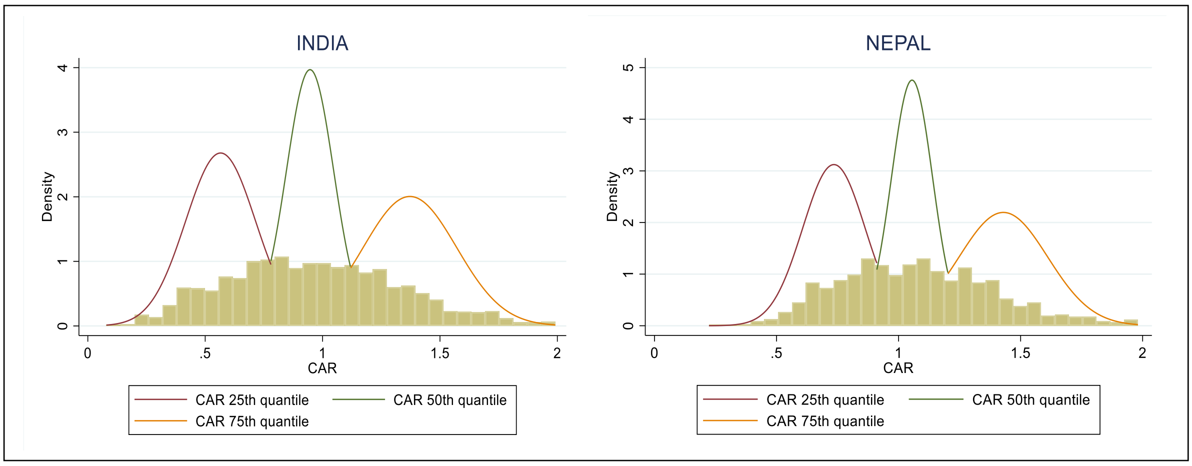

Figure 11: Quantiles of Caloric Adequacy Ratio

In the isometric log transformation for the 3-part physical activity variables, there are three sets (each for sedentary, light, moderate and vigorous activity) of two ilr-variables z_i, that is, three sets of z_1 and z_2, and for the 2-part diet composition variables (ultra-processed foods and non-ultra-processed foods), there are two sets of one ilr-variable z_i, that is, z_1. The z_i for each variable group is computed as:

$$z_i = \sqrt{\frac{d - i}{d - i + 1}} \cdot \ln\left(\frac{b_i}{\sqrt[d-i]{\prod_{j=i+1}^{d} b_j}}\right) \text{ with } i = 1, 2, \ldots, d - 1 \quad (5.1)$$

Where b_i is the number of minutes spent in each of sedentary, light, moderate and vigorous activity; d is the number of physical activity variables. The log ratio-transformed variables z_i are defined in Table 17

Table 17: Computation of the log ratio-transformed variables

Physical activity variables		Diet composition variables	
z_1-SA	$\sqrt{\frac{2}{3}}\ln(\frac{SA}{\sqrt{LA*MVPA}})$	z_1- UP	$\sqrt{\frac{1}{2}}\ln(\frac{UP}{\sqrt{NUP}})$
z_2-SA	$\sqrt{\frac{1}{2}}\ln(\frac{LA}{MVPA})$	z_1- NUP	$\sqrt{\frac{1}{2}}\ln(\frac{NUP}{\sqrt{UP}})$
z_1- LA	$\sqrt{\frac{2}{3}}\ln(\frac{LA}{\sqrt{SA*MVPA}})$		
z_2- LA	$\sqrt{\frac{1}{2}}\ln(\frac{SA}{MVPA})$		
z_1- MVPA	$\sqrt{\frac{2}{3}}\ln(\frac{MVPA}{\sqrt{SA*LA}})$		
z_2- MVPA	$\sqrt{\frac{1}{2}}\ln(\frac{LA}{SA})$		

Where SA= number of minutes in sedentary activity, LA= number of minutes spent in light activity, MVPA=number of minutes in moderate and vigorous activity. UP = calories derived from ultra-processed foods and NUP = calories derived from non-ultra-processed foods.

We model CAR as a function of the proportion of time spent in different physical activity intensities, taking by turn, the proportion of time spent in sedentary, light, moderate and vigorous activity, as the numerator in the z_i variable. The first log ratio represented as z_1 is the variable of interest in all the models. Similarly for the diet composition variables, b_i is the proportion of total calories derived from each of non-ultra-processed food and ultra-processed food and d is the number of diet composition variables. We model CAR as a function of the proportion of calories derived from taking by turn, the proportion calories derived from ultra-processed foods and non-ultra-processed foods, as the numerator in the z_i variable.

Motivated by the conceptual framework to understand how certain socio-demographic characteristics at the individual and household level moderates the relationship between CAR changes in physical activity intensity and diet composition across the distribution of the outcome, we estimate conditional quantile regressions (CQR) (Koenker & Bassett, 1978). CQR models "explains how the outcome of a person who is ranked above a specific quantile among people with the same characteristics change in relation to a change in their characteristics" (Rios-Avila & Maroto, 2022). CQR models, however, cannot estimate individual-level effects because such effects depend on the person's position in the conditional distribution (of the dependent variable).

To estimate group-specific CQR with cluster-robust standard errors (clustered around individual observations over days), the effects of socio-demographic characteristics on CAR was assessed by separately interacting z_1 and z_2 with the dummy variables of gender, age, caste and land size. Each of the socio-demographic characteristics are separately interacted with the ilr variables because the coefficients of the non-ilr variables are the same, making it impossible to distinguish effects across groups. The CQR for the interaction of the components of physical activity variables with each of the socio-demographic characteristics estimates two separate equations, the first equation is of the form Y ϵ {CAR} and k = {proportion of sedentary, light, moderate and vigorous activity}:

$$Y_\tau = \beta_{0\tau} + \beta_{1\tau} z_1^k + \beta_{2\tau} z_2^k + \boldsymbol{\beta_{3\tau} z_1^k * SES} + \boldsymbol{\beta_{4\tau} z_2^k * SES} + \beta_{5\tau} \textbf{\textit{Individual}} + \beta_{6\tau} \textbf{\textit{Household}} + \beta_{7\tau} \textbf{\textit{Control}} + \varepsilon_\tau \quad (5.2)$$

where superscript k indicate sedentary, light, moderate and vigorous activity. $\beta_{1\tau}$ and $\beta_{3\tau}$ are the quantile-specific coefficients of interest; z_1 and z_2 are the log ratio-transformed proportion of sedentary, light, moderate and vigorous activity variables; ***SES*** represents the socio-demographic variables of age, gender, caste, and land size. ***Individual*** represents the vector of individual characteristics such as age, sex, body mass index, marital status, employment status, self-reported health, participation in school meals, and self-reported health, ***Household*** represents the vector of household characteristics such as livestock ownership, land size, size of household, caste; ***Control*** is the vector of accelerometer non-wear time (in minutes), municipality and accelerometer wear day dummy variables and ε_I is error term.

The second equation is of the form Y ϵ {CAR} and k = {proportion of calories derived from ultra-processed foods and non-ultra-processed foods}:

$$Y_\tau = \alpha_{0\tau} + \alpha_{1\tau} z_1^k + \boldsymbol{\alpha_{2\tau} z_1^k} * \boldsymbol{SES} + \boldsymbol{\alpha_{3\tau}} \boldsymbol{Individual} + \boldsymbol{\alpha_{4\tau}} \boldsymbol{Household} + \boldsymbol{\alpha_{5\tau}} \boldsymbol{Control} + \varepsilon_\tau \quad (5.3)$$

Where $\alpha_{1\tau}$ and $\alpha_{2\tau}$ are the quantile-specific coefficients of interest; z_1 is the log ratio-transformed variable from the proportion of ultra-processed-foods and non-ultra-processed foods. ***SES*** represents the socio-demographic variables of age, gender, caste, and land size. ***Individual*** represents the vector of individual characteristics such as age, sex, body mass index, marital status, employment status, self-reported health, participation in school meals, and self-reported health; ***Household*** represents the vector of household characteristics such as livestock ownership, land size, size of household, caste; ***Control*** is the vector of accelerometer non-wear time (in minutes), municipality and accelerometer wear day dummy variables and ε_i is error term.

While the conditional quantile regressions in equation 5.2 and 5.3 are useful to provide group-specific effects, conditional on the independent variables, the conditional effects cannot be generalized to the whole population and from policy standpoint, the unconditional effects of the independent variables on the dependent variable are more relevant because the unconditional effects represents outcomes for the whole population – and such effects are affected by changes in the distribution of the other (non-focal) variables (Rios-Avila & Maroto, 2022). Therefore, unconditional quantile regression (UQR) is used to “analyse what would happen to the population τth quantile when there is a small change in the distribution of an independent variable, but not what would happen to a specific person or a specific group of individuals when independent variables changes” (Rios-Avila & Maroto, 2022). In other words, UQR measures how much the outcome for the population τth quantile changes as a result of a change in the distribution of an independent variable (Rios-Avila & Maroto, 2022). Therefore, we explain the relationship of (1) CAR with the proportion of sedentary, light, moderate and vigorous activity and (2) CAR with the proportion of ultra-processed foods and non-ultra-processed foods among the whole adolescent sample using UQR with fixed effects (Firpo et al., 2009). We use the UQR method also because the variation in the effects of the physical activity variables and diet composition variables, across the distribution (low and high levels) of the dependent variable (CAR) can be measured. The UQR, however, requires that Recentred Influence Function (RIF) for the dependent variable be computed. The RIF of a quantile is the contribution of an individual to the τth quantile. The RIF replacing the dependent variable in RIF-regressions implies that a regression of RIF (Y, q_τ) on independent variables is identical to the standard regression of Y on independent variables (Firpo, 2009). The RIF is computed as:

$$RIF\ (Y, q_\tau) = q_\tau + \frac{\tau - 1\ \{Y \leq q_\tau\}}{f_Y(q_\tau)} \qquad (5.4)$$

where Y is the outcome variable, CAR; q_τ is the value of Y at quantile τ, which is estimated by a kernel approach; $1\{Y \leq q_\tau\}$ is the indicator function of whether the outcome at quantile τ is greater or equal to outcome Y; and $f_Y(q_\tau)$ is the density of the marginal distribution of Y at quantile τ. Using individual-level data collected repeatedly over five days, the estimation of the RIF-regressions under linearity assumption (Firpo et al., 2009) is implemented in Stata using the *xtrifreg* command written by Borgen (2016). The *xtrifreg* works by first determining the value of the outcome variable at the specified quantile, then uses kernel approach to identify the density of the outcome variable at the quantile, computes the RIF and includes the RIF as outcome variable in the fixed effects model (Borgen, 2016).

Assessing the relationship of CAR and the proportion of time in sedentary, light intensity, moderate and vigorous intensity activity at 25th, 50th and 75th quantiles of the form $Y \epsilon \{CAR\}$ and k = {proportion of sedentary, light, moderate and vigorous activity} is:

$$Y_\tau = \beta_{0\tau} + \beta_{1\tau} z_1^k + \beta_{2\tau} z_2^k + \boldsymbol{\beta_{3\tau}} \textbf{\textit{Individual}} + \boldsymbol{\beta_{4\tau}} \textbf{\textit{Household}} + \boldsymbol{\beta_{5\tau}} \textbf{\textit{Control}} + \varepsilon_\tau \qquad (5.5)$$

Where Y is the RIF-transformed dependent variable RIF (Y, q_τ), $\beta_{1\tau}$ is the quantile-specific coefficient of interest, while z_1 and z_2 are the log ratio-transformed variables of sedentary, light, moderate and vigorous activity; ***Individual*** represents the vector of individual characteristics such as age, sex, body mass index, marital status, employment status, self-reported health, participation in school meals, and self-reported health, ***Household*** represents the vector of household characteristics such as livestock ownership, land size, size of household, caste, ***Control*** is the vector of accelerometer non-wear time (in minutes), municipality and accelerometer wear day dummy variables and ε_τ is the error term. Assessing the relationship of CAR and the proportion of calories derived from ultra-processed foods and non-ultra-processed foods at the 25th, 50th, and 75th quantiles of the form Y ϵ {CAR} and k = {proportion of calories from ultra-processed foods and non-ultra-processed foods} is:

$$Y_\tau = \alpha_{0\tau} + \alpha_{1\tau} z_1^k + \boldsymbol{\alpha_{2\tau}} \textbf{\textit{Individual}} + \boldsymbol{\alpha_{3\tau}} \textbf{\textit{Household}} + \boldsymbol{\alpha_{4\tau}} \textbf{\textit{Control}} + \varepsilon_\tau \qquad (5.6)$$

Where Y_τ is the RIF-transformed dependent variable RIF (Y, q_τ),$\alpha_{1\tau}$ is the quantile-specific coefficient of interest, while z_1 is the log ratio-transformed variable of ultra-processed foods and non-ultra-processed foods; ***Individual*** represents the vector of individual characteristics such as age, sex, body mass index, marital status, employment status, self-reported health, participation in school meals, and self-reported health; ***Household*** represents the vector of household characteristics such as livestock ownership, land size, size of household, caste, ***Control*** is the vector of accelerometer non-wear time (in minutes), municipality and accelerometer wear day dummy variables and ε_τ is the error term.

5.6 Results

5.6.1 Descriptive statistics

Table 18 presents the descriptive statistics of household-level characteristics. The majority of households are headed by males in India but more than a third of households are headed by females in Nepal. The average age of household head in both countries is 45 years. The number of literate household heads is relatively high in Nepal 71 per cent compared with India at 43 per cent. About 34 per cent of the sampled households heads in India and 69 per cent in Nepal are employed primarily in agriculture – either farming own land, working as sharecroppers, agricultural wage labourers, or food processors. The average size of cultivated land is small at 1 hectare in India. Farming households cultivate about 8 hectares average in Nepal. Using the United Nations Food and Agriculture Organization (FAO) guidelines to calculate the Total Livestock Unit (TLU) (FAO, 2011a), the average unit of livestock holding (in kilogram live weight of animals) among sampled households is less in India than in Nepal. The household wealth index as a proxy for household income is computed using the principal components analysis based on respondent's dwelling characteristics, ownership of farm equipment, transportation means, and consumer goods (Filmer & Pritchett, 2001). The average number of household size in both countries is four. The sex ratio among children, adults and the elderly is close, however, there are more adult female in Nepal households than are men. The number of households sampled across the four districts in both countries translates into 52 per cent of backward castes, 44 per cent of scheduled castes and 4 per cent of scheduled tribes in India and upper castes/ethnicities households (Brahmin and Chhetri) constitutes 14 per cent, the remaining 76 per cent is split between households belonging to the lower castes/ethnicities in Nepal.

Table 18: Descriptive summary of household characteristics in India and Nepal

	India		Nepal	
	Mean	SD	Mean	SD
Gender of household head (whether male)	0.84	-	0.65	-
Age of household head	44.91	10.45	45.19	11.16
Household head literacy (can read and write)	0.43	-	0.71	-
Primary occupation of household head (whether in agriculture)	0.34	-	0.69	-
Total land size (hectares)	1.01	1.68	8.31	7.14
Total livestock unit (FAO)	0.43	1.33	4.17	3.82
Wealth index	0.03	2.40	-0.02	2.07
Household size	4.36	1.26	4.48	1.52
Number of elderly male (>64 years old)	0.05	0.21	0.09	0.30
Number of elderly female (>64 years old)	0.08	0.26	0.14	0.36
Number of adult male (20-64 years old)	1.06	0.58	0.93	0.73
Number of adult female (20-64 years old)	1.09	0.43	1.17	0.57
Number of male children (0-9 years old)	0.19	0.55	0.27	0.58
Number of female children (0-9 years old)	0.18	0.60	0.28	0.68
Districts (%)				
Nawalparasi East	-	-	0.50	
Dhading	-	-	0.50	
Khammam	0.50	-	-	-
Mahbubnagar	0.50	-	-	-

Castes/ethnicities (%)				
Hill Brahmin/Chhetri	-	-	0.14	-
Terai Brahmin/Chhetri	-	-	0.00	-
Hill Janajati	-	-	0.52	-
Terai Janajati	-	-	0.07	-
Hill Dalit	-	-	0.20	-
Muslim	-	-	0.00	-
Newar	-	-	0.05	
Others	-	-	0.01	
Backward caste	0.52	-	-	-
Scheduled caste	0.44	-	-	-
Scheduled tribe	0.04	-	-	-
Number of households	344		351	

Notes: Total livestock unit followed the FAO guidelines for computing unit of livestock ownership. This index relies on the live weight of the animals, for example, 1 TLU = 250kg animal live weight. Therefore, the larger the animals, the higher the TLU. The TLU index allows for international comparison. The wealth index was computed using the principal component analysis using households' ownership of equipment, means of transportation and consumer goods, and living characteristics. SD is the standard deviation. Statistics is based on data of individuals having less than 3 hours of accelerometer non-wear time.

The descriptive statistics for individual-level characteristics of early adolescents aged 10-14 years old in India and Nepal is presented in Table 19. Although enrolment in school is high among sampled adolescents, enrolment rate is higher among boys than girls in both countries. Despite a near-total school enrolment observed in our data, some of the young adolescents worked as an employee for at least one hour in the month preceding the survey; 26% of boys, 15% of girls in India, and 91% of boys and 50% of girls in Nepal. The rate of children combining employment, work and study is known to be high in Nepal (The World Bank, 2014). None of the early adolescents was married in both countries. Girls are taller and weigh more relative to boys. More young adolescent boys and girls are underweight in India and more young adolescents in Nepal are of normal weight. Based on the WHO recommendation of BMI cut-offs[40] for adolescents aged 5-19 years, the proportion of underweight is higher among boys

[40] Underweight refers to the percentage of adolescents aged 10-19 years who have body mass index-for-age < -2SD according to the WHO BMI cut-offs (De Onis et al., 2007).

than girls; 71 per cent to 56 per cent and 37 per cent to 24 per cent in India and Nepal respectively. Energy intake and energy expenditure is higher among boys compared with girls in both countries. Yet, boys have a higher energy shortfall. This net energy deficit perhaps explains the relative disadvantage seen among boys relative to girls in long term nutritional indicators such as the BMI and the underweight rates. However, the caloric adequacy ratio – which is a short term measure of energy balance, reveal less gender disparity in nutritional status between boys and girls in both countries. The proportion of diet derived from ultra-processed food in India is somewhat higher in Nepal. This difference in diet composition between the two countries is not surprising given the dissimilarities in the rural characteristics of the study areas. Results indicates that on average, the percentage of energy intake from ultra-processed food is higher among young adolescent girls compared to their male peers in both countries. The total energy expenditure values for boys and girls in both countries is less than the recommended daily energy requirements for adolescents[41] (FAO, 2001). Also, more girls than boys reported being sick at least once in the month preceding the survey. Rather unexpected for young adolescents living in areas that are largely rural, the adolescents, on average, spend about 80 per cent of their daily time in sedentary and light intensity activities and about 10 per cent in moderate and vigorous activities. Girls, on average, have a more sedentary and light-intensity lifestyle than boys in both countries.

[41] Daily energy requirement in kcal/ day for 10-19 year old boys: light physical activity (1825 – 2900), moderate physical activity (2150 -3400), and heavy physical activity (2475-3925). For 10 -19 year old girls: light physical activity (1700 – 2125), moderate physical activity (2000 -2500), and heavy physical activity (2300-2875).

Table 19: Descriptive statistics of individual characteristics of early adolescents in India and Nepal

Early adolescents										
	India					Nepal				
	Males		Females		Mean Difference	Males		Females		Mean Difference
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Age	12.47	1.09	12.46	1.08	-0.01	12.58	1.03	12.73	1.10	0.15
School enrolment (per cent)	100.00	0.00	98.00	13.00	-2.00**	99.00	10.00	95.00	21.00	-3.00**
Employment (per cent)	26.00	44.00	15.00	36.00	-11.00***	91.00	29.00	50.00	50.00	-41.00***
Participate in school meals (per cent)	82.40	38.10	88.70	31.70	6.33**	68.00	1.51	41.00	1.22	-0.26**
Marital status (per cent)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Height (cm)	145.93	10.63	146.06	8.48	0.12	148.39	11.63	148.61	6.49	0.21
Weight (kg)	33.53	8.63	34.77	7.22	1.24*	38.42	8.97	41.80	8.58	3.37***
Underweight (per cent)	71.00	45.00	56.00	49.00	-14.00***	37.00	48.00	24.00	43.00	-13.00***
Normal weight (per cent)	24.00	43.00	40.00	49.00	15.00***	57.00	49.00	64.00	48.00	6.00
Overweight (per cent)	4.00	20.00	3.00	17.00	-1.00	5.00	22.00	11.00	31.00	6.00**
Caloric Adequacy Ratio	0.98	0.36	0.99	0.37	0.10	1.10	0.29	1.03	0.32	-6.00**
Calorie intake (kcals/day)	1596.56	549.61	1462.61	528.90	-133.94***	2032.95	506.37	1767.61	546.15	-265.33***
Ultra-processed food (per cent)	36.00	20.00	39.00	21.00	3.00*	8.00	9.00	12.00	14.00	3.00***
Total energy expenditure	1655.40	265.44	1488.75	169.57	-166.65***	1870.86	244.96	1722.35	221.01	-148.51***
Activity energy expenditure	475.00	161.71	392.84	128.73	-82.16***	592.22	184.64	547.51	180.84	-44.71***
Basal metabolic rate	1180.39	173.26	1095.91	81.12	-84.48***	1278.64	180.20	1174.84	96.42	-103.80***
Self-reported health (per cent)	30.00	46.00	1.56	10.12	1.26**	19.00	39.00	23.00	43.00	-13.00***

Physical Activity										
Sedentary activity (per cent)	66.00	6.00	69.00	6.00	3.00***	69.00	6.00	71.00	6.00	2.00***
Light activity (per cent)	17.00	3.00	17.00	3.00	-0.00**	15.00	3.00	15.00	3.00	-0.00
Moderate activity (per cent)	9.00	3.00	8.00	2.00	-1.00***	10.00	2.00	9.00	2.00	-0.00**
Vigorous activity (per cent)	3.00	1.00	2.00	1.00	-0.00***	4.00	2.00	3.00	1.00	-1.00***
Very vigorous activity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Accelerometer wear (over 1440 minutes)	1397.30	51.68	1385.88	51.45	-1.42	1401.42	50.19	1405.19	44.74	3.87
Observations/day-level	421		461			388		362		

Notes: Statistics is based on data having less than 3 hours of accelerometer non-wear time. Asterisks indicate level of significance *** = significance at 0.1% level, ** = significance at 1% and *= significant at 5%. SD = standard deviation.

Table 20: Descriptive statistics of individual level characteristics of late adolescents in India and Nepal.

Late adolescents										
	India					Nepal				
	Males		Females		Mean Difference	Males		Females		Mean Difference
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Age	16.78	1.45	16.98	1.42	0.20*	16.25	1.29	16.70	1.36	0.45***
School enrolment (per cent)	87.50	33.10	87.70	32.90	0.20	85.00	35.00	80.00	39.00	-4.00
Employment (per cent)	43.64	49.60	31.28	46.40	-12.40	98.00	15.00	67.00	47.00	-31.00***
Participate in school meals (per cent)	64.00	44.00	54.00	49.00	-10.00**	11.00	66.00	12.00	70.00	1.00
Marital status (per cent)	0.00	0.00	5.00	22.00	5.00***	4.00	19.00	14.00	34.00	9.00***
Height (cm)	164.16	8.39	154.04	6.47	-10.12***	162.83	8.86	152.23	5.18	-10.59***
Weight (kg)	49.11	7.78	43.91	6.90	-5.20***	51.05	7.41	47.12	7.61	-3.93***
Underweight (per cent)	64.00	48.00	52.00	50.00	-11.00***	38.00	48.00	24.00	43.00	-13.00***
Normal weight (per cent)	32.00	46.00	45.00	49.00	13.00***	57.00	49.00	65.00	47.00	8.00*
Overweight (per cent)	3.00	19.00	1.00	13.00	-2.00	4.00	19.00	9.00	29.00	5.00**
Caloric Adequacy Ratio	0.89	0.31	0.97	0.38	0.07**	1.12	0.28	1.03	34	-8.00***
Calorie intake (kcals/day)	1705.79	603.77	1486.21	589.64	-219.58***	2272.97	517.48	1791.59	560.05	-481.37***
Ultra-processed food (per cent)	36.00	21.00	37.00	22.00	0.00	9.00	9.00	13.00	16.00	4.00***
Total Energy Expenditure	1924.03	256.52	1544.92	174.39	-379.11***	2053.44	278.73	1767.14	294.92	-286.30***
Activity Energy Expenditure	430.89	178.44	346.37	144.93	-84.52***	521.26	227.83	535.48	235.90	14.22
Basal metabolic rate	1493.13	156.30	1198.55	77.50	-294.58***	1532.18	148.77	1231.65	105.94	-300.52***
Self-reported health (per cent)	64.00	48.00	53.00	50.00	-0.11***	19.00	39.00	33.00	47.00	13.00***
Physical Activity										
Sedentary activity (per cent)	71.00	7.00	75.00	6.00	3.00***	75.00	7.00	74.00	6.00	-1.00
Light activity (per cent)	16.00	5.00	15.00	4.00	-1.00***	14.00	4.00	15.00	3.00	1.00*
Moderate activity (per cent)	7.00	3.00	5.00	3.00	-1.00***	8.00	3.00	8.00	3.00	1.00*

Vigorous activity (per cent)	1.00	0.00	1.00	0.00	-0.00***	2.00	1.00	1.00	0.00	-0.00***
Very vigorous activity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Accelerometer wear (over 1440 minutes)	1395.53	52.47	1396.17	52.89	0.64	1392.85	49.14	1396.36	48.43	3.40
Observations/day-level	472		454			376		387		

Notes: Statistics is based on data having less than 3 hours of accelerometer non-wear time. Asterisks indicate level of significance *** = significance at 0.1% level, ** = significance at 1% and *= significant at 5%. SD = standard deviation.

