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Piloting the use of accelerometry devices to capture energy expenditure in agricultural and rural livelihoods: Protocols and findings from northern Ghana

Giacomo Zanello[a,*], C.S. Srinivasan[a], Paul Nkegbe[b]

[a] School of Agriculture, Policy, and Development, University of Reading, United Kingdom
[b] University for Development Studies, Ghana

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ABSTRACT

In this study we report on the protocols adopted and the findings from a pilot study in northern Ghana involving 40 respondents wearing accelerometry devices for a week. We show how integrating energy expenditure data from wearable accelerometry devices with data on activity and time-use can provide a window into agricultural and rural livelihoods in developing country contexts that has not been previously available for empirical research. Our findings confirm some of the stylised facts of agricultural and rural livelihoods, but the study also provides several new insights that come from the triangulation of energy expenditure, time use, and activity data. We report findings and explore the potential applications of using accelerometry devices for a better understanding of agriculture-nutrition linkages in developing countries.

1. Introduction

The limited uptake of agricultural innovations with proven productivity-enhancing potential and the translation of productivity increases into improvements in nutrition are two major challenges facing Low and Middle Income Countries (LMICs) (Gillespie and Kadiyala, 2012; Global Panel, 2015; IFPRI, 2015; Turner et al., 2013). The human energy expenditure patterns associated with agricultural and livelihood activities can be expected to have an important influence on the uptake of productivity-enhancing agricultural innovations and their nutrition impacts on the rural population in developing countries (Johnston et al., 2015). Assessments of the impacts of agricultural interventions in LMICs have been largely confined to examining productivity increases. However, it has been recognised that the uptake of innovations may be significantly influenced by human energy expenditure and time-use patterns linked to the use of innovations. Further, the impact of increased productivity on nutrition for individual members of agricultural households may be mediated by gender-differentiated intra-household labour and consumption allocation decisions (Johnston et al., 2015). Incorporating the human energy expenditure dimension in analyses of the uptake of agricultural innovations and their nutrition impacts has been constrained by a lack of reliable robust empirical measurement of energy expenditure associated with agricultural activities in free-living populations.

The Doubly-Labelled-Water (DLW) method has been the standard method used to capture energy expenditure levels of free-living humans. However, this method requires respondents to be brought into an experimental facility and does not allow study of a large and representative samples. Advances in accelerometry technology offer the opportunity to scale-up empirical measurement of energy expenditure profiles in developing countries, and the pilot study described in this paper takes advantage of this to generate rigorous energy expenditure profiles associated with agricultural and livelihood activities. Accelerometry devices (tri-axial accelerometers) are small watch-like devices worn with a clip or belt, suitable for constant wear, which continuously record the movement of the wearers along the three axes. The movement data can be translated into the energy expenditure associated with physical activities. Recent advances have led to development of rugged wearable accelerometry devices suitable for use in the context of rural/agricultural occupations. These allow non-intrusive data collection, requiring no user inputs, facilitating scaled-up empirical measurement of energy expenditure in rural free-living populations.

In this paper we report lessons learnt from using accelerometry devices in rural areas in a developing country context. We also develop a methodological framework in which energy expenditure data from accelerometry devices is integrated with information from activity and time-use questionnaires administered to respondents to

* Correspondence to: School of Agriculture, Policy and Development, University of Reading, Reading, United Kingdom.
E-mail address: g.zanello@reading.ac.uk (G. Zanello).

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build energy expenditure profiles associated with agricultural and livelihood activities. We report our experience with a pilot study in rural Ghana, provide preliminary results and highlight potential future applications.

2. Scientific justification of capturing energy expenditure in agricultural and rural livelihoods

Undernutrition remains a significant developmental challenge in the developing world with one in four children under the age of five suffering from stunting or chronic undernutrition (Black et al., 2013). The stubborn persistence of undernutrition in spite of the remarkable improvements in agricultural productivity and production in developing countries over the last five decades has generated considerable policy interest in making agriculture 'nutrition-sensitive', i.e. in designing agricultural interventions that lead to improved nutritional outcomes. The impact of productivity-enhancing agricultural interventions on nutrition and health outcomes in developing countries operates through complex pathways that are not well understood (Dangour et al., 2013; Headey et al., 2012). In many developing countries, there appears to be a perplexing disconnect between agricultural productivity growth and expected improvements in nutrition status (Meeker and Haddad, 2013; Gillespie and Kadiyala, 2012). Exploring and delineating agriculture-nutrition linkages is a priority area for research (Turner et al., 2013).