The descriptive statistics for individual characteristics of late adolescents aged 15-19 years old in India and Nepal is presented in Table 20. Like with the early adolescents group, the proportion of males enrolled in school is higher than females in India and Nepal. However, younger adolescents are likely to be in school and less likely to be in employment compared to older adolescents in both countries. While more young boys and girls reported participating in school meals than older adolescents, those eating such meals are substantially higher in India than Nepal. About 5 per cent in the Indian sample and 14 per cent of girls in the Nepal sample are married. Contrary to the pattern of anthropometric status seen in younger adolescents, late adolescents boys are taller and weigh more than the girls in both countries. Being underweight is more common in India than Nepal, nevertheless, the proportion of underweight is high in the whole sample – 64 per cent in India and 38 per cent in Nepal. The caloric adequacy ratio in this age-group is similar to what we found in the younger age-group: on average both boys and girls in India are in energy deficit and those in Nepal have adequate caloric adequacy. However, averages tend to mask differences especially in the tails of data distribution. The proportion of ultra-processed foods in diet is higher in the India sample, on average, girls reported more ultra-processed food consumption than boys in both countries. The total energy expenditure values for boys and girls in both countries is less than the recommended daily energy requirements for adolescents (FAO, 2001) yet, energy expenditure is higher than energy intake in India. Late adolescent boys are more likely to report sickness than their female peers in the last month preceding survey in India. However, in Nepal, girls are more likely to report sickness. The proportion of time spent in sedentary and light activity among older adolescents is higher than among younger adolescents in both India and Nepal. Similar to the younger age-group, older girls are more sedentary than their male counterparts.

The amount of activity energy expenditure per hour is presented in Table 21. These values were derived from matching hourly-based accelerometer data with adolescent time use data. Economic, domestic, and travel-related activities constitutes the

Table 21: Average Activity Energy Expenditure per hour among adolescents in India and Nepal.

India									Nepal							
	Early adolescents				Late adolescents				Early adolescents				Late adolescents			
Time use activities	Male AEE (kcal)	Female AEE (kcal)	Male AEE (%)	Female AEE (%)	Male AEE (kcal)	Female AEE (kcal)	Male AEE (%)	Female AEE (%)	Male AEE (kcal)	Female AEE (kcal)	Male AEE (%)	Female AEE (%)	Male AEE (kcal)	Female AEE (kcal)	Male AEE (%)	Female AEE (%)
Well-being			**0.07**	**0.07**			***0.07***	***0.07***			***0.06***	***0.07***			***0.06***	***0.06***
Sleeping and resting	1.00	1.21	0.00	0.01	1.06	1.10	0.01	0.01	1.95	1.65	0.01	0.01	1.82	1.46	0.01	0.00
Self-care	15.05	12.51	0.06	0.06	12.92	11.03	0.06	0.06	16.46	17.42	0.05	0.06	15.38	16.44	0.05	0.06
Education-related activities			**0.15**	**0.13**			**0.14**	**0.11**			**0.14**	**0.14**			**0.16**	**0.12**
Study	14.76	11.88	0.06	0.06	11.81	8.50	0.06	0.05	15.10	12.34	0.05	0.05	13.24	10.53	0.04	0.04
Non-study	21.00	15.71	0.09	0.08	17.03	11.00	0.08	0.06	31.06	26.00	0.10	0.10	33.26	24.55	0.11	0.08
Economic and Domestic activities			**0.29**	**0.32**			**0.22**	**0.35**			**0.31**	**0.25**			**0.32**	**0.31**
Paid economic	11.68	14.50	0.05	0.07	23.48	12.11	0.11	0.07	29.82	0.00	0.09	0.00	32.86	18.29	0.11	0.06
Unpaid economic	23.69	19.50	0.10	0.10	22.84	19.96	0.11	0.12	25.20	25.49	0.08	0.09	21.78	24.60	0.07	0.08
Inhouse domestic	17.46	15.65	0.07	0.08	15.24	13.60	0.07	0.08	22.13	18.88	0.07	0.07	18.14	18.07	0.06	0.06
Outside domestic	15.52	15.39	0.07	0.08	14.56	14.38	0.07	0.08	20.93	22.00	0.07	0.08	22.60	29.16	0.08	0.10
Leisure			**0.35**	**0.33**			**0.30**	**0.29**			**0.29**	**0.32**			**0.25**	**0.29**
Physical exercise and sports	20.14	17.86	0.09	0.09	18.79	10.03	0.09	0.06	27.70	23.98	0.09	0.09	23.37	30.00	0.08	0.10
Attending events	16.51	11.50	0.07	0.06	10.47	11.74	0.05	0.07	20.42	22.47	0.06	0.08	16.84	19.63	0.06	0.07
Socializing	15.38	13.52	0.07	0.07	13.07	10.81	0.06	0.06	16.85	16.54	0.05	0.06	13.93	15.62	0.05	0.05
Digital entertainment	14.28	13.14	0.06	0.06	11.55	8.82	0.05	0.05	11.44	10.90	0.04	0.04	8.53	8.07	0.03	0.03
Creative activities	15.00	11.84	0.06	0.06	9.96	9.22	0.05	0.05	17.31	13.12	0.05	0.05	12.93	9.35	0.04	0.03
Travelling			**0.08**	**0.08**			**0.07**	**0.09**			**0.11**	**0.14**			**0.11**	**0.14**
Travelling and commuting	18.72	16.75	0.08	0.08	15.71	15.05	0.07	0.09	33.73	38.03	0.11	0.14	33.04	39.96	0.11	0.14
Others	14.38	14.02	0.06	0.07	12.51	15.15	0.06	0.09	30.02	20.43	0.09	0.08	28.88	29.05	0.10	0.10

highest energy expenditure activity in Nepal, whereas economic, domestic, and leisure activities have the highest energy expenditure in India. Travel in Nepal involves higher energy expenditure especially among girls. As expected, early adolescents expend more energy in leisure and education-related activities than late adolescents. Gender and age differences in domestic work is evident as late adolescent males expended the least amount of energy on this activity in India. Well-being activities contributes the least to energy expenditure among adolescents in both countries.

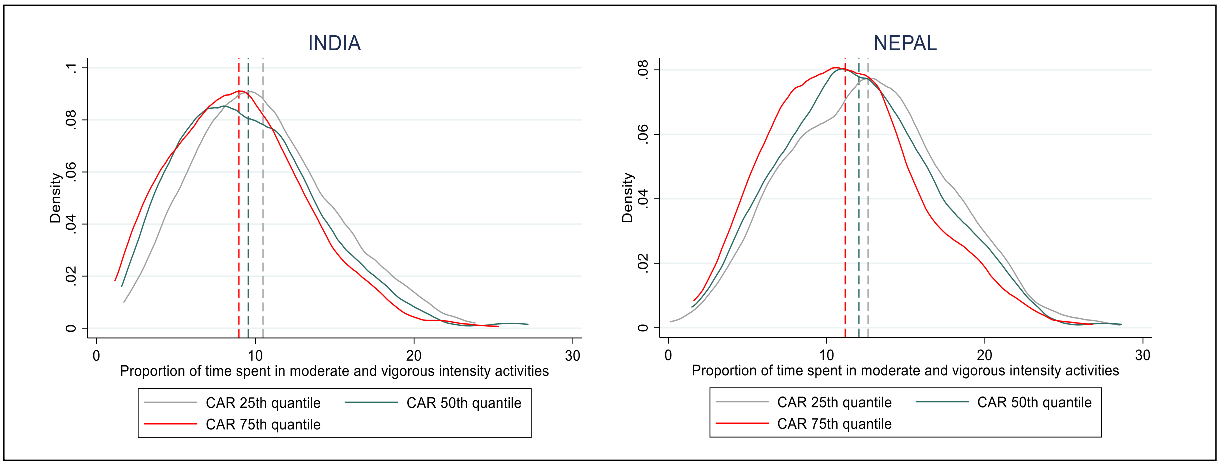

Figure 12: Distribution of time in moderate and vigorous intensity activity across the quantiles

Figure 12 show on average, the distribution of time in moderate and vigorous activities at the upper, middle, and lower levels of the CAR distribution. The proportion of time spent in moderate and vigorous activity is higher in Nepal than India. More importantly in both countries, is that there is a higher incidence of moderate and vigorous intensity activities at the lower tails of CAR distribution. Conversely, the proportion of calories derived from ultra-processed foods in Figure 13 is higher among caloric adequate and surplus groups relative to the caloric deficient groups in both India and Nepal. Some 33 per cent adolescents in Nepal did not consume ultra-processed foods while this is true for only 2 per cent adolescents in the lower tails of CAR in India. The difference in the proportion of ultra-processed food in diets along the CAR distribution is larger in India than Nepal.

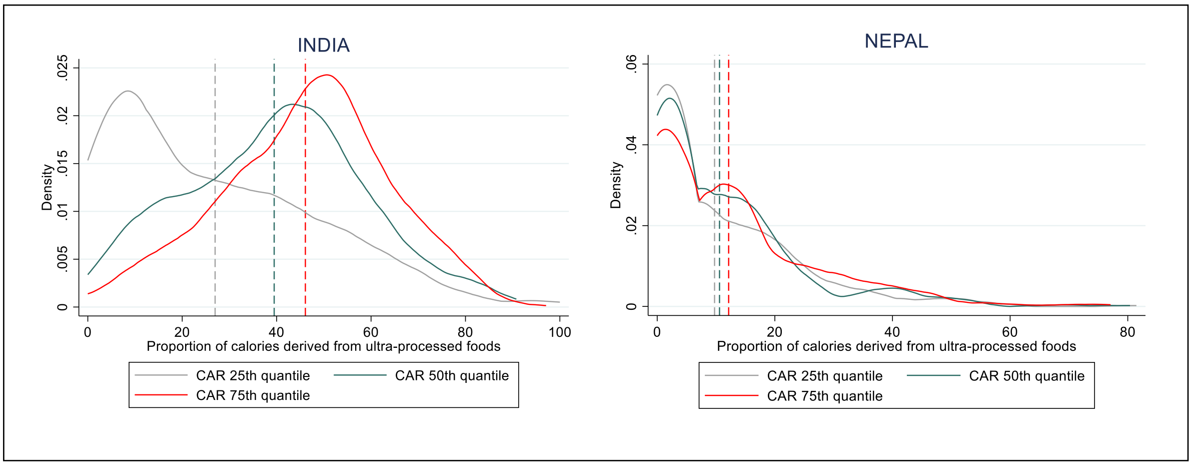

Figure 13: Distribution of calories from ultra-processed foods across the quantiles.

5.6.2 Regression results

5.6.2.1 Relationship between CAR with physical activity – and CAR with diet composition moderated by socio-demographic characteristics.

To understand the differentiating impacts of shifting physical activity and diets by socio-demographic groups, we estimate CQR in equations 5.2 and 5.4 (in section 5.5.3). Coefficients of the interactions between the sociodemographic characteristics of gender, age, caste, and land size with z1 variables are presented in Table 22. The full results of the CQR are presented in Tables 4-7 in the Appendix B of chapter 5.

Table 22: Dependent variable CAR. Conditional quantile regression results of gender, age, caste, and land size.

	India			Nepal		
Sociodemographic characteristics	25th quantile	50th quantile	75th quantile	25th quantile	50th quantile	75th quantile
A. Gender						
z1 - sedentary * boy	-0.01	0.10	0.07	-0.11	-0.09	-0.15**
	(0.06)	(0.08)	(0.08)	(0.07)	(0.06)	(0.07)
z1 - light * boy	0.11	-0.06	0.04	0.12	0.11	0.22**

	(0.08)	(0.10)	(0.10)	(0.08)	(0.08)	(0.09)
z1 - MVPA * boy	-0.10**	-0.04	-0.11*	-0.01	-0.02	-0.07
	(0.05)	(0.06)	(0.07)	(0.06)	(0.05)	(0.06)
z1 - ultra-processed foods * boy	-0.05***	-0.06**	-0.08***	0.01	0.01	0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
B. *Age*						
z1 - sedentary * early adolescent	-0.05	-0.03	0.12**	0.07**	0.04	0.01
	(0.04)	(0.05)	(0.05)	(0.03)	(0.03)	(0.04)
z1 - light * early adolescent	0.03	-0.05	-0.36***	-0.09	0.00	0.07
	(0.09)	(0.11)	(0.12)	(0.08)	(0.07)	(0.09)
z1 - MVPA * early adolescent	0.03	0.08	0.24***	0.02	-0.05	-0.08
	(0.06)	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)
z1 - ultra-processed foods * early adolescent	0.01	0.00	0.00	-0.04***	-0.02*	-0.03*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
C. *Caste*						
z1 - sedentary * lower caste	-0.05	0.02	-0.03	0.21**	0.17*	0.11
	(0.06)	(0.08)	(0.09)	(0.10)	(0.10)	(0.12)
z1 - light * lower caste	-0.01	-0.18*	-0.15	-0.28**	-0.17	-0.12
	(0.08)	(0.10)	(0.11)	(0.11)	(0.11)	(0.13)
z1 - MVPA * lower caste	-0.18**	-0.34***	-0.35***	-0.17*	-0.10	-0.21*
	(0.08)	(0.10)	(0.11)	(0.10)	(0.09)	(0.11)
z1 - ultra-processed foods * lower caste	0.13***	0.11***	0.09***	0.06	0.03	0.11***
	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)
D. *Land*						
z1 - sedentary * small land	-0.18***	-0.25***	-0.13	0.07	-0.00	-0.03
	(0.07)	(0.08)	(0.09)	(0.07)	(0.06)	(0.07)
z1 - light * small land	-0.00	0.18*	0.06	0.00	0.03	0.10
	(0.09)	(0.10)	(0.11)	(0.08)	(0.07)	(0.09)
z1 - MVPA * small land	0.18***	0.07	0.08	-0.07	-0.03	-0.07
	(0.06)	(0.07)	(0.07)	(0.06)	(0.05)	(0.06)
z1 - ultra-processed foods * small land	0.06***	0.06**	0.07***	-0.01	0.00	-0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)

Notes: MVPA is moderate and vigorous intensity physical activity. Asterisks indicate level of significance *** = significance at 0.1% level, ** = significance at 1% and *= significant at 5%. (boy = 1, girl = 0), (early adolescent = 1). (Late adolescent = 0, lower caste=1), (upper caste = 0, (small land = 1, large land = 0).

5.6.2.1.1 Gender

Table 22 shows that there are no significant gender differences in the association between the proportion of sedentary time use and CAR, as well as in the proportion of light activity and CAR in the India sample. However, there are gender differences in the association of time spent in moderate and vigorous activities with CAR in the 25th and 75th quantiles. MVPA relative to the other time uses among boys decreases CAR in the 25th and 75th quantiles in comparison with girls in India.

In Nepal, there are gender differences in the association between physical activity and CAR. Sedentary time use relative to light and MVPA is associated with an increase in CAR among girls compared with boys in the 75th quantile. Time spent in light activities relative to sedentary and MVPA is associated with an increase in CAR among girls in comparison with boys in the 75th quantile. There are no gender differences in the association of MVPA and CAR in Nepal.

Ultra-processed foods relative to unprocessed food among girls increases CAR across all quantiles in comparison with boys in India. The difference is highest in the 75th quantile and lowest in the 25th quantile. There are no significant gender differences in the association of ultra-processed foods with CAR in Nepal.

5.6.2.1.2 Age

Results in Table 22 shows significant age differences in the association between physical activity and CAR in India. Among late adolescents, sedentary time use relative to other time uses is associated with an increase in CAR in the 25th and 50th quantiles compared with early adolescents, but it increases CAR for early adolescents in the 75th quantile compared with late adolescents. Light activity time use relative to sedentary and MVPA increases CAR in the 75th

quantile among late compared to early adolescents. Similarly, increasing MVPA with a proportional reduction in sedentary and light activity is associated with a reduction in CAR in the 50th and 75th quantiles among late adolescents compared to early adolescents. There are no significant age differences in the relationship of MVPA and CAR in Nepal.

There are age differences in the association of ultra-processed foods and CAR in India and Nepal. Across the quantiles, the association of ultra-processed food with CAR is smaller for early adolescents compared with late adolescents.

5.6.2.1.3 Caste

There are no caste differences in the association of sedentary time use and CAR in India based on results in Table 22. Increasing light activity time use relative to sedentary and MVPA among lower castes increases CAR in the 50th quantile compared to upper castes in India. However, increasing MVPA among upper castes decreases CAR across the quantiles compared with lower castes in India. In the Nepal sample, caste moderates the association of light activity time use and CAR in the 25th quantile. Light activity time use increases CAR among lower castes while it reduces CAR in the upper castes. There are no caste differences in the association of MVPA and CAR in Nepal.

In India, upper caste is associated with an increase in CAR in the 25th quantile compared with those in lower caste, if they increases the proportion of ultra-processed food. In Nepal, being an adolescent in the upper caste leads to increases in CAR in the 75th quantile compared with those in lower caste, if there is an increase in the proportion of ultra-processed food but remain in the same position among her new peers.

5.6.2.1.4 Land size

Table 22 shows that there are significant land size differences in the association of sedentary time use and CAR in India. Increasing sedentary time use relative to light and MVPA among large land cultivators increases CAR in the 25th and 50th quantiles. While increasing light intensity time use relative to the other time uses increases CAR among large land cultivators in the 50th quantile compared with small land cultivators. Similarly, increasing MVPA time use relative to the other time uses reduces CAR in the 25th and 50th quantiles among large land cultivators compared with small land cultivators. Results show that there no land size differences in the association of activity time use and CAR in Nepal.

Across the quantiles, ultra-processed foods relative to unprocessed foods increases CAR of adolescents in small land size households compared to their peers cultivating large land areas. There are no land size differences in the association of diet composition and CAR in Nepal.

The UQR results showing the relationship between CAR and physical activity variables, as well as CAR and diet composition variables are presented graphically in Figure 5. The graphs in Figure 2 illustrates the estimates of each variable of interest on the y-axis against the quantiles of CAR on the x-axis, given that the 25th, 50th and 75th quantiles loosely corresponds to energy-deficient, energy-adequate, and energy-surplus groups respectively[42]. The blue line indicates the association of the variables across the distribution of CAR. Points above zero indicates a positive relationship and points below zero indicates a negative relationship between the dependent and the independent variables. The area under red depicts the confidence intervals. An estimated effect is insignificant, where the confidence interval touches zero on the x-axis. Figure 4 shows that the coefficients of the z1 variables relating to the proportion of time spent in sedentary, light, moderate and vigorous activities as well as the coefficient of z1 for the proportion of ultra-processed foods. The z1 varies across the distribution of CAR in all cases. The regression tables are presented in Tables 4, 5, and 6 in appendix B of chapter 5.

[42] CAR of the 25th and the 75th quantiles captures energy deficiency and energy surplus respectively. The 50th quantile ranges between 0.7 – 1.1.

5.6.2.2 Relationship between CAR and the change in physical activity patterns for the whole sample

RIF-regressions of UQR allows for a direct interpretation of the regression estimates as the strength of the association between dependent and independent variables, however, the compositional nature of the independent variables in the (CoDA) analysis requires that estimates are expressed in relative terms. Therefore the relationship between CAR and the physical activity variables in Figure 14 are interpreted as increase in the proportion of time spent in sedentary activity with a proportionate reduction of time spent in light, moderate and vigorous intensity activities (MVPA), will lead to an increase in CAR in India and Nepal. However, the effect sizes cannot be interpreted as the effect of one unit change in independent variable on the dependent variable.

Therefore, we estimated elasticities of the regression coefficients by deriving changes in CAR, that may arise by increasing time allocated to each of sedentary, light, moderate and vigorous intensity activity by 60 minutes. The elasticities estimation followed the methodology used in Srinivasan et al., (2020) [43]. For example, increasing time allocated to sedentary activities by 60 minutes, we assume an equi-proportional reduction in light, moderate and vigorous intensity activity. Separately, we estimate the change in CAR that may arise from increasing the proportion of energy derived from ultra-processed food by 10 per cent. These values are based on daily 60 minutes of moderate and vigorous activity recommended by the WHO for adolescents (Bull et al., 2020) and recommendation of obtaining less than 10 per cent of total energy intake from free sugars (WHO, 2015).

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[43] The main independent variables of interest are in log ratios formats, therefore, the methodology for estimating elasticities of the regression coefficients is based on the effects of the trade-offs between the elements of the log ratios under consideration on the dependent variable. A 60-minute increase in time allocated to sedentary activities equi-proportionally decreases time available for light, moderate and vigorous activities by 60 minutes. Similarly, 10 per cent increase in energy derived from ultra-processed food reduces the energy derived from non-ultra-processed food assuming a constant sum constraint in the number of available calories. The elasticities were computed as $\widehat{\mathrm{CAR}} = \hat{\rho}_{1\tau} . \sqrt{\frac{d-1}{d}} . \ln(\frac{\Delta}{1-s})$ where $\rho_{1\tau}$ is the coefficient of the first log ratio of the variable z_1 and Δ is the change prediction (60 minutes for physical activities and 10 per cent for diet composition), $s = 60 (\frac{x1}{1-x1})$ and x1 = number of minutes in each activity intensity category.

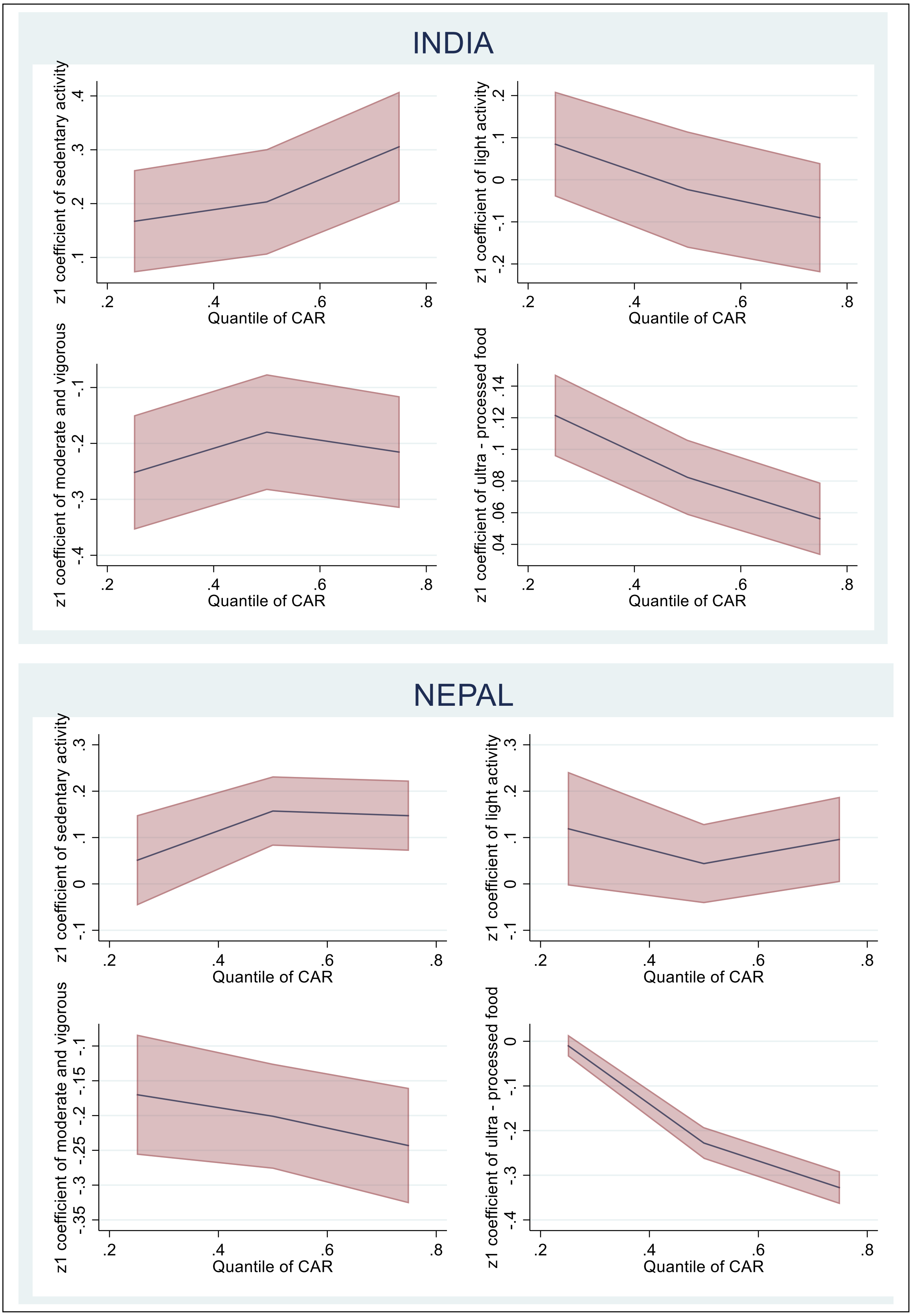

Figure 14: UQR results of the effects of physical activity and diets on CAR.

In the India sample, the effect of the proportion of time spent in sedentary activities is positive and increases from the 25th quantile and is highest at the 75th quantile. We do not observe significant relationship between CAR and the proportion of time spent in light-intensity activities, while increasing the proportion of allocated time to MVPA reduces CAR across the whole distribution. The effect is highest among the energy-deficient, that is, in the 25th quantile and it is lowest among in the 50th quantile. Table 23 shows elasticity estimates of shifting 60 minutes among the physical activity categories across the quantiles. Increasing time allocated to sedentary activities relative to light, moderate and vigorous activities increases CAR by 0.34, 0.42 and 0.63 across the quantiles whereas increasing time allocated to moderate and vigorous activities relative to sedentary and light activities decreases CAR by 0.59, 0.42 and 0.50 across the quantiles in India.

Table 23: Estimated elasticities of regression coefficients[44].

India	Dependent variable: CAR		
	25th quantile	50th quantile	75th quantile
Sedentary activities	0.34 [0.33 – 0.35]	0.42 [0.40 – 0.43]	0.63 [0.61 – 0.65]
Moderate and vigorous activities	-0.59 [-0.61 – -0.57]	-0.42 [-0.43 – -0.41]	-0.50 [-0.52 – -0.49]
Ultra-processed foods	0.22 [0.21 – 0.24]	0.15 [0.14 – 0.16]	0.10 [0.09 – 0.11]
Nepal			
	25th quantile	50th quantile	75th quantile
Sedentary activities	0.08 [0.08 – 0.08]	0.26 [0.25 – 0.26]	0.24 [0.24 – 0.25]
Moderate and vigorous activities	-0.30 [-0.31 – -0.30]	-0.36 [-0.37 – -0.35]	-0.44 [-0.45 – -0.43]
Ultra-processed foods	0.06 [0.05 – 0.06]	0.07 [0.06 – 0.07]	0.04 [0.04 – 0.04]

Notes: 95% confidence intervals in parenthesis

[44] Elasticity estimates of light intensity activities relative to sedentary and moderate and vigorous activities are not presented because the estimates are insignificant across quantiles in both India and Nepal.

In the Nepal sample, the effects of increasing sedentary time use with a proportionate reduction of time spent in light, MVPA are significant in the 50th and 75th quantiles. Increasing the proportion of sedentary time use relative to the other time uses increases CAR for the 50th and the 75th quantile. Similar to the results in the India sample, increasing time allocated to light activities is not significantly associated with CAR. Further, increasing the proportion of time spent in MVPA reduces CAR in the 25th and 50th quantiles. Table 21 shows elasticity estimates of shifting 60 minutes among the physical activity categories across the quantiles. Increasing time allocated to sedentary activities relative to light, moderate and vigorous activities increases CAR by 0.08, 0.26 and 0.24 across the quantiles whereas increasing time allocated to moderate and vigorous activities relative to sedentary and light activities decreases CAR by 0.30, 0.36 and 0.44 across the quantiles in Nepal.

5.6.2.3 Relationship between CAR and change in diet composition for the whole sample

In comparison with the CAR effects sizes observed with physical activity variables, estimated effects of diet composition on CAR are considerably smaller across the quantiles. Since diet composition is made up of two parts: the proportion of calories derived from ultra-processed foods and the proportion of calories derived from non-ultra-processed foods, increasing the proportion of one of the compositions leads to a proportional reduction in the other. Results show that calories derived from ultra-processed foods relative to non-ultra-processed food increases CAR across the quantiles in both countries. However, ultra-processed food is associated with higher CAR increases for adolescents in the lower quantiles compared with those in the higher quantiles. In the India sample, increasing the proportion of calories derived from ultra-processed food is associated with the largest CAR increases in the 25th quantile and the lowest increase in the 75th quantile. Increasing the energy derived from ultra-processed food by 10 per cent changes CAR by 0.22 and 0.15 and 0.10 across the 25th, 50th and 75th quantiles respectively.

In the Nepal sample, increasing the proportion of the ultra-processed component of food increases CAR most for the 50th quantile and the lowest for the 75th quantile. Increasing the energy derived from ultra-processed food by 10 per cent changes CAR by 0.06, 0.07 and 0.04 across the 25th, 50th and 75th quantiles respectively.

5.7 Discussion and future research suggestions

We assess how physical activity, time use, and dietary intake influence the nutritional outcomes – proxied by caloric adequacy for adolescents in the context of nutrition transition in rural areas. We find that there is a higher incidence of moderate and vigorous activity at the lower end of the CAR distribution in India and Nepal. Increasing sedentary time use with an equi-proportional reduction in light, moderate and vigorous intensity activities increases caloric adequacy, with the relationship being largest for energy surplus adolescents, followed by energy sufficient, and the smallest effect was observed among the energy deficient individuals. Conversely, raising the time allocated to moderate, and vigorous activity at the expense of sedentary and light intensity activities reduces caloric adequacy across all groups. This effect is highest in the lower tail of CAR in India but at the upper tail of CAR in Nepal. The deduction from these findings is that reducing activity-related energy expenditure in rural agricultural livelihoods can be effective in improving nutritional outcomes among calorie deficient groups, but it could tip caloric sufficient and surplus individuals into overnutrition. The results also indicate that there is a sizeable potential for safely reducing activity-related energy expenditure in rural livelihoods because the proportion of daily time that adolescents allocate to moderate and vigorous activity is still substantial; about 11 per cent (158 minutes) and 13 per cent (187 minutes) among early adolescents, and 7 per cent (100.8 minutes) and 10 per cent (144 minutes) of daily time use among late adolescents in India and Nepal respectively. These time allocation patterns is considerably more than the average daily 60 minutes of moderate and vigorous activity recommended by the WHO for adolescents (Bull et al., 2020).

Further, a close examination of the time use associated with the observed energy expenditure in the sample revealed that the more energy intensive activities are related to travelling, economic (paid and unpaid) and domestic activities. These time use domains constitutes areas where interventions should seek to reduce activity-related energy expenditure for adolescents; especially as time spent in economic and domestic work has been found in other studies to be child labour constituting trade-offs to adolescents' human capital development and well-being (Ibrahim et al., 2018). Reducing economic- and domestic-related energy expenditure among undernourished adolescents should not rapidly increase the risk of overweight and obesity as the adolescents in our study allocate considerable amount of energy to education, leisure, and self-care. Interventions in rural agricultural infrastructures, provision of incentives to parents to offset the contribution of adolescents to the economics of their respective households, technologies for work and home use can serve to improve nutritional outcomes by the lowering energy expenditure of adolescents. However, the higher effect sizes of sedentary time use on nutritional outcomes in comparison with effect sizes of moderate and vigorous activities on nutritional outcomes suggests that sedentariness in education, leisure, and self-care activities can rapidly lead to negative health outcomes.

The results also show that there are effect differences across sociodemographic groups, and reducing time spent in moderate and vigorous activity may be beneficial to some groups than their counterparts. At the lower tail of the caloric adequacy distribution, boys, compared with girls are likely to benefit more from reducing moderate and vigorous activities in India and Nepal. However, and in line with other studies (Gender and Water Alliance, 2013; Raskind et al., 2020), the descriptive analysis show that the proportion of energy (and number of hours[45]) allocated to the combined economic and domestic activities is higher among girls than boys in India and Nepal. Such energy expenditure (and time use) patterns poses nutrition and health

[45] Average number of hours spent in various activities disaggregated by gender and age group is presented in Tables 12 and 13 in the Appendix B

risks to girls, especially in the context of the ongoing feminization of agriculture in both countries – wherein women are spending more time in agricultural work, and the need for home food processing is likely to grow as farm productivity increases. Gender differences in labour division, like the one observed in our results, could imply that domestic and care work, as well as the related energy expenditure of adolescent girls will increase if they have to substitute for their mothers in performing domestic activities (Padmaja et al., 2019; Quisumbing et al., 2013).

Adolescents from upper castes[46] (in this study, these are the backward castes in India, Brahmin and Chhetri in Nepal) households are more likely to benefit from reduced time in moderate and vigorous intensity activities compared with those from lower castes (scheduled castes and scheduled tribes in India, Janajati and Dalits in Nepal). The suggestion of this finding contradicts prior evidence showing higher malnutrition rates among lower castes adolescents (FAO, 2004; Van de Poel & Speybroeck, 2010; van Tuijl et al., 2021). However, government's affirmative action in providing boarding school facilities for scheduled castes and scheduled tribes adolescents in the study area in India may have contributed to their nutrition relative to the backward castes (Gowdru et al., 2022).

Further, late adolescents have poorer nutrition relative to early adolescents (van Tuijl et al., 2021). This study corroborates this finding by showing that caloric adequacy of late adolescents improves with decreasing energy expenditure and increasing energy dense foods compared to early adolescents in India. Although nutrition interventions tend to target adolescent girls closer to child-bearing age to prevent the intergenerational transmission of malnutrition, it is possible that such interventions are more effective if they were initiated during early adolescents when adolescents can experience substantial catch-up growth (Prentice et al., 2013). Further, adolescents from large land households nutritionally benefit from doing less energy intensive

[46] Backward castes belong to the lower caste categories in India, but they are in a higher category than the scheduled tribes and scheduled castes in the caste hierarchy. They are designated as upper castes in this study only for ease of explanation.

activities which suggests that adolescents in agricultural households work on the farm to support the livelihood means in their households. The time use patterns and nutrition of this group of adolescents are likely to be affected by changes in the local agricultural sector.

On the role of diet, the results show that calories from ultra-processed food constitutes a substantial part of adolescent diets: about 36 per cent and 11 per cent in India and Nepal respectively. These figures are comparable to those in the other low and middle-income countries, much lower than figures from high income countries (Neri et al., 2021) but higher than WHO recommendations of obtaining less than 10% of total energy intake from free sugars (WHO, 2015)[47]. We also find that there is a higher occurrence of ultra-processed foods in the calorie adequate and surplus groups compared to the calorie deficient group. The inverse relationship between non-ultra-processed foods and calorie adequacy is an interesting result showing the positive contribution of ultra-processed foods to energy adequacy.

Girls, upper castes and large land households will benefit in comparison to their counterparts in India while late adolescents more than early adolescents in Nepal benefits from dietary improvements. The deduction from the results is that ultra-processed food seem to help malnourished adolescents achieve energy adequacy, even as non-ultra-processed food must be in adequate supply to achieve energy adequacy. In addition to taste and affordability considerations, the appeal of ultra-processed food among rural households perhaps stem from the less time and energy required for food preparation. Studies have shown that most of the drudgery experienced by women in domestic work is related to food preparation (Barrett & Browne, 1994; Masters, 2016; Srinivasan et al., 2020; Zanello et al., 2017). Food insecurity is known to facilitate the consumption of relatively cheap ultra-processed foods in high income countries (Morales & Berkowitz, 2016). In LMICs however, ultra-processed food is not always cheaper than non-ultra-processed foods (Passos et al., 2020). The attraction of ultra-processed

[47] Ultra-processed foods in this study include sweet and savoury-tasting foods.

foods for the undernourished perhaps lie in the convenience of utilizing such food items than cost considerations, but more evidence is required on this topic. If convenience matters more, then the costs of healthy diets (Herforth et al., 2020) must be lower than the cost of ultra-processed food to adequately reverse the trend in the growing consumption of ultra-processed foods, also given the hard labour involved in food preparation and the increasing opportunity cost of time for women (and girls) in rural livelihoods.

The contribution of ultra-processed foods to calorie adequacy in resource poor settings is perhaps at the expense of worsening diet quality. Adolescents exposed to ultra-processed foods may not show to be malnourished immediately, their adulthood may reflect those food choices later on (Monteiro et al., 2019). As such, even though ultra-processed foods helps in achieving caloric adequacy relative to non-ultra-processed foods, its intake may be restricted – possibly to food emergencies and cases of chronic energy deficiencies.

Consistent with other studies, we find that boys are preferred in food allocation yet have higher undernutrition prevalence in comparison to girls. The puzzle piece contribution of this study to this paradox lies in providing evidence of larger effect sizes between physical activity and nutritional outcomes in comparison with – between diet composition and nutritional outcomes. Boys allocate more time to moderate and vigorous activities overall. Less moderate and vigorous activities would benefit boys relative to girls in our sample. Girls nutritional outcomes, however, fare better with energy dense food relative to boys albeit at a smaller margin. One implication of this finding is that food-based interventions improves the nutrition of adolescents girls compared with boys, while reducing excessive physical labour is more beneficial to boys. The small gender difference in education and economic time allocation signals increase in the economic opportunities available to girls.

This study is not without limitations. Data collection in adolescent research settings may be prone to misreporting caused by recall bias and social desirability. These errors would affect the quality of data especially for time use and food intake information used in this study. This study has considered only calories as an indicator of nutritional outcomes because undernutrition is still widespread in the study sites. The limitation of such research emphasis is that quality of diets has not been considered. A more comprehensive view of the analyses would be the consideration of BMI measures. However, the anthropometric measurements in the data were collected only during the first round of data collection – making them less suitable to capture nutritional outcomes over time. While some information in the data was collected during the COVID-19 pandemic, no widespread social distancing policies were in place. However, it is conceivable that the pandemic indirectly affected information collected during that period. In the compositional data analysis, it is difficult to establish a closed form estimation of elasticity of the regression coefficients as the quantity of food an individual consumed, and the extent of physical activity performed may not be constrained. Therefore, the estimates may be interpreted with caution.

5.8 Conclusion

This chapter provides empirical evidence on the relationship between changes in physical activity, diet composition and nutritional outcomes among adolescents in india and Nepal. The situation that adolescents in LMICs are facing is that of increasing sedentary lifestyles, caused by the spread of technology use, including in agricultural livelihoods. Although these are avenues where physical activity is reducing, the data shows that there is still substantial physical labour in rural India and Nepal under which adolescents continue to perform, and this remain a concern. Nutrition interventions addressing the labour conditions in rural livelihoods will benefit poor malnourished adolescents. As such, mainstreaming youth empowerment through farm and off-farm employment should aim to reduce the impact of poor socio-economic conditions on nutrition without intensifying energy expenditure especially among the most nutritionally vulnerable groups. Equally, higher amounts of sedentary time use must be prevented to protect against all forms of malnutrition – as sedentariness can rapidly increase overnutrition especially among adolescents in the upper nutrition spectrum.

On the role of diets, the substitution of non-ultra-processed food by ultra-processed food increases energy adequacy among adolescents but likely presents a burden of unhealthy diets. Given that the effects of ultra-processed foods varies across the spectrum of caloric adequacy ratio indicate the benefits for energy-deficient adolescents but also hints at risks of tipping adequately nourished individuals into overnutrition. Thus, addressing malnutrition among adolescents will require different kinds of interventions- some targeted at the lower ends of the nutrition status and a different set for the upper end of the nutrition status. Nutrition interventions providing food support should be encouraged to sustainably reduce undernutrition through the provision of energy adequate, nutrient dense food items. In addition to nutrition interventions, ongoing nutrition transition may also present a useful contribution to nutritional outcomes and this viewpoint should guide the type of food items distributed or subsidized to rural households.

Future research must examine the health costs of using ultra-processed to improve nutritional outcomes and the appeal of convenience in utilizing ultra-processed food in resource poor settings.

Chapter 6: Conclusions

6.1 Research summary and the implications of findings

Despite being fundamental to nutritional outcomes, the contribution of time use and physical activity energy expenditure to malnutrition in rural livelihoods has been acutely understudied (FAO, 2001; Stevano et al., 2019). This research focused on overcoming this knowledge gap by leveraging substantially detailed datasets to explicate the role of time use, physical activity, and diet in influencing the incidence of malnutrition among adolescents and adults in rural areas of India and Nepal. Taking the agriculture-nutrition approach forward, this work adopts the rural transformation framework to study the research objective. The agriculture-nutrition literature has extensively explored the issues of agricultural income and productivity to explain malnutrition, and existing time use studies tend to focus on agricultural time use on nutritional outcomes in rural areas. While useful, agricultural livelihoods are no longer synonymous with rural livelihoods given the rural transformation processes (Koustab Majumdar, 2020). Hence, the prominence of agriculture in explaining nutritional outcomes in rural areas may no longer be sufficient.

The analysis contained in each independent chapter of this research – chapters three, four and five – pertains to three of the four earlier identified and discussed pathways of influence between rural transformation and nutrition (in chapter 2), namely: changes in intrahousehold dynamics, the change in the nature and pattern of work, and the nutrition transition. The summary of each independent chapter, including the implications of research findings are discussed hereafter.

6.1.1 Changes in intrahousehold dynamics

The first research question pertains to intrahousehold relations between spouses and its association with nutritional outcomes. Results of the analysis indicates that improving nutritional outcomes depend on households espousing a non-gender-differentiated time allocation; economic time allocation by males and domestic time allocation by females tend to reduce own and partners' nutrition. However, spending time in economic work is associated with improvements in nutritional outcomes for females. Nutritional improvements among males is associated with allocating time to domestic work. The understanding that resources in the hands of females benefits household nutrition more than if those resources are managed by males has been one of the premises for development and agricultural interventions to target women for improved nutritional outcomes (Ruel et al., 2018). However, if household factors limiting women's access to – and control of productive assets also affects their time allocation, a disconnect between development interventions and nutritional outcomes will be observed. Time and energy intensive interventions that targets poor rural women to improve household nutritional outcomes without offsetting women's work burdens in other domains, as well as engage male spouses (for women in male-headed households) will be less effective in achieving desirable nutritional outcomes. Indeed, a useful nutrition intervention entry point will be for gender attitudes towards economic, domestic and care time uses – to change.

6.1.2 Changes in the nature and pattern of work

The second question of this research focused on greater agricultural participation and its effects on energy expenditure. The results shows that agriculture is not the most energy demanding activity in rural livelihoods; men and women expend more energy when they perform non-agricultural economic activities – and increasing time allocated to domestic activities will increase energy expenditure than when the same is reallocated to agriculture amongst women, while men expend the most energy when performing non-agricultural economic work. The implication of this result is that although the greater participation of women in agriculture has generally been perceived as either good or bad for women, we argue that it is the characteristics of general rural livelihoods that determine how women experience increased agricultural participation. If rural economy distress has led women into performing more agricultural work, the related energy expenditure of such work is not solely responsible for the adversarial effects of time use on their well-being. Hence, increased female agricultural work should be supported to achieve nutritional well-being. Relevant policy intervention can be the provision of viable employment opportunities in the agricultural sector to ensure that women overcome labour and productivity gaps created by male outmigration. Perhaps are such interventions not sufficient to address the current levels of deprivation and undernutrition faced by rural people. A broader focus on improving the general characteristics of rural livelihoods can include the provision and the improvement of the conditions of non-agricultural economic work to enable women transition into the service and manufacturing sectors, while easing domestic, and care work burdens.

Further, the gender barriers to better rewarding employment opportunities go hand-in-hand with the bias in intrahousehold allocation of food especially in places where agriculture provides the bulk of female labour participation. The idea that females (especially less-literate, low-skilled) are less suited to economic production because of the characteristic physical nature of such work (Alesina et al., 2013) must be addressed to improve household nutrition. In resource-constrained contexts, households' attempt to compensate (and reinforce) males in food allocation for higher energy expenditure or economic contributions (Harris-Fry et al., 2017) can be inadequate, leaving males in net energy deficit whilst such food allocation patterns reduce the quantity of food available to females. Minimizing time and energy-mediated nutrition trade-offs can involve the provision of employment opportunities during non-peak agricultural work periods of the year, when underemployment is common in rural livelihoods (de Janvry et al., 2022).

6.1.3 Nutrition transition

The third research objective is related to changing diets, time allocation patterns and their association with nutritional outcomes among adolescents. Results indicates that the effects direction and the magnitude of the association between activity intensity and nutritional outcomes depend on adolescent nutritional status, and socio-demographic characteristics; allocating more time to less intensive activities such as sleep, education-related, and self-care improves nutritional outcomes among caloric-deficient adolescents, boys, adolescents in large landholding households and upper castes adolescents relative to their peers, but could tip sufficiently nourished adolescents into overweight. Economic and domestic time use which (in certain cases) may be construed as child labour is adversarial to nutritional outcomes among the calorie deficient, who also tend to allocate more time to high intensity activities than their peers. The analysis of the relationship between diet composition and nutritional outcomes indicates that ultra-processed food constitutes a substantial part of adolescent diets, especially among the calorie adequate adolescents. These results indicates that even in rural areas, which are known to have higher undernutrition and lower overweight rates (FAO, IFAD, UNICEF, WFP and WHO, 2022), there is a wide spectrum of nutritional status among adolescents. "Double duty" nutrition interventions involving diets and physical activity can be effective in addressing the incidence of malnutrition in rural areas, but these must be carefully targeted to the individuals at the lower ends of the nutrition status and a different set for those at the upper end of the nutrition status, because lifestyle and dietary shifts may aid the reduction of one form of malnutrition while exacerbating another form of malnutrition within the same population.

6.2 Study limitations

This research contributes to the literature by providing empirical evidence on the relationship between time allocation, physical activity, diet and nutritional outcomes. Caloric adequacy ratio as used in this research is the proxied indicator of nutritional outcomes. Due to its focus on calories, this indicator may not be appropriate for understanding other forms of quality in diets, such as the nutrient adequacy of diets and the healthiness of diets (Herforth et al., 2020). It is however appropriate as a benchmark to measure energy intake sufficiency in undernutrition contexts – which is the purpose of this research. Future research can extend this research area by incorporating nutrient adequacy and healthiness of diets in the analysis. This research did not reveal whether the observed daily caloric adequacy is sustained over a long period of time, affecting anthropometric and health outcomes.

Further, there are differences in the welfare implications of women participating in paid work against performing unpaid work on family farms. Women participating in income-earning activities are more likely to have higher intrahousehold bargaining power, which may translates into better nutritional outcomes than for their peers who spent equal amount of time in economic activities but were unpaid (Sangwan & Kumar, 2021b). The analysis did not distinguished between paid and unpaid economic activity time use. However, the conclusions of analysis underscores the importance of economic time use for women's nutrition. A distinction between paid and unpaid economic time allocation would have further buttressed the argument that economic time use contributes to better nutritional outcomes.

In addition, this research relied on novel, micro-level, secondary datasets which integrates information on sociodemographic characteristics, accelerometer-based physical activity, food intake and time use. The innovative datasets afforded a level of understanding of rural livelihoods that were previously unexplored (Zanello et al., 2017). Remarkably, capturing energy expenditure data through body-worn accelerometer devices made possible, the observation of individual calorie requirement. However, the sample sizes of the datasets were small and limited the generalizability of results. This limitation also implied that causality may not be inferred from certain sections of the study.

6.3 Suggestions for further research

Research on gender inequality in intrahousehold food allocation has shed light on some of the causes of the nutritional deficits faced by women in resource-constrained contexts but achieving gender equality in food allocation is perhaps not sufficient for desirable nutritional outcomes, especially if individual nutritional needs differ by gender. This research corroborates evidence showing females being nutritionally better off than males (even though undernutrition is prevalent among the respondents). As the double burden of malnutrition is underway in every country, including in rural areas of LMICs, more females than males are experiencing overweight and obesity as a result of the nutrition transition (Kanter & Caballero, 2012). In the same vein, report by FAO et al., (2020) show that more females than male are experiencing undernourishment. These findings suggests the complex nature of nutritional factors, and also hint at the heightened vulnerability of females to such nutritional factors in LMICs. Further research evidence on inequality in nutritional outcomes will be essential to eradicate malnutrition among females and males. Such efforts will require longitudinal, representative datasets that incorporates individually measured energy requirements (in contrast to normative measurements) and allow for assessing heterogeneities caused by sociodemographic characteristics. Beyond the factors pointed out in this research, further evidence on the evolving socio-economic, physiological and environmental factors likely affecting nutrition in the contexts of rural transformation are needed.

While the comprehensive review of literature conducted in this research identified four pathways linking rural transformation with nutritional outcomes, namely: changes in intrahousehold dynamics, changes in the patterns of work, nutrition transition, and income and agricultural productivity growth, this research has empirically investigated only three of those linkages, which are related to time use and physical activity. Further research may assess the impacts of time use and physical activity with nutritional outcomes in comparison to the relationship between income and nutritional outcomes.

Additional studies on the physical activity experiences of the poor are required to understand time use decisions and well-being outcomes, especially because physically demanding livelihoods are usually the most deprived (Palmer-Jones & Jackson, 1997). In the context of rural transformation processes, while declining energy demand of work may reduce energy requirements, it is not very clear whether less work-related physical activity is directly related to productivity increase. Such insights may help prioritise interventions that reduce work intensity simultaneously with the problems of poverty, food insecurity, malnutrition and low productivity.

Further, the reverse effect between time use patterns and nutritional outcomes is also possible, whereby food allocation determines time use (Edmundson & Edmundson, 1988). Current evidence on this line of inquiry seem outdated. Lifestyle changes in rural livelihoods implies that updating the evidence is required.