Productivity-enhancing agricultural interventions impact the calorie deficits of the undernourished via their effects on energy intakes and energy expenditure. At the level of the individual, these effects are further mediated by intra-household allocations of consumption and labour. Intra-household allocations of time, labour and consumption have been recognised as significant determinants of the adoption of productivity-enhancing agricultural innovations and their impact on the nutritional status of individual household members (Blackden and Wodon, 2006; Haddad et al., 1997; Ilahi, 2000). Gender and age-related differentiation in intra-household allocation decisions have been observed to have an important role in explaining the nutrition impacts of productivity-enhancing innovations in developing country contexts (Johnston et al., 2015). A key impact pathway to nutrition is the effect of innovations on energy expenditure and energy intakes of individuals, mediated by intra-household allocation decisions. However, reliable and accurate empirical measurement of energy expenditure and intake impacts of agricultural productivity-enhancing innovations at the level of the individual remains challenging. This research will take advantage of advances in accelerometry technologies that make it possible for scaled-up empirical measurement of energy expenditure of the rural population in developing countries.

A substantial body of literature has examined intra-household allocation decisions related to consumption. Unitary household models explaining consumption behaviour have been replaced by models of household behaviour with outcomes being decided through a complex bargaining process (Doss, 2013). Availability of data on food consumption at the level of the individual member of the household in developing countries is still extremely limited, which explains the reliance on indirect approaches to assessing equity in household consumption (Lise and Seitz, 2011). Most of the empirical studies on intra-household time use and labour allocation rely on self-reported activity diaries or profiles or on observational data. Translation of activity profiles or observational data into accurate estimates of energy expenditure remains problematic because such data do not capture the variability and heterogeneity of activity intensity over time intervals. The energy expenditure dimension associated with productivity-enhancing agricultural interventions and its implications for nutrition outcomes for individuals within a household are, therefore, still not well understood and remain a black box.

3. Literature review

3.1. Physical activity amongst farmers in low-income countries

Most of the research on studying nutrition in low and middle income countries has predominantly focused on changes in diets while changes in physical activities have been largely neglected (Popkin, 2006). Dufour and Piperata (2008) identified only 26 studies reporting physical activity levels (PAL) of rural populations in low-income countries. PAL provides a more suitable measure of physical effort compared to total energy expenditure (TEE) because it corrects for body size, allowing comparison across gender and body-types. Most of these studies have used the so-called factorial method, which infers the total energy expenditure of an individual based on activity diaries. The time spent on each activity is multiplied by the average energy intensity of the activity estimated by indirect calorimetry methods (Durnin and Brockway, 1959). Other studies have used the DLW method and heart rate monitors (HRM) which provide energy expenditure estimates with accuracy within 3–5% and 6% respectively of direct calorimetry estimates (Ceesay et al., 1989; Norgan, 1996).

A review of empirical studies shows an average PAL of males and females in agricultural settings of 1.9 and 1.7 respectively, which is at the high end of what is considered to be "moderate" activity level (FAO/WHO/UNU, 2004). However, significant variations have been found across geographical locations and seasons. Studies of male farmers in Burkina Faso (Bleiberg et al., 1981), Cameroon (Pasquet and Koppert, 1993), and India (Edmundson and Edmundson, 1989) show light activity level ($1.4 < PAL < 1.69$), while vigorous activity levels ($PAL > 2$) were found in Philippines (Guzman et al., 1974), Gambia (Heini et al., 1996), and Thailand (Murayama and Ohtsuka, 1999). For females, vigorous activity levels were found only in Bangladesh amongst tea pickers (Vinoy et al., 2000). A few studies have collected data across different agricultural seasons revealing the diversity of physical activity levels across seasons. Greater differences across seasons were found in environments with a strong wet-dry seasonality where people rely on harvest of cereals for their subsistence. For example, in Myanmar the PAL of farmers varies from a vigorous activity level (2.51) during the peak season to a light activity level (1.41) post-harvest. Females PALs tend to be more consistent throughout the year, possibly because of their involvement in domestic chores and children care that is constant (Dufour and Piperata, 2008).

The differences in PAL by gender and seasons are largely determined by the different activities that are carried out. Vaz et al. (2005) compiled an extensive database of energy costs of specified activities, some of which are typical of rural populations in low-income contexts. For each activity, energy cost of the activity (kcal min^{-1}) and physical activity ratios (PARs) computed as the energy cost of the activity divided by BMR were reported. Table 1 reports the information for agricultural related activities. There is a huge variation in energy cost of activities by crops and technologies. For example, estimates of energy costs of crop harvesting range from 1145 cal/hour recorded amongst groundnuts male farmers in Gambia to 288 cal/hour for rice growers. The energy costs of other activities, such as hoeing and ploughing, are less crop specific. These activities have more consistent energy requirements across farm households using similar technology. Such estimates are informative to compare the relative energy cost and PAL of activities. However, they do not take into account periods of rest and pauses during the performance of the activity and, therefore, likely to overestimate energy expenditure.

3.2. Use of accelerometry technology in low-income context

Scientific (physiological) empirical measurement of energy expenditure profiles in developing countries (e.g., using the "gold-standard" DLW method and indirect calorimetry methods) has been hampered by the high cost and difficulty in applying standard methods and protocols