6.4 Concluding remarks

Time (time poverty, time inequality, time tradeoffs) and physical activity burden of work have been hypothesized as mechanisms through which time use may affect nutritional outcomes. We have shown that time use, and physical activity can contribute to improving nutritional outcomes in the context of the rural transformation processes and agricultural development. We see time use inequality in the data but not time poverty (defined as allocating more than 10 hours of daily time use to work-related activities) - and it appears that the potential to address time and energy expenditure-mediated malnutrition lean towards influencing how economic (agricultural and non-agricultural), domestic and care time and energy are allocated. The time and energy allocated to sleep, and self-care seem adequate in all the three case studies examined in this research. Economic and domestic time use constitutes the activities that are the most physically demanding among adults and adolescents in rural livelihoods. Yet, time must be allocated to these domains to secure nutrition. Time and energy-reducing technologies, rural infrastructures and "do-no-harm" food system transformation policies may help improve nutritional outcomes in rural livelihoods. To avoid time and energy trade-offs to nutrition, agricultural and development support to rural households, requiring additional labour requirements should ponder on the possible time and energy consequences, as non-labour-intensive rural transformation will be beneficial to undernourished individuals. However, concerns about workloads may not deter interventions from economic empowerment. Instead, the nutritional trade-offs caused by additional work burdens will need to be weighed against the benefits afforded by the other dimensions of empowerment.

A pertinent question arising from this research is that: over time, and with the rural transformation processes underway in LMICSs, might the changing nutrition factors be sufficient to net out malnutrition? The literature suggests rural transformation leading towards increasing calorie availability, as well as livelihoods which are no longer as arduous as they are assumed to be. Nonetheless, lifestyle and dietary shifts continue to co-exist with poverty and food insecurity – and current socio-economic trends suggests that the prevailing malnutrition incidences will likely persist in rural LMICs. This outlook justifies continued attention to the nutritional factors that were examined in this research as they evolve, including monitoring the mediation enabled by the diverse socio-demographic characteristics. Strategies to manage time and energy expenditure trade-offs are likely going to be context specific as shown in effect differences across study areas. Other studies have argued on the importance of distinguishing between the role of time use, from that of physical activity on well-being outcomes (Becker, 1985; Palmer-Jones & Jackson, 1997; Picchioni et al., 2020).

In summary, the patterns of time use, physical activity and diet composition are associated with the incidence of malnutrition observed in low- and middle-income countries. In addition to continued income and productivity growth, this research identified that to address persistent malnutrition in rural transformation, agricultural and development interventions can influence time allocation to improve nutritional outcomes by (1) leveraging interdependencies at the intrahousehold level, (2) guide rural transformation processes towards development that enable economic empowerment for females and other marginalized groups, and (3) carefully manage the nutrition transition to ensure that adolescents' patterns of physical activity and diets delivers the necessary nutritional improvements.

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Appendices: Chapter 1

Table 1: Economic development

A. Economic indicators						
		India (district level)				
Infrastructure	Year	Adilabad	Khammam	Mahbubnagar	JG	Trend
Road length (kilometres)	1990	6,298	6,589	8,641	-	↑
	2000	7,249	8,172	10,750	-	
	2010	9,649	9,505	13,651	-	
Number of banks	1990	134	145	190	-	↑
	2000	146	154	194	-	
Number of post offices	1990	517	600	841	-	↑
	2000	517	605	846	-	
Population (1000)	2011	708	1,401	919	609	
Gross domestic Product (GDP)						
Average GDP per capita (1000 in Rupees)	2007 - 2010	46.00	45.25	36.50	-	↑
	2010 - 2013	66.00	66.00	60.33	-	
B. Economic indicators	Year	India		World	Nepal	Trend
Average GDP per capita (USD)	2000 - 2010	773.16		7,362	345.26	↑
	2011-2021	1,758		10,863	973.42	
Industry employment (%)	2000 - 2010	18.84		21.32	11.88	↑
	2011-2021	25.50		23.02	14.08	
Service employment (%)	2000 - 2010	25.29		41.95	15.47	↑
	2011-2021	30.13		47.85	18.92	
Agricultural employment (%)	2000 - 2010	55.87		36.73	72.68	↓
	2011 - 2021	45.37		27.16	67.00	

Notes: JG = Jogulamba-Gadwal. The economic indicators in part A of the table (district level) used data sourced from the District Level Database (DLD) for Indian agriculture and allied sectors provided by the International Crop Research Institute for the Semi-Arid Tropics. Available at http://data.icrisat.org/dld/src/about-dld.html accessed on 23.01.2023. Equivalent district-level data for Jogulamba-Gadwal district was unavailable. GDP is at current prices. Arrows in the right column indicate the direction of trend – upward-facing arrow indicates an upward trend of the indicator over time, downward-facing is the opposite. The economic indicators in part B of the table used data from the World Bank's World Development Indicators available at https://databank.worldbank.org/source/world-development-indicators accessed on the 23.01.2023.

Table 2: Agricultural transformation[48]

[48] "The agricultural transformation is a term referring to systematic changes in farm production and food markets observed alongside economic development, as part of the larger process of structural transformation and industrialization." (Masters et al., 2016)

Agricultural indicators					
	Year	India	World	Nepal	Trend
Agriculture contribution to the GDP (%)*	2000 - 2010	18.36	3.43	33.78	↓
	2011 - 2021	16.81	4.45 ↑	25.46	
Agricultural employment (%)	2000 - 2010	55.87	36.73	72.68	↓
	2011 - 2021	45.37	27.16	67.00	
Rural population growth (%)	2000 - 2010	0.32	1.15	0.65	↓
	2011 - 2021	0.16	0.54	0.43	

Notes: Data was from the World Bank's World Development Indicators https://databank.worldbank.org/source/world-development-indicators accessed on the 23.01.2023. Blue arrows in the right column indicate the direction of trend – upward-facing arrow indicates an upward trend of the indicator over time, downward-facing is the opposite. *This indicator consists of agriculture, forestry, and fishing value added, that is, net output minus intermediate inputs.

Table 3: Nutrition transition

A. Nutrition indicators	Year	India (Telangana)	World	Nepal	Trend
Thinness in adolescents (%)	2018	28.48	-	-	-
Shortness in adolescents (%)	2018	20.92	-	-	-
Overweight and obesity in adolescents	2018	5.80	-	-	-
B. Nutrition indicators	Year	India	World	Nepal	Trend
Prevalence of undernourishment (% of adults)	2000 - 2010	18.96	10.40	16.43	↓
	2011 - 2021	14.58	8.06	5.78	
Prevalence of overweight (% of adults)	2000 - 2010	14.24	33.15	16.56	↑
	2011 - 2021	18.32	37.55	19.53	

Notes: Data for part A was sourced from Sethi et al., 2019, while part B was from the World Bank's World Development Indicators https://databank.worldbank.org/source/world-development-indicators accessed on the 23.01.2023. Arrows in the right column indicate the direction of trend – upward-facing arrow indicates an upward trend of the indicator over time, downward-facing is the opposite. Thinness refers to the percentage of adolescents aged 10-19 years who have body mass index-for-age < -2SD. Shortness refers to the percentage of adolescents aged adolescents aged 10-19 years who have height-for-age < -2SD. Overweight and obesity refers to body mass index-for-age >+1SD and >+1SD above the World Health Organization growth reference for 5-19 years old[49].

Table 4: Social development

Social indicators					
	Year	India	World	Nepal	Trend
Female married at age 15 (% of women ages 20-24)	2000 - 2010	13.10	-	12.15	↓
	2011 - 2021	5.40	-	8.33	
Female married at age 18 (% of women ages 20-24)	2000 - 2010	53.75	-	44.50	↓
	2011 - 2021	37.4	-	25.30	
Female labour force participation (%)	2000 - 2010	29.90	-	80.32	↓
	2011 - 2021	21.46	-	80.66	

[49] https://www.who.int/tools/growth-reference-data-for-5to19-years

Female employment in agriculture (%)	2000 - 2010	70.94	36.18	82.35	↓
	2011 - 2021	58.13	27.93	76.48	
Gender Inequality Index (GII) (UNDP)*	2000	0.66	0.56	0.68	↓
	2020	0.49	0.47	0.45	

Notes: Data sourced from the World Bank's World Development Indicators https://databank.worldbank.org/source/world-development-indicators accessed on the 23.01.2023. Blue arrows in the right column indicate the direction of trend – upward-facing arrow indicates an upward trend of the indicator over time, downward-facing is the opposite.*Data sourced from the https://hdr.undp.org/data-center/thematic-composite-indices/gender-inequality-index#/indicies/GII, accessed 24.01.2023. The lower the gender inequality index, the better the country's performance score. 0 indicates gender parity while 1 indicate the poorest gender parity.

Appendices: Chapter 3

Appendix A

Table A1: Data description for variables used

Dependent variables	*Variable description*
Physical activity level	Ratio of total energy expenditure and basal metabolic rate
Energy Intake (Kcal/day)	Total amount of calories in food consumption over a 24hr period
Calorie Adequacy Ratio	Ratio of daily energy intake to energy expenditure
Independent variables	*Variable description*
Total Energy Expenditure (Kcal/day)	Total amount of calories used to perform physical activities and support physiological functions daily
Domestic activity	Total amount of hours spent in domestic work person-day
Economic activity	Total amount of hours spent in economic work per day
Leisure	Total amount of hours spent in leisure per day
Accelerometer wear	Daily accelerometer wear compliance between 5am-10pm
Day 1	Dummy for the first day of the week when data was collected
Day 2	Dummy for the second day of the week when data was collected
Day 3	Dummy for the third day of the week when data was collected
Day 4	Dummy for the fourth day of the week when data was collected
Day 5	Dummy for the fifth day of the week when data was collected
Day 6	Dummy for the sixth day of the week when data was collected
Number of adult females (18-64 years)	Total number of female adults aged 18-64, within the household
Number of adult males (18-64 years)	Total number of male adults aged 18-64, within the household
Number of children (0-1 years)	Total number of male and female children aged between 0 and 1 years old within the household
Number of infants (2-12 years)	Total number of male and female children aged between 2 and 12 years old within the household
Number of adolescents (13-17 years)	Total number of male and female adolescents aged between 13 and 17 years old within the household
Female	Dummy for if gender of respondent is female
Male	Dummy for if gender of respondent is male
Irrigation	Dummy for if household adopts irrigation system
Land cultivated (acres)	Total area of land cultivated by household
Asset index	Index of sum of values of household assets
Land preparation	Dummy for agricultural season whether agricultural season is when land preparation takes place
Sowing	Dummy for agricultural season whether agricultural season is when sowing and seeding takes place
Land maintenance	Dummy for agricultural season whether agricultural season is when land maintenance takes place
Harvest	Dummy for agricultural season whether agricultural season is when harvest takes place
Self-reported health	Dummy for if self-reported health reduced the amount of work done at work and home
Caste	Dummy for if respondent belong to the backward caste, scheduled caste if otherwise

Appendix B

Table B1: REML regression results. Economic time use on PAL, EI and CAR, CAR <1 and CAR>=1

Fixed effects					
Variables	PAL	EI	CAR	CAR <1	CAR>=1
Male	1.11***	2,329.98***	1.29**	0.87***	1.22**
	(0.41)	(779.89)	(0.57)	(0.30)	(0.57)
Female	1.21***	2,525.22***	1.64***	1.03***	1.48***
	(0.41)	(776.60)	(0.57)	(0.30)	(0.55)
Age centred	-0.01	27.70*	0.04***	0.01**	0.03
	(0.01)	(14.30)	(0.01)	(0.01)	(0.02)
Literacy centred	-0.05***	-6.69	0.04***	0.02**	0.04
	(0.01)	(20.27)	(0.01)	(0.01)	(0.03)
Male own economic activity	0.04***	-4.13	-0.02***	-0.01	-0.01
	(0.00)	(9.48)	(0.01)	(0.00)	(0.01)
Female own economic activity	0.03***	28.46***	-0.00	0.01	0.01
	(0.00)	(9.56)	(0.01)	(0.00)	(0.01)
Male partner economic activity	-0.01**	-26.27***	-0.01*	-0.01***	-0.01
	(0.00)	(9.45)	(0.01)	(0.00)	(0.01)
Female partner economic activity	0.00	30.53***	0.00	0.01	-0.00
	(0.00)	(9.54)	(0.01)	(0.00)	(0.01)
Mean household economic activity	-0.02	-35.45	-0.07	-0.03	-0.00
	(0.04)	(67.35)	(0.05)	(0.02)	(0.05)
Mean age	0.00	-6.21	0.00	-0.00	0.00
	(0.01)	(12.79)	(0.01)	(0.00)	(0.01)
Mean literacy	0.05	-212.29*	-0.20**	-0.07*	-0.11
	(0.06)	(114.03)	(0.09)	(0.04)	(0.08)
Number of males	-0.04	97.47	0.08	0.03	0.02
	(0.06)	(112.92)	(0.09)	(0.03)	(0.08)
Number of females	-0.06	-21.87	-0.09	0.02	-0.02
	(0.06)	(113.04)	(0.09)	(0.04)	(0.08)
Number of infants (0-1 year)	-0.08	-175.30	-0.11	-0.04	0.06
	(0.12)	(210.14)	(0.16)	(0.06)	(0.14)
Number of children (2-12 years)	0.05	-92.14	-0.02	-0.02	-0.03
	(0.05)	(87.51)	(0.07)	(0.03)	(0.06)
Number of adolescents (13-17 years)	0.08	-33.30	0.01	-0.01	-0.00
	(0.07)	(123.10)	(0.09)	(0.04)	(0.09)
Irrigation system	0.12	232.81	0.24	0.08	0.06
	(0.12)	(223.41)	(0.17)	(0.07)	(0.15)
Land cultivated	0.02**	9.33	0.01	-0.01	0.00
	(0.01)	(18.94)	(0.01)	(0.01)	(0.01)
Assets index	-0.00	2.05	-0.02	-0.00	-0.00
	(0.02)	(38.94)	(0.03)	(0.01)	(0.03)
Land preparation	0.09***	35.84	-0.04*	0.01	-0.05
	(0.02)	(39.09)	(0.03)	(0.02)	(0.04)
Sowing	0.12***	203.35***	0.06**	0.06***	0.00
	(0.02)	(37.63)	(0.02)	(0.02)	(0.04)
Land maintenance	0.05***	43.83	0.01	0.05***	-0.02
	(0.02)	(37.79)	(0.02)	(0.02)	(0.04)
Accelerometer wear centred	-0.05***	-3.22	0.03***	0.01***	0.01**

	(0.00)	(8.58)	(0.01)	(0.00)	(0.01)
Self-reported health	-0.01	-130.86	-0.01	0.01	0.00
	(0.06)	(129.26)	(0.08)	(0.07)	(0.09)
Caste	-0.36**	695.77***	0.63***	0.13*	0.42**
	(0.14)	(250.16)	(0.19)	(0.08)	(0.18)
Day 1	-0.01	-144.39***	-0.08**	-0.02	-0.05
	(0.02)	(50.85)	(0.03)	(0.02)	(0.05)
Day 2	0.00	-68.76	-0.04	0.01	-0.01
	(0.02)	(49.12)	(0.03)	(0.02)	(0.05)
Day 3	-0.01	-57.99	-0.03	0.02	-0.03
	(0.02)	(49.31)	(0.03)	(0.02)	(0.05)
Day 4	-0.00	13.13	0.02	0.02	0.01
	(0.02)	(49.09)	(0.03)	(0.02)	(0.04)
Day 5	0.01	-67.40	-0.05	-0.00	-0.04
	(0.02)	(49.13)	(0.03)	(0.02)	(0.05)
Day 6	-0.02	40.91	0.05	0.01	0.03
	(0.02)	(49.27)	(0.03)	(0.02)	(0.04)
Observations	1,120	1,104	1,104	722	382
Number of groups	20	20	20	20	20
Random effects					
Between household variance	0.01	38416.38	0.28	0.00	0.01
	(0.00)	(19826.58)	(0.01)	(0.00)	(0.01)
Within household variance	0.04	193198.60	0.08	0.02	0.06
	(0.00)	(8348.95)	(0.00)	(0.00)	(0.00)

Notes: Restricted maximum likelihood (REML) estimates of the effects of own and partners time use in economic on dependentvariables - Physical Activity Level (PAL), Energy Intake (EI), Calorie Adequacy Ratio (CAR), Calorie Adequacy Ratio less than 1 (CAR<1), Calorie Adequacy Ratio greater or equals to 1 (CAR>=1). Mean Household is the average household time use which accounts for household-level contextual effect of time use. Standard errors in parenthesis. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01.

Table B2: REML regression results. Domestic time use on PAL, EI, CAR, CAR<1, and CAR>=1

Fixed effects					
Variables	PAL	EI	CAR	CAR<1	CAR>=1
Male	1.14***	2,238.16***	0.89	0.74**	1.14**
	(0.42)	(781.64)	(0.66)	(0.33)	(0.45)
Female	1.00**	2,170.17***	1.31**	0.86***	1.45***
	(0.42)	(779.72)	(0.66)	(0.33)	(0.43)
Age centred	-0.02**	23.12	0.04***	0.01**	0.03
	(0.01)	(14.20)	(0.01)	(0.01)	(0.02)
Literacy centred	-0.06***	-12.63	0.04***	0.01*	0.05*
	(0.01)	(20.01)	(0.01)	(0.01)	(0.03)
Male own domestic activity	-0.04***	-4.68	0.01	0.00	0.02
	(0.01)	(22.39)	(0.01)	(0.01)	(0.03)
Female own domestic activity	-0.01*	-40.58***	-0.02***	-0.01**	-0.00
	(0.01)	(11.55)	(0.01)	(0.00)	(0.01)
Male partner domestic activity	0.02*	42.06*	0.01	0.01	0.05**
	(0.01)	(22.42)	(0.01)	(0.01)	(0.02)
Female partner domestic activity	-0.01	-42.17***	-0.01*	-0.01	0.00
	(0.01)	(11.55)	(0.01)	(0.00)	(0.01)
Mean household domestic activity	0.06	170.74	0.12	0.05	0.12*
	(0.07)	(131.50)	(0.12)	(0.05)	(0.07)
Mean age	0.00	-10.12	-0.00	-0.00	-0.00
	(0.01)	(11.63)	(0.01)	(0.00)	(0.01)
Mean literacy	0.03	-238.53**	-0.19*	-0.06*	-0.18***
	(0.06)	(109.26)	(0.10)	(0.04)	(0.06)
Number of adult males	-0.02	161.76	0.11	0.04	0.12*
	(0.07)	(119.35)	(0.11)	(0.04)	(0.07)
Number of adult females	-0.09**	-19.90	-0.01	0.05*	-0.02
	(0.04)	(79.87)	(0.07)	(0.03)	(0.04)
Number of infants (0-1 year)	-0.11	-241.19	-0.14	-0.05	-0.03
	(0.12)	(210.40)	(0.19)	(0.08)	(0.11)
Number of children (2-12 years)	0.04	-146.89*	-0.11	-0.05*	-0.11**
	(0.05)	(82.99)	(0.08)	(0.03)	(0.05)
Number of adolescents (13-17 years)	0.07	-103.41	-0.09	-0.04	-0.11
	(0.07)	(119.91)	(0.11)	(0.04)	(0.07)
Irrigation system	0.18*	222.05	0.08	0.02	0.12
	(0.09)	(163.99)	(0.15)	(0.06)	(0.08)
Land cultivated	0.03***	11.64	-0.00	-0.01*	0.01
	(0.01)	(16.03)	(0.01)	(0.01)	(0.01)
Assets index	-0.00	14.34	0.00	0.01	0.01
	(0.02)	(36.32)	(0.03)	(0.01)	(0.02)
Land preparation	0.06***	22.28	-0.03	0.01	-0.03
	(0.02)	(37.99)	(0.02)	(0.02)	(0.04)
Sowing	0.09***	190.20***	0.06***	0.06***	0.03
	(0.02)	(37.43)	(0.02)	(0.02)	(0.03)
Land maintenance	0.05**	43.83	0.01	0.05***	0.00
	(0.02)	(38.00)	(0.02)	(0.02)	(0.04)
Accelerometer wear centred	-0.05***	-3.70	0.03***	0.01***	0.01**
	(0.00)	(8.50)	(0.01)	(0.00)	(0.01)
Self-reported health	0.01	-132.56	-0.02	0.00	-0.03
	(0.06)	(128.97)	(0.08)	(0.07)	(0.09)

Caste	-0.34**	778.48***	0.69***	0.15*	0.53***
	(0.13)	(241.99)	(0.22)	(0.09)	(0.13)
Day 1	-0.02	-130.83***	-0.07**	-0.01	-0.03
	(0.02)	(50.51)	(0.03)	(0.02)	(0.05)
Day 2	-0.00	-65.61	-0.04	0.01	-0.01
	(0.02)	(49.13)	(0.03)	(0.02)	(0.05)
Day 3	-0.03	-52.18	-0.02	0.03	-0.04
	(0.02)	(49.14)	(0.03)	(0.02)	(0.05)
Day 4	-0.00	20.20	0.02	0.02	0.00
	(0.02)	(49.05)	(0.03)	(0.02)	(0.04)
Day 5	0.01	-43.56	-0.03	0.00	-0.03
	(0.02)	(49.26)	(0.03)	(0.02)	(0.05)
Day 6	-0.03	55.98	0.06*	0.02	0.03
	(0.02)	(49.24)	(0.03)	(0.02)	(0.04)
Observations	1,120	1,104	1,104	722	382
Number of groups	20	20	20	20	20
Random effects					
Between household variance	0.01	40288.41	0.03	0.00	0.01
	(0.01)	(20730.76)	(0.02)	(0.00)	(0.00)
Within household variance	0.04	192454.50	0.08	0.02	0.06
	(0.00)	(8316.87)	(0.00)	(0.00)	(0.00)

Notes: Restricted maximum likelihood (REML) estimates of the effects of own and partners time use in domestic on dependent variables - Physical Activity Level (PAL), Energy Intake (EI), Calorie Adequacy Ratio (CAR), Calorie Adequacy Ratio less than 1 (CAR<1), Calorie Adequacy Ratio greater or equals to 1 (CAR>=1). Mean Household is the average household time use which accounts for household-level contextual effect of time use. Standard errors in parenthesis. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01.

Table B3**:** REML regression results. Leisure time use on PAL, EI, CAR, CAR<1, and CAR>=1.

Fixed effects					
Variables	PAL	EI	CAR	CAR<1	CAR>=1
Male	1.03	2,975.57**	1.39	0.88*	2.10**
	(0.66)	(1,225.73)	(1.12)	(0.49)	(0.87)
Female	0.91	2,874.19**	1.77	0.96**	2.44***
	(0.66)	(1,224.53)	(1.12)	(0.49)	(0.87)
Age centred	-0.01	27.38*	0.04***	0.01**	0.02
	(0.01)	(14.61)	(0.01)	(0.01)	(0.02)
Literacy centred	-0.06***	-9.58	0.04***	0.02**	0.04
	(0.01)	(20.43)	(0.01)	(0.01)	(0.03)
Male own leisure activity	-0.02***	-13.35	0.00	-0.00	0.01
	(0.01)	(12.51)	(0.01)	(0.00)	(0.01)
Female own leisure activity	-0.03***	2.73	0.02**	0.01	0.01
	(0.01)	(14.17)	(0.01)	(0.01)	(0.01)
Male partner leisure activity	0.01	-3.25	-0.01	0.00	-0.01
	(0.01)	(12.52)	(0.01)	(0.01)	(0.01)
Female partner leisure activity	-0.00	-4.61	0.00	-0.00	-0.00
	(0.01)	(14.18)	(0.01)	(0.01)	(0.02)
Mean household leisure activity	0.04	-48.13	-0.04	-0.01	-0.08
	(0.06)	(105.75)	(0.10)	(0.04)	(0.07)
Mean age	0.00	-12.11	-0.00	-0.00	-0.01
	(0.01)	(13.89)	(0.01)	(0.01)	(0.01)
Mean literacy	0.04	-227.57**	-0.18*	-0.06	-0.15*
	(0.06)	(110.72)	(0.10)	(0.04)	(0.08)
Number of males	-0.04	128.65	0.08	0.03	0.07
	(0.06)	(114.01)	(0.11)	(0.04)	(0.08)
Number of females	-0.09*	33.66	0.03	0.06	0.04
	(0.05)	(100.31)	(0.09)	(0.04)	(0.07)
Number of infants (0-1 year)	-0.08	-222.37	-0.12	-0.05	0.02
	(0.11)	(207.13)	(0.19)	(0.08)	(0.14)
Number of children (2-12 years)	0.07	-141.77	-0.09	-0.04	-0.10
	(0.06)	(101.87)	(0.10)	(0.04)	(0.08)
Number of adolescents (13-17 years)	0.10	-97.00	-0.07	-0.04	-0.10
	(0.08)	(139.83)	(0.13)	(0.05)	(0.11)
Irrigation system	0.18*	102.49	-0.00	-0.00	-0.07
	(0.11)	(197.56)	(0.19)	(0.08)	(0.13)
Land cultivated	0.03***	3.00	-0.01	-0.01**	-0.00
	(0.01)	(15.22)	(0.01)	(0.01)	(0.01)
Assets index	-0.01	16.15	0.00	0.00	0.02
	(0.02)	(40.40)	(0.04)	(0.02)	(0.03)
Land preparation	0.06***	19.86	-0.03	0.01	-0.05
	(0.02)	(38.43)	(0.02)	(0.02)	(0.04)
Sowing	0.09***	191.77***	0.07***	0.06***	0.01
	(0.02)	(37.65)	(0.02)	(0.02)	(0.03)
Land maintenance	0.05***	58.52	0.01	0.05***	-0.02
	(0.02)	(38.21)	(0.02)	(0.02)	(0.04)
Accelerometer wear centred	-0.05***	-3.30	0.03***	0.01***	0.01**

	(0.00)	(8.59)	(0.01)	(0.00)	(0.01)
Self-reported health	0.01	-133.46	-0.02	0.01	-0.02
	(0.06)	(130.61)	(0.08)	(0.07)	(0.09)
Caste	-0.38**	784.13***	0.68***	0.14	0.56***
	(0.15)	(276.30)	(0.26)	(0.11)	(0.19)
Day 1	-0.03	-134.95***	-0.07**	-0.01	-0.04
	(0.02)	(51.20)	(0.03)	(0.02)	(0.05)
Day 2	-0.00	-73.63	-0.04	0.01	-0.01
	(0.02)	(49.59)	(0.03)	(0.02)	(0.05)
Day 3	-0.03	-60.04	-0.03	0.03	-0.03
	(0.02)	(49.80)	(0.03)	(0.02)	(0.05)
Day 4	-0.00	9.51	0.01	0.02	0.01
	(0.02)	(49.59)	(0.03)	(0.02)	(0.04)
Day 5	0.01	-63.86	-0.04	-0.00	-0.03
	(0.02)	(49.74)	(0.03)	(0.02)	(0.05)
Day 6	-0.03	39.61	0.05*	0.01	0.03
	(0.02)	(49.80)	(0.03)	(0.02)	(0.04)
Observations	1,120	1,104	1,104	722	382
Number of groups	20	20	20	20	20
Random effects					
Between household variance	0.01	37123.47	0.03	0.00	0.02
	(0.01)	(19259.32)	(0.01)	(0.00)	(0.01)
Within household variance	0.04	196807.60	0.08	0.02	0.06
	(0.00)	(8504.98)	(0.00)	(0.00)	(0.00)

Notes: Restricted maximum likelihood (REML) estimates of the effects of own and partners time use in domestic on dependent variables - Physical Activity Level (PAL), Energy Intake (EI), Calorie Adequacy Ratio (CAR), Calorie Adequacy Ratio less than 1 (CAR<1), Calorie Adequacy Ratio greater or equals to 1 (CAR>=1). Mean Household is the average household time use which accounts for household-level contextual effect of time use. Standard errors in parenthesis. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01.

Appendix C

Table C1: Regression results. Economic activity time use on PAL, EI, CAR, CAR<1, and CAR>=1

Fixed Effects					
Variables	PAL	EI	CAR	CAR<1	CAR>=1
Male	1.10***	2,410.54***	1.32***	0.92***	1.25***
	(0.28)	(561.11)	(0.40)	(0.24)	(0.42)
Female	1.20***	2,604.71***	1.67***	1.07***	1.50***
	(0.28)	(556.63)	(0.39)	(0.24)	(0.41)
Age centred	-0.01	27.48*	0.04***	0.01**	0.03
	(0.01)	(14.18)	(0.01)	(0.01)	(0.02)
Literacy centred	-0.05***	-6.34	0.04***	0.02*	0.04*
	(0.01)	(20.10)	(0.01)	(0.01)	(0.03)
Male own economic activity	0.04***	-3.64	-0.02***	-0.01	-0.01
	(0.00)	(9.37)	(0.01)	(0.00)	(0.01)
Female own economic activity	0.03***	28.17***	-0.00	0.01*	0.01
	(0.00)	(9.45)	(0.01)	(0.00)	(0.01)
Male partner economic activity	-0.01*	-25.78***	-0.01**	-0.01***	-0.01
	(0.00)	(9.34)	(0.01)	(0.00)	(0.01)
Female partner economic activity	0.00	30.22***	0.01	0.01*	-0.00
	(0.00)	(9.43)	(0.01)	(0.00)	(0.01)
Mean household economic activity	-0.02	-35.62	-0.07**	-0.04***	-0.01
	(0.02)	(40.38)	(0.03)	(0.01)	(0.03)
Mean age	0.00	-6.27	0.00	-0.00	0.00
	(0.00)	(7.56)	(0.01)	(0.00)	(0.01)
Mean literacy	0.05	-211.78***	-0.20***	-0.08***	-0.15***
	(0.04)	(67.35)	(0.05)	(0.02)	(0.05)
Number of males	-0.04	97.72	0.08	0.04**	0.03
	(0.04)	(66.77)	(0.05)	(0.02)	(0.05)
Number of females	-0.06*	-22.34	-0.09*	0.01	-0.01
	(0.04)	(66.66)	(0.05)	(0.02)	(0.05)
Number of infants (0-1 year)	-0.08	-175.55	-0.11	-0.05	0.04
	(0.07)	(124.39)	(0.09)	(0.03)	(0.08)
Number of children (2-12 years)	0.05*	-92.46*	-0.02	-0.02	-0.02
	(0.03)	(51.65)	(0.04)	(0.01)	(0.04)
Number of adolescents (13-17 years)	0.07*	-33.65	0.01	-0.02	-0.01
	(0.04)	(72.69)	(0.06)	(0.02)	(0.05)
Irrigation system	0.12	231.13*	0.24**	0.10**	0.12
	(0.07)	(131.87)	(0.10)	(0.04)	(0.08)
Land cultivated	0.02***	9.33	0.01	-0.01*	0.00
	(0.01)	(11.19)	(0.01)	(0.00)	(0.01)
Assets index	-0.00	2.21	-0.02	0.00	-0.01
	(0.01)	(23.00)	(0.02)	(0.01)	(0.02)
Land preparation	0.09***	35.83	-0.04*	0.00	-0.05
	(0.02)	(38.76)	(0.02)	(0.02)	(0.04)
Sowing	0.11***	203.42***	0.06**	0.06***	-0.00
	(0.02)	(37.31)	(0.02)	(0.02)	(0.03)
Land maintenance	0.05***	42.75	0.01	0.05***	-0.02

	(0.02)	(37.47)	(0.02)	(0.02)	(0.04)
Accelerometer wear centred	-0.05***	-3.19	0.03***	0.01***	0.01**
	(0.00)	(8.51)	(0.01)	(0.00)	(0.01)
Self-reported health	-0.01	-156.31	-0.02	0.00	-0.01
	(0.06)	(127.77)	(0.08)	(0.07)	(0.09)
Caste	-0.35***	693.34***	0.63***	0.14***	0.42***
	(0.08)	(148.24)	(0.11)	(0.05)	(0.11)
Day 1	-0.01	-144.27***	-0.08**	-0.02	-0.06
	(0.02)	(50.43)	(0.03)	(0.02)	(0.05)
Day 2	0.00	-68.79	-0.04	0.01	-0.01
	(0.02)	(48.71)	(0.03)	(0.02)	(0.05)
Day 3	-0.01	-57.90	-0.03	0.02	-0.04
	(0.02)	(48.90)	(0.03)	(0.02)	(0.04)
Day 4	-0.00	13.08	0.02	0.02	0.00
	(0.02)	(48.69)	(0.03)	(0.02)	(0.04)
Day 5	0.01	-67.31	-0.05	-0.00	-0.04
	(0.02)	(48.72)	(0.03)	(0.02)	(0.04)
Day 6	-0.02	41.00	0.05	0.01	0.03
	(0.02)	(48.86)	(0.03)	(0.02)	(0.04)
Observations	1,120	1,104	1,104	722	382
Number of groups	20	20	20	20	20
Random Effects					
Between household variance	0.01	15230.29	0.01	0.00	0.00
	(0.00)	(5955.72)	(0.00)	(0.00)	(0.00)
Within household variance	0.04	190904	0.08	0.02	0.05
	(0.00)	(8349.07)	(0.00)	(0.00)	(0.00)

Notes: Full information maximum likelihood estimates of Physical Activity Level (PAL), Energy Intake (EI), Calorie Adequacy Ratio (CAR), Calorie Adequacy Ratio less than 1 (CAR<1), Calorie Adequacy Ratio greater or equals to 1 (CAR>=1) on own and partners time use in economic work on dependent variables. Mean Household is the average household time use which accounts for household-level contextual effect of time use. Standard errors in parenthesis. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01.

Table C2: Regression results. Domestic activity time use on PAL, EI, CAR, CAR<1, and CAR>=1

Fixed effects					
Variables	PAL	EI	CAR	CAR<1	CAR>=1
Male	1.12***	2,325.19***	0.91**	0.73***	1.15***
	(0.29)	(557.65)	(0.44)	(0.26)	(0.40)
Female	0.99***	2,256.60***	1.33***	0.85***	1.46***
	(0.29)	(555.01)	(0.44)	(0.26)	(0.39)
Age centred	-0.01**	22.88	0.04***	0.01**	0.03
	(0.01)	(14.08)	(0.01)	(0.01)	(0.02)
Literacy centred	-0.06***	-12.23	0.04***	0.01*	0.05*
	(0.01)	(19.84)	(0.01)	(0.01)	(0.03)
Male own domestic activity	-0.04***	-6.16	0.01	0.00	0.02
	(0.01)	(22.10)	(0.01)	(0.01)	(0.02)
Female own domestic activity	-0.01	-40.27***	-0.02***	-0.01**	-0.00
	(0.01)	(11.43)	(0.01)	(0.00)	(0.01)
Male partner domestic activity	0.02	40.69*	0.01	0.01	0.05**
	(0.01)	(22.13)	(0.01)	(0.01)	(0.02)
Female partner domestic activity	-0.01	-41.73***	-0.01*	-0.01*	0.00
	(0.01)	(11.44)	(0.01)	(0.00)	(0.01)
Mean household domestic activity	0.06	171.03**	0.12*	0.05*	0.12**
	(0.04)	(78.45)	(0.07)	(0.03)	(0.06)
Mean age	0.00	-10.12	-0.00	-0.00	-0.00
	(0.00)	(6.86)	(0.01)	(0.00)	(0.01)
Mean literacy	0.03	-237.70***	-0.19***	-0.07***	-0.19***
	(0.04)	(64.45)	(0.06)	(0.02)	(0.05)
Number of males	-0.02	161.50**	0.11*	0.05*	0.12**
	(0.04)	(70.39)	(0.06)	(0.02)	(0.06)
Number of females	-0.09***	-20.52	-0.01	0.05***	-0.01
	(0.03)	(47.06)	(0.04)	(0.02)	(0.04)
Number of infants (0-1 year)	-0.11	-241.38*	-0.14	-0.06	-0.04
	(0.07)	(124.34)	(0.11)	(0.05)	(0.09)
Number of children (2-12 years)	0.05*	-147.00***	-0.11**	-0.05***	-0.11**
	(0.03)	(48.91)	(0.04)	(0.02)	(0.04)
Number of adolescents (13-17 years)	0.07*	-103.42	-0.09	-0.05**	-0.11**
	(0.04)	(70.70)	(0.06)	(0.03)	(0.06)
Irrigation system	0.18***	220.82**	0.08	0.02	0.13**
	(0.05)	(96.72)	(0.09)	(0.04)	(0.06)
Land cultivated	0.03***	11.68	-0.00	-0.01***	0.01
	(0.01)	(9.46)	(0.01)	(0.00)	(0.01)
Assets index	-0.00	14.28	0.00	0.01	0.01
	(0.01)	(21.42)	(0.02)	(0.01)	(0.02)
Land preparation	0.06***	22.08	-0.03	0.01	-0.03
	(0.02)	(37.67)	(0.02)	(0.02)	(0.04)
Sowing	0.09***	189.88***	0.06***	0.06***	0.03
	(0.02)	(37.12)	(0.02)	(0.02)	(0.03)
Land maintenance	0.04**	42.18	0.00	0.05***	0.00
	(0.02)	(37.68)	(0.02)	(0.02)	(0.04)
Accelerometer wear centred	-0.05***	-3.69	0.03***	0.01***	0.01**
	(0.00)	(8.43)	(0.01)	(0.00)	(0.01)
Self-reported health	0.01	-161.15	-0.03	0.01	-0.03
	(0.06)	(127.43)	(0.08)	(0.07)	(0.09)
Caste	-0.34***	774.29***	0.69***	0.16***	0.54***

	(0.08)	(143.48)	(0.13)	(0.06)	(0.11)
Day 1	-0.02	-131.01***	-0.07**	-0.01	-0.03
	(0.02)	(50.09)	(0.03)	(0.02)	(0.05)
Day 2	-0.00	-65.48	-0.04	0.01	-0.01
	(0.02)	(48.72)	(0.03)	(0.02)	(0.05)
Day 3	-0.03	-52.22	-0.02	0.03	-0.04
	(0.02)	(48.73)	(0.03)	(0.02)	(0.04)
Day 4	-0.00	20.07	0.02	0.02	0.00
	(0.02)	(48.64)	(0.03)	(0.02)	(0.04)
Day 5	0.01	-43.90	-0.03	0.00	-0.03
	(0.02)	(48.85)	(0.03)	(0.02)	(0.04)
Day 6	-0.03	55.62	0.06*	0.02	0.03
	(0.02)	(48.83)	(0.03)	(0.02)	(0.04)
Observations	1,120	1,104	1,104	722	382
Number of groups	20	20	20	20	20
Random Effects					
Between household variance	0.00	16012.77	0.01	0.00	0.00
	(0.00)	(6217.17)	(0.00)	(0.00)	(0.01)
Within household variance	0.04	190176.5	0.08	0.02	0.05
	(0.00)	(8170.30)	(0.00)	(0.00)	(0.00)

Notes: Full information maximum likelihood estimates of the effects of own and partners time use in domestic on dependent variables - Physical Activity Level (PAL), Energy Intake (EI), Calorie Adequacy Ratio (CAR), Calorie Adequacy Ratio less than 1 (CAR<1), Calorie Adequacy Ratio greater or equals to 1 (CAR>=1). Mean Household is the average household time use which accounts for household-level contextual effect of time use. Standard errors in parenthesis. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01.

Table C3: Regression results. Leisure activity time use on PAL, EI, CAR, CAR<1, and CAR>=1

Fixed effects					
Variables	PAL	EI	CAR	CAR<1	CAR>=1
Male	1.02**	3,048.88***	1.40**	0.85**	2.09***
	(0.42)	(791.90)	(0.69)	(0.34)	(0.64)
Female	0.90**	2,946.91***	1.78***	0.93***	2.43***
	(0.42)	(790.09)	(0.69)	(0.34)	(0.63)
Age centred	-0.01	27.13*	0.04***	0.01**	0.02
	(0.01)	(14.49)	(0.01)	(0.01)	(0.02)
Literacy centred	-0.06***	-9.23	0.04***	0.02**	0.05*
	(0.01)	(20.26)	(0.01)	(0.01)	(0.03)
Male own leisure activity	-0.02***	-13.05	0.00	-0.00	0.01
	(0.01)	(12.40)	(0.01)	(0.00)	(0.01)
Female own leisure activity	-0.03***	2.17	0.02**	0.01	0.01
	(0.01)	(14.03)	(0.01)	(0.01)	(0.01)
Male partner leisure activity	0.01*	-3.08	-0.01	0.00	-0.01
	(0.01)	(12.40)	(0.01)	(0.01)	(0.01)
Female partner leisure activity	-0.00	-5.25	0.00	-0.00	-0.00
	(0.01)	(14.04)	(0.01)	(0.01)	(0.01)
Mean household leisure activity	0.04	-47.29	-0.04	-0.01	-0.08
	(0.03)	(63.46)	(0.06)	(0.02)	(0.05)
Mean age	0.00	-12.12	-0.00	-0.00	-0.01
	(0.00)	(8.21)	(0.01)	(0.00)	(0.01)
Mean literacy	0.04	-226.72***	-0.18***	-0.06**	-0.18***
	(0.04)	(65.46)	(0.06)	(0.03)	(0.05)
Number of males	-0.04	128.40*	0.08	0.03	0.09
	(0.04)	(67.41)	(0.06)	(0.03)	(0.06)
Number of females	-0.09***	32.79	0.03	0.06***	0.06
	(0.03)	(59.37)	(0.06)	(0.02)	(0.05)
Number of infants (0-1 year)	-0.08	-221.80*	-0.12	-0.05	-0.00
	(0.07)	(122.59)	(0.11)	(0.05)	(0.09)
Number of children (2-12 years)	0.07**	-141.90**	-0.09	-0.04*	-0.10*
	(0.03)	(60.13)	(0.06)	(0.02)	(0.06)
Number of adolescents (13-17 years)	0.10**	-96.90	-0.07	-0.04	-0.12
	(0.05)	(82.55)	(0.08)	(0.03)	(0.07)
Irrigation system	0.18***	101.80	-0.00	-0.00	-0.03
	(0.06)	(117.08)	(0.11)	(0.05)	(0.08)
Land cultivated	0.03***	3.06	-0.01	-0.01***	-0.00
	(0.00)	(9.03)	(0.01)	(0.00)	(0.01)
Assets index	-0.01	16.21	0.00	0.01	0.01
	(0.01)	(23.85)	(0.02)	(0.01)	(0.02)
Land preparation	0.06***	19.82	-0.03	0.01	-0.06
	(0.02)	(38.11)	(0.02)	(0.02)	(0.04)
Sowing	0.09***	191.66***	0.07***	0.06***	0.01
	(0.02)	(37.34)	(0.02)	(0.02)	(0.03)
Land maintenance	0.05***	57.12	0.01	0.06***	-0.02
	(0.02)	(37.89)	(0.02)	(0.02)	(0.04)
Accelerometer wear centred	-0.05***	-3.31	0.03***	0.01***	0.01**
	(0.00)	(8.52)	(0.01)	(0.00)	(0.01)
Self-reported health	0.02	-158.20	-0.02	0.02	-0.03
	(0.06)	(129.05)	(0.08)	(0.07)	(0.09)
Caste	-0.38***	780.78***	0.68***	0.15**	0.56***
	(0.09)	(164.01)	(0.15)	(0.07)	(0.13)

Day 1	-0.03	-135.22***	-0.07**	-0.01	-0.04
	(0.02)	(50.77)	(0.03)	(0.02)	(0.05)
Day 2	-0.00	-73.60	-0.04	0.01	-0.01
	(0.02)	(49.18)	(0.03)	(0.02)	(0.05)
Day 3	-0.03	-60.16	-0.03	0.03	-0.04
	(0.02)	(49.38)	(0.03)	(0.02)	(0.05)
Day 4	-0.00	9.51	0.01	0.02	0.01
	(0.02)	(49.18)	(0.03)	(0.02)	(0.04)
Day 5	0.01	-64.01	-0.04	-0.00	-0.04
	(0.02)	(49.32)	(0.03)	(0.02)	(0.04)
Day 6	-0.03	39.54	0.05*	0.01	0.03
	(0.02)	(49.38)	(0.03)	(0.02)	(0.04)
Observations	1,120	1,104	1,104	722	382
Number of groups	20	20	20	20	20
Random Effects					
Between household variance	0.00	13016.29	0.01	0.00	0.01
	(0.00)	(5888.71)	(0.00)	(0.00)	(0.00)
Within household variance	0.04	193389.5	0.08	0.02	0.05
	(0.00)	(8307.98)	(0.00)	(0.00)	(0.00)

Notes: Full information maximum likelihood (FIML) estimates of the effects of own and partners time use in leisure on dependent variables - Physical Activity Level (PAL), Energy Intake (EI), Calorie Adequacy Ratio (CAR), Calorie Adequacy Ratio less than 1 (CAR<1), Calorie Adequacy Ratio greater or equals to 1 (CAR>=1). Mean Household is the average household time use which accounts for household-level contextual effect of time use. Standard errors in parenthesis. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01.

Table C4: FIML estimation -Own and partner elasticities of time use relative to PAL, EI, CAR, CAR<1, and CAR>1.

Economic activities	PAL	EI	CAR	CAR<1	CAR>=1
Male Own	0.10*** (0.01)	-0.01 (0.02)	-0.09*** (0.03)	-0.04 (0.03)	-0.02 (0.02)
Female Own	0.08*** (0.01)	0.06*** (0.02)	-0.00 (0.02)	0.03* (0.02)	0.05 (0.03)
Male Partner	-0.02*** (0.01)	-0.07*** (0.02)	-0.06** (0.03)	-0.06*** (0.01)	-0.07 (0.04)
Female Partner	0.01 (0.01)	0.06*** (0.02)	0.02 (0.03)	0.04* (0.02)	0.00 (0.02)
Mean Household	-0.09 (0.11)	-0.16 (0.18)	-0.60** (0.26)	0.42** (0.14)	0.06 (0.18)
Domestic activities					
Male Own	-0.01*** (0.00)	-0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.03)
Female Own	-0.01 (0.01)	-0.04*** (0.01)	-0.04*** (0.01)	-0.02** (0.01)	-0.00 (0.04)
Male Partner	0.00 (0.00)	0.01* (0.00)	0.00 (0.00)	0.00 (0.00)	0.01** (0.00)
Female Partner	-0.01 (0.01)	-0.04*** (0.01)	-0.03* (0.01)	-0.02* (0.01)	0.00 (0.01)
Mean Household	0.08 (0.05)	0.20** (0.09)	0.25* (0.15)	0.14* (0.08)	0.18** (0.10)
Leisure activities					
Male Own	-0.04*** (0.01)	-0.02 (0.02)	0.01 (0.02)	-0.00 (0.02)	0.01 (0.03)
Female Own	-0.05*** (0.01)	0.00 (0.02)	0.05*** (0.02)	0.02 (0.02)	0.01 (0.02)
Male Partner	0.02* (0.01)	-0.01 (0.02)	-0.03 (0.02)	0.01 (0.02)	-0.02 (0.03)
Female Partner	-0.00 (0.01)	-0.01 (0.02)	0.01 (0.02)	-0.01 (0.02)	-0.01 (0.02)
Mean Household	-0.13 (0.10)	-0.14 (0.18)	0.22 (0.31)	0.06 (0.14)	-0.07 (0.19)

Notes: Elasticites of the multilevel model estimates of the effects of own and partners time use in economic, domestic and leisure work on dependent variables - Physical Activity Level (PAL), Energy Intake (EI), Calorie Adequacy Ratio (CAR), Calorie Adequacy Ratio less than 1 (CAR<1), Calorie Adequacy Ratio greater or equals to 1 (CAR>=1). 'Male (female) own' is male (female) time use effect on own outcome. 'Male (female) partner' is male (female) time use effect on the female (male) outcome. Mean Household is the average household time use which accounts for household-level contextual effect of time use. Standard errors in parenthesis. Asterisks show level of significance *p<0.1, **p<0.05 and ***p<0.01.

Appendices: Chapter 4

Appendix A

Table A1: Data description for variables used in all regression models.

Dependent variable	*Variable description*
Activity energy expenditure	Total amount of calories used to perform physical activities daily
Physical activity level	Ratio of total energy expenditure and basal metabolic rate
Independent variable	*Variable description*
Agricultural time use	Total amount of hours spent in agricultural- crop and livestock activities in a day
Non-agricultural economic time use	Total amount of hours spent in non-agricultural- economic activities in a day
Domestic time use	Total amount of hours spent in domestic, care and voluntary activities in a day
Leisure time use	Total amount of hours spent in leisure activities in a day
Self-care time use	Total amount of hours spent in self-care activities in a day
Sleep time use	Total amount of hours spent in sleep in a day
Body mass index	Body weight divided by the square of body height
Number of elderly females	Total number of female adults older than 64, within the household
Number of elderly males	Total number of male adults older than 64, within the household
Number of adult females	Total number of female adults aged 18-64, within the household
Number of adult males	Total number of male adults aged 18-64, within the household
Number of male children	Total number of male children aged between 5 and 10 years old within the household
Number of female children	Total number of female children aged between 5 and 10 years old within the household
Number of male pre-school aged children	Total number of male children aged between 0 and 4 years old within the household
Number of female pre-school aged children	Total number of female children aged between 0 and 4 years old within the household
Total land cultivated (hectares)	Total area of land cultivated by household
Total livestock unit	Ownership of livestock units based on the Food and Agricultural Organization 2011 guidelines
Asset index	Index of sum of values of household assets
Crop production decision-making index	Additive index with scale ranging between 0 and 1 for whether female (0) or male (1) makes more crop production decisions within the household
Weeding	Dummy for agricultural season whether agricultural season is when weeding takes place
Harvesting	Dummy for agricultural season whether agricultural season is when harvesting takes place
Fertilizer application	Dummy for agricultural season whether agricultural season is when fertilizer application takes place
Day	Count of the day of the week when data was collected

Table A2: Regression results. Log ratio-transformed time use variables on AEE for female and male groups.

	Females						Males					
	Agriculture	Non-agriculture	Domestic	Leisure	Self-care	Sleep	Agriculture	Non-agriculture	Domestic	Leisure	Self-care	Sleep
lr1	9.52***	5.79**	19.12***	0.94	36.62***	-72.00***	16.09***	13.06***	-2.26	-9.74	37.03	-54.18**
	(2.23)	(2.52)	(4.40)	(2.65)	(13.43)	(14.00)	(3.59)	(3.27)	(2.61)	(7.02)	(23.16)	(24.46)
lr2	7.69***	10.67***	13.34***	9.70***	16.84***	30.80***	16.28***	18.70***	15.64***	14.14***	23.50***	52.03**
	(2.23)	(1.90)	(2.47)	(2.44)	(2.93)	(10.71)	(3.14)	(3.46)	(3.65)	(4.16)	(5.54)	(20.36)
lr3	22.95***	22.95***	12.95***	8.40***	17.32***	-0.90	5.02*	5.02*	16.52***	14.65***	26.34***	15.23***
	(4.49)	(4.49)	(2.46)	(2.28)	(4.19)	(2.55)	(2.94)	(2.94)	(3.31)	(3.97)	(6.36)	(3.87)
lr4	12.41***	12.41***	12.41***	24.54***	36.43***	12.12***	-0.77	-0.77	-0.77	4.20	19.80**	4.98
	(3.20)	(3.20)	(3.20)	(4.59)	(6.00)	(3.53)	(7.64)	(7.64)	(7.64)	(4.11)	(8.24)	(5.08)
lr5	54.31***	54.31***	54.31***	54.31***	36.47***	35.68***	45.60*	45.60*	45.60*	45.60*	22.22	46.77*
	(13.41)	(13.41)	(13.41)	(13.41)	(7.40)	(13.67)	(23.32)	(23.32)	(23.32)	(23.32)	(13.72)	(24.45)
Age	-2.48						-3.98					
	(1.88)						(2.57)					
Literacy	15.63*						-10.29					
	(9.11)						(11.06)					
Body mass index	22.52***						26.21***					
	(2.37)						(3.39)					
Wealth index	-5.50						20.10***					
	(3.63)						(5.79)					
Total livestock unit	-2.84						-14.29					
	(5.10)						(9.03)					
Total land cultivated	-9.57						-16.49*					
	(5.81)						(9.26)					
Village Kamaipet	-68.54***						-81.24*					

	(25.21)						(43.80)					
Village Kommuguda	-29.71											
	(28.80)						(48.62)					
Village Mathadiguda	-65.48***						-170.48***					
	(16.91)						(32.10)					
Dwelling distance to a tarred road	-3.63						6.87					
	(4.61)						(8.04)					
Number of elderly male	20.04						66.66					
	(25.32)						(47.31)					
Number of female elderly	-110.90***						-81.87**					
	(26.97)						(38.12)					
Number of male adult	86.69***						60.77*					
	(24.02)						(34.73)					
Number of female adult	-90.73***						-130.53***					
	(27.99)						(38.48)					
Number of male adolescent	22.42**						-27.77*					
	(10.39)						(16.71)					
Number of female adolescent	33.43**						-14.72					
	(13.62)						(23.82)					
Number of male children	-19.69						3.57					
	(18.63)						(35.95)					
Number of female children	-3.28						-7.09					

	(14.27)						(22.05)					
Number of male pre-schooler	2.67						-27.60					
	(18.39)						(28.68)					
Number of female pre-schooler	11.66						51.00					
	(21.78)						(36.53)					
Day1	36.63**						58.25*					
	(17.38)						(29.94)					
Day2	15.51						34.14					
	(17.65)						(30.25)					
Day3	26.69						12.25					
	(17.46)						(30.61)					
Day4	29.42*						41.93					
	(16.89)						(29.10)					
Weeding season	-15.86						6.85					
	(15.48)						(26.46)					
Harvesting season	-4.38						18.25					
	(11.82)						(20.30)					
Farm production decision-making index	16.30**						32.62***					
	(6.78)						(8.85)					
Intercept	138.28						419.90**					
	(86.25)						(165.88)					
Observations	434						457					
F	13.60***						12.37***					
R-squared	0.52						0.48					
Adjusted R-squared	0.48						0.44					

Notes: Standard errors in parentheses * p<0.10, ** p<0.05, *** p<0.01. lr1 is designated as the first log-ratio variable for each of agriculture, non-agriculture economic, domestic, leisure, self-care, and sleep time uses. lr1, lr2, lr3, lr4, and lr5 are the other ratio-transformed time use variables. AEE = Activity Energy Expenditure.

Table A3: Regression results. Log ratio-transformed time use variables on PAL for female and male groups.

	Females						Males					
	Agriculture	Non-agriculture	Domestic	Leisure	Self-care	Sleep	Agric.	Non-agric.	Domestic	Leisure	Self-care	Sleep
lr1	0.01***	0.01**	0.02***	0.00	0.03***	-0.06***	0.01***	0.01***	-0.00	-0.01	0.03*	-0.04**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.02)
lr2	0.01***	0.01***	0.01***	0.01***	0.01***	0.03***	0.01***	0.01***	0.01***	0.01***	0.02***	0.04***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)
lr3	0.02***	0.02***	0.01***	0.01***	0.02***	-0.00	0.00	0.00	0.01***	0.01***	0.02***	0.01***
	(0.00)	(0.004)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
lr4	0.01***	0.01***	0.01***	0.02***	0.03***	0.01***	-0.00	-0.00	-0.00	0.00	0.02**	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)
lr5	0.05***	0.05***	0.05***	0.05***	0.03***	0.03***	0.04**	0.04**	0.04**	0.04**	0.02*	0.04**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Age	0.00						-0.00					
	(0.00)						(0.00)					
Literacy	0.01*						-0.01*					
	(0.00)						(0.01)					
Body mass index	0.01***						0.01***					
	(0.00)						(0.00)					
Wealth index	-0.01						0.01***					
	(0.00)						(0.00)					
Total livestock unit	-0.00						-0.01					
	(0.00)						(0.01)					
Total land cultivated	-0.01*						-0.01*					
	(0.01)						(0.01)					
Village Kamaipet	-0.06***						-0.04					
	(0.02)						(0.03)					

Village Kommuguda	-0.03						-0.12***					
	(0.02)						(0.04)					
Village Mathadiguda	-0.06***						-0.11***					
	(0.01)						(0.02)					
Dwelling distance to a tarred road	-0.00						0.01					
	(0.00)						(0.01)					
Number of elderly male	0.01						0.06*					
	(0.02)						(0.03)					
Number of female elderly	-0.08***						-0.06**					
	(0.02)						(0.03)					
Number of male adult	0.07***						0.03					
	(0.02)						(0.03)					
Number of female adult	-0.06***						-0.05*					
	(0.02)						(0.03)					
Number of male adolescent	0.02**						-0.01					
	(0.01)						(0.01)					
Number of female adolescent	0.02**						-0.01					
	(0.01)						(0.02)					
Number of male children	-0.03*						0.00					
	(0.02)						(0.03)					
Number of female children	-0.01						-0.01					
	(0.01)						(0.02)					
Number of male pre-schooler	0.01						-0.02					

	(0.02)						(0.02)					
Number of female pre-schooler	0.00						0.02					
	(0.02)						(0.03)					
Day1	0.03*						0.04*					
	(0.01)						(0.02)					
Day2	0.01						0.02					
	(0.01)						(0.02)					
Day3	0.02						0.01					
	(0.01)						(0.02)					
Day4	0.02						0.03					
	(0.01)						(0.02)					
Weeding season	-0.01						0.00					
	(0.01)						(0.02)					
Harvesting season	-0.00						0.02					
	(0.01)						(0.02)					
Farm production decision-making index	0.01**						0.02***					
	(0.01)						(0.01)					
Intercept	1.17***						1.43***					
	(0.07)						(0.12)					
Observations	434						457					
F	11.11***						8.38***					
R-squared	0.47						0.38					
Adjusted R-squared	0.42						0.34					

Notes: Standard errors in parentheses * p<0.10, ** p<0.05, *** p<0.01. lr1 is designated as the first log-ratio variable for each of agriculture, non-agriculture economic, domestic, leisure, self-care, and sleep time uses. lr1, lr2, lr3, lr4, and lr5 are the other ratio-transformed time use variables. PAL = Physical Activity Level

Table A4: Regression results. Log ratio-transformed time use variables on AEE for female and male groups.

	Lower wealth females	Lower-wealth males	Upper wealth females	Upper wealth males	Small landholding females	Small landholding males	Large landholding females	Large landholding males	No pre-schoolers females	No pre-schooler males	With pre-schooler females	With pre-schooler males
lr1	10.93***	18.57***	11.65***	20.06***	9.72***	21.650***	4.93	17.71***	6.46**	11.06**	11.82***	31.20***
	(3.14)	(4.79)	(2.87)	(5.42)	(3.49)	(4.49)	(3.11)	(5.17)	(2.95)	(4.66)	(3.66)	(5.47)
lr2	10.92***	12.50***	5.53*	24.21***	10.27***	10.87***	7.19**	20.82***	12.73***	17.97***	4.93	12.60***
	(3.22)	(4.31)	(2.84)	(4.93)	(3.72)	(3.77)	(2.92)	(4.97)	(2.98)	(4.46)	(3.74)	(4.48)
lr3	17.37***	1.74	17.18*	16.28***	22.02***	4.25	7.49	9.49**	22.63***	2.66	0.35	11.46***
	(5.64)	(3.93)	(9.82)	(4.56)	(6.48)	(3.59)	(7.38)	(4.52)	(5.37)	(4.13)	(9.21)	(4.06)
lr4	15.74***	4.03	11.09**	5.450	13.45***	4.15	5.84	-7.82	14.74***	3.46	2.03	0.36
	(4.25)	(10.96)	(5.36)	(10.45)	(4.52)	(9.46)	(5.28)	(11.25)	(4.69)	(13.83)	(5.35)	(9.07)
lr5	42.37**	48.19	55.66***	110.78***	51.57**	29.96	44.26**	95.82***	55.11***	66.45**	22.82	91.58***
	(19.71)	(32.27)	(15.68)	(32.44)	(20.33)	(27.39)	(18.84)	(33.57)	(18.63)	(30.86)	(19.49)	(32.79)
Age	-3.77**	-11.61***	6.99***	-9.78***	-0.61	-9.49***	7.27***	-10.49***	4.60*	-14.86***	-1.34	-0.73
	(1.69)	(1.95)	(1.850)	(3.08)	(1.73)	(1.69)	(2.69)	(2.86)	(2.41)	(3.46)	(5.25)	(3.91)
Literacy	31.59***	-37.78***	17.39**	-17.73	17.64*	12.11	-1.70	-60.34***	44.22***	-46.28***	0.98	-29.76*
	(11.61)	(10.33)	(7.59)	(20.08)	(9.07)	(11.25)	(17.28)	(19.94)	(15.61)	(13.58)	(11.85)	(15.98)
Body mass index	22.24***	32.59***	19.12***	14.86***	21.48***	22.23***	20.49***	32.650***	19.18***	29.48***	24.65***	31.52***
	(2.66)	(6.38)	(3.59)	(5.71)	(3.03)	(3.83)	(4.13)	(7.28)	(5.47)	(5.43)	(3.13)	(5.18)
Tropical Livestock Unit (FAO)	16.66**	-8.89	-9.18**	-46.87***	14.05*	15.40	-6.04	-32.91**	-18.47**	-30.47**	11.21	3.24
	(6.93)	(10.30)	(4.490)	(14.78)	(7.81)	(10.23)	(4.71)	(12.69)	(8.93)	(15.25)	(7.17)	(11.44)
Village Chanduri	-14.91	54.04	-19.41	196.82*	9.28	99.89***	185.11***	101.61	241.36***	74.38	3.69	29.53
	(32.25)	(52.75)	(40.02)	(102.66)	(21.17)	(33.31)	(58.14)	(77.73)	(50.43)	(71.37)	(22.62)	(47.52)

Village Kamaipet	108.57***	109.35***	44.17	292.10***	72.72***	34.56	-198.20***	266.99***	-171.27***	322.07***	52.88	11.59
	(25.725)	(37.514)	(47.878)	(100.45)	(27.96)	(36.84)	(44.29)	(75.65)	(40.44)	(67.32)	(34.98)	(57.65)
Village Kommuguda	116.32***	13.99	95.22*	124.33	126.82***	72.29	-180.48***	56.73	-194.27***	212.57***	211.58***	-86.92
	(33.33)	(48.81)	(51.01)	(109.32)	(36.77)	(48.82)	(50.85)	(81.84)	(45.13)	(75.65)	(43.67)	(72.25)
Dwelling distance to a tarred road	-4.29	-6.18	-41.15***	-9.65	-6.56	-7.95	61.00***	-28.95	59.91***	-54.86***	-4.69	13.68**
	(4.32)	(5.99)	(15.47)	(35.09)	(4.15)	(5.55)	(16.60)	(21.40)	(13.36)	(20.61)	(4.29)	(6.92)
Number of elderly male	20.34	20.34	20.34	20.34	20.34	20.34	67.12	67.12	67.12	67.12	67.12	67.12
	(25.34)	(25.34)	(25.34)	(25.34)	(25.34)	(25.34)	(47.22)	(47.22)	(47.22)	(47.22)	(47.22)	(47.22)
Number of female elderly	-111.82***	-111.82***	-111.82***	-111.82***	-111.82***	-111.82***	-80.34**	-80.34**	-80.34**	-80.34**	-80.34**	-80.34**
	(26.99)	(26.99)	(26.99)	(26.99)	(26.99)	(26.99)	(38.043)	(38.043)	(38.043)	(38.043)	(38.043)	(38.043)
Number of male adult	86.94***	86.94***	86.94***	86.94***	86.94***	86.94***	57.491*	57.491*	57.491*	57.491*	57.491*	57.491*
	(24.03)	(24.03)	(24.03)	(24.03)	(24.03)	(24.03)	(34.729)	(34.729)	(34.729)	(34.729)	(34.729)	(34.729)
Number of female adult	-91.02***	-91.02***	-91.02***	-91.02***	-91.02***	-91.02***	-127.68***	-127.68***	-127.68***	-127.68***	-127.68***	-127.68***
	(28.00)	(28.00)	(28.00)	(28.00)	(28.00)	(28.00)	(38.40)	(38.40)	(38.40)	(38.40)	(38.40)	(38.40)
Number of male adolescent	22.01**	22.01**	22.01**	22.01**	22.01**	22.01**	-27.46	-27.46	-27.46	-27.46	-27.46	-27.46
	(10.39)	(10.39)	(10.39)	(10.39)	(10.39)	(10.39)	(16.68)	(16.68)	(16.68)	(16.68)	(16.68)	(16.68)
Number of female adolescent	32.83**	32.83**	32.83**	32.83**	32.83**	32.83**	-14.09	-14.09	-14.09	-14.09	-14.09	-14.09
	(13.62)	(13.62)	(13.62)	(13.62)	(13.62)	(13.62)	(23.79)	(23.79)	(23.79)	(23.79)	(23.79)	(23.79)
Number of male children	-19.58	-19.58	-19.58	-19.58	-19.58	-19.58	5.42	5.42	5.42	5.42	5.42	5.42
	(18.63)	(18.63)	(18.63)	(18.63)	(18.63)	(18.63)	(35.86)	(35.86)	(35.86)	(35.86)	(35.86)	(35.86)
Number of female children	-3.37	-3.37	-3.37	-3.37	-3.37	-3.37	-7.86	-7.86	-7.86	-7.86	-7.86	-7.86

	(14.28)	(14.28)	(14.28)	(14.28)	(14.28)	(14.28)	(22.00)	(22.00)	(22.00)	(22.00)	(22.00)	(22.00)
Number of male pre-schooler	2.31	2.31	2.31	2.31	2.31	2.31	-27.75	-27.75	-27.75	-27.75	-27.75	-27.75
	(18.39)	(18.39)	(18.39)	(18.39)	(18.39)	(18.39)	(28.61)	(28.61)	(28.61)	(28.61)	(28.61)	(28.61)
Number of female pre-schooler	11.70	11.70	11.70	11.70	11.70	11.70	51.26	51.26	51.26	51.26	51.26	51.26
	(21.77)	(21.77)	(21.77)	(21.77)	(21.77)	(21.77)	(36.44)	(36.44)	(36.449)	(36.44)	(36.44)	(36.44)
Day 1	19.94	22.04	39.66*	102.64**	23.65	44.38	42.77*	74.64*	16.34	27.84	46.26*	120.21***
	(25.75)	(39.91)	(20.12)	(43.69)	(26.09)	(35.32)	(23.11)	(44.83)	(24.15)	(40.43)	(24.31)	(42.52)
Day 2	4.31	13.42	14.12	51.00	10.47	23.60	11.09	50.12	-14.98	-0.13	37.60	95.63**
	(25.97)	(40.75)	(20.29)	(43.38)	(26.21)	(35.40)	(23.47)	(45.29)	(24.64)	(40.71)	(24.54)	(42.45)
Day 3	11.22	2.56	31.69	18.38	21.42	23.90	23.26	11.76	7.94	-1.28	35.51	48.11
	(25.64)	(40.74)	(20.36)	(44.03)	(26.04)	(36.11)	(23.35)	(45.48)	(24.60)	(40.85)	(24.19)	(43.77)
Day 4	27.84	42.96	20.38	44.03	31.48	32.03	19.42	56.85	21.84	20.68	30.02	78.69*
	(25.28)	(39.25)	(19.14)	(42.58)	(25.57)	(34.50)	(22.32)	(43.58)	(23.61)	(39.28)	(23.80)	(41.30)
Weeding season	-22.12	15.79	22.32	42.79	-44.31*	-106.33***	23.87	110.81***	-6.82	23.82	-21.75	3.48
	(25.00)	(38.65)	(17.14)	(37.35)	(23.75)	(31.57)	(21.20)	(40.35)	(22.03)	(38.39)	(23.17)	(36.25)
Harvesting season	-39.55**	9.01	47.25***	36.77	-22.81	-26.95	16.12	63.36**	-5.46	4.09	-13.41	47.55
	(18.01)	(27.50)	(13.56)	(30.04)	(18.31)	(24.21)	(15.66)	(30.40)	(15.88)	(27.03)	(18.03)	(30.34)
Farm production decision-making index	-1.23	-18.62*	9.34*	34.64***	1.79	-1.47	-3.35	43.48***	30.92*	6.80	3.10	26.26***
	(6.92)	(10.31)	(5.32)	(11.39)	(5.53)	(7.39)	(7.03)	(13.61)	(15.78)	(18.25)	(5.45)	(8.25)
Intercept	187.54*	613.46***	-122.88	785.42***	145.91	490.61***	-332.68***	543.33**	-308.54**	900.19***	-101.93	-39.93
	(97.572)	(151.37)	(83.44)	(258.62)	(102.09)	(137.32)	(108.99)	(215.64)	(123.63)	(185.24)	(161.38)	(194.18)
Observations	220	243	214	214	228	233	206	224	229	252	205	205
F	12.21***	7.53***	12.98***	12.55***	10.83***	10.68***	9.56***	11.99***	10.32***	11.70***	11.25***	8.62***
R-squared	0.56	0.42	0.59	0.58	0.53	0.51	0.52	0.55	0.51	0.51	0.56	0.50

Adjusted R-squared	0.52	0.36	0.54	0.53	0.48	0.47	0.47	0.51	0.46	0.47	0.51	0.44

Notes: Standard errors in parentheses * p<0.10, ** p<0.05, *** p<0.01. lr1 is designated as the first log-ratio variable for each of agriculture, non-agriculture economic, domestic, leisure, self-care, and sleep time uses. lr1, lr2, lr3, lr4, and lr5 are the other ratio-transformed time use variables. AEE = Activity Energy Expenditure

Table A5: Regression results. Log ratio-transformed time use variables on PAL for female and male groups.

	Lower wealth females	Lower-wealth males	Upper wealth females	Upper wealth males	Small landholding females	Small landholding males	Large landholding females	Large landholding males	No pre-schoolers females	No pre-schooler males	With pre-schooler females	With pre-schooler males
lr1	0.01***	0.01***	0.01***	0.02***	0.01***	0.02***	0.01***	0.01***	0.01***	0.01**	0.01***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.004)
lr2	0.00	0.01**	0.01***	0.01***	0.01**	0.01**	0.00	0.01***	0.01***	0.01***	0.00	0.01*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.003)
lr3	0.00	0.00	0.01	0.01***	0.01	0.00	0.00	0.01*	0.01	0.00	0.01	0.01**
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
lr4	0.00	-0.00	0.01	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	-0.00
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)
lr5	0.01	0.02	0.04***	0.08***	0.02	0.01	0.02	0.06**	0.01	0.05**	0.01	0.054**
	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)
Age	-0.04**	0.01	-0.02	-0.07*	-0.02***	0.01**	-0.04	0.06	0.00	-0.03***	0.08*	-0.13***
	(0.02)	(0.01)	(0.02)	(0.04)	(0.01)	(0.01)	(0.02)	(0.04)	(0.01)	(0.01)	(0.05)	(0.03)
Literacy	-0.13*	0.01	-0.03	0.10	-0.07***	0.10***	-0.03	0.03	0.06***	0.07**	0.21	0.07**
	(0.07)	(0.03)	(0.03)	(0.06)	(0.02)	(0.04)	(0.08)	(0.09)	(0.02)	(0.03)	(0.19)	(0.03)
Body mass index	0.01	0.03**	0.02*	-0.01	0.03***	0.02***	0.02	0.02	0.03***	0.03***	-0.03**	0.05*
	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
Wealth index	-0.07**	0.02	-0.06*	-0.22*	-0.02**	-0.02	0.02	-0.17**	0.02***	0.01	0.07	-0.17***
	(0.03)	(0.03)	(0.03)	(0.12)	(0.01)	(0.01)	(0.03)	(0.07)	(0.01)	(0.01)	(0.08)	(0.06)

Total livestock unit	-0.02	0.04	-0.00	0.03	0.12***	0.01	-0.06	0.21**	0.02	-0.21***	0.00	0.42***
	(0.03)	(0.04)	(0.03)	(0.10)	(0.03)	(0.02)	(0.07)	(0.090)	(0.02)	(0.06)	(0.02)	(0.12)
Total land cultivated	0.02	-0.05	0.03	0.24	-0.05*	0.15*	-0.03	0.19**	-0.08***	-0.04*	0.11***	-0.20***
	(0.03)	(0.05)	(0.03)	(0.18)	(0.03)	(0.08)	(0.04)	(0.07)	(0.01)	(0.02)	(0.03)	(0.04)
Village Kamaipet	0.40**	-0.08	0.77***	0.38	0.49***	0.02	-0.02	2.01***	-0.71***	0.25	-0.45**	0.04
	(0.15)	(0.08)	(0.29)	(0.69)	(0.12)	(0.07)	(0.01)	(0.72)	(0.13)	(0.15)	(0.20)	(0.32)
Village Kommuguda	0.45***	-0.14	0.83***	0.28	0.55***	0.029	0.000	1.851**	-0.728***	0.191	-0.315	-0.034
	(0.16)	(0.08)	(0.30)	(0.70)	(0.12)	(0.071)	(0.000)	(0.718)	(0.132)	(0.160)	(0.211)	(0.326)
Village Mathadiguda	0.02	0.12	0.32**	-0.09	0.16***	0.24**	0.12	0.47***	-0.32***	-0.12	0.41	-0.81**
	(0.05)	(0.10)	(0.14)	(0.59)	(0.04)	(0.104)	(0.097)	(0.16)	(0.06)	(0.08)	(0.25)	(0.33)
Dwelling distance to a tarred road	-0.02**	0.01	-0.22***	-0.22	-0.02***	0.03***	0.01	-0.29***	0.08***	-0.05**	0.02	-0.18***
	(0.01)	(0.01)	(0.07)	(0.24)	(0.00)	(0.01)	(0.01)	(0.09)	(0.01)	(0.02)	(0.03)	(0.06)
Number of elderly male	0.00	0.00	-0.11**	-0.25	-0.09**	0.077	0.270	0.375	-0.25**	0.38**	0.08	-0.54***
	(0.00)	(0.00)	(0.05)	(0.34)	(0.04)	(0.04)	(0.27)	(0.26)	(0.11)	(0.16)	(0.18)	(0.17)
Number of female elderly	1.15***	-0.39	0.00	-0.99*	0.32***	0.03	0.00	-1.32***	0.16*	-0.25*	0.04	-2.16***
	(0.37)	(0.497)	(0.00)	(0.51)	(0.08)	(0.07)	(0.00)	(0.46)	(0.10)	(0.14)	(0.09)	(0.67)
Number of male adult	-0.38**	0.20	0.00	-0.646	0.00	0.00	0.17	0.21*	0.022	0.69***	-0.55	2.86***
	(0.15)	(0.16)	(0.00)	(0.51)	(0.00)	(0.00)	(0.13)	(0.12)	(0.05)	(0.23)	(0.46)	(0.74)
Number of female adult	0.12	-0.01	0.03	0.44	0.42**	-0.01	-0.16	0.42***	-0.79***	0.76**	0.00	-3.18***
	(0.22)	(0.17)	(0.08)	(0.32)	(0.21)	(0.13)	(0.24)	(0.16)	(0.19)	(0.30)	(0.00)	(0.80)
Number of male adolescent	-0.22	0.20	0.20**	0.24	-0.07*	0.07*	0.06	0.05	0.07**	-0.01	0.62***	-1.84***
	(0.17)	(0.12)	(0.09)	(0.26)	(0.03)	(0.04)	(0.06)	(0.05)	(0.03)	(0.03)	(0.16)	(0.54)
Number of female adolescent	-0.08	0.18	0.20	0.51	0.00	-0.12***	0.12	-0.66*	0.21***	-0.25**	0.63*	0.97**
	(0.09)	(0.11)	(0.12)	(0.31)	(0.02)	(0.04)	(0.09)	(0.36)	(0.04)	(0.10)	(0.38)	(0.4)

Number of male children	-0.12	0.33*	-0.03	0.00	0.02	0.21***	-0.08	0.00	-0.56***	0.34*	0.58*	0.00
	(0.15)	(0.17)	(0.18)	(0.00)	(0.03)	(0.06)	(0.25)	(0.00)	(0.09)	(0.18)	(0.34)	(0.00)
Number of female children	-0.08***	-0.02	-0.00	0.60*	-0.07**	0.16**	0.00	0.00	-0.35***	0.37**	0.15	-1.62***
	(0.02)	(0.03)	(0.09)	(0.35)	(0.03)	(0.06)	(0.00)	(0.00)	(0.09)	(0.15)	(0.39)	(0.51)
Number of male pre-schooler	-0.18*	0.17**	0.26	0.34	-0.11**	0.14*	-0.08	-0.01	0.00	0.00	0.37***	-0.35***
	(0.09)	(0.07)	(0.15)	(0.51)	(0.04)	(0.08)	(0.09)	(0.14)	(0.00)	(0.00)	(0.12)	(0.10)
Number of female pre-schooler	-0.33*	0.26*	0.09	0.00	-0.20***	0.16**	0.01	0.00	0.00	0.00	0.47	0.61***
	(0.19)	(0.15)	(0.14)	(0.00)	(0.05)	(0.06)	(0.23)	(0.00)	(0.00)	(0.00)	(0.35)	(0.18)
Day1	0.02	0.01	0.03**	0.06**	0.01	0.02	0.03***	0.05*	0.01	0.02	0.03**	0.08***
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)
Day2	0.02	0.01	0.01	0.04	0.01	0.01	0.01	0.03	0.00	0.00	0.02	0.06**
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)
Day3	0.01	0.00	0.02*	0.01	0.02	0.01	0.02*	0.01	0.01	-0.00	0.02*	0.03
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)
Day4	0.02	0.03	0.01	0.03	0.02	0.02	0.01	0.03	0.01	0.01	0.02	0.05**
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)
Weeding season	-0.06***	0.02	-0.01	-0.01	-0.05***	-0.05**	-0.00	0.12***	0.01	-0.01	0.03	-0.05
	(0.02)	(0.02)	(0.02)	(0.03)	(0.01)	(0.02)	(0.02)	(0.03)	(0.01)	(0.02)	(0.04)	(0.03)
Harvesting season	-0.05***	0.02	0.01	-0.01	-0.02**	0.00	-0.01	0.10***	0.02*	-0.01	0.05	-0.02
	(0.01)	(0.02)	(0.02)	(0.03)	(0.01)	(0.01)	(0.02)	(0.03)	(0.01)	(0.02)	(0.04)	(0.03)
Farm production decision-making index	-0.09	0.02	-0.01	0.19**	-0.07***	-0.01	0.07	-0.11	-0.09**	0.32***	0.08	0.23***
	(0.06)	(0.04)	(0.03)	(0.09)	(0.02)	(0.01)	(0.11)	(0.07)	(0.04)	(0.11)	(0.06)	(0.05)
Intercept	3.57***	-0.24	1.44**	3.16*	1.50***	-0.53	1.92***	-2.23	2.04***	0.29	-2.14	5.40***
	(0.81)	(0.64)	(0.64)	(1.71)	(0.29)	(0.81)	(0.68)	(1.58)	(0.19)	(0.50)	(2.26)	(1.70)
Observations	220	243	214	214	228	233	206	224	229	252	205	205

F	12.11***	4.91***	13.93***	8.18***	10.13***	4.82***	17.18***	8.63***	15.21***	6.62***	12.21***	7.03***
R-squared	0.66	0.41	0.69	0.57	0.61	0.42	0.73	0.56	0.69	0.47	0.68	0.55
Adjusted R-squared	0.61	0.33	0.64	0.50	0.55	0.33	0.69	0.49	0.65	0.40	0.63	0.47

Notes: Standard errors in parentheses * p<0.10, ** p<0.05, *** p<0.01. lr1 is designated as the first log-ratio variable for each of agriculture, non-agriculture economic, domestic, leisure, self-care, and sleep time uses. lr1, lr2, lr3, lr4, and lr5 are the other ratio-transformed time use variables. PAL = Physical Activity Level

Table A6: Proportion of time spent on different activities (percent) by gender and season per hour daily

	Weeding				Harvesting				Fertiliser Application			
Activity	Female		Male		Female		Male		Female		Male	
	Time	%	Time	%	Time	%	Time	%	Time	%	Time	%
1.Agriculture-Ploughing, levelling, bunding	0.01	0.03	0.53	2.21	0.01	0.05	0.27	1.11	0.00	0.00	0.15	0.63
1.Agriculture-Sowing	0.23	0.97	0.03	0.13	0.00	0.00	0.03	0.13	0.35	1.45	0.13	0.55
1.Agriculture-Weeding	4.73	19.69	1.69	7.04	0.00	0.00	0.00	0.00	1.68	7.02	0.54	2.24
1.Agriculture-Fertilizer application	0.27	1.11	0.56	2.34	0.00	0.00	0.00	0.00	1.48	6.18	1.28	5.34
1.Agriculture-Irrigation	0.00	0.00	0.03	0.13	0.00	0.00	0.27	1.11	0.00	0.00	0.10	0.42
1.Agriculture-Pesticides	0.00	0.00	0.32	1.33	0.05	0.19	0.30	1.24	0.15	0.65	0.67	2.79
1.Agriculture-Harvesting	0.00	0.00	0.00	0.00	4.81	20.05	2.21	9.22	0.00	0.00	0.01	0.03
1.Agriculture-Threshing /Post harvesting	0.00	0.00	0.00	0.00	0.10	0.43	0.13	0.56	0.00	0.00	0.01	0.03
1.Agriculture-Livestock care and management	0.15	0.64	2.55	10.61	0.04	0.16	1.76	7.32	0.41	1.69	1.58	6.56
1.Agriculture-Collecting forest produce	0.01	0.03	0.03	0.13	0.02	0.08	0.19	0.78	0.00	0.00	0.00	0.00
1.Agriculture-Others	0.06	0.27	0.42	1.77	0.08	0.35	0.20	0.83	0.00	0.00	0.23	0.94
2.Salaried/formal employment-Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.Salaried/formal employment-Private	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.Salaried/formal employment-Others	0.10	0.40	0.00	0.00	0.00	0.00	0.07	0.28	0.00	0.00	0.13	0.52
3.Non-farm-Wages	0.00	0.00	0.07	0.28	0.00	0.00	0.41	1.69	0.00	0.00	0.17	0.70
3.Non-farm-MGNREGA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.Non-farm-Business/petty vending	0.00	0.00	0.00	0.00	0.06	0.24	0.13	0.56	0.01	0.05	0.00	0.00
3.Non-farm-Others	0.00	0.00	0.02	0.06	0.00	0.00	0.13	0.56	0.00	0.00	0.00	0.00

4.Household maintenance-Food management	1.74	7.26	0.11	0.47	1.48	6.18	0.18	0.73	1.47	6.13	0.01	0.03
4.Household maintenance-Cleaning and upkeep of dwelling and surroundings	1.26	5.24	0.35	1.45	1.24	5.16	0.11	0.45	1.18	4.92	0.04	0.16
4.Household maintenance-Washing clothes and utensils	0.66	2.76	0.01	0.03	0.37	1.56	0.01	0.03	0.61	2.53	0.00	0.00
4.Household maintenance-Small repairs	0.00	0.00	0.01	0.03	0.01	0.03	0.08	0.35	0.00	0.00	0.00	0.00
4.Household maintenance-Shopping	0.04	0.17	0.45	1.86	0.12	0.48	0.31	1.29	0.03	0.13	0.13	0.55
5.Care for household members-Caring for children/physical care	0.46	1.92	0.25	1.04	0.27	1.13	0.13	0.56	0.44	1.83	0.13	0.55
5.Care for household members-Adult care	0.00	0.00	0.00	0.00	0.05	0.19	0.00	0.00	0.07	0.30	0.00	0.00
5.Care for household members-Caring for sick, disabled	0.06	0.24	0.02	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.Voluntary activities-Unpaid help to other households	0.00	0.00	0.03	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.21
6.Voluntary activities-Community-organized services	0.13	0.54	0.00	0.00	0.00	0.00	0.13	0.53	0.08	0.32	0.21	0.89
7.Education-General Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.Education-Career, professional development training and studies	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00
7.Education-Adult study, non-formal education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.Socialisation/Recreation-Talking	1.08	4.50	2.81	11.71	1.37	5.70	2.60	10.83	1.57	6.56	2.98	12.42
8.Socialisation/Recreation-Reading: Newspaper/books	0.00	0.00	0.02	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.Socialisation/Recreation-Watching TV, video etc	0.26	1.08	0.77	3.22	0.41	1.72	0.39	1.62	0.95	3.98	0.83	3.44
8.Socialisation/Recreation-Internet Surfing	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.10
9.Personal care/Self-care-Sleep and related activities	8.67	36.12	8.19	34.12	8.08	33.68	8.15	33.96	8.03	33.47	8.23	34.27
9.Personal care/Self-care-Eating	2.69	11.22	2.74	11.43	3.19	13.28	2.77	11.54	2.90	12.10	2.71	11.30
9.Personal care/Self-care-Personal care: bathing, brushing, exercise	1.19	4.94	1.60	6.66	1.30	5.43	1.77	7.37	1.52	6.34	2.01	8.36
10.Travel-For economic activity/employment	0.06	0.27	0.12	0.51	0.74	3.06	0.94	3.91	0.88	3.66	1.27	5.29
10.Travel-For pleasure	0.10	0.40	0.14	0.57	0.05	0.19	0.13	0.56	0.05	0.19	0.10	0.42

10.Travel-For essentials	0.05	0.20	0.14	0.57	0.15	0.62	0.21	0.88	0.12	0.51	0.31	1.30
Total	24.00	100	24.00	100	24.00	100	24.00	100	24.00	100	24.00	100.00

Appendices: Chapter 5

Appendix A

Table 1: Data description for variables used in the regression analysis.

Dependent Variable	*Variable description*
Calorie Adequacy Ratio	Ratio of daily energy intake to energy expenditure
Energy Intake (Kcal/day)	Total amount of calories in food consumption over a 24hr period
Total Energy Expenditure (Kcal/day)	Total amount of calories used to perform physical activities and support physiological functions daily
Independent Variable	*Variable description*
Ultra-processed foods	Proportion of daily total calories intake derived from ultra-processed food
Unprocessed foods	Proportion of daily total calories intake derived from unprocessed and minimally processed foods, processed culinary ingredients, processed food
Sedentary activity	Proportion of daily time spent in sedentary activities
Light activity	Proportion of daily time spent in light activities
Moderate and vigorous activity	Proportion of daily time spent in moderate and vigorous activities
Accelerometer wear	Daily accelerometer wear compliance over 1440 minutes
Day 1	Dummy for the first day of the week when data was collected
Day 2	Dummy for the second day of the week when data was collected
Day 3	Dummy for the third day of the week when data was collected
Day 4	Dummy for the fourth day of the week when data was collected
Household size	Total number of persons living under the same roof
Number of adult females (20-64 years)	Total number of female adults aged 18-64, within the household
Number of adult males (20-64 years)	Total number of male adults aged 20-64, within the household
Number of children (0-9 years)	Total number of male and female children aged between 0 and 9 years old within the household
Number of adolescents (10-19 years)	Total number of male and female adolescents aged between 10 and 17 years old within the household
Sex	Dummy variable for gender of respondent, male = 1, female = 2
Total land (hectares)	Total area of land cultivated by household
Wealth index	Index of the sum of values of household assets
Districts India	Categorical variable of district in India for Khammam and Mahbubnagar districts
Districts Nepal	Categorical variable of districts in Nepal, namely: Hupsekot, Dhunibeshi, Galchhi, Netrawati municipalities
Primary occupation of household head (whether in agriculture)	Dummy variable for occupation of household head is agriculture = 1, others = 0
Age of household head	Age of male or female household head in number of years
Household head literacy	Dummy variable for whether household head is literate, can read and write = 1, cannot read and write = 0
Castes India	Dummy variable indicating caste membership in India – lower castes = 1 and upper castes = 2
Castes / ethnicities Nepal	Dummy variable indicating caste membership in Nepal – lower castes/ethnicities = 1 and upper castes /ethnicities = 2

Table 2: Unconditional quantile regression (RIF model) results. Physical activity time use on CAR

	India			Nepal		
Dependent variable: CAR	Q25	Q50	Q75	Q25	Q50	Q75
z1-proportion of time spent in sedentary activity	0.16** (0.07)	0.20** (0.07)	0.30*** (0.08)	0.05 (0.07)	0.15*** (0.05)	0.14** (0.05)
z2-proportion of time spent in sedentary activity	0.19** (0.09)	0.09 (0.10)	0.07 (0.09)	0.16** (0.08)	0.14** (0.06)	0.19*** (0.07)
z1-proportion of time spent in light activity	0.08 (0.09)	-0.02 (0.10)	-0.09 (0.10)	0.11 (0.09)	0.04 (0.06)	0.09 (0.07)
z2-proportion of time spent in light activity	0.24*** (0.06)	0.22*** (0.06)	0.30*** (0.07)	0.12** (0.06)	0.20*** (0.05)	0.22*** (0.05)
z1-proportion of time spent in moderate and vigorous activity	-0.25*** (0.08)	-0.18** (0.08)	-0.21*** (0.07)	-0.17** (0.06)	-0.20*** (0.05)	-0.24*** (0.06)
z2-proportion of time spent in moderate and vigorous activity	0.04 (0.08)	0.13 (0.09)	-0.22** (0.09)	-0.04 (0.09)	0.06 (0.06)	0.02 (0.06)
Accelerometer wear	0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Day 1	-0.06 (0.05)	-0.05 (0.05)	-0.02 (0.05)	0.00 (0.03)	-0.00 (0.03)	-0.02 (0.03)
Day 2	-0.00 (0.04)	-0.06* (0.04)	-0.09** (0.04)	-0.01 (0.03)	-0.03 (0.03)	-0.02 (0.03)
Day 3	-0.03 (0.03)	-0.07* (0.03)	-0.11*** (0.04)	0.02 (0.03)	0.03 (0.03)	-0.03 (0.03)
Day 4	-0.02 (0.03)	-0.03 (0.03)	-0.08** (0.04)	0.00 (0.03)	0.02 (0.03)	-0.03 (0.03)
Constant	0.37*** (0.10)	0.65*** (0.10)	0.79*** (0.11)	0.73*** (0.10)	0.78*** (0.09)	1.03*** (0.08)
R-squared	0.01	0.01	0.02	0.01	0.02	0.02
F-test	6.41***	4.64***	7.60***	1.28***	3.68***	3.46***
Observations	1630	1630	1630	1479	1479	1479

Notes: Asterisks indicate level of significance *** = significance at 0.1% level, ** = significance at 1% and *= significant at 5%. Cluster-robust standard deviation in parenthesis

Table 3: Unconditional quantile regression (RIF model) results. Diet composition on CAR

	India			Nepal		
Dependent variable: CAR	Q25	Q50	Q75	Q25	Q50	Q75
z1-proportion of diet derived from ultra-processed food	0.11*** (0.01)	0.09*** (0.01)	0.06*** (0.01)	0.03** (0.01)	0.04*** (0.01)	0.02 (0.01)
z1-proportion of diet derived from non-ultra-processed food	-0.11*** (0.01)	-0.09*** (0.01)	-0.06*** (0.01)	-0.03** (0.01)	-0.04*** (0.01)	-0.02 (0.01)
Constant	0.97*** (0.04)	1.17*** (0.10)	1.41*** (0.04)	0.91*** (0.04)	1.12*** (0.03)	1.34*** (0.04)
R-squared	0.01	0.01	0.02	0.01	0.02	0.01
F-test	40.66***	2.22***	4.26***	1.61***	3.09***	1.52***
Observations	1630	1630	1630	1479	1479	1479

Notes: Asterisks indicate level of significance *** = significance at 0.1% level, ** = significance at 1% and *= significant at 5%. Cluster-robust standard deviation in parenthesis.

Table 4: Dependent variable CAR. Conditional quantile regression results. Gender interaction with the physical activity and diet compositional variables

	India						Nepal					
	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75
Z1- sedentary				0.06	-0.04	0.04				0.16*	0.22**	0.38***
				(0.10)	(0.12)	(0.12)				(0.09)	(0.08)	(0.10)
Z1 - sedentary * boy				-0.00	0.10	0.07				-0.10	-0.08	-0.15**
				(0.06)	(0.07)	(0.08)				(0.06)	(0.06)	(0.07)
Z2- sedentary				-0.10	0.08	-0.14				0.00	-0.02	-0.10
				(0.11)	(0.13)	(0.13)				(0.11)	(0.10)	(0.11)
Z2 - sedentary * boy				0.12*	-0.00	0.08				0.07	0.07	0.16**
				(0.07)	(0.08)	(0.08)				(0.07)	(0.06)	(0.07)
Z1- light activity				-0.12	0.09	-0.14				-0.07	-0.13	-0.28**
				(0.12)	(0.15)	(0.15)				(0.11)	(0.10)	(0.12)
Z1 - light activity * boy				0.10	-0.05	0.03				0.11	0.10	0.22**
				(0.08)	(0.10)	(0.10)				(0.08)	(0.07)	(0.08)
Z2- light activity				-0.00	0.00	-0.03				0.15*	0.18**	0.28***
				(0.07)	(0.09)	(0.09)				(0.08)	(0.07)	(0.09)
Z2 - light activity * boy				0.05	0.08	0.10*				-0.05	-0.04	-0.04
				(0.04)	(0.05)	(0.06)				(0.05)	(0.05)	(0.06)
Z1- moderate and vigorous activity				0.06	-0.05	0.10				-0.09	-0.08	-0.10
				(0.08)	(0.10)	(0.10)				(0.09)	(0.08)	(0.09)
Z1 - moderate and vigorous activity * boy				-0.10**	-0.04	-0.10*				-0.01	-0.01	-0.06
				(0.05)	(0.06)	(0.06)				(0.05)	(0.05)	(0.06)

Z2- moderate and vigorous activity				0.10	-0.08	0.10				0.14	0.21**	0.38***
				(0.12)	(0.15)	(0.15)				(0.11)	(0.10)	(0.12)
Z2 - moderate and vigorous activity * boy				-0.06	0.09	0.02				-0.12	-0.11	-0.21**
				(0.07)	(0.09)	(0.09)				(0.08)	(0.07)	(0.08)
Z1- ultra-processed foods	0.15***	0.18***	0.19***				0.01	0.01	-0.01			
	(0.02)	(0.03)	(0.03)				(0.03)	(0.03)	(0.04)			
Z1 - ultra-processed foods * boy	-0.04***	-0.05**	-0.07***				0.00	0.01	0.03			
	(0.01)	(0.02)	(0.02)				(0.02)	(0.02)	(0.02)			
Age	0.01	0.00	0.00	-0.01	-0.01**	-0.01**	-0.01***	-0.01***	-0.00	-0.02***	-0.02***	-0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Gender	-0.07*	-0.10*	-0.15**	-0.01	-0.10	-0.08	-0.08*	-0.03	0.01	0.04	0.03	0.16
	(0.04)	(0.06)	(0.06)	(0.08)	(0.10)	(0.10)	(0.05)	(0.04)	(0.05)	(0.09)	(0.08)	(0.10)
Underweight	0.24***	0.30***	0.38***	0.29***	0.32***	0.39***	0.22***	0.26***	0.26***	0.21***	0.26***	0.31***
	(0.04)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)
Normal weight	0.18***	0.25***	0.31***	0.22***	0.22***	0.32***	0.15***	0.18***	0.19***	0.14***	0.17***	0.22***
	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.04)	(0.04)	(0.05)	(0.04)	(0.03)	(0.04)
Marital status	0.09	0.07	0.12	0.15*	0.13	0.12	0.07	0.07	-0.03	0.05	0.10*	0.12*
	(0.07)	(0.10)	(0.10)	(0.08)	(0.10)	(0.10)	(0.06)	(0.06)	(0.07)	(0.06)	(0.05)	(0.06)
Participates in school meal	0.02	0.05*	0.08***	0.02	0.04*	0.04	-0.10**	0.06	0.17***	-0.08*	0.03	0.10**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Employment status	-0.00	0.00	0.00	0.00	0.00*	0.00	0.04	0.01	-0.04	0.05*	0.02	0.01
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)
School enrolment	0.00	-0.00	-0.00	0.00*	0.00	0.00	0.00	-0.05	-0.08*	-0.06	-0.06	-0.03
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)

Occupation of household head	-0.00***	-0.00**	-0.00	-0.00***	-0.00***	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age of household head	-0.00	0.00***	0.00**	0.00	0.00**	0.00***	0.00*	0.00**	0.00	0.00*	0.00**	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Gender of household head	-0.06**	-0.09**	-0.15***	0.01	-0.08**	-0.15***	0.01	-0.00	-0.02	-0.00	-0.01	-0.01
	(0.030)	(0.041)	(0.042)	(0.033)	(0.040)	(0.041)	(0.028)	(0.027)	(0.033)	(0.028)	(0.026)	(0.03)
Municipality/ District	-0.10**	-0.05	-0.01	-0.10**	0.00	0.05	-0.02*	-0.04***	-0.04***	-0.02	-0.03***	-0.04***
	(0.04)	(0.05)	(0.06)	(0.04)	(0.05)	(0.05)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Total livestock unit	-0.00	-0.01	0.00	-0.01*	-0.01	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Land size	-0.03	-0.01	-0.03	-0.03	-0.01	-0.04	0.04	0.01	0.00	0.02	0.02	0.01
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Caste	0.03*	0.05**	0.04	0.04*	0.01	0.04*	0.07**	0.07**	0.13***	0.07**	0.08***	0.15***
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Wealth index	-0.04***	-0.06***	-0.06***	-0.03***	-0.05***	-0.05***	0.00	0.00	0.00	0.00	0.00	-0.01
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household size	-0.00	-0.02*	-0.00	-0.01	-0.02**	-0.00	0.00	0.00	0.01	0.00	-0.00	0.01
	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Father’s literacy level	-0.00	-0.00	-0.01	0.00	-0.00	-0.01	-0.00	0.00	-0.01	-0.00	-0.00	-0.00
	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Mother’s literacy level	0.01	0.02**	0.03***	0.00	0.01	0.03***	0.00	0.03***	0.04***	0.00	0.03***	0.03**
	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Self-reported health	0.00	0.00	-0.00	0.00	0.00	-0.00	0.01	-0.00	-0.01	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)
Accelerometer wear	0.00	-0.00	-0.00	0.00	-0.00	-0.00**	0.00	0.00	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Day 1	-0.03	-0.01	-0.02	-0.06*	-0.02	0.00	-0.04	-0.07	-0.05	-0.00	-0.03	-0.04
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)
Day 2	-0.01	-0.06*	-0.06	-0.04	-0.07*	-0.04	-0.02	-0.03	-0.00	-0.01	-0.00	0.00
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)
Day 3	-0.03	-0.08**	-0.09**	-0.05*	-0.10***	-0.10***	-0.04	-0.04	0.00	-0.04	-0.03	0.01
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)
Day 4	-0.02	-0.01	-0.08**	-0.03	-0.04	-0.09**	-0.01	-0.02	-0.03	-0.00	-0.01	-0.03
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)
Constant	1.36***	1.25***	1.32***	0.99***	0.92***	0.71**	0.88***	1.03***	1.05***	0.75***	0.85***	0.60***
	(0.23)	(0.31)	(0.31)	(0.27)	(0.33)	(0.34)	(0.17)	(0.16)	(0.20)	(0.21)	(0.19)	(0.22)
Pseudo R-squared	0.16	0.13	0.12	0.13	0.10	0.10	0.06	0.08	0.08	0.07	0.09	0.10
Observations	1630	1630	1630	1630	1630	1630	1479	1479	1479	1479	1479	1479

Notes: asterisks indicate level of significance *** = significance at 0.1% level, ** = significance at 1% and *= significant at 5%. boy = 1, girl = 0

Table 5: Dependent variable CAR. Conditional quantile regression results. Age interaction with the physical activity and diet compositional variables.

	India						Nepal					
	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75
Z1- sedentary				0.15**	0.16*	0.00				-0.09	0.04	0.15**
				(0.08)	(0.09)	(0.10)				(0.06)	(0.06)	(0.07)
Z1 - sedentary * early adolescent				-0.05	-0.03	0.12**				0.07**	0.04	0.01
				(0.04)	(0.05)	(0.05)				(0.03)	(0.03)	(0.04)
Z2- sedentary				0.12	0.25	0.58***				0.17	-0.01	-0.04
				(0.15)	(0.18)	(0.19)				(0.14)	(0.13)	(0.16)
Z2 - sedentary * early adolescent				0.00	-0.08	-0.35***				-0.06	0.03	0.09
				(0.09)	(0.10)	(0.11)				(0.08)	(0.07)	(0.09)
Z1- light activity				0.03	0.13	0.50**				0.19	-0.03	-0.11
				(0.16)	(0.19)	(0.20)				(0.14)	(0.13)	(0.16)
Z1 - light activity * early adolescent				0.03	-0.05	-0.36***				-0.09	0.00	0.07
				(0.09)	(0.11)	(0.12)				(0.08)	(0.07)	(0.09)
Z2- light activity				0.19***	0.26***	0.29***				0.01	0.03	0.11
				(0.06)	(0.07)	(0.07)				(0.06)	(0.06)	(0.08)
Z2 - light activity * early adolescent				-0.05*	-0.07**	-0.07**				0.03	0.05	0.05
				(0.03)	(0.03)	(0.03)				(0.03)	(0.03)	(0.04)
Z1- moderate and vigorous activity				-0.18	-0.29**	-0.51***				-0.10	-0.02	-0.04
				(0.11)	(0.13)	(0.14)				(0.11)	(0.10)	(0.13)
Z1 - moderate and vigorous activity * early adolescent				0.03	0.08	0.24***				0.02	-0.05	-0.08
				(0.06)	(0.07)	(0.07)				(0.06)	(0.06)	(0.07)
Z2- moderate and vigorous activity				0.07	0.01	-0.29*				-0.16	0.04	0.15
				(0.13)	(0.15)	(0.16)				(0.10)	(0.10)	(0.12)

Z2 - moderate and vigorous activity * early adolescent				-0.05	0.01	0.27***				0.09	0.02	-0.04
				(0.08)	(0.09)	(0.10)				(0.06)	(0.06)	(0.07)
Z1- ultra-processed foods	0.07***	0.08***	0.07***				-0.03*	-0.02	-0.02			
	(0.02)	(0.02)	(0.02)				(0.02)	(0.02)	(0.03)			
Z1 - ultra-processed foods * early adolescent	0.01	0.00	0.00				-0.04***	-0.02*	-0.03*			
	(0.01)	(0.01)	(0.01)				(0.01)	(0.01)	(0.02)			
Age	0.01	0.00	0.00	0.00	-0.00	-0.03***	-0.03***	-0.03***	-0.02*	-0.04***	-0.03***	-0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Gender	0.05***	0.03	0.04	0.02	0.04*	0.06**	-0.09***	-0.07***	-0.04	-0.08***	-0.07***	-0.03
	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)
Underweight	0.25***	0.33***	0.38***	0.31***	0.30***	0.40***	0.23***	0.28***	0.27***	0.23***	0.25***	0.31***
	(0.05)	(0.07)	(0.07)	(0.05)	(0.06)	(0.07)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Normal weight	0.19***	0.27***	0.32***	0.25***	0.21***	0.32***	0.16***	0.20***	0.22***	0.17***	0.18***	0.23***
	(0.05)	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Marital status	0.09	0.09	0.13	0.13	0.12	0.11	0.07	0.12*	-0.05	0.08	0.10*	0.14**
	(0.08)	(0.11)	(0.10)	(0.08)	(0.10)	(0.10)	(0.06)	(0.06)	(0.08)	(0.06)	(0.06)	(0.07)
Participates in school meal	0.02	0.05*	0.09***	0.02	0.05**	0.03	-0.08*	0.03	0.19***	-0.08*	0.02	0.12**
	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Employment status	-0.00	0.00	-0.00	0.00	0.00*	0.00	0.05*	-0.00	-0.02	0.06**	0.01	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
School enrolment	0.00	-0.00	-0.00	0.00*	0.00	0.00	-0.01	-0.05	-0.06	-0.03	-0.08**	-0.03
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Occupation of household head	-0.00***	-0.00**	-0.00	-0.00***	-0.00***	-0.00	-0.00	-0.00*	-0.00	-0.00	-0.00*	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age of household head	-0.00	0.00**	0.00**	0.00	0.00***	0.00**	0.00*	0.00***	0.00	0.00**	0.00**	0.00

	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Gender of household head	-0.06*	-0.11**	-0.17***	0.00	-0.08**	-0.14***	0.02	-0.01	-0.03	-0.00	-0.02	-0.02
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Municipality	-0.11**	-0.09	-0.03	-0.10**	0.01	0.03	-0.03*	-0.05***	-0.04**	-0.02	-0.04***	-0.05***
	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Total livestock unit	-0.01	-0.02*	0.00	-0.01*	-0.01	0.00	-0.00	0.00	-0.00	-0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Land size	-0.04	-0.03	-0.02	-0.03	-0.04	-0.01	0.03	0.01	-0.01	0.03	0.03	0.00
	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)
Caste	0.04*	0.06**	0.05*	0.04*	0.03	0.05*	0.08**	0.07**	0.12***	0.07**	0.09***	0.13***
	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Wealth index	-0.04***	-0.06***	-0.06***	-0.03***	-0.05***	-0.05***	0.01	0.00	0.00	0.01*	0.00	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Household size	-0.01	-0.02*	-0.01	-0.01	-0.03**	-0.00	0.00	0.00	0.01	-0.00	-0.00	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Father's literacy level	-0.00	-0.00	-0.01	-0.00	-0.00	-0.01	-0.00	0.00	-0.01	-0.01	-0.00	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Mother's literacy level	0.01	0.03**	0.03***	0.00	0.02	0.02**	0.00	0.04***	0.04***	0.01	0.03***	0.03**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Self-reported health	0.00	0.00	-0.00	0.00	0.00	-0.00	0.02	0.02	-0.01	-0.00	0.01	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)
Accelerometer wear	0.00	-0.00	-0.00	0.00	-0.00	-0.00***	0.00	0.00	0.00	0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Day 1	-0.04	0.00	-0.01	-0.07*	-0.03	0.01	-0.03	-0.07**	-0.06	-0.00	-0.05*	-0.05
	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Day 2	-0.02	-0.06	-0.05	-0.04	-0.07**	-0.07*	-0.02	-0.04	0.01	-0.01	-0.02	0.00
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)

Day 3	-0.04	-0.09**	-0.09**	-0.05*	-0.11***	-0.12***	-0.04	-0.04	0.01	-0.04	-0.05	0.00
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Day 4	-0.04	-0.03	-0.07*	-0.03	-0.05	-0.11***	-0.01	-0.03	-0.03	-0.01	-0.03	-0.04
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Constant	1.19***	1.21***	1.12***	0.75***	0.51*	0.81**	1.11***	1.26***	1.31***	1.15***	1.21***	1.11***
	(0.24)	(0.32)	(0.31)	(0.27)	(0.31)	(0.33)	(0.17)	(0.17)	(0.21)	(0.18)	(0.18)	(0.17)
Pseudo R-squared	0.15	0.12	0.12	0.13	0.11	0.11	0.07	0.09	0.08	0.07	0.10	0.09
Observations	1630	1630	1630	1630	1630	1630	1479	1479	1479	1479	1479	1479

Notes: asterisks indicate level of significance *** = significance at 0.1% level, ** = significance at 1% and *= significant at 5%. For the age dummy, early adolescent = 1,late adolescent = 0

Table 6: Dependent variable CAR. Conditional quantile regression results. Caste interaction with the physical activity and diet compositional variables

	India						Nepal					
	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75
Z1- sedentary				0.14	0.05	0.18				-0.22*	-0.07	0.03
				(0.10)	(0.12)	(0.14)				(0.12)	(0.11)	(0.14)
Z1 - sedentary * lower caste				-0.05	0.02	-0.03				0.21**	0.17*	0.11
				(0.06)	(0.08)	(0.09)				(0.10)	(0.10)	(0.12)
Z2- sedentary				0.13	0.37***	0.30**				0.32***	0.16	0.22
				(0.11)	(0.13)	(0.15)				(0.12)	(0.11)	(0.14)
Z2 - sedentary * lower caste				-0.03	-0.20**	-0.20**				-0.20**	-0.10	-0.07
				(0.07)	(0.08)	(0.09)				(0.10)	(0.09)	(0.11)
Z1- light activity				0.04	0.29*	0.17				0.39***	0.18	0.17
				(0.13)	(0.16)	(0.18)				(0.14)	(0.13)	(0.16)
Z1 - light activity * lower caste				-0.01	-0.18*	-0.15				-0.28**	-0.17	-0.12
				(0.08)	(0.10)	(0.11)				(0.11)	(0.11)	(0.13)
Z2- light activity				0.18**	0.23**	0.30***				-0.03	0.02	0.14
				(0.07)	(0.09)	(0.10)				(0.10)	(0.09)	(0.11)
Z2 - light activity * lower caste				-0.06	-0.08	-0.13*				0.08	0.10	0.06
				(0.05)	(0.06)	(0.06)				(0.08)	(0.08)	(0.10)
Z1- moderate and vigorous activity				-0.18**	-0.34***	-0.35***				-0.17*	-0.10	-0.21*
				(0.08)	(0.10)	(0.11)				(0.10)	(0.09)	(0.11)
Z1 - moderate and vigorous activity * lower caste				0.05	0.16**	0.19***				0.07	-0.00	0.01
				(0.05)	(0.06)	(0.07)				(0.08)	(0.07)	(0.09)

Z2- moderate and vigorous activity				0.05	-0.14	0.00				-0.35**	-0.14	-0.08
				(0.13)	(0.15)	(0.17)				(0.14)	(0.13)	(0.16)
Z2 - moderate and vigorous activity * lower caste				-0.02	0.12	0.07				0.28**	0.20*	0.13
				(0.08)	(0.10)	(0.11)				(0.12)	(0.11)	(0.14)
Z1- ultra-processed foods	0.13***	0.11***	0.09***				0.06	0.03	0.11***			
	(0.03)	(0.03)	(0.03)				(0.04)	(0.03)	(0.04)			
Z1 - ultra-processed foods * lower caste	-0.03*	-0.02	-0.01				-0.03	0.01	-0.07*			
	(0.02)	(0.02)	(0.02)				(0.03)	(0.03)	(0.03)			
Age	0.01	0.00	0.00	-0.01	-0.01**	-0.02**	-0.02***	-0.02***	-0.00	-0.02***	-0.02***	-0.02***
	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Gender	0.05**	0.03	0.03	0.03	0.05*	0.07**	-0.10***	-0.06**	-0.05	-0.09***	-0.07***	-0.03
	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)
Underweight	0.24***	0.33***	0.38***	0.32***	0.31***	0.41***	0.23***	0.27***	0.27***	0.24***	0.25***	0.31***
	(0.05)	(0.07)	(0.07)	(0.05)	(0.07)	(0.07)	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Normal weight	0.18***	0.27***	0.31***	0.25***	0.24***	0.33***	0.16***	0.18***	0.19***	0.16***	0.17***	0.23***
	(0.05)	(0.07)	(0.07)	(0.06)	(0.07)	(0.07)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Marital status	0.11	0.09	0.14	0.14	0.15	0.13	0.08	0.07	-0.04	0.06	0.10*	0.14**
	(0.08)	(0.11)	(0.10)	(0.08)	(0.10)	(0.11)	(0.07)	(0.06)	(0.07)	(0.06)	(0.06)	(0.07)
Participates in school meal	0.03	0.05*	0.09***	0.02	0.04	0.04	-0.11**	0.05	0.17***	-0.08*	0.02	0.11**
	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Employment status	-0.00	0.00	-0.00	0.00	0.00	0.00	0.05	0.01	-0.04	0.05*	0.02	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
School enrolment	0.00	-0.00	-0.00	0.00	0.00	0.00	0.01	-0.03	-0.08	-0.07	-0.06	-0.02
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)

Occupation of household head	-0.00***	-0.00**	-0.00	-0.00***	-0.00**	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00*	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age of household head	0.00	0.00**	0.00**	0.00	0.00***	0.00***	0.00	0.00**	0.00	0.00	0.00**	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Gender of household head	-0.07**	-0.10**	-0.17***	0.01	-0.10**	-0.13***	0.01	0.00	-0.04	-0.00	-0.01	-0.03
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Municipality	-0.10**	-0.08	-0.03	-0.09*	0.03	0.04	-0.03*	-0.04***	-0.05***	-0.02	-0.04***	-0.05***
	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Total livestock unit	-0.01	-0.02*	0.01	-0.02**	-0.01	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Land size	-0.04	-0.01	-0.02	-0.04	-0.03	-0.02	0.03	0.02	-0.00	0.03	0.02	0.01
	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)
Caste	-0.04	0.02	0.04	0.13	0.09	0.19	0.00	0.08	0.01	-0.17	-0.14	-0.01
	(0.05)	(0.06)	(0.06)	(0.09)	(0.11)	(0.12)	(0.07)	(0.06)	(0.08)	(0.15)	(0.14)	(0.17)
Wealth index	-0.04***	-0.06***	-0.06***	-0.03***	-0.05***	-0.05***	0.01	0.00	-0.00	0.01	-0.00	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Household size	-0.01	-0.02	-0.01	-0.01	-0.02	0.01	0.00	0.00	0.01	0.00	-0.00	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Father's literacy level	-0.00	-0.00	-0.01	0.00	-0.01	-0.00	-0.01	-0.00	-0.01	-0.01	-0.00	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Mother's literacy level	0.01	0.03**	0.04***	0.00	0.02**	0.03**	0.01	0.03***	0.04***	0.01	0.03***	0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Self-reported health	0.00	0.00	-0.00	0.00	-0.00	-0.00	0.01	-0.01	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)
Accelerometer wear	0.00	-0.00	-0.00	0.00	-0.00	-0.00**	0.00	0.00	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Day 1	-0.05	0.00	-0.00	-0.06*	-0.05	0.01	-0.04	-0.07**	-0.07*	0.00	-0.03	-0.04
	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Day 2	-0.03	-0.06	-0.05	-0.03	-0.07*	-0.07*	-0.03	-0.04	0.00	-0.01	0.00	-0.01
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Day 3	-0.04	-0.09**	-0.09**	-0.06*	-0.11***	-0.12***	-0.05	-0.05	0.00	-0.05	-0.03	0.00
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Day 4	-0.03	-0.02	-0.06*	-0.03	-0.04	-0.11***	-0.02	-0.02	-0.04	0.00	-0.01	-0.04
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Constant	1.25***	1.19***	1.15***	0.67**	0.51	0.27	1.02***	1.07***	1.35***	1.21***	1.23***	1.10***
	(0.24)	(0.32)	(0.31)	(0.28)	(0.34)	(0.38)	(0.18)	(0.17)	(0.20)	(0.23)	(0.21)	(0.26)
Pseudo R-squared	0.15	0.12	0.12	0.13	0.11	0.11	0.07	0.08	0.08	0.07	0.09	0.10
Observations	1630	1630	1630	1630	1630	1630	1479	1479	1479	1479	1479	1479

Notes: asterisks indicate level of significance *** = significance at 0.1% level, ** = significance at 1% and *= significant at 5%. For the caste dummy, lower caste = 1, upper caste = 0

Table 7: Dependent variable CAR. Conditional quantile regression results. Land size interaction with the physical activity and diet compositional variables

	India						Nepal					
	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75
Z1- sedentary				0.31***	0.48***	0.35**				-0.09	0.11	0.21*
				(0.11)	(0.13)	(0.14)				(0.10)	(0.09)	(0.11)
Z1 - sedentary * small land size				-0.18***	-0.25***	-0.13				0.07	-0.00	-0.03
				(0.07)	(0.08)	(0.09)				(0.07)	(0.06)	(0.07)
Z2- sedentary				0.24**	-0.05	-0.01				0.04	0.02	-0.03
				(0.11)	(0.13)	(0.14)				(0.11)	(0.10)	(0.12)
Z2 - sedentary * small land size				-0.11	0.07	-0.01				0.04	0.03	0.10
				(0.07)	(0.09)	(0.09)				(0.07)	(0.06)	(0.08)
Z1- light activity				0.05	-0.29*	-0.18				0.08	-0.04	-0.13
				(0.13)	(0.16)	(0.17)				(0.12)	(0.11)	(0.13)
Z1 - light activity * small land size				-0.00	0.18*	0.06				0.00	0.03	0.10
				(0.09)	(0.10)	(0.11)				(0.08)	(0.07)	(0.09)
Z2- light activity				0.39***	0.39***	0.30***				-0.06	0.11	0.17*
				(0.08)	(0.10)	(0.10)				(0.09)	(0.07)	(0.09)
Z2 - light activity * small land size				-0.21***	-0.19***	-0.12*				0.08	0.02	0.02
				(0.05)	(0.06)	(0.07)				(0.06)	(0.05)	(0.06)
Z1- moderate and vigorous activity				-0.37***	-0.20**	-0.17				0.01	-0.07	-0.08
				(0.08)	(0.10)	(0.11)				(0.09)	(0.08)	(0.10)
Z1 - moderate and vigorous activity * small land size				0.18***	0.07	0.08				-0.07	-0.03	-0.07
				(0.06)	(0.07)	(0.07)				(0.06)	(0.05)	(0.06)
Z2- moderate and vigorous activity				0.15	0.44***	0.31*				-0.10	0.09	0.20
				(0.13)	(0.16)	(0.17)				(0.12)	(0.10)	(0.13)

Z2 - moderate and vigorous activity * small land size				-0.10	-0.25**	-0.11				0.04	-0.02	-0.07
				(0.08)	(0.10)	(0.11)				(0.08)	(0.07)	(0.09)
Z1- ultra-processed foods	-0.01	-0.01	-0.03				0.04	0.03	0.05			
	(0.03)	(0.04)	(0.04)				(0.03)	(0.03)	(0.04)			
Z1 - ultra-processed foods * small land size	0.06***	0.06**	0.07***				-0.01	0.00	-0.01			
	(0.02)	(0.02)	(0.02)				(0.02)	(0.02)	(0.02)			
Age	0.01	0.00	0.00	-0.01	-0.01*	-0.02**	-0.02***	-0.01***	-0.01	-0.02***	-0.02***	- 0.02***
	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Gender	0.05**	0.03	0.04	0.05**	0.06**	0.07**	-0.09***	-0.06***	-0.06*	-0.09***	-0.07***	-0.02
	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)
Underweight	0.25***	0.31***	0.39***	0.29***	0.37***	0.40***	0.22***	0.26***	0.26***	0.22***	0.26***	0.33***
	(0.05)	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)
Normal weight	0.21***	0.25***	0.32***	0.22***	0.28***	0.33***	0.15***	0.18***	0.20***	0.15***	0.17***	0.23***
	(0.05)	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
	0.00	0.00	0.00	0.00	0.00	0.00						
Marital status	0.12	0.13	0.12	0.15*	0.13	0.09	0.07	0.07	-0.02	0.06	0.11**	0.14**
	(0.08)	(0.11)	(0.09)	(0.09)	(0.10)	(0.11)	(0.07)	(0.06)	(0.07)	(0.06)	(0.06)	(0.07)
Participates in school meal	0.02	0.05*	0.08***	0.03	0.03	0.04	-0.10**	0.05	0.18***	-0.10**	0.03	0.12**
	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)
Employment status	-0.00	0.00	0.00	0.00**	0.00	0.00	0.05*	0.01	-0.05	0.05*	0.02	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
School enrolment	0.00	-0.00	-0.00	0.00**	0.00	0.00	0.00	-0.03	-0.09*	-0.05	-0.06	-0.02
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)

Occupation of household head	-0.00***	-0.00**	-0.00	-0.00***	-0.00***	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00*	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age of household head	0.00	0.00**	0.00***	0.00	0.00**	0.00***	0.00**	0.00**	0.00	0.00**	0.00**	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Gender of household head	-0.07**	-0.10**	-0.16***	-0.01	-0.06	-0.15***	0.01	-0.00	-0.03	-0.01	-0.01	-0.03
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)
Municipality	-0.10**	-0.03	-0.01	-0.08*	0.01	0.06	-0.03*	-0.04***	-0.05***	-0.03*	-0.03**	- 0.05***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.06)	(0.06)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Total livestock unit	-0.01	-0.01	0.01	-0.01	-0.02**	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Land size	0.09	0.09	0.15**	0.30***	0.35***	0.17	0.00	0.02	-0.02	-0.08	0.02	0.02
	(0.06)	(0.08)	(0.07)	(0.10)	(0.12)	(0.13)	(0.05)	(0.05)	(0.06)	(0.09)	(0.08)	(0.10)
Caste	0.03	0.05*	0.04*	0.05**	0.02	0.05*	0.06*	0.07**	0.13***	0.06*	0.09***	0.12***
	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Wealth index	-0.04***	-0.06***	-0.06***	-0.04***	-0.06***	-0.05***	0.01	0.00	0.00	0.01	-0.00	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Household size	-0.01	-0.02	-0.01	-0.01	-0.01	-0.00	0.00	0.00	0.01	-0.00	0.00	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Father’s literacy level	-0.01	-0.00	-0.01	0.00	-0.00	-0.01	-0.00	0.00	-0.01	-0.01	0.00	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Mother’s literacy level	0.01	0.03**	0.04***	0.01	0.01	0.03***	0.01	0.03***	0.04***	0.01	0.03***	0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Self-reported health	0.00	0.00	-0.00	0.00	0.00	-0.00	0.02	-0.00	-0.00	-0.00	-0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)
Accelerometer wear	0.00	-0.00	-0.00	0.00	-0.00	-0.00**	0.00	0.00	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Day 1	-0.06	-0.02	-0.00	-0.05	-0.00	0.01	-0.04	-0.07**	-0.07*	-0.01	-0.04	-0.05
	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Day 2	-0.03	-0.08**	-0.06	-0.04	-0.04	-0.06	-0.03	-0.04	-0.00	-0.01	-0.01	-0.01
	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Day 3	-0.05	-0.11***	-0.07**	-0.05	-0.11***	-0.10**	-0.05	-0.04	0.00	-0.05	-0.04	0.00
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Day 4	-0.02	-0.05	-0.07*	-0.03	-0.04	-0.11***	-0.02	-0.02	-0.04	-0.01	-0.02	-0.03
	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)
Constant	0.94***	0.76**	0.72**	0.27	-0.09	0.14	0.97***	1.09***	1.24***	1.15***	0.94***	0.86***
	(0.26)	(0.35)	(0.30)	(0.30)	(0.35)	(0.38)	(0.18)	(0.17)	(0.20)	(0.21)	(0.18)	(0.23)
Pseudo R-squared	0.16	0.12	0.12	0.13	0.11	0.10	0.07	0.08	0.08	0.07	0.09	0.10
Observations	1630	1630	1630	1630	1630	1630	1479	1479	1479	1479	1479	1479

Notes: asterisks indicate level of significance *** = significance at 0.1% level, ** = significance at 1% and *= significant at 5%. For the land size dummy, small land size = 1, large land size = 0

Table 8: The average number of hours spent on daily activities by adolescents in India

Time use	Mean	Standard error	[95% conf. interval]
Well-being			
Early adolescent male	15.12	0.10	14.92- 15.32
Early adolescent female	15.67	0.09	15.48- 15.86
Late adolescent male	14.94	0.09	14.76- 15.13
Late adolescent female	15.29	0.09	15.10- 15.47
Education			
Early adolescent male	6.42	0.08	6.26- 6.59
Early adolescent female	6.94	0.08	6.78- 7.10
Late adolescent male	5.38	0.07	5.24- 5.52
Late adolescent female	6.00	0.07	5.86- 6.15
Economic			
Early adolescent male	0.57	0.02	0.51- 0.62
Early adolescent female	0.46	0.02	0.42- 0.51
Late adolescent male	1.05	0.03	0.98- 1.12
Late adolescent female	0.53	0.02	0.49- 0.58
Domestic			
Early adolescent male	0.94	0.03	0.87- 1.01
Early adolescent female	1.48	0.04	1.39- 1.56
Late adolescent male	0.97	0.03	0.91 1.04
Late adolescent female	2.53	0.05	2.43- 2.63
Leisure			
Early adolescent male	4.69	0.07	4.55- 4.84
Early adolescent female	3.69	0.06	3.57- 3.82
Late adolescent male	4.60	0.06	4.46- 4.73
Late adolescent female	3.74	0.06	3.61- 3.86
Travel			
Early adolescent male	2.00	0.05	1.90- 2.10
Early adolescent female	1.40	0.04	1.32- 1.48
Late adolescent male	2.77	0.05	2.67- 2.88
Late adolescent female	1.48	0.04	1.40- 1.56
Others			
Early adolescent male	0.22	0.01	0.18- 0.25
Early adolescent female	0.32	0.02	0.28- 0.36
Late adolescent male	0.25	0.01	0.22- 0.28
Late adolescent female	0.39	0.02	0.35- 0.43

Table 9: The average number of hours spent on daily activities by adolescents in Nepal

Time use	Mean	Std. err.	[95% conf. interval]
Well-being			
Early adolescent male	14.39	0.10	14.19- 14.59
Early adolescent female	14.23	0.10	14.02- 14.44
Late adolescent male	14.68	0.10	14.48- 14.88
Late adolescent female	13.95	0.10	13.75- 14.15
Education			
Early adolescent male	4.98	0.07	4.83- 5.13
Early adolescent female	4.47	0.07	4.32- 4.62
Late adolescent male	4.04	0.07	3.90- 4.18
Late adolescent female	2.98	0.06	2.86- 3.10
Economic			
Early adolescent male	1.93	0.05	1.83- 2.02
Early adolescent female	1.76	0.05	1.66- 1.86
Late adolescent male	2.38	0.05	2.27- 2.48
Late adolescent female	2.13	0.05	2.03- 2.24
Domestic			

Early adolescent male	1.75	0.04	1.65- 1.84
Early adolescent female	2.29	0.05	2.18- 2.41
Late adolescent male	2.11	0.05	2.01- 2.22
Late adolescent female	3.21	0.06	3.09- 3.34
Leisure			
Early adolescent male	5.86	0.08	5.70- 6.02
Early adolescent female	5.94	0.08	5.77- 6.10
Late adolescent male	5.81	0.08	5.65- 5.97
Late adolescent female	6.52	0.08	6.36- 6.69
Travel			
Early adolescent male	1.03	0.03	0.95- 1.10
Early adolescent female	0.96	0.03	0.88- 1.03
Late adolescent male	0.88	0.03	0.81- 0.94
Late adolescent female	0.71	0.03	0.65- 0.77
Others			
Early adolescent male	0.04	0.00	0.03- 0.06
Early adolescent female	0.31	0.02	0.27- 0.35
Late adolescent male	0.07	0.01	0.05- 0.09
Late adolescent female	0.46	0.02	0.41- 0.50